EFFECT OF COMPRESSION TIME SETTINGS ON AIDED SPEECH PERCEPTION IN ELDERLY INDIVIDUALS WITH TEMPORAL PROCESSING DEFICITS

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MAY, 2015

Dedicated To

My Family & My Guide

CERTIFICATE

This is to certify that this dissertation entitled '**Effect of Compression Time Settings on Aided Speech Perception in Elderly Individuals with Temporal Processing Deficits**' is a bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student (Registration No: 13AUD013). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any of the University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled '**Effect of Compression Time Settings on Aided Speech Perception in Elderly Individuals with Temporal Processing Deficits**' is the result of my own study under the guidance of Mr. Jijo. P.M, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier in other University for the award of any Diploma or Degree.

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ABSTRACT

Background: In addition to hearing loss, older individuals exhibit temporal processing problems that hamper their speech perception in adverse listening conditions. Hearing aids with a short release time, known to distort the temporal envelope of speech, may compromise speech understanding in elderly. In contrast, use of a long release time settings that preserve the temporal envelope might improve speech perception. **Purpose**: To investigate the effect of compression time settings and presentation levels on speech perception in adverse listening condition in elderly individuals with hearing loss. **Study Sample**: Twenty participants having mild moderate sensorineural hearing loss in the age range of 60 to 70 years. **Data Collection and Analysis**: Phonetically balanced sentences in Kannada, mixed with a speech shaped noise at different signal to noise ratios (SNR) ranged from +12 to -6 dB SNR served as stimuli. Aided SNR-50 was determined after fitting binaural hearing aids having different compression time settings (fast and slow) at three different presentation levels (40, 60 & 80 dB HL). Additionally, temporal processing abilities were evaluated by estimating gap detection thresholds. Analysis of variance and correlation analysis were carried out to analyze the data. **Results**: There was a significant effect of release time settings and presentation levels on SNR-50. Significantly better SNR-50 was found at two higher presentation levels compared to lower presentation level. Additionally, slow release time settings showed significantly better SNR-50 compared to fast release time, only at two higher presentation levels. There was a strong positive correlation between gap detection threshold and SNR-50 at higher presentation levels for both the release time settings. **Conclusions**: A hearing aid with a long release time settings led to significantly better speech perception in noise compared to that of a hearing aid having fast compression time settings.

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INTRODUCTION

Compression hearing aids are widely used for individuals with hearing impairment. A hearing aid with compression provides more gain to a soft signal whereas lesser gain is provided for a louder input. The compression time settings of the hearing aid decide the speed with which a hearing aid goes in and out of compression. A hearing aid with fast compression time settings can abruptly changes the gain depending on the level of input signal. In contrast, a hearing aid with slow compression time setting slowly changes the gain (Dillon 1988). The time taken by the hearing aid to activate compression is called attack time whereas the time taken to come out of compression is the release time.

Studies have shown that compression time settings of hearing aids can affect speech acoustics. It is reported that a hearing aid with short release time distorts the temporal envelope of speech whereas; a long release time minimally changes the envelope (Van Tasell 1993; Jenstad & Souza 2005). Jenstad and Souza (2005) evaluated the effect of three hearing aid release times (12, 100 & 800 ms) on speech acoustics. They presented vowel-consonant syllables at three different input levels of 50, 65 and 85 dB SPL. Acoustic analysis of hearing aid output using envelope difference index (EDI) and consonant vowel ratio (CVR) were carried out along with speech recognition scores. The results of EDI showed little change in temporal envelope at 50 dB SPL but the change was more at higher presentation levels for all three-release times. Short release time caused greater level difference between consonant and vowel. Further, at higher input levels greater acoustic change are observed. However, there was no significant difference in speech recognition across release time settings. Similarly, Souza and Turner (1996) showed alterations in temporal envelope using a compression release time of 15 ms are not sufficient to deteriorate speech recognition. The lack of difference in speech recognition in these studies has been attributed to availability of spectral cues when the speech stimuli are presented in quiet. This implies that the presence of noise that limits the availability of spectral cues might deteriorate speech perception while using fast compression time settings. The combined effect of noise and fast compression time settings may cause increased speech perception problems especially in those individuals having temporal processing deficits.

Studies on temporal processing in elderly showed severe temporal processing deficits. Kumar and Sangamanatha (2011) evaluated temporal processing in 176 participants belong to 6 cross sectional age groups from 20 to 80 years. They administered different tests to evaluate temporal processing skills. The results of gap detection test revealed that individuals greater than 40 years had significantly poorer gap detection compared to individuals less than 30 years. Subjects with more than 70 years of age had poor thresholds compared to younger age groups. Similar trend was observed in duration discrimination test. Other tests like duration pattern test and Modulation detection threshold also showed deterioration in performance after the age of 60 years. Regression analysis showed a strong relation between age and temporal processing abilities. However, hearing loss had no significant influence on temporal processing abilities.

Temporal processing deficits in elderly listeners probe research on speech perception through wide dynamic range compression hearing aids that alters temporal envelope of speech. Souza and Kitch (2001) studied the importance of temporal envelope on sentence identification and the effect of compression ratio in elderly listeners. They had four groups of subjects; young and older normal hearing as well as hearing impaired subjects. Perception of synthetic sentences processed using three different compression ratios of (1:1, 2:1 and 5:1) was studied. The results revealed that aged listeners performed poorly than young listeners in all test conditions. Even though with the increase in compression ratio, the performance of both young and elderly listeners deteriorated, there was a consistent performance gap between the two groups. They inferred that older individuals use temporal envelope cues similar to that of young adults.

Vasil and Cienkowski (2005) studied the effect of varying release time on speech perception in three participant groups. The groups were 14 young adults with normal hearing, 7 older adults with slight high frequency hearing loss and 5 older adult with moderate hearing loss. Release time setting used were fast (2560 ms), slow (40 ms) and intermediate (160 & 640 ms). Sentence perception at two signal to noise ratio was evaluated (+3 dB & +5 dB). The results revealed that young participants had significantly higher perception than both the older groups. However, there was no significant difference in performance among various release time settings. It was attributed that factors such as large variability in speech perception scores, relatively small sample size (5 individuals), level of presentation of signal below the compression threshold of the hearing aid and the task that determine the percentage correct score at two SNR levels might have caused the insignificance. They recommended studying the temporal resolution, cognitive abilities and degree of hearing loss. This might helps to identify the individual who perform well with fast or slow release time.

1.1. Need for the Study

Studies have shown that hearing aids with short release time distort the temporal envelope of speech (Van Tasell, 1993). Highest envelope distortion was observed when the stimuli were presented at high presentation levels than low (Jenstad & Souza 2005). In contrast, a hearing aid with a long release time found to preserve the temporal envelope of speech (Jenstad & Souza 2005). Studies on temporal processing in elderly individuals showed severe temporal resolution problems and hence they rely more on temporal envelope of speech compared to young individuals (Kumar & Sangamanatha 2011; Fitzgibbons & Gordon-Salant 1995). Hence, it can be hypothesized that hearing aids with short release time might deteriorate speech perception in elderly individuals who are known to have temporal resolution problems. Conversely, it is possible to preserve speech perception in elderly when a hearing aid with long release time is used.

Investigations by Souza and Kitch (2001) showed reduced speech perception in elderly, when stimuli were spectrally poor and temporal envelope was compressed using a hearing aid. However, the extend of deterioration was similar for both young and elderly listeners. They concluded that elderly listeners use amplitude envelope cues similar to that of young individuals. Similarly, Jestand and Sauza (2007) showed that envelope distortion alone did not significantly deteriorate speech perception in elderly individuals. However, combined effect of rapid speech rate and envelope distortion significantly deteriorates speech perception in elderly. From these studies it is evident that envelope distortion due to short release time may not deteriorate speech perception in elderly. However, in a complex listening situation (noise or rapid rate), envelope distortion can severely deteriorate speech perception in elderly. Hence, in such a listening situation use of a long release time might be effective for elderly listeners.

Vasil and Cienkowski (2005) showed no significant difference in speech perception in noise in elderly, when varying release times was used. Though insignificant, at +5 dB SNR older adults performed best with slow release time. Whereas, young listeners and older normal hearing listeners performed best with fast release time. Authors reported that release time might influence speech perception performance for some individuals. They recommended studying the temporal resolution, cognitive abilities and degree of hearing loss. This might helps to identify the individual who perform well with fast or slow release time. Similarities in speech perception scores in four release time settings might possibly because compression settings were not activated in the hearing aid. This highlights the need to study perception at different input levels.

Studies that investigated the effect of release time on speech perception usually investigated at a single presentation level (Neuman et al., 1995; Novick, Bentler, Dittberner, & Flamme, 2001). Since compression is triggered only when there is a changing input, the effect of release time may be studied for varying input signal (Jestand & Sauza, 2005). It is reported that listeners rely heavily on temporal envelope of speech while listening to sentences rather than speech syllables. In that case, use of short release time hearing aid that is known to distort the temporal envelope of speech may adversely affect perception of sentences. In contrast, hearing aids with a long release time either improve or will not deleteriously affect sentence perception.

1.2. Aim

To study the effect compression time settings on aided speech perception in elderly individuals with temporal processing deficits

1.3. Objectives

1. To compare speech perception in noise using a hearing aid with slow compression time settings at three different input levels
2. To compare speech perception in noise using a hearing aid with fast compression time settings at three different input levels
3. To obtain the relation between temporal processing abilities and aided SNR-50

Chapter 2

REVIEW OF LITERATURE

It is known that older adults show change in audiometric threshold that occur with age. Amplification using hearing aid is helpful to compensate their loss of audibility. However, when considering amplification for older individuals, it is important to look at the characteristics of age related hearing loss. It is known that older individuals exhibit deficits in temporal processing and speech processing that might make hearing aid fitting different these individuals. This review of literature provides an insight into the temporal processing problems and speech perception impairments of older individuals. Additionally, modifications required while fitting hearing aids for elderly are also described.

2.1. Temporal processing in elderly individuals

Studies on temporal processing in elderly showed severe temporal processing deficits. Kumar and Sangamanatha (2011) evaluated temporal processing in 176 participants who were divided into 6 cross sectional age groups (20-30, 31-40, 41- 50, 51-60, 61-70, 71-85). Gap detection test, duration discrimination test, duration pattern test and temporal modulation detection test were carried out. The results of gap detection test revealed that individuals greater than 40 years had significantly poor gap detection compared to that of individuals less than 30. Further, those who greater than 70 years had significantly poor gap detection compared to rest of the group. Similar trend was observed in duration discrimination test. The duration pattern test showed significantly poorer scores in individuals greater than 60 years compared to that of individuals less than 60. Modulation detection threshold differed at different modulation frequencies as a function of age. At higher modulation frequencies (60 & 200 Hz), modulation detection threshold started deteriorating at a younger age. Whereas for the low modulation frequencies (8 & 20 Hz) deterioration in modulation detection threshold began only at 60 years. Regression analysis showed a strong relation between age and temporal processing abilities. However, hearing loss had no significant influence on temporal processing abilities.

Snell and Frisina (2000) conducted two experiments to investigate the effect of age related changes in gap detection and word recognition abilities. In the first experiment there were 80 participants belong to two age groups. Among the 80 participants, 40 were young adults between the age range of 17 to 40 years and the remaining 40 were older adults between 61 to 82 years. The stimulus used was a modulated low pass noise bursts with cut off frequencies of 1 kHz or 6 kHz and a duration of 150 ms. Stimuli presented at three different background conditions. They were, quite, continuous noise floor, high frequency masker with noise floor. The presentation level was 80 dB SPL. The results of the study showed that the mean gap detection threshold ranged between 2.6 and 7.8 ms for the younger adults whereas the older adults had it from 3.4 to 10.0 ms. So it is clear that the gap threshold is significantly larger for the older adults in all the six conditions. But there was no correlation between gap threshold and audiometric thresholds.

In the second study, they examined the relationship among the gap threshold, audiometric threshold and spondee-in-babble threshold. Their aim was to find out whether the word recognition has any correlation with gap detection in the presence of background noise. Among the 80 subjects from the first study, only 66 had spondee-in-babble threshold. They obtained spondee-in-babble threshold using 11 spondees from CID W-1 word list and 12-talker speech babble from the recorded revised spin test for testing. They presented stimuli at 70 and 80 dB SPL in the presence of continuous white noise with and without high frequency masker.

Compared with the older subjects, the younger group recognized the spondees at significantly lower (more difficult) spondee-to-babble ratios. In the younger group, spondee-in-babble thresholds were significantly correlated with gap thresholds in conditions of high-frequency masking. In the older group, spondee-in-babble thresholds, gap thresholds, and audiometric thresholds were not significantly correlated, but the spondee-in-babble thresholds and two audiometric thresholds increased significantly with age. These results demonstrate that significant age-related changes in auditory processing occur throughout adulthood.

Pinheiro, Dias, Pereira (2012) investigated the effect of acoustic stimulation on temporal processing in older adults before and after hearing aid fitting. There were 60 subjects (20 males and 40 females) between the age range of 61 to 85 years. The participants were divided into two groups based on their audiometric thresholds. Group I (GI) had hearing threshold ranged between 41 to 50 dB HL and group II (GII) had it ranged from 51 to 70 dB HL. All were native Brazilian Portuguese language speakers having bilateral symmetrical sensorineural hearing loss. Investigations were carried out before fitting hearing aid and after an effective time of hearing aid use, it was a minimum of three months. To assess the temporal processing ability of the individuals they did Pattern Duration Test (PDT) and Gap in Noise Detection Test (GIN).

For PDT the stimulus frequency was 1000 Hz with two different durations (250 ms and 500 ms, short and long respectively). The gaps were kept constant as 300 ms and the presentation level was 30 dB SL. To assess the gap detection threshold and temporal acuity GIN test was performed. Here the presentation level was same as PDT. There were six second white noise stimuli along with five second intervals between these stimuli. At specific positions there were gaps inserted with various durations. The temporal acuity threshold was the minimum value at which the individual was able to find the gap in at least 4 of the 6 stimuli presented.

The results showed that the performance of young adults with and without hearing loss was better than elderly subjects in both the tasks. Additionally, there was deterioration in performance when the subject had any pathology that involves central nervous system or auditory pathways. The result of present study revealed that there was a significant improvement in performance of individuals before and after the use of hearing aids. This improvement was similar in two different age groups. There was no significant difference between the two groups in their improvement in performance for PDT and percentage of gap detection in noise. The degree of hearing loss did not show any influence in the performance of PDT. Even though it was not significant there was a better performance by the GI individuals in recognizing the duration pattern. However it is clear that with the use of hearing aids (acoustic stimulation) there was an improvement in the temporal processing skills of elderly individuals.

Strouse, Ashmead, Ohde and Grantham (1998) conducted a study to find the temporal processing ability in aging auditory system. They measured temporal processing monoaurally and binaurally by administering Gap Detection Test and inter aural time difference (ITD) respectively. They had two groups of subjects, 12 normally hearing young adults with an age range of 20 to 30 years and a group of normal hearing elderly subjects aged between 65 to 75years. The groups were matched for gender. Gap detection threshold was measured using an adaptive two interval forced choice method. The stimuli for ITD was 400 ms long trains of 40 rectangular clicks each click lasting 50 ms with an inter-click interval of 10 ms. They also measured the ability to discriminate changes in Voice Onset Time (VOT) and Masking Level Difference (MLD). VOT was examined by creating a sound continuum which varied in the duration of VOT in small steps. A continuum of consonant–vowel (CV) syllables ranging from /ba/ to /pa/ was created using the Computerized Speech Research Environment (CSRE) cascade/parallel synthesis program modeled after Klatt (1980). MLD measured using speech as stimulus. The stimuli were 36 spondaic words from the CID W- 1 list.

Results of the study shows, even though all the subjects had normal hearing sensitivity elderly subjects performed significantly poor in all the tasks. There was no correlation between the measured test results and their audiometric thresholds. Elderly listeners showed a clear deficit in the ability to process temporal information than young adults. Also they had inability to lateralize source of the sound in the basis of inter aural time difference. They were having poor sensitivity to changes in VOT; they performed poorly in distinguishing phoneme categories. MLD results showed elderly subjects performed poorly than young adults mainly for $S\pi N0$ condition. It supports the ITD results that they are poor in processing inter aural time cues even though they have normal hearing thresholds.

Fitzgibbons and Gordon-Salant (1996) examined on the hypothesis that the auditory temporal processing in elderly listeners is impaired. They reviewed many studies that were showing that the temporal processing get worsen with increase in age. The temporal processing was measured through assessing temporal resolution by finding gap detection thresholds or detection of temporal modulations in the stimulus. Also they assessed duration discrimination and sequential processing of complex stimulus pattern. Here they were finding the differential limen for the changes in the duration of the stimuli. Along with the temporal resolution and duration discrimination tests researchers tried to find the effect of age in temporal ordering ability. They concluded that the age related deficits are significantly evident in older individuals. They showed poor performance in Gap Detection scores temporal ordering and duration discrimination tasks. Another important conclusion was deterioration in performance with increase in the complexity of the stimulus and difficulty of the listening tasks.

Humes and Christopherson (1991) conducted a study to find the contribution of auditory processing in speech identification of elderly listeners. They administered several speech identification tests along with several temporally based measures of auditory processing. All the tests were administered in four groups of subjects. They were, (1) normal hearing young adults, (2) hearing impaired elderly subjects aged between 65 to 75 years (3) hearing impaired elderly subjects with 76 to 86 years of age (4) normal hearing young adults with simulated hearing loss same as older individuals by using specially developed spectrally shaped masking noise. The results of the study revealed that both the groups of older adults performed significantly poorer in all the measures of auditory processing. They got poor scores in speech identification tasks also. The group of adults having simulated hearing loss got a score comparatively better than that of older individuals. According to their results hearing impairment is the major factor for reduction in speech identification scores. It clearly shows the reduction in the temporal processing ability for individuals with age and hearing loss.

Moore, Peters and Glasberg (1992) conducted a study on elderly subjects with and without hearing loss to find their ability in detection of temporal gaps in sinusoidal signals were measured as a function of frequency. They had 15 elderly hearing impaired subjects, 11 near normally hearing elderly subjects and a group of young adults. They estimated Gap Detection Threshold and detection ability of sinusoids in noise for the measurement auditory filters. The results of the study showed a decrease in gap threshold with increase in the level of presentation. But a few subjects got slightly worse scores at higher level. The variations in gap threshold across frequencies were similar in all the groups but both elderly groups got similar gap threshold in all the frequencies. It was higher than that of young normal hearing individuals in a few older adults. Authors opined that the overall increase in the GDT threshold of older adults may be because of thaose outliers. And as expected the filter band width was larger for elderly hearing impaired subjects. As conclusion authors explains the reason for reduced temporal resolution is due to the presence of hearing impairment rather than aging.

Philips, Gordan-Salant, Fitzgibbons, Yeni-Komshian (1994) conducted a study to find the duration discrimination ability in young and older individuals with normal hearing. They had 10 elderly subjects with age range of 65 to 80 years and 10 young adults with an age range of 18 to 35 years. They used three interval forced choice method to find the Just Noticeable Difference (JND) in duration. A standard tone with 1000Hz frequency and 40 ms duration was used. A comparison tone of longer duration was also given. In the second experiment they provide a tonal masker with a tonal stimulus at three delay times. They were, 80 ms, 240 ms, and 720 msec. The results of the study shows there was difficulty for elderly subjects in duration discrimination tasks and the JND was higher for elderly when compare to younger subjects. It clearly proves that the time required to process duration characteristics of acoustic stimuli with increase in complexity and rapidly fluctuating acoustic stimulus are longer in elderly subjects.

Pichora- Fuller and Singh (2006) highlighted the importance of auditory and cognitive processes for fitting of hearing aid and other audiological rehabilitation. They opined that present views of rehabilitating hearing impairment could be modified by uniting the site of lesion based view that is anatomical lesion oriented and the processing based view which is based on the psychophysical measurements of auditory system. They tried to provide an integrated framework for understanding how cognitive and auditory processing interacts when older individuals listen communicate and comprehend in realistic situations. With the help of enough literatures, they concluded that it is important to measure individual differences in their cognitive status along with their audiological conditions while fitting or prescribing a particular hearing aid instead of making decisions only based on their age. It is because there will be significant decrease in temporal processing ability and decrement in their cognitive abilities with the aging.

Price and Simon (1984) did a study to find the effect of age and intensity on perception of temporal differences in speech by normal hearing adults. They had two groups of subjects, a group of normal hearing young subjects with an age range of 18 to 26 years and another group of older individuals above 59 years of age. Hearing thresholds of the older group were almost closer to normal hearing young subjects. Here they provide stimulus with voicing distinction by changing initial vowel duration and altering closure characteristics. They provided stimuli like naturally produced tokens of “rabid” were low-pass filtered at 3500 Hz and edited to create silent space and vowel. The stimuli were randomized by changing intensities (60 and 80 dB HL). The results of the study shows older subjects need more vowel duration to predict the voicing character especially in cases of shorter vowels and at higher intensities. By this data, they showed that effect of age is greater when we provide stimuli at higher sensation levels. In addition, it has a clear correlation with the neural response of the auditory system to the release of the stop consonant. It may be due to the lengthening of recovery time of neural fibers with age.

Schneider, Pichora-Fuller, Kowalchuk and Morag Lamb (1993) did a study to find the effect of gap detection and precedence effect in young and older adults. Their subjects were 18 young adults with a mean age of 23 years and 18 older adults with a mean age of 69.2 years. All subjects had normal hearing sensitivity. The results of the study revealed that in older subjects, the GDT threshold was more variable and it was greater than younger individuals (twice). There was no correlation between GDT and audiometric thresholds in both the groups. The larger GDT in older subjects shows that the larger temporal window in older adults. It is clear that the loss of temporal acuity is not because of the presence of sensorineural hearing loss, as there was no correlation between the audiometric thresholds and GDT.

Snell (1997) did a study to find the age related changes in the Gap Detection Threshold. He had two groups of subjects, younger subjects with an age range of 17 to 40 years and a group of older subjects with the age range of 64 to 77 years. He wanted to see the changes in temporal resolution skills in young and older normal hearing individuals and gap detection threshold in different listening situations. The signals for the testing were noise bursts, which varied in upper cut-off frequency, overall level and sinusoidal amplitude modulation depth. They presented the signal in quiet, in noise floor and in gated high frequency masker in noise floor. The results shows significantly higher gap thresholds for older subjects when compare to the younger subjects. It was clearly observable in all the condition. Introduction of the noise floor significantly increased the gap detection threshold of the older individuals, and the change was present in younger subjects also when noise was introduced, but it was comparatively less. So the results of the study pointing to the poorer temporal resolution for older individuals.

From the above literature, it is clear that the elderly subject’s shows poor performance in temporal processing tasks. Associated hearing loss and increasing task complexity might cause the problem worse. Hence, it is necessary that hearing aids for older adults should alleviate the deficits in temporal processing rather than addressing the problems of audibility alone.

2.2. Speech perception in noise for elderly individuals

Larsby, Hallgren, Lyxell (2008) evaluated the interference due to different type of background noise on speech processing in elderly subjects. A total of 24 subjects (10 men and 14 women) with an age range of 56 to 83 years (mean age 66.2) were participated in the study. The participants were grouped into two in which younger age group with an age range of 56 to 63 and an older group with 64 to 83 years of age. All of them had bilateral sharply sloping sensory neural hearing impairment and were fitted with hearing aid at least one year before the testing. For the assessment of speech recognition they used Hagerman test (Hagerman, 1982). This speech material consists of 11 lists and each list had 10 sentences. Each sentence was containing five low redundancy words. All the sentences were in same structure (name- verb - number - adjective - noun). They used same 50 words in all the sentences but they were in different combinations. After each word there will be a gap, it will be long enough for the subject to repeat the word that he/she recognized. After providing some training trials they assessed the SNR for 50% and 80% at +5dB and 0 dB SNR levels. They also administered a cognitive test battery SVIPS- speech and visual information processing system (Hallgren et al, 2001). It helps to asses both accuracy and processing speed. The test done in a sound treated room and they were not wearing hearing aid during testing. The presentation level was 70 dBSPL. The sentences presented in three different noise conditions, they were Hagerman's noise, speech and reversed speech.

The results of the study revealed that the unmodulated noise (HN) was most difficult condition at 50% level and modulated noise was more difficult at the 80% condition. A significant interaction between age group and noise types were also evident. In the modulated noise condition the elderly subjects were needed more favorable SNR for a better performance compare to the younger subjects. In the case of response time the elderly were needed a longer response time than younger group, and it was longer for both the groups at lower SNR condition from their higher SNR condition. So the interaction between noise conditions and age groups shows elderly subjects performed worse than younger subjects especially in the presence of modulated noise. They were unable to use the valley cues from the signal and they were really distracted by the level fluctuations. They performed comparatively better in the presence of un modulated noise.

Helfer and Wilber (1990) conducted a study to find the effect of reverberation and noise in elderly hearing impaired subjects. There were four groups of subjects involved, each group consist of 8 participants. The first two groups had participants less than 36 years. One of these groups had 8 normal hearing individuals and the other group had 8 individuals having high frequency sensorineural hearing loss which was not poorer than 50 dB HL. The other two groups consisted of subjects who were above 60 years of age. One of these two groups had subjects who had minimal peripheral hearing impairment and the other group was high frequency hearing impaired subjects having mean PTA of 45 dB HL.

To control the differences related to the linguistic background, intellect, memory and response bias among subjects, authors administered Nonsense Syllable Test (developed by Resnick et al. 1975). It consists of 91 syllables divided in to11 subsets. The stimuli presented in two situations they were, quite and in the presence of cafeteria noise. The result of their study revealed that majority of the elderly subjects with hearing impairment had severe difficulty in understanding nonsense syllable. The difficulty increased when stimulus distorted by reverberation and noise. Younger adults who had hearing impairment performed better than that of older adults. Younger adults also had difficulty in performing when the stimulus was distorted by noise and reverberation. They showed a strong correlation between pure tone threshold and nonsense syllable test performance. So this study clearly points that hearing loss and adverse listening conditions will largely affect the performance of elderly subjects in speech related tasks.

Martin and Jerger (2005) investigated the effect of age on central auditory mechanism. They reviewed many previous articles and also summarize event- related and behavioral test results from their own laboratory's research on effect of aging on dichotic listening performance. Based on that they concluded that along with the increase in difficulty in cognitive skills and reduction in inter hemispheric transmission of information, the left hemisphere performance will decrease and even reversed asymmetry in elderly and because of that the performance speech recognition become poor. It will get worse in the presence of noise.

A study done by Takahashi and Bacon (1992) to find the modulation detection, modulation masking and speech perception in noise for elderly subjects. Thirty subjects participated in this study. Each age range had ten subjects, age ranges were 50-59, 60-69 and 70-79 with normal hearing and mild sensorineural hearing loss. They also had ten young subjects with 20 to 26 years of age. They did three different experiments. First one was they presented broadband noise with a sinusoidal amplitude modulation. The modulation frequencies were ranging from 2 to 1024 Hz. In the second experiment the subjects were asked to detect the modulation in the presence of 100 % modulated sinusoidal amplitude modulated masker. The modulation frequencies for masker were varied from 2 to 64 Hz. As the final experiment they administered the speech understanding in the presence of both un modulated and modulated background noise as a function of signal to noise ratio. The results showed no significant age effect in subjects in any of the experiments. But in the presence of a hearing impairment the scores were become poorer. Even though the hearing loss component is very mild they had a difficulty in almost all the tasks. In the presence of modulated background noise and in un modulated background noise they performed comparatively poorer. The authors were explained it as elderly subjects will have at least a minimal component of hearing loss and that can cause attenuation in understanding speech. This study correlates with the study done by Humes and Christophorson (1991) results. They got poorer performance for subjects with an age range of 76 to 86 years in speech understanding tasks when compared to the other group aged between 65 to 75 years.

Divenyi, Stark and Haupt (2005) conducted a study to find the decline in speech understanding and auditory threshold with the age in elderly subjects. The subject strength was 29 and the age at the beginning of the study was 63 to 83.7 years. Their hearing threshold was not greater than moderate in the beginning of the study. They evaluated pure tone threshold, word recognition in quiet, speech understanding in the presence of various type of distortions (low-pass filtering, time compression) or interference (single speaker, reverberation, babble noise). They administered all the tests twice, with an average gap of 5.27 years.

The results of the study they observed that performance of the elderly subjects significantly deteriorated in the second testing when compared to the first. The changes in the audiometric thresholds were not much higher, but the deterioration in the speech understanding tasks they got significantly poorer scores. They also compared the test results with a younger group of subjects with normal hearing. From this they observed that the decrease in speech understanding will get accelerated relative to the audiometric threshold decrement and it happens especially in the age range of seventh to ninth decade. They also explained the limited success of hearing aid in elderly population particularly in the presence of noise could be an effect of this decline.

Dubno, Dirks and Morgan (1984) evaluated the effect of mild hearing loss and age on speech recognition in noisy condition. The participants belong to two age groups, less than 40 years and above 65 years each group having participants with either normal hearing sensitivity or mild sensorineural hearing impairment. The subjects with mild hearing loss had excellent speech understanding in quiet. They evaluated the speech recognition in babble, selected 50 sentences from the speech perception in noise test and selected 11 spondaic words. Among the 50 sentences 25 were high predictable and other 25 were low predictable. The required signal-to-babble ratio was 50%. The subjects with normal hearing sensitivity in both age ranges matched in their thresholds and speech recognition in quiet, the condition was same in the case of subjects with mild hearing loss in both age groups. From the study they observed that a significant difference in scores in the presence of noise in both normal and hearing impaired group as a function of age. But there was no significant difference for performance in quiet condition. In both the groups the subjects with mild hearing loss showed significantly worse performance with their normal counterparts. Also as expected the scores were good with high predictable sentences than low predictable sentences. Hence, they concluded that both normal and hearing-impaired subjects showed significant decrement in their performance with increasing age.

Gelfand, Piper and Silman (1985) did a study to find the consonant recognition ability in quiet as a function of aging in normal hearing individuals. They administered Nonsense Syllable Test on 62 normal hearing subjects with an age range of 20 to 65 years. The presentation level of the stimulus was at most comfortable level and 8 dB above and below of it. As expected the consonant recognition scores were high for all the subjects since they had normal hearing sensitivity. But still they observed a decreased consonant recognition ability among older adults when compare to the younger individuals, and it was statistically significant. The decrease was more evident at below MCL level. So they concluded that normal hearing older individuals have a difficulty in consonant recognition in quite but they have similar pattern of confusion with younger subjects for consonants.

Gelfand, Piper and Silman (1986) did another study among normal hearing subjects to find the consonant recognition in quiet and in noise with aging. They had 64 subjects with an age range of 21 to 68 years. They administered Nonsense Syllable Test and the stimuli presented at most comfortable level (MCL) in quiet and also in two S/N conditions. They were +10 and +5dB. The MCLs were approximated to the conversation speech level and they were not significantly different between the age groups. There was a significant effect for age groups and S/N conditions. The findings of this study shows there is a significant decrease in consonant recognition ability for normal and older individuals in quiet and also in noisy condition. But both younger and older subjects had similar nature of phoneme confusion, there was no significant difference. They also observed increased 8000Hz threshold in older subjects with poor consonant recognition.

Another study by Humes and Roberts (1990) to find the contribution of audibility in speech identification performance of elderly hearing impaired subjects. They had three groups of subjects. First group was with normal hearing young adults, hearing impaired older adults with an age range of 65 to 75 years and young adults with simulated equivalent hearing impairment with spectrally shaped masking noise. A total of 36 subjects participated in this study. Variety of speech recognition tests and temporal processing measures were administered. The results of their study reveal that the audibility plays very important role in speech understanding. Both the groups with hearing loss (one is simulated) got significantly poorer scores in the tests measures. The primary reason for the elderly subjects to fail in speech understanding tasks is the elevation of audiometric thresholds. The effect was more in the reverberant condition in elderly hearing-impaired individuals.

Souza and Turner (1996) conducted a study to find the speech understanding ability for young and elderly hearing-impaired subjects in the presence of different type of maskers. They had three groups of participants. One was normal hearing young adults, one group with young adults with an age range of 22 to 35 years, they had mild to moderate sensorineural hearing loss, and the final group was elderly subjects with an age range of 64 to 77 years and same level of sensory neural hearing loss. They obtained speech recognition scores for monosyllables in the presence of high pass noise and also in three different noise conditions. Each condition had high pass noise plus one of the noise backgrounds among speech spectrum noise, speech-spectrum noise temporally modulated by the envelope of multi-talker babble, and multi-talker babble. The results of their study revealed that in all the conditions the hearing impaired subjects performed significantly poorer than normal hearing subjects. And also when the masker become closer to the speech babble the scores are getting more worsen. But the effect of masker conditions was not statistically significant in their study. They couldn’t observe a significant effect of age over the groups. From the results it is evident that difficulties in the perception of monosyllable are mainly due to the presence of hearing loss and not due to aging. Authors view for the reason for that was the stimuli was not sufficiently demanding the speech identification tasks which is used by Gordon-salant (1987). Also their speech material was not allowing the use of syntactic cues by the listeners shows the possibility of aging effects can be present in the central level.

Older individuals exhibit difficulty in understanding speech especially in adverse listening conditions. The type of noise and stimuli can influence the performance of these individuals. Studies have reported poor speech understanding in the presence of modulated background noise compared to that of un-modulated noise. It is also reported that perception of monosyllabic words are related to degree of hearing loss rather than age of the individuals. Thus it can be concluded that in order to investigate speech perception of older individuals in adverse listening condition, sentences can be utilized rather than monosyllabic words.

2.3. Hearing aid release time and speech perception in elderly individuals

Compression hearing aids are widely used for individuals with hearing impairment. A hearing aid with compression provides more gain to a soft signal whereas lesser gain is provided for a louder input. The compression time settings of the hearing aid decide the speed with which a hearing aid goes in and out of compression. A hearing aid with fast compression time settings can abruptly change the gain depending on the level of input signal. In contrast, a hearing aid with slow compression time setting slowly changes the gain (Dillon 1988). The time taken by the hearing aid to activate compression is called attack time whereas the time taken to come out of compression is the release time.

Temporal processing deficits in elderly listeners probe research on speech perception through wide dynamic range compression hearing aids that alters temporal envelope of speech. Souza and Kitch (2001) studied the importance of temporal envelope on sentence identification in elderly listeners. Additionally the effect of compression ratio and number of channels were studied. The participants involved were 8 young normal hearing (mean age 23) and 7 young hearing impaired (mean age 25) as well as 12 elderly normal hearing (mean age 74) and 9 aged hearing impaired (mean age 78). Sentences from synthetic sentence identification test were processed using an attack time of 3 ms and release time of 25 ms. Three different compression ratios of 1:1, 2:1 and 5:1 were used. The results revealed that aged listeners performed poorly than young listeners in all test conditions. As both young and aged listeners had similar hearing sensitivity, poor performance in elderly subjects was attributed to age related temporal processing deficit. As the compression ratio increased performance of both young and elderly listeners deteriorated. However, there was a consistent performance gap between two groups. This indicates that elderly listeners use amplitude envelope cues similar to that of young individuals. Authors attributed that impaired fine structure processing or higher-level dysfunction might have caused poor performance in elderly.

Studies have shown distorted temporal envelope when stimuli were processed using a hearing aid with short release time. In contrast, a long release time had only a minimal effect on the envelope (Van Tasell 1993*;* Jenstad & Souza 2005). Jenstad and Souza (2005) evaluated the effect of three hearing aid release time (12, 100 & 800 ms) on speech acoustics. A wide dynamic range compression hearing aid with a compression threshold of 45dB, attack time of 6 ms and compression ratio 3:1 was used. The stimuli used were vowel-consonant syllables presented at three different input levels of 50, 65 and 85 dB SPL. Acoustic analysis of hearing aid output using envelope difference index (EDI) and consonant vowel ratio (CVR) were carried out. Additionally, speech recognition scores using hearing aid processed stimuli were also estimated.

The results of EDI showed little change in temporal envelope when the stimuli were presented at 50 dBSPL for all three release times. As the input level increased from 65 to 80 dB SPL, EDI values increased, indicating a large change in temporal envelope. Similarly, release time had significant effect on consonant vowel ratio. Short release time had greater level difference between consonant and vowel. The results of the study revealed greater acoustic change when higher input levels are used. However, there was no significant difference in speech recognition across the release times. Lack of difference in speech recognition is attributed to availability of spectral cues though temporal cue might be distorted. . Similarly, Souza and Turner (1996) showed alterations in temporal envelope using a compression release time of 15 ms are not sufficient to deteriorate speech recognition. They have attributed to availability of spectral cue when the speech is audible.

Vasil and Cienkowski (2005) studied the effect of varying release time on speech perception in three participant groups. The participants included were 14 young adults with normal hearing (18-35 years), 7 older adults with slight high frequency hearing loss (65-85 years) and 5 older adult with moderate hearing loss(65- 85 years). Release time setting used were fast (2560 ms), slow (40 ms) and intermediate (160 & 640 ms). Sentence perception at two signal to noise ratio was evaluated (+3dB & +5dB). The results revealed that young participants had significantly higher perception than both the older group. However, there was no significant difference in speech perception scores between older adults with moderate hearing loss and older adults with slight hearing loss. Additionally, there was no significant difference in performance among or within groups when release time settings were varied. Though insignificant at +5dB SNR older adults performed best with slow release time. Whereas the other two groups performed best with fast release time. Authors reported that release time might influence speech perception performance for some individuals. They recommended studying the temporal resolution, cognitive abilities and degree of hearing loss. This might helps to identify the individual who perform well with fast or slow release time.

Ghiringhelli and Iorio (2013) studied speech recognition in noise of elderly subjects with hearing aids of different recovery times according to their cognitive impairment status. There were 50 subjects with an age range of 60 to 80 years. The subjects were grouped based on their cognitive status using a cognitive sub-scale test of Alzheimer’s disease assessment scale. The participants with and without cognitive impairment were given hearing aid amplification with slow and fast compression time settings. Thus there were four groups two without cognitive impairment (fast and slow compression settings) and the remaining two with cognitive impairment (fast and slow compression settings). They administered speech recognition performance and hearing handicap inventory for the elderly – questionnaire along with the basic audiological evaluation.

The results of their study reveals regardless of cognitive impairment and compression time settings every subjects showed improvement in performance speech recognition in noise. But the performance of subjects who had hearing aid with slow compression time settings was higher for speech recognition in noise. However, for the group of subjects who had cognitive impairment and were using fast compression time setting hearing aid required comparatively more favorable signal to noise ratio to achieve 50% performance. But the group without cognitive impairment did not show difficulty in any of the compression time settings. Anyhow there is an improvement in performance in all the elderly subjects who were exposing to the hearing aid amplification.

Souza (2000) compared the ability of older and younger subjects to use the temporal information in speech when that information is altered by compression amplification. They had four groups of subjects. Normal hearing young adults, normal hearing older adults, hearing impaired young and older adults. They measured their ability to recognize vowel-consonant-vowel syllable in four different conditions. Stimuli presented with linear amplification here there is no restriction for temporal and spectral information and wide dynamic range compression (WDRC) amplification. In each condition they measured recognition ability for syllable containing only temporal information and for syllable containing temporal and spectral information. In the results the scores they obtained was lower for WDRC amplified speech than linearly amplified speech. Also they observed that older listeners performed poorly than younger subjects. When provided unrestricted spectral information there was no change in age related decrement among groups. When it restricted, in normal hearing subjects they observed age related decrement in WDRC speech than linear speech. But it was not there in hearing impaired group. Here the decrement was similar. So *the* results imply that when spectral cues are available older listeners can use WDRC hearing aids as same as younger listeners. For older individual with normal hearing got, poorer scores for compression amplified speech it shows that the presence of age related decline in temporal processing ability.

Verschuure, Benning, Van Cappellen, Dreschler, and Boeremans (1998) conducted a study to find speech intelligibility of individuals in the presence of noise with a fast compression hearing aid. The subjects participated in this study were a group of moderately hearing impaired subjects and another group of severely hearing impaired subjects. They obtained speech intelligibility skills in quiet and in different noisy environments. The type of noises they used were multi talker babble, noise in an industrial plant, in a printing office and in a city noise background. The results shows that syllabic compression is useful for individuals with poor speech discrimination score in quiet. But for hearing impaired individuals with good speech discrimination score could not benefit from syllabic compression. Also they observed that hearing impaired listeners with poor speech scores will get benefitted with this fast compression settings in noisy situation when the noise has fluctuations, but this advantage was not evident when provided stimulus in the presence a steady noise. In any noisy situation there was no improvement in the scores for hearing impaired individuals with good speech recognition scores. So from this study it is clear that hearing impaired listener with poor speech scores will get benefitted with fast compression settings in fluctuating noisy situations and in quiet environment.

From the above literature, we can conclude that elderly subject's show poor speech understanding especially in the presence of noise. There are many reasons for the poor speech understanding, which includes poor temporal processing and hearing loss. With increasing age there will be changes in the auditory system, it includes both peripheral and central level. The changes in the central auditory system will decrease the temporal resolution in elderly subjects. That in turn affects the speech understanding in the elderly in different situations. Modifications in compression settings of hearing aids are an effective approach to improve speech perception in elderly, especially in adverse listening conditions.

Chapter 3

METHOD

The present study aimed to investigate the effect of compression time constants and level of presentation on speech perception in adverse listening conditions in elderly individuals with hearing loss. Aided sentence identification in noise was evaluated using binaurally fitted hearing aids. This was carried out at three different presentation levels (40, 60 & 80 dB HL) using two different compression time settings (slow and fast) of a hearing aid. A repeated measure design was used to determine SNR-50 in the unaided and six different aided conditions.

3.1. Participants

There were twenty individuals with sensorineural hearing loss (SNHL) who participated in the study. The age of the participants ranged from 60-70 years with the mean age being 66.6 years standard deviation being 3.36. All the participants were native speakers of Kannada. The demographic and audiologic details of participants can be found in Table 1.

3.2. Procedure for the selection of participants

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

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

Table.3.1. Demographic and audiological details of participants

Sl No	Age/ Gender	PTA(dB HL)		SIS (%)		Tympanometry (bilateral)	Reflexometry (bilateral)	DPOAE (bilateral)	ABR (bilateral)
		Right	Left	Right	Left				
1	70/M	50	55	88	84	'A' type	Absent	Absent	Present
2	70/M	42.5	40	96	92	'A' type	Present	Absent	Present
3	65/M	35	35	100	100	'A' type	Present	Present	Present
4	67/F	47	43	72	88	'A' type	Present	Absent	Present
5	65/M	50	52	68	76	'A' type	Present	Absent	Present
6	70/F	45	50	72	72	'A' type	Absent	Absent	Present
7	65/M	50	55	52	60	'A' type	Absent	Absent	Present
8	70/M	43	45	100	96	'A' type	Present	Absent	Present
9	60/F	53	50	92	92	'A' type	Absent	Absent	Present
10	70/M	53	55	72	76	'A' type	Absent	Absent	Present
11	64/M	40	43	60	64	'A' type	Present	Absent	Present
12	70/M	35	33	100	100	'A' type	Present	Present	Present
13	70/M	40	43	68	68	'A' type	Present	Absent	Present
14	64/M	30	30	72	72	'A' type	Present	Present	Present
15	69/M	55	55	60	60	'A' type	Absent	Absent	Present
16	69/M	50	48	56	60	'A' type	Present	Absent	Present
17	68/F	50	53	80	84	'A' type	Absent	Absent	Present
18	63/M	40	37	92	96	'A' type	Present	Absent	Present
19	60/M	36	30	100	100	'A' type	Present	Present	Present
20	67/M	35	38	100	100	'A' type	Present	Absent	Present

In addition to the above exclusion criteria, participants who manifest the following audiological findings were included for the study:

- Pure-tone hearing threshold indicating mild to moderate sloping sensorineural hearing loss,
- Symmetrical hearing loss, where the difference in threshold between the two ears were not exceeding 10 dB HL at any frequency,
- ‘A’ type tympanogram, with no middle ear related problems and
- Presence of auditory brainstem response (ABR) at 90 dB nHL.

Prior to data collection, all the participants had undergone a detailed audiological evaluation. Pure-tone thresholds were obtained via the modified Hughson and Westlake procedure, using a diagnostic audiometer (GSI 61) that was calibrated in a regular interval. A calibrated immittance instrument (GSI-Tympstar) was used to obtain tympanograms and acoustic reflex thresholds. Speech identification score (SIS) were obtained using a phonemically balanced word test in Kannada, developed by Yathiraj and Vijayalakshmi (2005). Distortion product otoacoustic emissions (DPOAE) were recorded using either an Otodynamics ILO 292 or Madsen Capella 1.3. Normal cochlear amplification was confirmed when the DPOAEs had signal to noise ratio more than 6 dB. In order to rule out the presence of retro-cochlear dysfunction, ABR was recorded using a two-channel auditory evoked potential system (Biologic Navigator Pro).

3.4. Preparation of the test Stimuli

Six lists of sentences were taken from the recorded version of a phonetically balanced sentence test in Kannada (Geetha, Sharath, Manjula & Pavan, 2014). Each list comprised of ten sentences each having four key words. Each sentence in a list was mixed with a speech shaped noise at a particular signal to noise ratio (SNR) ranged from +12 to -6 dB SNR. An SNR difference of 2 dB was maintained across the sentences. In order to generate the speech shaped noise, the sentences were concatenated and spectrally analyzed to derive its long-term average speech spectrum (LTASS). The LTASS was then used to design an infinite impulse response (IIR) filter using MATLAB software (v. 7.12). Speech shaped noise was derived using white noise subjected to the designed IIR filter. The speech shaped noise was mixed to each sentence using AUXVIEWER software. With the help of this software any two signals can be added, subtracted, multiplied or divided. Here we have added two signals, they were sentences and the speech shaped noise by providing appropriate intensities to get the desired SNRs. The output stimuli was then RMS normalized to maintain equal loudness. For each sentence, the duration of noise was adjusted in such a way to provide sufficient duration of noise before and after the stimulus.

The SNR at which 50% of the sentences are perceived were calculated using the Spearman–Kärber equation (Finney, 1952), which is as follows:

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

Where, 'I' is the initial presentation level (dB SNR), 'd' is the decrement step size (attenuation), and 'w' is the number of words per decrement.

3.5. Test Environment

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

3.6. Calibration

In order to calibrate the test setup, a sound level meter (SLM) that was connected to a half inch microphone was kept 1 meter away from the loudspeaker at an angle of 0^0azimuth. A calibration tone of 1 k Hz was played in a personal computer, routed through an audiometer and presented via the loud speaker. Three different levels of calibration tones (40, 60 & 80 dB HL) were presented with the volume unit meter adjusted to 0 dB. Among the three different input levels, 40 dB HL was used so that stimuli be presented below the compression threshold (55 dB SPL) of the hearing aid. The other two input levels were well above the compression threshold of the hearing aid. The output recorded on the SLM was monitored so that 12.5 dB above the RETSPL of 1000 Hz was recorded.

3.7. Hearing aid programming

Two Starkey 'S' series, Receiver in the canal (RIC) hearing aids having option to manipulate the attack/release time were utilized for the study. This wide dynamic range compression hearing aid had a compression threshold of 55 dB SPL and compression ratio less than 3:1. The hearing aids were programmed using a personal computer loaded with a NOAH (version-3) in which the hearing aid specific software was installed. Programming was done separately for each participant to provide appropriate output characteristics. Programming was done using the NAL-NL1 prescriptive formula. While programming the hearing aid compression time settings activated were either; slow (20 ms attack time and 2000 ms release time) or fast (5ms attack time and 10ms release time). Additional settings such as directionality, noise reduction, volume control and feedback cancellation were switched off while programming.

3.8. Testing Procedure

Each participant, who fitted with binaural hearing aids was seated in the test room. Aided SNR 50 was obtained from each participant using two different compression settings (fast and slow) at three different presentation levels (40, 60 and 80 dB HL). Hence, each participant was tested in six different test conditions that were performed in a random order. Six sentence lists, each list having 10 sentences were utilized obtain the SNR-50. The participants heard the noise mixed sentences presented through the loud speaker. The sentences were presented in a random order irrespective of their SNR. The participants were instructed to repeat the sentences even if they understand only one word out of the entire sentence. The responses were noted down by the experimenter. A similar procedure was adopted to test the participants for both the compression time setting in all three presentation levels.

3.9. Evaluation of temporal processing ability

In order to determine the temporal resolution abilities participants in the clinical group were evaluated using gap detection test. A broadband noise having 750 ms duration served as the standard stimuli. The broadband noise having 0.5 m sec cosine ramps at the beginning and end of the gap served as the variable stimuli. A maximum likelihood procedure (MLP) implemented in MATLAB software (v. 7.12) was used to obtain the gap detection thresholds. The gap detection thresholds were obtained at two different intensities (60 dBHL and 80 dBHL). The MLP employs a large number of candidate psychometric functions and after each trial calculates the probability (or likelihood) of obtaining the listener’s response to all of the stimuli that have been presented. The function, yielding the highest probability is used to determine the stimulus to be presented on the next trial. Within about 12 trials, the maximum likelihood procedure usually converges on a reasonably stable estimate of the most likely psychometric function, which then can be used to estimate threshold (Green1993, 1990). The stimuli were presented through the loudspeaker placed one meter away from the listener at an angle of 0^0 azimuth. A two-interval alternate forced-choice method using an MLP was employed to track an 80% correct response criterion. During each trial, stimuli were presented in each of the two intervals: One interval contained a reference stimulus, the other interval the variable stimulus. The participant indicated after each trial which interval contained the variable stimulus.

3.10. Analysis

Data obtained using slow and fast compression time settings of the hearing aid at three different input levels were analyzed using both descriptive and inferential statistics.

Chapter 4

RESULTS

The present study investigated the effect of compression time constants and level of presentation on speech perception in adverse listening conditions in elderly individuals with hearing loss. Aided sentence identification in noise (SNR-50) was carried out using two different compression time settings (slow and fast) of a hearing aid at three different presentation levels (40, 60 & 80 dB HL). Additionally, temporal processing abilities were evaluated using gap detection test, administered at two different presentation levels (60 & 80 dB HL).

4.1. Effect of presentation level on SNR-50

The mean and standard deviation of SNR-50 obtained using two compression time settings, each at three presentation levels are given in Table 1. It can be found that hearing aid with a slow release time had better mean SNR, required to obtain 50% score compared to that of the hearing aid having fast release time. Additionally, with increasing presentation level there was an improvement in SNR 50.

Table. 4.1. The mean and standard deviation of SNR-50 obtained using two compression time settings and three presentation levels

Compression time setting	Presentation level (dBHL)	Mean SNR-50	Standard Deviation
Slow	40	+5.02	3.70
	60	+2.17	3.40
	80	+1.30	3.78
Fast	40	+5.37	3.45
	60	+3.05	3.38
	80	+3.20	3.24

Two-way repeated measure ANOVA was carried out to investigate the effect of release times and level of presentations on SNR-50. Where, the release time (2 levels) and level of presentation (3 levels) served as independent variables and SNR 50 was the dependent variable. The results of the analysis showed that there was a significant effect of release time $F (1, 19) = 36.765$, $p = 0.00$ and the level of presentation $F (2, 38) = 11.595$, $p = 0.00$ on SNR-50. Similarly, there was a significant interaction between release time and level of presentations $F (2, 38) = 3.744$, $p=0.033$. The significant interaction revealed that for a particular release time, SNR-50 varied depending on the level of presentation of stimuli. Hence, the effect of presentation level on SNR-50 was analyzed separately fast and slow release times.

One way repeated measure ANOVA was performed to investigate the effect of presentation level on SNR-50. This was carried out separately for fast and slow release times. Where, the level of presentation (3 levels) served as independent variables and SNR 50 was the dependent variable. The results showed a significant effect of presentation level on SNR-50 while using slow release time settings F (2, 38) = 11.741, p= 0.00. Further Boneferroni pair wise comparison showed that SNR-50 obtained at 60 and 80 dB HL were significantly better (lower) than that of SNR-50 at 40 dB HL. However, there was no significant difference in SNR-50 between the presentation levels 60 and 80 dB HL (Table 2).

Similarly, the effect of presentation level on SNR-50 was investigated while using a fast release time. The results of one way repeated measure ANOVA showed a significant effect of presentation level on SNR-50 F (2, 38) = 8.208, p= 0.001. Boneferroni pair wise comparison was carried to investigate the significance of difference between two pairs of presentation levels. Similar to slow release time, SNR-50 was significantly better (lower) while using presentation levels of 60 dB HL and 80 dB HL compared to 40 dB HL. However, SNR-50 was not significantly different while presented the stimuli at 60 and 80dB HL (Table 2).

Table.4.2. **Pair wise comparison of SNR-50 obtained at different presentation levels for the two compression time settings**

Compression time setting	Presentation level pairs (dBHL)	**Significance**
Slow	40 vs. 60	S
	40 vs. 80	S
	60 vs. 80	NS
Fast	40vs 60	S
	40 vs. 80	S
	60 vs. 80	NS

Note. S = significant ($p < 0.05$), NS = not significant

4.2. Effect of release time on SNR-50

In order to compare the effect of fast and slow release time on SNR-50, paired sample t-test was performed at each presentation levels. As there was no significant difference in SNR-50 at 60 and 80 dB HL, their mean was considered for further analysis. The mean SNR-50 was calculated for both slow and fast release times. The results showed no significant difference between fast and slow release times when the stimuli were presented at 40 dB HL $t(19) = -1.092$, $p = 0.289$. In contrast, a significant difference in SNR-50 was found between slow and fast release times when the mean of the two higher presentation levels were compared $t(19) = -6.13$, $p = 0.00$. In this case, the SNR-50 obtained using slow release time was significantly better than fast release times.

4.3. Relation between temporal processing abilities and SNR-50

Results of gap detection test carried out at two different presentation levels showed identical thresholds. The mean GDT score at 60 dB HL was 15.60 and at 80 dB HL was 15.45 and the standard deviation was 11.60 and 11.70 respectively. In order to compare the gap detection thresholds obtained at the two different presentation levels a paired sample t-test was performed. The results showed no significant difference in thresholds between the two intensity levels, $t(19) = 0.311$, $p = 0.759$. As there was no significant difference in gap detection thresholds, average thresholds of two presentation levels were taken for further analysis.

The relation between gap detection thresholds (average threshold at two presentation levels) and SNR-50 were obtained using Pearson's product moment correlation (Table 3). This was performed separately for SNR-50 obtained using fast and slow release times both at three presentation levels. The results revealed a strong positive correlation between gap detection thresholds and SNR-50 obtained using slow release time for the two higher presentation levels. In contrast, there was only a moderate correlation between these two when the stimuli were presented at a low level (40 dB HL). Similarly, while using fats release time there was a strong positive correlation between gap detection thresholds and SNR-50 obtained for the presentation levels of 60 dB HL and 80 dB HL. In contrast, there was only a moderate correlation between these two when the stimuli were presented at 40 dB HL.

Table.4.3. **Correlation between gap detection thresholds and SNR-50 obtained using fast and slow release times both at three presentation levels.**

Release time	Intensity (dB HL)	Pearson's correlation coefficient(r)	Significance
Slow	40	r= 0.503, N=20,	p= 0.024
	60	r= 0.793, N=20,	p= 0.000
	80	r= 0.719, N=20,	p= 0.000
Fast	40	r= 0.627, N=20,	p= 0.003
	60	r= 0.821, N=20,	p= 0.000
	80	r= 0.760, N=20,	p= 0.002

The relation between gap detection thresholds and SNR-50 obtained using slow release time for three presentation levels are depicted in Figure 1. Identical results were found using fast release time (hence not depicted). The relation between gap detection threshold and word recognition scores also showed a strong negative correlation between them in both right ($r = -0.788$, $p < .00$) and left ears ($r = -0.744$, $p < 0.00$).

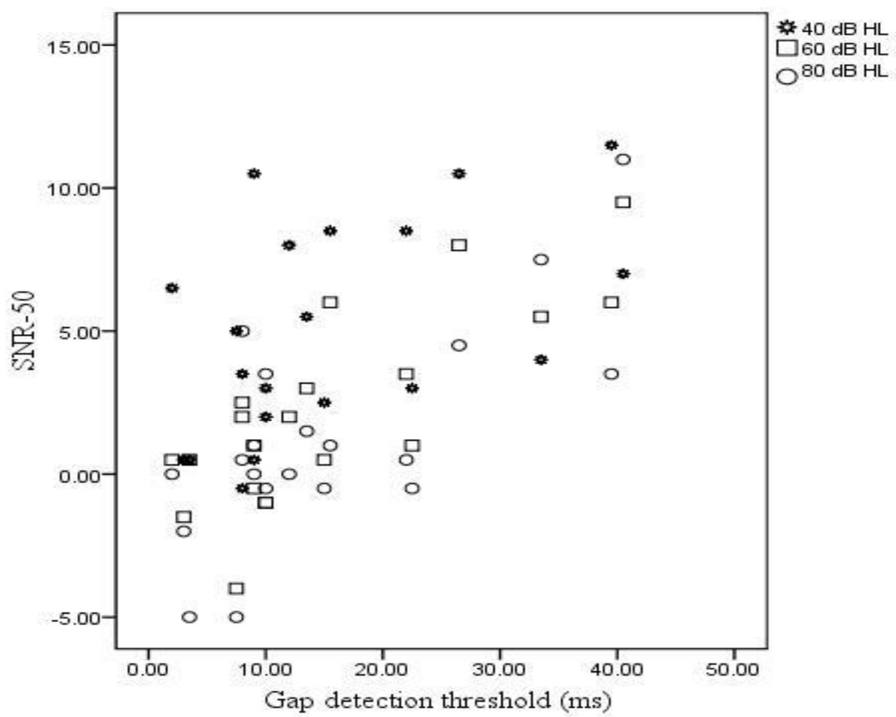

Figure.4.1. The relation between gap detection threshold and SNR-50 obtained using slow compression settings at three different presentation levels.

Chapter 5

DISCUSSION

Current study investigated the effect of presentation level and compression time settings on speech perception in adverse listening condition in older individuals. The results of the study revealed significant effect of presentation level and compression time settings on SNR-50. Further, temporal processing abilities of participants correlated well with their speech perception abilities.

5.1. Effect of presentation level on SNR-50

The results of the present study revealed that presentation level had a significant effect on SNR-50. Compared to lower presentation level (40 dB HL), SNR-50 improved significantly in both the higher presentation levels (60 & 80 dB HL). However, there was no significant difference in SNR-50 between the two higher presentation levels. Similar trend was observed while using both slow and fast release times.

The possible reason for improvement in speech perception with increasing presentation level could be lesser amount of distortion produced by the current hearing aids. In the current study, we used complete digital, wide dynamic range compression hearing aids having a small compression ratio. Investigations of Bentler and Duve (2000) that evaluated speech perception in noise at different SNRs (0, +5, +10 & +15) and presentation levels (53, 63, 83 & 93 dB SPL) revealed improvement in scores with increasing presentation levels. The improvement was reported for both syllabic and slow compression hearing aids. In contrast to these two hearing aids, there was a large deterioration in performance while increasing presentation levels for a body level hearing aid. Comparison of distortion of these three classes of hearing aids showed significantly higher distortion while using the body level hearing aids. They reported that reduced distortion and low compression threshold are accountable to higher performance across multiple input levels. Thus amplification strategies utilized in the current study (both slow and fast compression) having lesser distortion and a low compression threshold might have shown an improvement in SNR with increasing presentation levels.

5.2. Effect of release time on SNR-50

It was found that SNR-50 obtained while using a slow release time was significantly better than fast release time. This difference was found only at higher presentation level (mean of 60 & 80 dB HL) whereas no such difference was observed when the stimuli were presented at a lower level (40 dB HL). Inferior speech perception while using a fast compression setting could be due to acoustic alterations caused by a short release time. In contrast, slow compression setting having a long release time might have caused little acoustic changes in the signal.

Findings of Sauza, Jestand and Boike (2006) supported the acoustic effect of compression amplification on speech stimuli mixed with noise. They used an inversion technique to separate speech and noise. Using this technique, they studied the amplified signal (speech signal mixed with background noise) received by a listener. Sentences mixed with speech shaped noise at different SNRs (+2, -2, +6 and +10) were recorded using a linear as well as wide dynamic range compression algorithm. Signal-to-noise ratio before and after WDRC processing showed that at less favorable SNRs (−2 to +6 dB), the resulting SNR is even less favorable after compression. At the most favorable SNR +10 dB, compression has little effect upon the output SNR. In contrast, linear amplification does not lead to any change in input SNR. They speculated that the steady state noise that is amplified by the compression amplifier, especially during the speech pauses might have caused variation in SNR. At a +10 input SNR, there is little change in the output SNR, perhaps because the noise level is below the compression threshold, to activate compression.

In the present study, in order to determine SNR-50 we presented signals at different SNRs ranging from +12 to -6 dB in 2 dB steps. We also utilized a steady state speech shaped noise and presented to the hearing aid having two different compression settings of a WDRC hearing aid (slow and fast). Similar to earlier reports the fast WDRC setting might have caused less favorable SNRs at hearing aid output especially when the input SNR was poor. In contrast, the long release time settings of slow WDRC hearing aid might have caused similar effect as that of linear amplification. Hence, the participants of the present study required relatively better SNR to obtain 50% score when they were aided using fast compression time settings over the slow settings.

Analogous findings have been reported by Hansen (2002) who compared signals (continuous speech mixed with noise) processed using four different attack/release time settings (1/40, 10/40, 1/4000 & 100/4000). A simulated digital hearing aid with 15 independent WDRC channels having a compression threshold of 20 dB SPL was utilized for the experiment. Superior speech quality and intelligibility was reported in both normal hearing and older individuals with hearing loss whenever long release time settings were utilized.

In contrast to the findings of the current study, Vasil and Cienkowski (2005) reported no significant difference in performance in participant groups when release time settings were varied. There were three participant groups that included 14 young adults with normal hearing (18-35 years), 7 older adults with slight high frequency hearing loss (65-85 years) and 5 older adult with moderate hearing loss (65- 85 years). Release time setting used were fast (40 ms), slow (2560 ms) and intermediate (160 & 640 ms). Sentence perception at two signal to noise ratio was evaluated (+3 dB & +5 dB). Authors reported that release time might influence speech perception performance for some individuals. However, insignificant effect of release time was attributed to factors such as large amount of variability in speech perception scores, relatively small sample size (5 individuals), level of presentation of signal below the compression threshold of the hearing aid and the nature of the task that determine the percentage correct score only at two SNR levels. They recommended studying the temporal resolution, cognitive abilities and degree of hearing loss. This might helps to identify the individual who perform well with fast or slow release time.

In the current study, we addressed the above mentioned issues by including a relatively larger sample (20 individuals) and the level of presentation well above the compression threshold of the hearing id (60 & 80 dB HL). In addition rather than measuring percentage scores SNR-50 was determined by presenting a range of SNRs. Thus, Significantly better SNR found at normal conversational level using a slow compression time settings indicate the need for such a hearing aid setting for older individuals rather than using the most commercially available fast compression settings.

Comparable scores obtained at 40 dB HL for both fast and slow compression time settings could probably due the level of presentation. At this presentation level, the stimuli reached the hearing aid might be below its compression threshold (55 dB SPL) causing similar output for both slow and fast release times. Jenstad and Souza (2005) evaluated the effect of three hearing aid release time (12, 100 & 800 ms) on speech acoustics. A wide dynamic range compression hearing aid with a compression threshold of 45 dB, attack time of 6 ms and compression ratio 3:1was used. The stimuli used were vowel-consonant syllables presented at three different input levels of 50, 65 and 85 dB SPL. Acoustic analysis of hearing aid output using envelope difference index (EDI) showed little change in temporal envelope for stimuli presented at 50 dB SPL for all three-release times. As the input level increased from 65 to 80 dB SPL, EDI values increased, indicating a large change in temporal envelope.

5.3. Relation between temporal processing abilities and SNR-50

It was found that the participants of the current study had gap detection threshold ranged from 2 to 40 ms with the mean threshold being 15.6 ms. It was also noted that relatively better gap detection thresholds were found in younger participants whereas older individuals had poor gap thresholds. The poor gap detection thresholds in these participants can be attributed to the effect of aging on temporal resolution abilities. Similarly, temporal resolution abilities measured using gap detection test showed poor temporal processing in elderly individuals (Kumar & Sangamnatha, 2011). They reported greater gap threshold in individuals above 70 years (23.17 ms) whereas those participants between 61-70 years had better gap thresholds (6 ms). They reported that age is a strong predictor of gap detection abilities. Thus, in the present study, having participants aged between 60 to 70 years exhibited wide range of gap detection thresholds.

The results showed a strong correlation between gap detection threshold and aided SNR-50 obtained at two higher presentation levels. This was observed for both slow and fast release times. Similarly, there was a strong correlation found between gap detection threshold and unaided word recognition scores in both the ears. However, there was only a moderate correlation found when gap detection threshold and SNR-50 at lower presentation level (40 dB HL) were correlated. These results indicate that temporal processing abilities are good indicator of speech perception in adverse listening condition. As none of the participants in the study had any cognitive impairment and well-fitted binaural hearing aids overcome the problems related to audibility, speech perception problems in these individuals can solely be attributed to temporal processing impairments. Fostick, Ben-Artzi and Babkoff (2013) studied the effect of aging on speech perception in adverse listening condition after controlling the effect of hearing loss and cognitive impairments. Their findings revealed that temporal processing abilities were the major predictor of decline in speech perception in older individuals.

From the findings of the study, it can be concluded that older individuals exhibit temporal processing problems that adversely affect their speech perception in noise. Hearing aids with long release time lead to significantly better speech perception in adverse listening condition compared to that of hearing aids having fast compression settings. Well-fitted digital hearing aids having small compression ratio and lesser distortion help speech perception even at higher presentation levels.

Chapter 6

SUMMARY AND CONCLUSION

The present study investigated the effect of compression time settings and presentation level on speech perception in adverse listening condition in elderly individuals with hearing loss. Additionally, temporal processing abilities were evaluated using gap detection test, administered at two different presentation levels (60 & 80 dB HL). Twenty individuals in the age range of 60 to 70 years having mild to moderate sensorineural hearing loss were participated in the study. Aided SNR-50 was obtained using two different compression time settings (slow and fast) at three different presentation levels (40 dB HL, 60 dB HL, 80 dB HL).

Six lists of sentences taken from the recorded version of a phonetically balanced sentence test in Kannada (Geetha, Sharath, Manjula & Pavan, 2014) were used. Each list comprised of ten sentences each having four key words. Each sentence in a list was mixed with a speech shaped noise at a particular signal to noise ratio (SNR) ranged from +12 to -6 dB SNR. An SNR difference of 2 dB was maintained across the sentences.

In order to investigate the effect of release times and level of presentations on SNR-50 two-way repeated measure ANOVA was carried out. The results revealed a significant interaction between release time and level of presentation. Hence, the effect of presentation level on SNR-50 was analyzed separately for fast and slow release times. The results of one way repeated measure ANOVA revealed a significant effect of presentation level in both the compression time settings. Boneferroni pair wise comparison was carried to investigate the significance of difference between two pairs of presentation levels. The results showed significantly better SNR-50 at higher presentation levels (60 dB HL & 80 dB HL) compared to that of lower presentation level (40 dB HL). However, there was no significant difference in

SNR-50 between two higher presentation levels (60 and 80 dB HL). In order to compare the effect of fast and slow release times on SNR-50, paired sample t-test was performed at each presentation levels. As there was no significant difference in SNR-50 at 60 and 80 dB HL, their mean was considered for further analysis. The results showed that the performance (SNR-50) was significantly better with slow compression time setting than fast compression settings at higher presentation level (average of 60 and 80 dB HL). However, there was no such difference observed at the lower presentation level.

The relation between gap detection thresholds and SNR-50 were obtained using Pearson's product moment correlation. This was performed separately for fast and slow release times for the three presentation levels. The results revealed a strong positive correlation between gap detection thresholds and SNR-50 obtained for 60 and 80 dB HL for both fast and slow release times. However, there was only a moderate correlation between these two when the stimuli were presented at a low level (40 dB HL).

It is clear from the study that older individuals exhibit temporal processing problems that adversely affect their speech perception in noise. Hearing aids with long release time lead to significantly better speech perception in adverse listening condition compared to that of hearing aids having fast compression time settings. Well-fitted digital hearing aids having small compression ratio and lesser distortion preserve speech perception even at higher presentation levels.

Future Directions

The present study showed significantly higher speech perception in adverse listening condition, while using a hearing aid with long release time compared to that of a short release time. However, long term usefulness of such a compression setting need to be investigated. In the current study, speech shaped noise was used to bring an adverse listening environment. Testing with different types of noise or speech babble will help to understand clearly the difficulties in speech perception in different listening situations. Inclusion of medium compression time setting along with fast and slow settings will give more clear information about the involvement of compression time settings in the performance of elderly subjects. As most of the studies showed severe decrement in temporal processing skills after 70 years, similar investigations can be performed in a group of subjects above 70 years.

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