EFFECT OF RATE AND NOISE ON COMPRESSION RELEASE TIME IN SENTENCE RECOGNITION IN OLDER-ADULTS

Saale Roja

Register No. 12AUD025

A Masters Dissertation Submitted in Part Fulfillment of Final Year

Master of Science (Audiology)

University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSORE-570006

MAY, 2014

Certificate

This is to certify that this Masters dissertation entitled ó**Effect of Rate and Noise on Compression Release Time in Sentence Recognition in Older-Adults’** is a bonafide work in part fulfillment for the degree of Master of Sciences (Audiology) of the student with Registration Number 12AUD025. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other Universities for the award of any Diploma or Degree.

Mysore,

May, 2014

Prof. S.R. Savithri

Director

All India Institute of Speech and Hearing

Manasangangothri,

Mysore-570006

Certificate

This is to certify that Masters dissertation entitled ‘**Effect of Rate and Noise on Compression Release Time in Sentence Recognition in Older-Adults’** is a bonafide work in part fulfilment for the degree of Master of Sciences (Audiology) of the student with Registration Number 12AUD025. This has been carried out under my guidance and has not been submitted earlier to any other Universities for the award of any Diploma or Degree.

Mysore

May, 2014

Mr. Hemanth.N

Guide

Lecturer in Audiology

Department of Audiology

All India Institute of Speech and Hearing

Manasangangothri,

Mysore-570006

Declaration

This Masters dissertation entitled **'Effect of Rate and Noise on Compression Release Time in Sentence Recognition in Older-Adults'** it is the result of my own study and has not been submitted to any other university for the award of any other Diploma or Degree.

Mysore **Registration No. 12AUD025**

May, 2014

అంకితం....

My Dear AMMA, NANNA & Sibilings

THANKYOU FOR YOUR UNCONDITIONAL SUPPORT WITH MY STUDIES. I AM HONOURED TO HAVE YOU AS MY PARENTS. THANKYOU FOR GIVING ME A CHANCE TO PROVE AND IMPROVE MYSELF THROUGH ALL MY WALKS OF LIFE. THANKS A LOT MOM & DAD.

I LOVE YOU......

Acknowledgement

I would like to thank Lecturer in Audiology at AIISH Mr. Hemanth.N , for his constant support, guidance and understanding patience. sir, without your help and your constructive criticisms, this work would not have attained this shape. There is a saying that ***"If they can't learn the way we teach, we teach the way they learn*** - O. Ivar Lovaas" you are the one who follows it. Thanks you for all the support and encouragement.

I would like to thank two people, for making me responsible social being, they are my dear parents, whose prayers and motivation had made me what I am now. My Dear అమ్మ మరియు నాన్న*, I have no words to convey my love & gratitude towards you both. You have taken all the pains and sorrows to give me best of everything you can &* thanks for being the most adorable parents, without your love and affection I would not have reached where I am..... Thanks a loté ..

I would like to thank, Prof. S. R. Savithri , DIRECTOR AIISH, MYSORE, for giving me the opportunity to undertake this project.

I would like to thank Geetha mam and Sharath sir, for giving our project a starting point by providing the stimuli.

I would like to express my gratitude to all the participants of the study, for their kind co-operation throughout the study.

I would like to acknowledge all faculty in departments of audiology, AIISH for their care and constant criticisms which give us heart to withstand to the disasters. Thanks to One-and-all....

I extend my wholehearted thanks to library staff for giving us such a great access to knowledge... I would also continue to thank the Department of electronics, faculty Prof. Ajish Abraham, HOD, Mr. Purushotham, Mr. Ravi, Mr Raghavendra, and Mr. Shiva Kumar for providing us the superhighway connective (wi5) and clearing technical issues during the study.

I like to extend my sincere thanks to, Prof. P. Manjula, in the department of audiology, AIISH, for the knowledge she has shared regarding the Hearing Aids and her constant support and encouragement during our masters.

I am thankful for, Staff of AYJNIHH, SRC my 1st teachers in starting this career, in department of Audiology & speech Language pathology. For the knowledge you had shared and your constant teaching and encouragement, & for your care and support long way in my bachelors and masters and extended till now....Thank you allé é é é é

Thanks to Mr. KRANTHI, Mr. SHARATH (ANNA) youøre the role models in my life, where I learned how to withstand the wave's and rise higher and higher to lead this life. Thank you for your valuable SMILE at every movement, Please... have that smile always to enlighten our life's.

My Dearest Brothers VAMSHI and DINNU thanks for being more than a friendé a guideé a teacher.... n an inspirationé . Thanks a zillion.

Dear VIKKY (BAVA), MADHURI (SISTER) nd our Lion...i.e. Uncle MUKANTI... we all miss you a loté é . Hope your blessings are always with me.

Thank to RANGARAO BABHAI, BUJJI BABAI, SUDHA PINNI & LATHA PINNI & all my family members thanks for your affection and care mean a lot to me.

Itøs by chance we met, by choice we became friendsé é , AMAR, RANJITH, SRUJAN, HARIKA, UMA DEVI , RAMANA, VIJAY, SHILPA SHREE, ZEBU , TEJU SUHANI, SHABARISH & RAKI Thank you for being very good friends to meé . Rememberé our friendship is like wine it gets better as it grows older. My dear Guru ka.. GURU Ki shishya DeepU... and MaMu.. Thanks a lot 4r u, 4r being with me all the way and giving me support to get it done....

I would also like to thank all my crazy classmates.... SUMAN, RAMIZ, NIKHIL, RAJAN[3], SOUJI, PRAGI, SWATHI, MERIN, ROJI.

My dearest little friends, ANIL, CHITTI, SEENU, DIVYA ABHI, SHILPA, BALA, JAgu, (my b.sc)é itôs been fun growing up with you all, thanks for being the greatest fun in my life.

Thanks for my lovely juniors that I have irritated...d most, You guys are fun to be with and I will miss the time spent with you guys... AnyWays tC.. & I wish you all- The -Best.

I finally, thank my siblings CHINNA, CHINNU, SAHITHI & VISHALI Kutti Ibe.. 4r ur care and valuable time spent with me!!!!!!.....

Twinkle Twinkle little star!!! All I wonder where you areé é é our so called dear GOD,,, plz..give us the strength to put **out** of our life's é é

Thanks to all the passing clouds in my life, who taught me what is life either by hurting me or by being with me.. thanks a lot 4r one and all....!!!!

Even after 9yrs...! I still MisS U ***SOoₒ*** Your Furry Cuddles....; Your CUET face.. & Ur unconditional LOVE.. "Thanks" can't finish it off..My dear REX (PUPPY) my memories is with you, plz... come back.

My heart feals to thank MYyyyyy... cute LAPTOP.. 4r baring my stress all through & getting my work done... Thank U very much DeAr...

Yet another one to be acknowledged... There was a lot of people who called that name because of the Learning problem.. It felt like the whole world is falling down on me! having hard times at school...often, tears added up to the pouring rain... That's non-other than ROJA SAALE, I thank a lot myself.. 4r being the best 2 me & having the strength to face things. Keep dt Cute SMILE on ur face 4r Ever..thinking All Izz Well...... All Izz... Though I still wonder 4r my walk till here... This is only possible because of my HERO DAD & my Teachers.. Thanks a lot.. :)

Thanks to all whose names I might have missed out by mistakeé é ..

TABLE OF CONTENTS

LIST OF FIGURS

LIST OF TABLES

CHAPTER-1 INTRODUCTION

Speech is a complex acoustic signal, in which the spectral and temporal cues vary rapidly as a function of time (Jenstad & Souza, 2007). To understand speech, auditory neurons fire synchronously to the rapid time varying acoustic cues (Tremblay, Billings, Curtis, Rohila, & Neeru, 2004). Though in the absence of hearing loss, most often the older adultôs complaint, that they can hear but difficult to follow the speech in less-than-ideal conditions (Dubno, Dirks & Morgan, 1984). The decline in the recognition of speech may be due to reduced signal strength (Salthouse, 1985) as the noise mask the softer consonant (Helfer & Wilber, 1990) and fill the space of modulation depth (Houtgast & Skeenken, 1985) and also alter the spectral components in speech (Cohen, 2003). Feldman and Reger (1967) reported that older adults required 9 dB more to perceive speech compared to young adults, especially in the presence of noise.

In addition, the listeners are exposed to varied rates of speech. In a rapid rate of speech, though the phonemic spectrum is persevered the inter-phonemic gaps were reduced (Gordon-Salante & Fitzgibbons, 1997). Thus, the older adults having an impaired auditory system unable to capture these rapid temporal fluctuations (Gordon-Salant & Fitzgibbons, 2004). Further, deleterious effect on speech perception was noted in multiple degraded conditions (i.e., noise and rate) as the cues were distorted (Harris & Reitz, 1985; Wingfield, Poon, Lombardil, & Lowe, 1985) and its effect on recognition of target speech becomes difficult for older adults having hearing loss (Pichora-Fuller, Schneider & Daneman, 1995). Despite, the multiple cues were distorted by the environmental factors the older adults utilizes the rich contextual cues and/or redundancy of target test stimulus (Humes, Burk, Coughlin, Busey, & Strauser, 2007).

In the presence of hearing loss the problem in understanding of speech aggravates. It is well documented that older adult with hearing loss have impaired temporal precision (Gordon-Salant & Fitzgibbons, 2001). Hearing loss in older adults is associated with acquired changes in the peripheral auditory system, includes loss of hair cells, tissue of the stria-vascularis, and neural cells (Mills, Richard, Schmiedt, Larry & Kulish, 1990) spiral ganglion cells (Mills, Schmiedt,Schulte, & Dubno, 2006 , Bao, & Ohlemiller, 2010). The damage in stria- vascularis results hearing loss at higher frequencies (Dubno, Lee, Matthews, & Mills, 1997) which leads to significant reduction of endo-cochlear potentials (EP). Decreased EP either affects the excited nerve fibers or their synchronicity (Schulte & Schmiedt, 1992). These metabolic alterations may have concomitant changes at the higher auditory levels (Mazziotta, Phelps, Carson, & Kuhl, 1982).

To compensate hearing loss, hearing aids are prescribed. A hearing aid is one among the rehabilitative device alleviate hearing loss by providing gain, such that the aided threshold at different frequencies were well within the speech spectrum. Van Tasell (1987) reported that fast compression release time in the hearing aid has a greater negative effect upon the temporal envelope of speech. In a yet another report by Van Tasell, Soli, Kirby, and Widin (1987) stated that high frequency emphasis from amplification increases the consonant vowel (CV) ratio and thereby alters the temporal envelope of speech (ANSI, 1969). However, longer release time in compression preserve the temporal envelope than in shorter release time, which was quantified using envelope difference index (Jenstad & Souza, 2005). In addition, the speech stimuli processed from slow compression release time rated higher intelligibility (Jenstad & Souza, 2005), clarity and pleasantness (Neuman, Matthew, Bakke, Carol ,Mackersie, Sharon, Hellman, & Levitt 1998). However, the effect of noise and or rate of speech processed by the different strategies utilized in the amplification device are still questionable on the speech perception, especially in older adults having hearing loss.

The signal to noise ratio in conjunction with compression hearing aid can have a significant impact on an individualôs ability to perceive a target speech signal. The competing signals effectively mask the softer components (consonant phonemes) of the speech signal and the noise will be amplified in the region of pause within the sentence there by degrades the signal to noise ratio. Further, for low redudent sentence at varied rates (Normal, 50% time compressed and Time restored) processed by hearing aid compression showed altered temporal envelope, particularly the faster rate of speech resulted in dramatic reduction of sentence recognition. The difficulty of sentence recognition even increases with advancing in age of older adults (Jenstad & Souza, 2007).

Thus, the following research questions were formulated as a) Is any of the strategies (linear; fast and slow release time compression) improve the sentence recognition in lesser signal to noise ratio for the normal and 35 % compressed rate of sentences in older adults with and without hearing loss b) If it improves then in which strategy the study participants recognises the normal and 35% compresed rate of sentences in the presence of noise and c) Is the sentence recognition same in different experimental condition between older adults having with and without hearing loss.

Need of the study

In older adults, temporal precision is impaired (Gordon-Salant, 2005). One among the rehabilitative device is hearing aid. Though hearing aid alleviates the audibility, temporal alteration is more likely in shorter release time than the longer release time and it depends on the intensity of the signal (Jenstad & Souza, 2007). Additionally, the environmental factors such as noise and rate of speaker has a deleterious effect on speech perception. The rate at which speaker conveys information may alter the subtle temporal cues of speech (Anderson, Schwoch, Clark, & Kraus, 2013). Further, the presence of noise masks the temporal modulation of speech (Drullman, 1995). Thus, there is a need to know, how these environmental factors (rate and noise) interact in each of the amplification strategy (linear; fast and slow release time compression) on the recognition of sentences in the older adults having bilateral sloping sensorineural hearing loss.

Aim of the study

The aim of the present study was to investigate the combined effect of rate and noise on recognition of amplified sentences in older adults with and without hearing loss.

Objectives of the study

1. Recognition of the normal rate of sentences processed from each strategy, in different SNRs from the participants of older adults without hearing loss (group-I) and older adults with hearing loss (group-II).
2. Recognition of the normal rate of sentences processed from different strategy, in each SNR from the participants of the group-I and group-II
3. Recognition of 35 % compressed rate of sentences processed in each strategy, in different SNRs from the participants of group-I and group-II

4. Recognition of 35 % compressed rate of sentences processed from different strategies, in each SNR from the participants of the group-I and group-II
5. Recognition of sentences between group-I and group-II for the normal rate and in 35 % compressed rate of sentences processed in each strategy, in different SNRs.

Hypotheses

1. None of the strategie improves the sentence recognition for either normal or 35 % compressed rates of sentences presented in different SNR in older adults having with and without hearing loss.
2. There is no difference in the recognition of sentences between strategies in each SNR for either normal or 35 % compressed rates of sentences in older adults with and without hearing loss and
3. There is no difference in the performance between older adults having with and without hearing loss in different experimental conditions.

CHAPTER-2 REVIEW OF LITERATURE

Speech perception is a process of decoding a message from a steam of input sound coming from speakers (Borden &Harris, 1980). To interpret speech a series of processes involved in the different parts of the auditory pathway. The information processed by the auditory system is rapid. In older adults having hearing loss, spectral and temporal impairment are apparent. However, in the presence of noise at various intensities around the environment has a detrimental effect on the speech perception. In addition, rate of speech from different speakers varies from realistic situation, which has a negative impact on speech perception. To mitigate the audibility, hearing aid is prescribed, but its working principle in multiple degraded conditions is still unresolved. Though there is an advent of hearing aid technology to preserve the acoustic content of speech, the extent of benefits avail from the hearing aid is unpredictable especially in the presence of noise and or rate of speech. In this connection, the literature has been reported under the following headings.

1. Perception of speech in the presence of noise in older adults.
2. Speech perception in the varied rate of speech in the older adults.
3. Perception of speech in combined effect of noise and ratein the older adults.
4. Compression release times of hearing aid on speech perception in older adults.

Perception of speech in individuals with older adults having with and out hearing loss

Hearing impairment caused due to aging is referred as presbycusis which is one of the most chronic condition affecting older listeners above 60 years of age

(Cruickshanks et al. 1998). The older listeners often report difficulty communicating in adverse listening situations. Perception of speech is a process of decoding a message spoken by the speaker (Borden &Harris, 1980). The speech spectrum and temporal cues changes rapidly in a going stimulus over time. These changes might occur in slow or rapidly (Kewley-Port 1983; Kewley-Port & Neel 2003). However, in the presence of noise older individual find it more difficult to capture inherent cues as the modulation depth present in the speech signal were filled by noise and also alters the spectral components of speech (Cohen, 2003).

Perception of speech in noise condition. To interpret speech a series of processes involved in the different parts of auditory pathway (Hickok & Poepple). A group of researchers Dubno, Dirks, and Morgan, (1984); Gordon-Salant and Fitzgibbons, (1993) and Helfer and Wilber (1990) has well documented regarding age-related decline in understanding speech in degraded situation. Helfern and Wilber (1990) used nonsense syllables to assess the performance in the older adults having with and without hearing loss. They presented nonsense syllables in the presence of multiple degraded conditions (i.e., noise and reverberation). The results revealed that older adults failed to perceive acoustic cues in nonsense syllables. It was concluded that the low intense portion of non syllables are obscured by noise and reflection of previously heard stimulus overlap on subsequent phoneme of syllable alter the spectral cues. These caused detrimental effect on perceiving nonsense syllables in older adults having hearing loss.

In a similar line of research by Philips, Richter and McPherson (2009) who examined perception of voiced consonant vowel (CV) syllables in older adults with normal hearing and two groups of listeners with mild to moderate sensory neural loss. The two groups were formulated based on their good and poor word recognition scores. The study participants were instructed to identify CV syllables spoken separately by male and female talkers. Results revealed that older adults with hearing loss and those older adults who had poorer word recognition scores (WRS) showed more errors in the presence of noise compared to listeners with hearing loss who had good word recognition.

In yet another study by Hornsby et al (2011) who investigated the word recognition scores in younger adults and older listeners in the presence of competing speech babble noise, which is temporally or spectrally distorted. The results revealed that the word recognition scores reduced significantly in older adults having hearing loss than older adults without having hearing loss. They attributed their finding to combined effect of aging and hearing loss and its concomitant changes at their central auditory pathway.

It is evident from the earlier research that perception scores were reduced irrespective of stimulus used in investigating the perception ability in older adults having hearing loss. These makes to rethink on which cues the older adults finds difficult to recognize speech. Thus, Hopkins and Moore (2011) conducted study in measuring temporal fine structure sensitive, frequency sensitive and speech reception in noise in the normal hearing younger adults (NHY) and normal hearing older adults (NHO) and older adults with hearing impairment (OHI). The results revealed that NHO group performed significantly poorer than the NHY group in TFS. In addition, the OHI group received lesser sensitivity scores on TFS and frequency sensitive than other groups, these differences found significant. The findings suggest that TFS sensitivity declines with age in the absence of elevated audiometric thresholds or broadened auditory filters. However, in older adults having hearing loss have problem in utilizing both TFS and frequency sensitivity.

Though the older adults with hearing loss have spectral and temporal impairment, in the contextual rich condition the deterioration of perception scores is minimized. Pichora-Fuller et,al. (1995) reported that the older adults having near normal hearing and hearing loss had the perceptual scores similar that of younger adults for the high level predictive sentences in the presence of noise. In yet another study by Fuller (2003) who reported that older adults most often utilizes the contextual cues if the speech is embedded in the noise.

To summaries, the older adults having hearing loss suffer from impaired temporal resolution due to impaired synchronous neural firing. In addition, spectral resolution is impaired because of broadened auditory filters. The impaired physiological mechanism in older adults unable to process the inherent cues in speech which is embedded by noise at varying signal to noise ratios. Thus, in adverse listening situation the older adults tend to look for contextual cues.

Speech perception in the varied rate of conditions. The rate of speech from different speakers varies in the realistic environment, which has negative impact on speech perception. Stine et al, (1990) reported a slow conversational speech lies within 90 words per minute (Wpm) and it may go up to 140-180 wpm. However, the conversation from a prepared script i.e. in radio, television and news reading exceed the rate of 210 wpm.

There are many studies with reference to the effect of age related hearing loss on the perception of varied rate of speech. Wingfield, McCoy, Peelle, Tun and Cox (2006) formulated the study designed to see the effect of hearing sensitivity and age-related change on the perception of syntactic complex sentences. These sentences are presented at different rates in younger and older adults with normal hearing and with mild-to-moderate hearing loss. The results revealed that those older adults having normal hearing sensitivity had better comprehension of syntactically complex sentences, even presented at rapid speech rates than their counterparts. Gordon-Salant and Fitzgibbons, (2004) opined that older adults having hearing loss are unable to follow the rapidly altering cues in an ongoing speech, as the inter-phonemic gap reduces in sentences, though the spectral component of speech is preserved. Salthouse (1982) studied relationship between speech perception and cognitive mechanism in older adults. He investigated the role of reaction time in understanding speech presented at varied rate. The result revealed that those older adult individuals who had good reaction time performered relatively better than their counterparts. Further, Bryan et al (1999) reported that older adults have difficult in switching the attention from one stimulus to another. In yet another study by Sommers et al (1994) who investigated the effect of rate manipulated across the stimuli. The findings showed that young listeners have poorer speech recognition scores in these variable conditions than in older adults. It suggest though the hearing acuity was normal, the increased cognitive lode on perceptual can limit the speech identification.

To summaries, in varied rate of speech the inter-phonemic gaps were reduced. In addition at higher rate of speech the spectrum of adjacent phoneme overlap on the previous phoneme. Thus, these distortions led to unfamiliar sound pattern. However, on the other hand the older adults have problem to encode the rapid fluctuations and the reaction time taken to attend to the stimulus was longer, such that adjacent stimulus occupies the previously processed segments of speech lead to the confusion. These might bring load to the cognitive system.

Perception of speech in combined effect of noise and rate conditions. In real life condition speech is seldom free from noise. In addition, the rate of speech varies from speaker to speaker. Gordon-Salant and Fitzgibbons, (1997) conducted experiment on effect of combined interaction of rate and noise on speech perception in older adults having with and without hearing loss. The results revealed that older adults having hearing loss showed deleterious effect on speech perception. They attributed multiple degraded conditions affected the acoustic cues and these distorted cues did not even transfer the modest cues to access the redundancy present in the sentences. In such condition, 30 dB signal intensity was required by the impaired older adults to process the information (Summers & Molis, 2004). In yet another study in the similar line of experiment by Gordon-Salant and Fitzgibbons, (1995) who reported that young adults with hearing loss performed relatively better in the 40 % time compressed rate and with the + 16 dB SNR than other combinations of compressed rates and SNRs of the target test stimuli.

Compression release times of hearing aid on speech perception

Hearing aid is one among the rehabilitative device prescribed to restore the audibility in the cohort of hearing impairment. The working principle of compression parameter in the hearing aid is same of the cochlear amplifier. That is the amplification is provided for the low level sounds and compression for the high level sounds. Unlike cochlear mechanism, the hearing aid in compressor is not rapid. Thus, to retain the function of hearing aid to work similar to that of human cochlea, the attack and release time are incorporated. However, in the literature there is equivocal opinion among the effectiveness of release times in the hearing aid on sentence perception in the older adults especially in the presence of noise.

Thus, in this section the effect of amplification release time in the older adults are reviewed and explained elaborately.

The individuals with sensorineural hearing loss (SNHL) are limited in their ability to make use of information from the amplified speech particularly at high frequencies (Amos & Humes, 2007). Several investigations have proved that this limited benefit is related to the degree of high-frequency hearing loss. Specifically, if the degree of high frequency (3000 to 4000 Hz) hearing loss exceeds 55 to 80 dB HL, the benefit from amplification of speech components within this high-frequency region is limited (Hogan & Turner 1998). This is because the older adults hearing acuity were reduced in the high frequencies and required higher gain of the amplification device. This affects the communication abilities, quality of life and well being of older individuals. Difficulties in communication for hearing impairment can lead to a reduction in social networks, depression (Hickson & Worrall, 1997). The fundamental aim of Audiological rehabilitation is to maintain and improve communicative function in older adults. Although after being fitted with hearing aid many older adults with hearing impairment might have or not continue to have substantial communication difficulties (Hickson & Worrall) due to their environmental and physiological factors. In addition, the strategies utilized in the hearing aid help the hearing impaired individuals to lessen communication difficulties.

Humes et al (1999) investigated the aided performance from the linear and two channels wide dynamic range compression hearing aid. Fifty five individuals with sensori-neural hearing loss were participated in the study. All the participants were regular hearing aid users for one year. The aided performance was evaluated using monosyllabic words and sentences presented at three different intensity levels in quiet and noise. Evaluations were done after one month use of linear or wide dynamic range compression hearing aid. Speech identification scores for both words and sentences in quiet condition showed significantly higher perception using wide dynamic range compression than linear amplification. Similarly, ease of listening and quality were also rated higher using wide dynamic range compression hearing aid than linear hearing aid. The higher performance using compression hearing aid over linear was attributed to nonlinear gain characteristics which provided more gain to the lower input signal (weaker consonants) than higher level input. Among compression hearing aids of different release time there is mixed opinion. Van Tasell (1987) reported that fast compression release time in the hearing aid has greater negative effect upon the temporal envelope of speech. In a yet another report by Van Tasell, Soli, Kirby, & Widin (1987) stated that high frequency emphasis amplification increase the consonant vowel (CV) ratio and there by alters the temporal envelope of speech (ANSI, 1969) and some hearing impaired individuals increased CVR provided cues for the understanding of consonants. However, longer release time in compression preserves the temporal envelope than in fast release time, which was quantified using envelope difference index (Jenstad & Souza, 2005).

Jenstad and Souza (2005) carried out a study to assess the effect of compression release time (12, 100 and 800 ms) on speech perception skills in individuals with moderate sensorineural hearing loss, in quiet and noise conditions. The speech stimuli used was Vowel consonant (VC) syllables. These speech stimuli were processed through a hearing aid having the option to change the compression release time. These processed VC syllables were presented at three input levels (55, 65 and 85 dB SPL). The results revealed that shorter release times (12 and 100 ms) had a greater alteration in temporal envelope, which was varied by envelope difference index (EDI) and consonant vowel ratio (CVR). However, the longer release time preserved the temporal envelope of VC syllables (800 ms). The results revealed that the perception is equivocal at 55 dB SPL. At 65 dB SPL and 85 dB SPL the speech perception was relatively good at the longer release time compared to shorter release time in the older adults having hearing loss. This is because the compression in the vowel will not be released and continued even in time to amplify for the consonants and thus the gain alteration is minimized.

Further, the quality of speech processed by different compression release time was studied by Neuma, Matthew, Bakkea, Hellman and Levitt (1995). They varied the compression ratios (1.5:1, 2:1, and 3:1) and compression release time (60, 200, and 1000 ms) in the hearing aid with the constant attack time 5 ms. Twenty participants with sensorineural neural hearing loss were evaluated for quality of speech using Paired comparison method. The results revealed that the study participants rated higher sound quality for the stimuli, which were processed through longer release time and lesser compression ratio.

In a Similar study, Neuman, Bakke, Mackersie, Hellman and Levitt (1998) evaluated the clarity and pleasantness of hearing aid processed different compression ratios (1.5:1, 2:1, and 3:1) and release times (60ms, 200ms, 1000ms) and other parameter such as compression threshold (65 dB SPL peak) and attack time (5ms) were kept constant. Rating of pleasantness using release time of 200 ms and 1000ms was significantly higher than the release time of 60 ms. Further, rating of clarity and pleasantness were minimal for the stimuli processed by higher compression ratios with longer release time. Hence, authors concluded that release time have negligible effect when higher compression ratio was used.

Thus, from literature it was evident that longer release preserve temporal envelope. In addition, the speech stimuli processed by the longer release time were rated superior on speech quality, intelligibility, clarity and pleasantness by the study participants. However, its effect is only apparent if the stimuli were presented at conversational level or at the higher level.

Till now we have reported the studies on effect of compression release time on speech perception in the presence of noise. However, in the realistic environment, along with noise the rate of speech is altered by some speakers which might be an annoyance for the hearing aid users. In this connection Jenstand and Souza (2007) investigated the combined effects of rate and compression on the recognition of low predictive sentences in the older adults having hearing loss. In their first experiment the effect of compression in the processing of varied rate of low predictive sentences (Normal rate, 50 % compressed rate of sentence and time restored) on the temporal envelope were verified by envelope difference index. Further, the processed sentences were presented to young, old adults and old-old adults. The results revealed that performance scores were reduced irrespective of age for those sentences having altered temporal envelope. That is a greater temporal alteration noted in 50 % compressed speech processed by the compression hearing aid circuit than other normal rate and time restored amplified speech. They conclude that temporal alteration is detrimental to the recognition of sentences, especially in the rapid rate of speech. In this scenario older adults tend to use redundancy cues rather than following the rapid fluctuation in the sentences. However, the effect of rate processed by compression release time in the presence of noise has not been studied. Thus, there is need to study the combined effect of rate and noise on the recognition of amplified sentences on older adults having bilateral sloping sensorineural hearing loss.

CHAPTER- 3 METHOD

One short pre-test, post-test only repeated measures design was used to study the effect of rate and noise in linear and in two compression release times on sentence recognition upon older adults with bilateral sloping sensorineural hearing loss.

Participant selection criteria

In total, twenty two participants were included in the study. They were classified into two groups, i.e., Group I (older adults with normal hearing) and Group II (older adults with hearing impairment). The group I comprised of twelve participants having normal hearing sensitivity to the age range of 55 to 70 years (mean age 69 years). Ten participants of age matched Group II (mean age 75 years) having bilateral sloping sensorineural hearing loss were included in the study.

Inclusion criteria

The following criteria were considered for the selection of participants in group I and in group II.

Group I.

1. Hearing sensitivity was Ò15 dB HL in each octave, frequency, i.e. from 125 Hz to 2000 Hz and Ò25 dB HL from 3000 to 8000 Hz.
2. The speech recognition score was Ó90 % (Dirks, & Wilson, 1969).

3. Participants had normal middle ear status with óAô type tympanogram and measurable ipsi- and contra- lateral reflexes were present at octave frequencies from 250 Hz to 4000 Hz.
4. Participants had normal intelligence quotient (IQ) scores in the mini mental status examination.

Group II.

1. Hearing sensitivity ranged from mild to moderate sensorineural hearing loss, which is operationally defined as thresholds from 125 Hz to 2000 Hz Óto 25 dB HL and from 3000 to 8000 Hz Óto 65 dB HL (Pittman, & Stelmachowicz, 2003).

2. The speech recognition score was Ó70 % (Dirks, & Wilson, 1969).

3. Participants had normal middle ear status with óAô type tympanogram.

4. Measurable ipsi- and contra- lateral reflexes were present at octave frequencies from 250 Hz to 4000 Hz.

5. Participants had normal intelligence quotient (IQ) scores obtained in the mini mental status examination.

None of the participants (group I and group II) had no complaint of neurological, psychological, cognitive or otological problems. All the participants had adequate speech and language skills. All the participants are the native speakers of Kannada.

Test environment

Testing was carried out in a sound treated double room, with the ambient noise levels within permissible limits as recommended by ANSI (1999).

Instrumentation

The following instruments were used (a) to select the participants of two groups, (b) prepare the sentences at compressed rate, (c) to add noise at various signal to noise ratios in the normal and compressed rate of sentences and (d) to deliver the prepared sentences.

1. A calibrated diagnostic two channel audiometer (Orbiter 922 Version 2) was used to obtain hearing sensitivity and also to present the sentences in participant desired intensity.
2. Immittance audiometer (GSI Version 2) was used to evaluate the status of the middle ear.
3. Behind the Ear (BTE) digital hearing aid, which had the option of varying the compression release times was selected to record the output of processed sentences.
4. Fonix 7000 real ear measurement system was used to verify the compression release times in the hearing aid.
5. Pratt software (Version 4.6.09) was used to change the rate of sentence (i.e., 35 % compression rate) using algorithm Time-Domain Pitch- Synchronous

Overlap-and- Add (TD-PSOLA) developed by Moulines and Charpentier (1990).

6. Cubase software (Version 6) was used to make a separate audio - track for normal rate and 35 % compressed rate of sentences and also served as a platform to present the sentences.
7. Sound level meter (SLM) with ½ inch (free field) microphone was used to calibrate the target test sentences.
8. Loudspeaker (Genelec 8020 B Speakers) which were mounted on the ISO - Pod™ (Isolated position/ decoupler™) vibrating insulating table stand and is located at 0° Azimuth, was used to present the prepared target test sentences.
9. SLM with one inch (pressure field) microphone and 2 cc coupler were used to record processed target sentences (i.e., in linear and in two release times in the hearing aid i.e., 40 ms and 640 ms).
10. MATLAB (Version 2009B) software was used to add speech babble noise to the sentences at various signal to noise ratios (i.e., +10 dB SNR, +5 dB SNR and +3 dB SNR).
11. Compact disk (CD-R 700MB) player was used to play the recorded target test sentences, which was connected to an auxiliary input of audiometer (Figure 1). The output of audiometer was delivered through headphone THD 49.

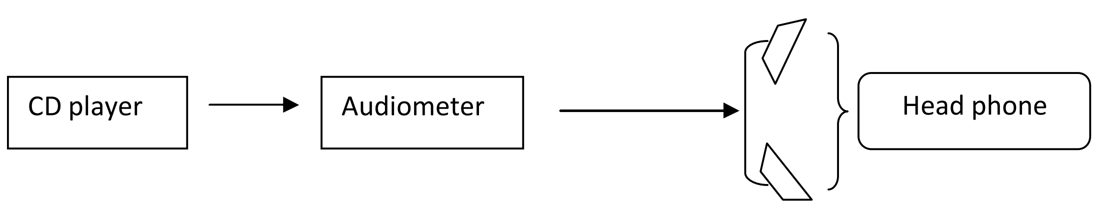


Figure 1. Instrumentation for presenting the target test sentences

Test materials

1. Mini Mental Status Examination (MMSE) questioner was used to rule out the cognitive deficits in both the groups.
2. Six lists of 25 words in each list prepared by Yathiraj and Vijayalakshmi (2005) were used to identify Speech Identification Score (SIS).
3. Kannada passage (Sairam & Manjula, 2002) was utilized to obtain the most comfortable level.
4. In total, 180 low predictive sentences prepared by Geetha and Sharath (2013) were used for sentence recognition task.

Procedure

The following procedure was used to select the participants, preparation of stimulus and listening conditions.

Selection of participants.

1. Pure tone air conduction threshold in each octave frequency from 250 Hz to 8000 Hz was obtained by modified Hughson & Westlach procedure using +5 (no response) and -10 dB (response) rule (Carhart & Jarger, 1965). Similarly, pure tone bone conduction threshold was obtained in each octave frequency from 250 Hz to 4000 Hz.
2. The speech identification test developed by Yathiraj & Vijayalaksmi, 2005 was administered at a level of 40 dB SL (re: speech reception threshold, SRT). Each participant was instructed to repeat the words heard. The total number of correctly identified words was noted down and then converted to percentage to calculate the speech identification scores (SIS).

3. Immittance test was done in each participant to know the status of the middle ear. Tympanometry evaluation was carried out using a probe tone of 226 Hz with a pump rate of 600/200 daPa/ sec. Change in air pressure rate of 200 daPa /Sec. Ipsilateral and contralateral acoustic reflex thresholds were measured at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz by varying the intensity of stimulus in 5 dB-steps to observe changes in acoustic admittance.

Preparation of Stimulus. A total of 24 lists of sentences was required for the preparation of processed target test sentences at the two rates (normal rate and 35 % compressed rate) in each condition (quiet, +10 dB SNR, +5 dB SNR, and +3 dB SNR) under different strategies (linear, 40 ms compression release time and 640 ms compression release time). Eighteen lists of sentences were adapted from Geetha and Sharath (2013). Another 6 lists of sentences were randomly selected from the 18 lists of sentences using randperm m-code. These 24 lists of sentences were randomized and equally divided into two having 12 lists of sentences in each. The first 12 lists of the normal rate of sentences were made into 3 sets of 4 lists in each. Another 12 lists of sentences were time compressed by 35 %. The 12 lists of compressed rate of sentences were made into 3 sets of 4 lists in each.

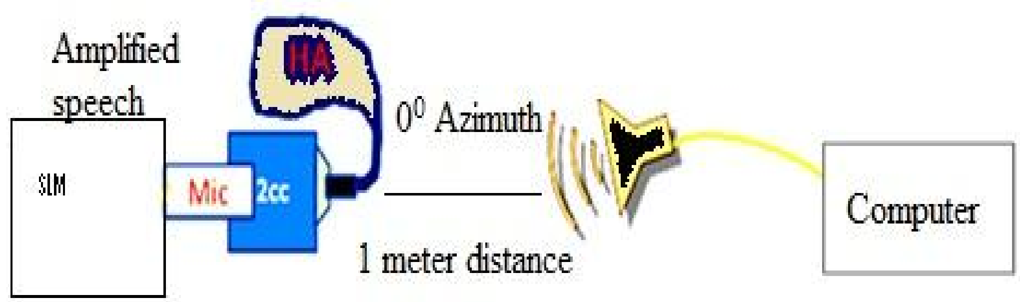
Preparation of compressed sentence: The sentences in each list were compressed using the TD-PSOLA in the Praat software. The “lengthen” option was selected to alter the tempo of the signal without affecting its pitch. Initially, each sentence was decomposed into short-time signals based on pitch synchronous marks. A factor of 0.65 was specified to squeeze the entire duration of the original sentence to 35 % compressed rate. This was done by removing the same pitch period within each short-time signal.

This method preserves the intelligibility in the compressed version of the sentence, but the naturalness was compromised.

Sentences processed in different strategy and adding noise: Prerecorded sentences in normal rate and prepared 35 % compressed rate of sentences are imported into the CU base software (Version 6). The 12 lists of the normal rate of sentences were audio- tracked separately. In each audio-track, ten sentences were concatenated with the inter-sentence interval of 5 Sec. A similar procedure was carried out to audio-track the 35 % compressed rate of sentences. The intensity of each sentence was presented at 65 dB SPL for recording the processed sentences under each strategy (i.e. Linear and two compression release time). The Sound level meter (SLM) connected with ½ inch (free field) microphone was positioned at one meter distance at 0^0 Azimuth away from the loudspeaker. The CU base Mixer was used in order to adjust the volume level to get the desired intensity level.

Further, the hearing aid was programmed for high frequency sloping sensorineural hearing loss. The following procedure was carried out to program hearing aid. The test hearing aid was connected to the HiPro that in turn connected to a computer in which the NOAH and hearing aid specific software are installed. Through the hearing aid programming software, the hearing aid was detected. The option of first fitting was selected for programming. The hearing aid was programmed using NAL NL1 prescriptive formula at an acclimatization level of 2. The compression ratio was made 1:1, such that hearing aid function linearly.

After programming, the hearing aid was attached to one end of the coupler and to the other end of coupler one inch pressure microphone was connected, which in turn attached to the SLM. The microphone of the hearing aid was positioned at one meter distance at 0^0 Azimuth away from the loudspeaker (Figure- 2). The first set of four lists, of the normal rate of sentences (four separate audio-tracks) were presented and the output of the hearing aid was recorded. The recorded output of each sentence from the four audio-tracks were cropped and saved separately. Apart from the first list, each sentence in the second list of normal sentence rate was digitally mixed with speech spectrum-shaped noise at +10 dB signal to noise ratio (SNR) using the SNR MATLAB code. The noise onset preceded the onset of a sentence by 600 ms and continued till 600 ms after the end of the each sentence. The noise was ramped using the Cosine square function with ramp duration of 200 ms The onset of the noise before the onset of sentence is believed to guard against unintended onset effects. Each sentence in the third and fourth lists of the normal rate of sentences were digitally mixed with speech spectrum-shaped noise at + 5 dB SNR and + 3 SNR, respectively. Similarly, the first four lists of 35 % compressed rate of sentences were recorded from the hearing aid (linear strategy).



Figures 2. Illustration of instrumentation used to record the processed sentences in different strategies.

In addition, the hearing aid was programmed to 40 ms compression release time with the compression threshold set at 55 dB SPL. From here onwards the 40 ms compression release time described as fast compression. The hearing aid time constant was verified using Fonix 7000 hearing aid analyzer. The second set of four lists of the normal rate of sentences was presented and the output of the hearing aid (in fast compression) was recorded. Apart from the first list, each sentence in the second, third and fourth lists of the normal rate of sentences was digitally mixed with speech spectrum-shaped noise at +10 dB SNR, +5 dB SNR and +3 dB SNR, respectively. Similarly, the second set of four lists of 35 % compressed rate of sentences was recorded from the hearing aid (fast compression strategy). Further, the entire procedure was repeated by recording the output of the hearing aid programmed to 640 ms compression release time for the third set of normal rate and 35% compressed rate of sentences. From here onwards the 640 ms compression release time described as slow compression. The matrix of sentence present in different experimental conditions is depicted in Figure 3

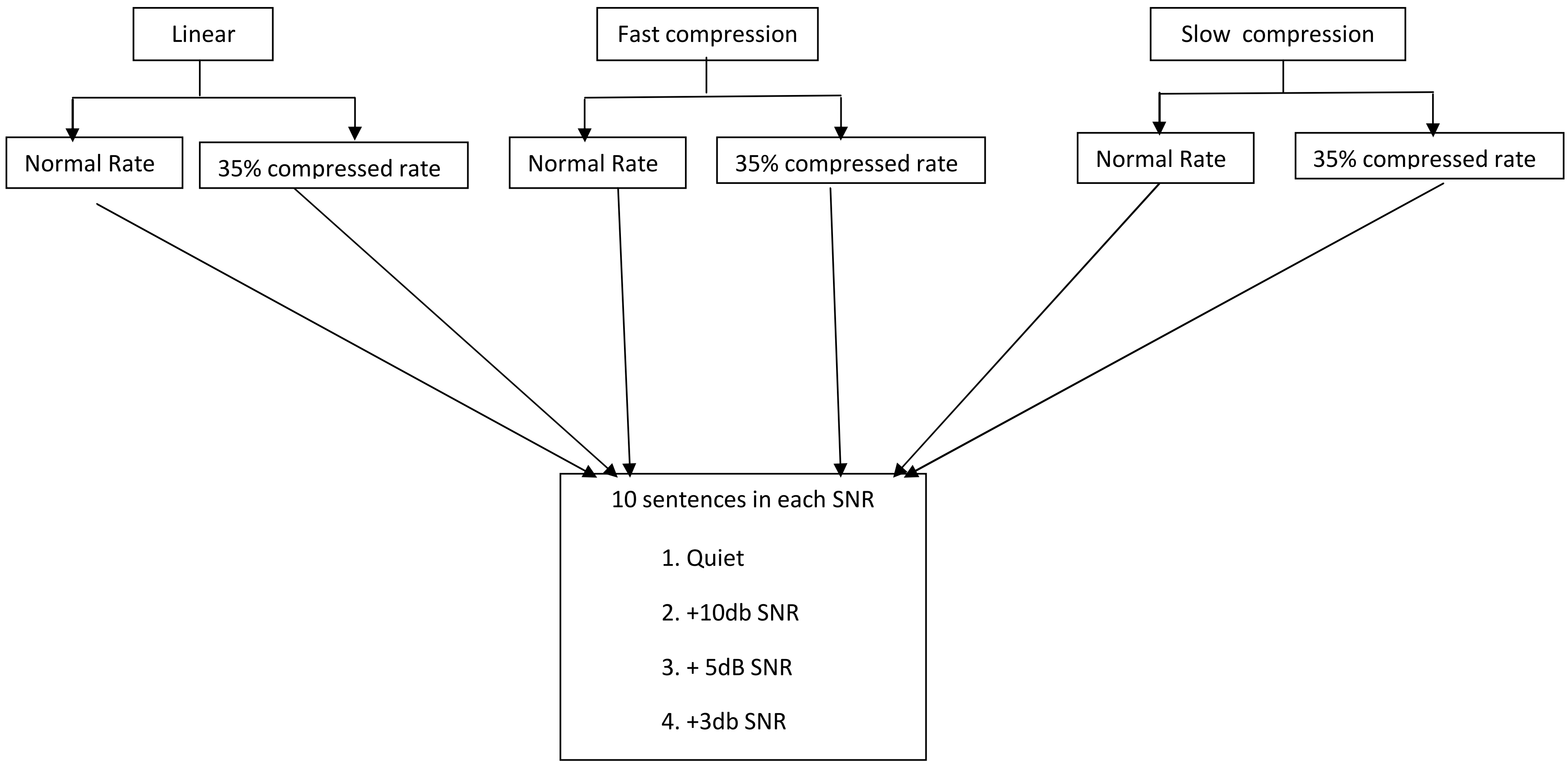


Figure- 3. The paradigm of sentence presentation in linear and in two hearing aid time constants.

Listening condition

Each participant was tested for a total of 24 lists of test sentences [two rates (normal rate and 35 % compressed rate) in each condition (quiet, +10 dB SNR, +5 dB SNR, and +3 dB SNR) under different strategies (linear; fast and slow compression)]. These lists were loaded in compact disk. These sentences were presented at each participant most comfortable level (MCL) level. The MCL was determined by presenting the recorded Kannada passage, though the auxiliary input of the audiometer. The output of the audiometer was delivered through headphone at the level of individual SRT. Gradually, the level was adjusted in 5 dB-steps up to the level of MCL and then in 2 dB steps until the MCL of the participant was established reliably using a bracketing technique (-2 dB and +1 dB).

Further, the recorded sentences in compact disk were routed through the audiometer and delivered into headphones. The recorded sentences were presented in randomized order with inter sentence interval of 10 Sec at the level of MCL. Each participant was instructed to repeat the sentences heard. Ten minutes break was provided after every presentation of 40 sentences. A total of approximately one hour time was required to complete the data collection on one participant. For each correct recognition of a full sentence, one mark was assigned.

CHAPTER- 4 RESULT

The aim of the present study is to know the effect of rate and noise on compression release time in the recognition of sentences upon older adults having a bilateral sensorineural hearing loss. The date of sentence recognition scores obtained from each strategy (linear; fast and slow compression release times) in normal rate and in 35 % compressed rate presented in different SNRs (quiet, +10 dB SNR, +5 dB SNR and 0 dB SNR) upon older adults with normal hearing (Group-I) and older adults with bilateral sloping sensorineural hearing loss (Group-II). These data were subjected to statistical analyses. The Statistical Package for Social Science (SPSS) was utilized to carry out the statistical analyses. The analyses performed under each objective of the study are reported as follows.

Recognition of the normal rate of sentences processed from each strategy, in different SNRs from the participants of the group-I and group-II

Descriptive statistical analyses were performed to document the mean and standard deviation of sentence recognition scores for the normal rate of sentences processed through each strategy, in different SNRs from the group-I and group-II. Further, two way repeated measure ANOVA (strategies and SNRs) with between subject factor as groups was conducted to see the interaction effect of strategies and SNRs on the normal rate of sentences.

The mean and standard deviation of sentence recognition scores in each strategy, in different SNRs obtained from the participants of the group-I and group-II are tabulated in Table 1. It was noted that the mean sentence recognition scores were reduced linearly as a function of SNR, in each strategy from the participants of the group-I (Figure -4) and group-II (Figure-5). That is, the sentence recognition scores were reduced with lesser SNRs.

Table 1. *Mean and Standard Deviation (SD) of sentence recognition scores obtained from each strategy in different SNRs from the participants of the group-I and group-II.*

	Group -I			Group -II		
Conditions	Liner Mean ± SD	FC* Mean ±SD	SC* Mean ± SD	Liner Mean ± SD	FC* Mean ± SD	SC* Mean ± SD
Quite	9.91 ± 0.28	9.5 ± 0.66	9.8 ± 0.38	8.2 ± 0.91	8.5 ± 0.84	8.8 ± 1.22
+ 10dB SNR	9.7 ± 0.62	9.4 ± 0.77	9.0 ± 1.12	7.6 ± 0.69	6.6 ± 1.31	7.7 ± 1.01
+ 5 dB SNR	9.4 ± 0.79	9.3 ± 1.15	8.9 ± 1.22	6.3 ± 0.94	6.1 ± 1.59	6.6 ± 1.77
+ 3 dB SNR	7.90 ± 1.08	8.9 ± 1.37	6.9 ± 1.32	5.8 ± 1.87	5.9 ± 1.85	4.6 ± 1.31

*FC ï fast compression; *SC ï slow compression

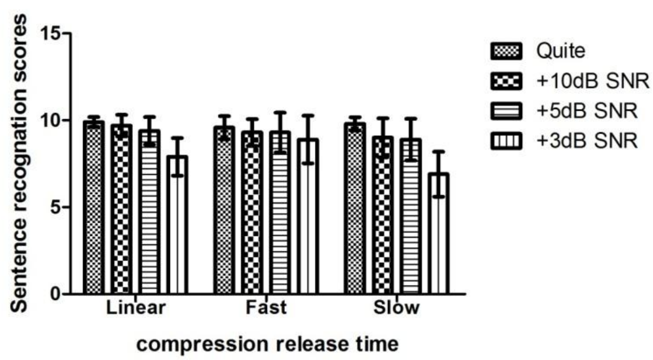


Figure 4. Mean and standard deviation of sentence recognition scores obtained from the participants of the group-I in each strategy as a function of SNRs.

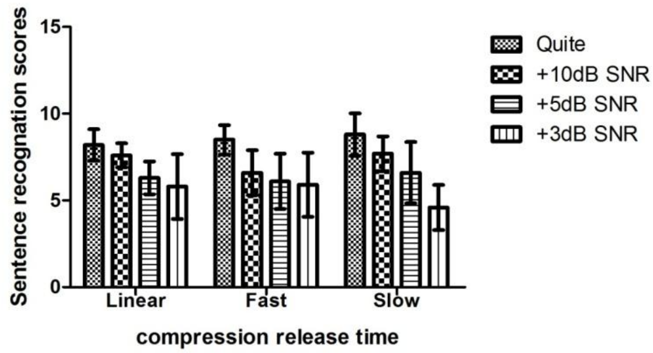


Figure 5. Mean and standard deviation of sentence recognition scores obtained from the participants of group-II in each strategy as a function of SNRs.

In order to know the effect of SNRs on each strategy in the sentence recognition scores in group-I and group-II, two way repeated Measure ANOVA with between subject factor as group was performed. The results revealed that there was no significant interaction effect in strategy*SNRs*group [F (6,120) = 0.87, p = 0.514], such that sentence recognition scores were reduced as a function of SNRs, in each strategy from the participants of the group-I and group-II.

Recognition of the normal rate of sentences processed from different strategy, in each SNR from the participants of the group-I and group-II

Descriptive statistical analyses were performed to document the mean and standard deviation of sentence recognition scores obtained from different strategies in each SNR for the normal rate of sentences upon the participants of the group-I and group-II. Further, two way repeated measure ANOVA (SNRs and strategies) with between subject factor as groups was performed to see the interaction effect of SNRs and strategies in the normal rate of sentences.

The mean and standard deviation of sentence recognition scores obtained from different strategies in each SNR for the normal rate of sentences upon the participants of group-I and group-II are tabulated in Table-1 In group-I, except in quiet condition, the mean sentence recognition scores were better in linear strategy followed by fast compression and then the slow compression release time (Figure-6). In addition, the sentence recognition scores in + 3dB SNR were better in fast compression release time than the linear strategy followed by a slow compression release time. However, in group-II, except in quiet condition, there is no trend in the sentence recognition scores between strategies in each SNR. In quiet conditions, sentence recognition scores were better in slow compression release time than the fast compression and the linear strategy (Figure-7)

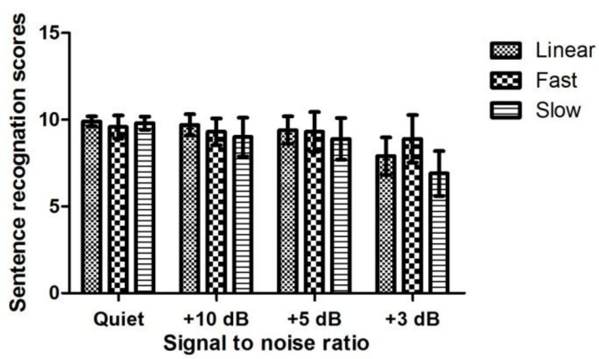


Figure 6. Mean and standard deviation of sentence recognition scores obtained from different strategies in each SNR from the participants of the group-I.

In order to know the effect of strategies in each SNR on the sentence recognition scores in group-I and group-II, two way repeated Measure ANOVA with between subject factor as group was performed. The results revealed that there was no significant interaction effect in SNR*strategies*group [F (6,120) = 1.52, p = 0.175], such that, except in quiet and + 3 dB SNR conditions the sentence recognition scores were better in linear strategy than other strategies in the participants of the group-I, but in group-II, except in quiet condition, there was no trend between strategies in each SNR.

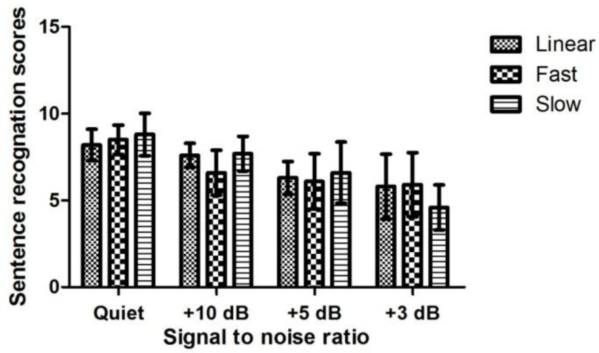


Figure 7. Mean and standard deviation of sentence recognition scores obtained from different strategies in each SNR from the participants of group-II.

Recognition of 35 % compressed rate of sentences processed in each strategy, in different SNRs from the participants of the group-I and group-II.

Descriptive statistical analyses were performed to report the mean and standard deviation of sentence recognition scores for the 35 % compressed rate of sentences processed through each strategy in different SNRs from the participants of the group-I and group-II. In addition, two way repeated measure ANOVA (strategies and SNRs) with between subject factor as groups was performed to see the interaction effect of strategies and SNRs at 35 % compressed rate of sentences. If indicated, paired sample t tests were carried out to identify under which SNRs in each strategy caused significant difference.

The mean and standard deviation of the sentence recognition scores of 35% compressed sentence processed in each strategy at different SNRs are tabulated in Table-

2. It was noted that the mean sentence recognition scores for 35 % compressed rate of sentences were reduced linearly as a function of SNR in each strategy from the participants of the group-I (Figure-8) and group-II (Figure-9).

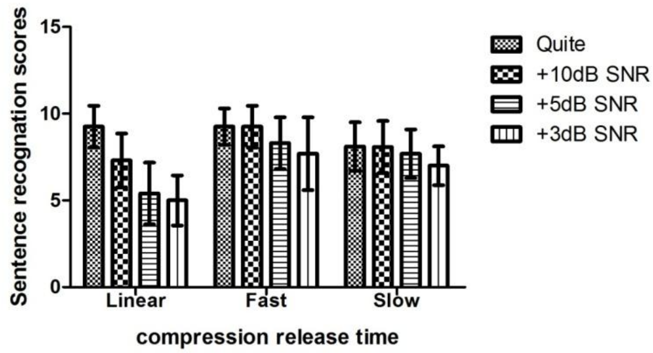


Figure 8. Mean and standard deviation of sentence recognition scores for the 35 % compressed rate of sentences obtained from the participants of the group-I in each strategy as a function of SNRs.

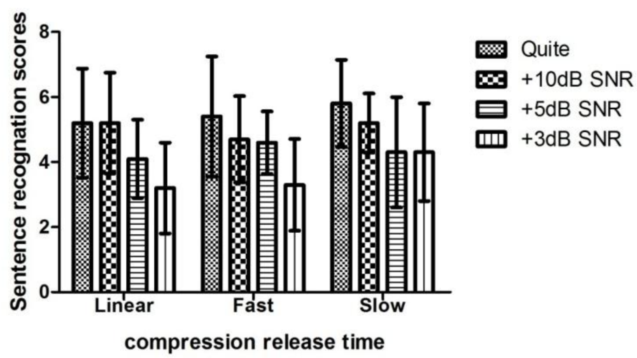


Figure 9. Mean and standard deviation of sentence recognition scores for the 35 % compressed rate of sentences obtained from the participants of group-II in each strategy as a function of SNRs.

Table 2. *Mean (M) and Standard Deviation (SD) of sentence recognition scores for the 35 % rate of sentences obtained in each strategy ,in different SNRs from the participants of the group-I and group-II.*

	Group ï I			Group - II		
Condition	Linear	FC*	SC*	Linear	FC*	SC*
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Quite	9.25 ± 1.21	9.25 ± 1.05	8.1 ± 1.4	5.2 ± 1.68	5.4 ± 1.85	5.8 ± 1.34
+ 10 dB SNR	7.3 ± 1.55	9.25 ± 1.21	8.0 ± 1.5	5.2 ± 1.55	4.7 ± 1.33	5.2 ± 0.91
+ 5 dB SNR	5.4 ± 1.78	8.3 ± 1.49	7.7 ± 1.42	4.1 ± 1.21	4.6 ± 0.96	4.7 ± 1.72
+ 3 dB SNR	5.0 ± 1.44	7.7 ± 2.12	7.0 ± 1.12	3.2 ± 1.42	3.3 ± 1.41	4.3 ± 1.52

*FC ï fast compression; *SC ï slow compression

Further, to know the effect of SNRs in each strategy on the sentence recognition scores for 35 % compressed rate of sentences in group-I and group-II, two way repeated Measure ANOVA with between subject factor as group was performed. The results revealed that there was a significant interaction effect in strategy*SNRs*group [F (6,120) = 2.198, p = 0.048], such that sentence recognition scores were reduced as a function of SNRs, in each strategy from the participants of the group-I and group-II.

In order to identify under which SNRs in each strategy caused significant difference, we conducted post hoc analyses using paired samples t tests with Holm's sequential Bonferroni` adjustment of alpha level for controlling type I error. Six paired comparisons were conducted to evaluate which SNRs caused the significant difference in each strategy, in group-I and group-II separately. These comparisons resulted, a power of significance 0.008 instead of 0.05. The results of these paired comparisons are tabulated in Table 3.

Table 3. Paired sample t- test results for the sentence recognition scores in different SNRs, in each strategy from the group-I and group- II.

	Group-I		Group-II	
Different SNR	t-value	p-value	t-value	p-value
Linear				
Quiet vs. + 10 dB SNR	3.83	0.003*	0.34	0.742
Quiet vs. + 5 dB SNR	7.95	0.000*	1.67	0.129
Quiet vs. + 3 dB SNR	8.78	0.000*	4.74	0.001*
10 dB SNR vs. + 5 dB SNR	-2.61	0.024	-1.35	0.210
10 dB SNR vs. + 3 dB SNR	-3.38	0.06	-2.32	0.045
5 dB SNR vs. + 3 dB SNR	-1.07	0.305	-1.40	0.193
Fast compression time				
Quiet vs. + 10 dB SNR	0.00	1.000	1.90	0.089
Quiet vs. + 5 dB SNR	2.11	0.059	1.92	0.087
Quiet vs. + 3 dB SNR	3.44	0.005*	6.03	0.000*
10 dB SNR vs. + 5 dB SNR	-1.34	0.204	-0.71	0.495
10 dB SNR vs. + 3 dB SNR	-2.56	0.026	-4.11	0.003*
5 dB SNR vs. + 3 dB SNR	-0.81	0.430	-3.88	0.004*
Slow compression time				
Quiet vs. + 10 dB SNR	0.16	0.876	0.61	0.555
Quiet vs. + 5 dB SNR	0.76	0.459	1.38	0.200
Quiet vs. + 3 dB SNR	3.38	0.006*	1.76	0.111

10 dB SNR vs. + 5 dB SNR	-0.650	0.529	-1.36	0.204
10 dB SNR vs. + 3 dB SNR	-3.46	0.004*	-1.96	0.081
5 dB SNR vs. + 3 dB SNR	-1.32	0.212	0.00	1.000

The results of paired comparisons revealed that in group -I, the sentence recognition scores for normal rate of sentences processed from linear strategy, in quiet condition was significantly better from other SNRs. At fast compression release times, the sentence recognition scores in quiet were significantly better from +3 dB SNR. Similar results were noted in slow compression release time strategy. In addition, the sentence recognition scores in + 10 dB SNR were significantly better than in +3 dB SNR. However, in group-II, the sentence recognition scores for normal rate of sentences processed from linear strategy, in quiet condition was significantly better from+3 dB SNR alone. At fast compression release times, the sentence recognition scores in quiet were significantly better than in +3 dB SNR. In addition, + 3 dB SNR was significantly better than in +10 dB SNR and in + 5 dB SNR, respectively. At slow compression release times, there was no significant difference between SNRs.

Recognition of 35 % compressed rate of sentences processed from different strategy, in each SNR from the participants of the group-I and group-II

Descriptive statistical analyses were performed to document the mean and standard deviation of sentence recognition scores for the 35 % compressed rate of sentences processed in different strategies in each SNR from the participants of the group-I and group-II. In addition, two way repeated measure ANOVA (SNR and strategies) with between subject factor as groups was conducted to see the interaction effect of SNRs and strategies in the 35 % compressed rate of sentences. If indicated, paired sample t tests were carried out to identify under which strategies in each SNR caused significant difference.

The mean and standard deviation of sentence recognition scores obtained from different strategies in each SNR for the 35 % compressed rate of sentences upon the participants of the group-I and group-II are tabulated in Table-2. In group-I, except in quiet condition, the mean sentence recognition scores were better in fast compression release time, followed by slow compression and then the linear strategy (Figure-10). However, in group-II, the mean sentence recognition scores were better in slow compression strategy than fast compression and linear strategies in quiet and in different SNRs (Figure-11)

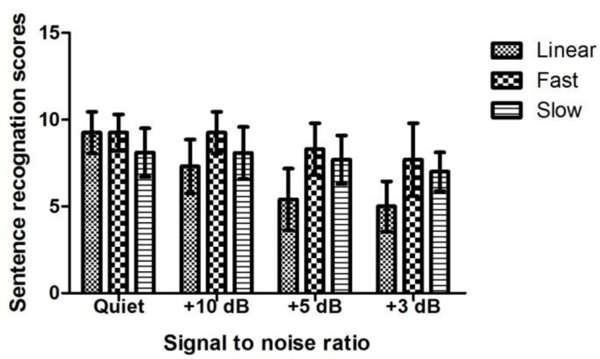


Figure 10. Sentence recognition scores for 35% compressed rate of sentences processed from different strategies in each SNR for Group I.

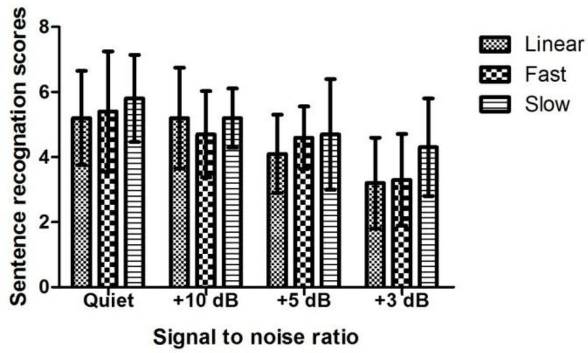


Figure 11. Sentence recognition scores for 35% compressed rate of sentences processed from different strategies in each SNR for Group II.

Further, to know the effect of different strategies in each SNR on the sentence recognition scores for 35 % compressed rate of sentences in a group-I and group-II, two way repeated Measure ANOVA with between subject factor as group was performed. The results revealed that there was a significant interaction effect in strategy*SNRs*group [F (6,120) = 2.198, p = 0.048]. In order to identify under which strategy in each SNR caused significant difference, we conducted post hoc analyses using paired samples t tests with Holm's sequential Bonferroni` adjustment of alpha level for controlling type I error. Six paired comparisons were conducted to evaluate which strategy in each SNR caused significant difference, in group-I and group-II separately. These comparisons resulted power of significance 0.008 instead of 0.05. The results of these paired comparisons are tabulated in Table 4.

Table 4. Paired samples t- tests results of the sentence recognition scores for the 35 % compressed rate of sentences from different strategy in each SNR,in group-I and group-II.

	Group- I		Group-II	
	t-value	p-value	t-value	p-value
Quite				
Linear ï Fast	0.00	1.000	-0.27	0.790
Linear - Slow	2.23	0.047	-0.24	0.811
Slow - Fast	2.49	0.030	0.00	1.000
+ 10 dB SNR				
Linear - Fast	-3.53	0.005*	0.29	0.775
Linear - Slow	-1.56	0.145	-0.81	0.434
Slow - Fast	2.12	0.057	-1.00	0.343
+ 5 dB SNR				
Linear - Fast	-4.60	0.001*	-0.88	0.397
Linear - Slow	-4.84	0.001*	-0.28	0.785
Slow - Fast	0.85	0.409	0.51	0.616
+ 3 dB SNR				
Linear - Fast	-5.06	0.000*	-0.14	0.888
Linear - Slow	-3.28	0.007*	-2.01	0.075
Slow - Fast	1.00	0.339	-2.23	0.052

The results of paired comparisons revealed that in group -I, the sentence recognition scores for 35 % compressed rate of sentences in quiet condition showed no significant difference between strategies. However, in + 10 dB SNR, sentence recognition scores in fast compression release time were significantly better than linear strategies. In addition, in +5 dB SNR and in +3 dB SNR, the sentence recognition scores in fast compression release time were found significantly better than slow compression and linear strategies. In group II, the sentence recognition scores processed in different strategies were found, no significant difference, in quiet condition. Similar results was noted in each SNR.

Recognition of sentences between group-I and group-II in normal rate and in 35 % compressed rate processed in each strategy, in different SNRs.

To see the difference between groups in each experimental condition, the main effect of group was noted from the result of two way repeated measure ANOVA with between subject factor as groups. Further, MANOVA was performed to identify the difference between groups in each experimental condition.

Table 5. *Results of MANOVA on the sentence recognition scores between group-I and group-II for the normal rate of sentences from each strategy in different SNRs.*

Experimental Conditions	***F- ratio***	***p- value***
Linear strategy		
Quiet	37.748	0.000
+10 dB SNR	58.297	0.000
+5dB SNR	70.566	0.000
+3dB SNR	10.979	0.003
Fast compression release time		
Quiet	11.214	0.003
+10 dB SNR	35.334	0.000
+5dB SNR	30.359	0.000
+3dB SNR	19.159	0.000
Slow compression release time		
Quiet	7.630	0.012
+10 dB SNR	7.650	0.012
+5dB SNR	12.920	0.002
+3dB SNR	16.578	0.001

It was found that the main effect of group [F (1, 20) =79. 78, p = 0.000] was found in two way repeated measure ANOVA and between subject factor as groups, in the normal rate of sentences. Further, MANOVA was performed to know the group difference in each experimental condition. The results of MANOVA (Table 5) revealed that the sentence recognition scores were significantly better in group-I then compared to group-II, in each experimental condition (Figure- 12).

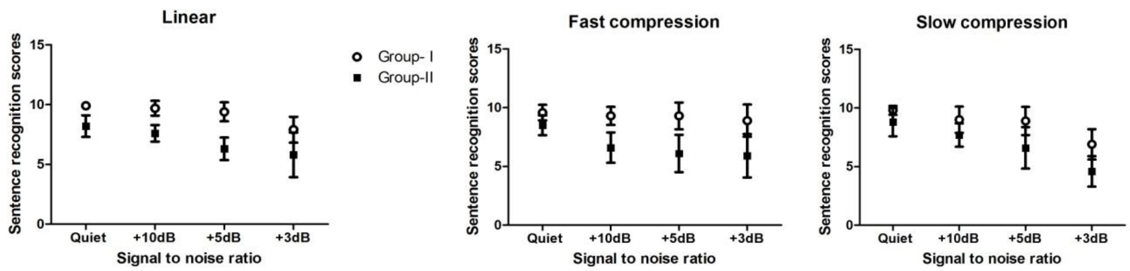


Figure- 12 *Sentence recognition scores for the normal rate of sentences in group I and group II from each strategy in different SNRs.*

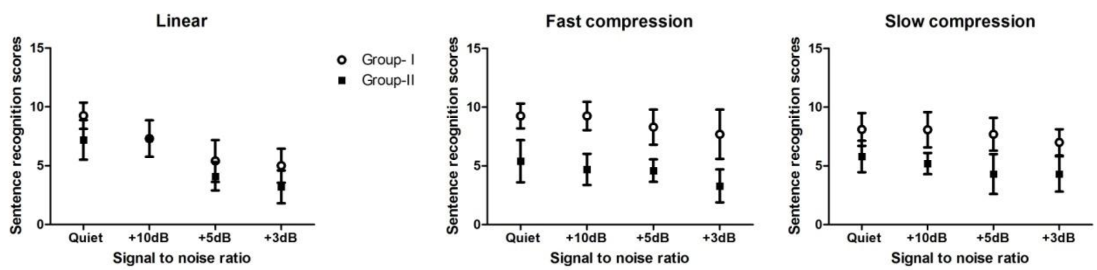


Figure-13 Sentence recognition scores for the 35 % compressed rate of sentences in group I and group II from each strategy in different SNRs.

Table 6. Results of MANOVA *on the sentence recognition scores between group-I and group-II for the 35 % compressed rate of sentences from each strategy in different SNRs.*

Experimental Conditions	***F- ratio***	***p- value***
Linear strategy		
Quiet	42.754	0.000
+10 dB SNR	14.826	0.001
+5dB SNR	3.796	0.066
+3dB SNR	9.101	0.007
Fast compression release time		
Quiet	39.779	0.000
+10 dB SNR	69.813	0.000
+5dB SNR	45.982	0.000
+3dB SNR	31.606	0.000
Slow compression release time		
Quiet	21.936	0.000
+10 dB SNR	27.892	0.000
+5dB SNR	26.855	0.000
+3dB SNR	22.030	0.000

Further, a main effect of group [F (1, 20) =79. 78, p = 0.000] was found in two way repeated measure ANOVA and between subject factor as groups, in the 35 % compressed rate of sentences. Further, MANOVA was performed to know the group difference in each experimental condition. The results of MANOVA (Table 6) revealed that the sentence recognition scores were significantly better in group-I then compared to group-II, in each experimental condition for 35 % compressed rate of sentences (Figure-13).

CHAPTER – 5 DISCUSSION

The purpose of the study was to investigate the effect of rate and noise in linear and in compression release times on the sentence recognition task in 12 normal hearing older adults (Group - I) and in 10 older adults with mild to moderate sensory neural hearing loss (Group-II). The findings of the present study were discussed under the following objectives.

Recognition of the normal rate of sentences processed from each strategy, in different SNRs from the participants of the group-I and group-II

It is evident from the present study that irrespective of the strategies the sentence recognition scores were reduced with decrease in signal to noise ratios (SNRs) in Group I. To be specific, in quiet condition, the linear hearing aid amplifies the consonants and vowels in the sentence. The depth of modulation after application is same as that of the original signal (Hickson & Thyler, 2003), which provided cues for the older adult individuals (Pichora-Fuller & Souza, 2003). At faster compression release time the consonant vowel ratio (CVR) increases (Jenstand & Souza, 2005) as the consonant portions are amplified and the vowel components in sentences are reduced there by the upward spread of masking was minimized. Ohde and Steven (1983) reported that CVR provides subtle cues for the perception of weaker consonents. At the slower release time, it is speculated that the envelope of the sentence is smoothened and preserved the temporal envelope. This speculation is supported by Jenstand and Souza, (2005) who objectively verified the sentences processed by slow release time using an envelope difference index. Thus, preserved envelope in slower release time provide cues for older adults. In addition, the filters in the hearing aid preserve the spectral components of speech. The available Spectro-temporal cues in the sentences processed by different strategies might be accessed by the older adults having near normal frequency resolution (Gordon-Salant, 1987) caused the increased sentence recognition. However, in lesser SNR condition, processed in each strategy the inherent acoustic cues in sentences are not well preserved. This is because the noise reduces the modulation depth (Houtgast & Skeenken, 1985) and masks the weak intense consonants (Helfer & Wilber, 1990). Further, the noise obscures the spectral component of speech (Cohen, 2003). Despite, alteration in the sentence by the noise, recognition did not significantly differed as a function of SNRs in each strategy.

In group II, the sentence recognition scores were reduced with decrease in signal to noise ratios (SNRs) in each strategy. The reason could be the hearing impairment in older adults have reduced frequency selectivity and near normal temporal resolution (Moore & Glasberg, 1990); and its concomitant changes at the central auditory level (Pichora-Fuller & Souza, 2003). Thus, the older individuals require extra cues than what is actually required by normal hearing subjects to process the information in degraded listening condition. However, in the presence of noise, there will be an additional load on the auditory system to decipher the information and might have occurred due to redendency cues. Thus, in lesser signal to noise ratio, the sentence recognition scores decreased in the present study, but did not account significant difference in the sentence recognition. This is true for each processing strategy in the presence of noise.

Recognition of the normal rate of sentences processed from each strategy, in each SNRs from the participants of the group-I and group-II

There were no differences in the sentence recognition scores between strategies in each SNR, in group I. In quiet conditions, the each strategy enhances the temporal cues as explained earlier, which provide cues for the sentence recognition in older adults having near normal temporal resolution (Moore & Glasberg, 1990). Though the noise obscure the cues in sentences processed by the hearing aids of different strategies, the sentence recognition is preserved. It infers that older adults having normal hearing sensitivity have well divided attention skills (Tun, O'Kane & Wingfield, 2002) such that they separate speech in the presence of noise and or inhibit the irrelevant information (Hasher & Zacks, 1988).

Further, in group -II, the sentence recognition scores was better in slow compression release time compared to other two strategies (linear and fast compression) though no significant differences were noted. The result of the present study was in accordance with previous reports by Humes, Christensen, Thomas, Bess, Williams and Bentler, (1999). The slow compression release time smoothens the envelope of speech and preserve the temporal envelope relatively better than other strategies (Jenstand & Souza, 2005). Additionally, the intelligibility and quality of sentences processed in slow compression hearing aid were appreciated from the current study participants, which were informally noted during data collection. Jenstand and Souza, (2005) who opined that in slower release time, the compression for vowel could not be released and continued even in time to amplify for the consonants and thus the gain alteration was minimized, which made their study participants to rate higher on the intelligibility scale.

Yet another study in the similar experiment reported by Neuman, Bakke, Mackersie, Hellman, and Levitt (1998) who stated that slower release time rated higher pleasantness and clarity. However, there was detrimental effect of noise on sentence recognition and no particular trend was noted between strategies. This is because older adults might have access to the residence cues as the noise obscures inherent cues of sentences and the available cues are unable to process by the physiologically impaired auditory system, which in turn, lode the cognitive system (Brungart, D, 2001).

Recognition of 35 % compressed rate of sentences processed in each strategys, in different SNRs from the participants of the group-I and group-II

In time compressed speech, though the spectral components are preserved the gap in the inter phonemic cues reduces, thereby leads to an unfamiliar pattern of sounds (Gordon-Salante & Fitzgibbons, 1995). In addition noise masks the soft consonants. These two combined effect reduces the overall intelligibility of the speech signal. Although the temporal cues are altered by time compressed speech in quiet condition, the sentence recognition was good at linear strategy for older adults having normal hearing. However, the sentence recognition scores reduced dramatically in the lesser signal to noise ratio. Harris and Reitz (1985) reported that multiple degradation of sentence by noise and time compressed rate can have more acoustic distortions. In addition, the older adult auditory system to decode the rapid fluctuation of speech in the presence of noise is limited (Gordon-Salant & Fitzgibbons, 1997).

Although the sentence recognition scores were poorer in each time constant as a function of SNRs, the increased CVR from fast compression and preserved envelope from slow compression hearing aids might have enhanced the temporal parameter. This might have provided cues to at least access to the redundancy cues (Humes, Burk, Coughlin, Busey, & Strauser, 2007).

Further, irrespective of strategies, the sentence recognition scores are deteriorated in older adults having hearing loss due to the combined effect of time compressed rate and noise. This might be because the distorted acoustic cues by the combined effect of rate and noise unable the impaired physiological system of older adults to access the available cues and interpret the meaning from the heard sentences. That is, although appropriate release time was set in the hearing aids, neither overcome the reduced frequency selectivity and temporal resolution of the impaired physiology nor the adverse effect of noise and rate of speech.

Recognition of 35 % compressed rate of sentences processed from different strategy, in each SNR from the participants of the group-I and group-II

The result of the study revealed that, except in quiet condition, the sentence recognition scores in fast compression were significantly better than linear and slow compression release time in different signal to noise condition.

It was speculated that the older auditory system having normal hearing relay more on spectral cues to understand the time compressed sentences processed through the hearing aids having different strategies, as the compressed rate alter temporal cue. In fast compression, the amplification was provided to low level consonants and compresses the vowel portion, thus increases the audibility of consonants (Hickson & Byrne, 1997). These in turn augment the level difference between consonant and vowel, there by which increases the modulation depth and reduce the upward spread of masking.

In older adults having hearing loss, the sentence recognition scores in each SNR are better in slow release time than in linear and in fast release time, but these differences did not cause no significant. It suggests that participants might have used redundancy cues for sentence recognition. It was also speculated that the distorted acoustic cues by the combined effects of rate and noise direct the impaired physiological system of older adults to rely on processing strategy which preserve the naturalness of speech. Jenstand and Souza (2005) and Neuman, Bakke, Mackersie, Hellman, and Levitt, (1998) reported that the slow compression release time preserve the intelligibility, pleasantness and clarity of speech. This information might have utilized the contextual cues by older adults having hearing loss to interpret meaning from the heard sentences.

Recognition of sentences between group-I and group-II in normal rate and in 35 % compressed rate processed in each strategy, in different SNRs

As expected that in the normal rate of sentences processed in different strategies in each SNR, the sentence recognition scores were significantly poorer in group II than in group I. These findings attributed to two sources of distortions. The fist source of distortion is the noise which obscures the temporal modulation depth (Houtgast & Skeenken, 1985) and spectral cues in sentences (Cohen, 2003). The limited cues in the sentences after embedding with noise unable to process effectively by older adults having reduced frequency selectivity due to broadened auditory filters and near normal temporal resolution (Moore & Glasberg, 1990); and its concomitant changes at the central auditory level (Pichora-Fuller & Souza, 2003). In addition, older adults with hearing loss exhibit lesser ability to inhibit the irrelevant information, i.e. listening to speech in competing message. Thus, the strategies in the hearing aid did not help older adults to follow the message in the reduced signal to noise ratio. It infers that the combined effect of physiological impairment and the alteration of cues from noise did not mitigate by any of the strategy. It suggests that processing strategy which enhances the acoustic cues optimally even in the presence of noise is warranted (directional microphone and noise reduction circuits).

At 35 % compressed rate processed by different strategies, in each SNR the sentence recognition score is poorer in group II than in group I. It was evident from the present study that the combined effect of noise and rate affected the sentence recognition scores to the greatest extent in older adults having hearing loss than without hearing loss. This is because the compressed rate of sentences sound unfamiliar due to temporal alteration as the gap in the in the sub-phonemic cues (i.e., the place of articulation and vowel duration) reduces in time compressed speech resulted in rapid change of acoustic cues (Gordon-Salant & Fitzgibbons, 1995). Gordon-Salant and Fitzgibbons (1995) and Tun, O'Kane, Wingfield, 2002; Hasher & Zacks (1998) reported that perception of compressed sentences in the background noise is even more difficult. They attributed that the available gap between sub-phonemes were filled with noise. Thus, the fidelity of inherent cues in sentences is questionable after varied the rate and combined with the noise. The limited available acoustic cues after combined effect of rate and noise unable the impaired auditory system to follow the sentences processed by different strategies.

CHAPTER–6 SUMMARY AND CONCLUSION

The aim of study was to investigate the effect of rate and noise in linear and in two compression release times on sentence recognition upon older adults with bilateral sloping sensorineural hearing loss. The following objectives were formulated as follows a) Recognition of the normal rate of sentences processed from each strategy, in different SNRs from the participants of the group-I and group-II. b) Recognition of the normal rate of sentences processed from different strategy, in each SNR from the participants of the group-I and group-II. c) Recognition of 35 % compressed rate of sentences processed in each strategy, in different SNRs from the participants of the group-I and group-II. d) Recognition of 35 % compressed rate of sentences processed from different strategy, in each SNR from the participants of the group-I and group-II and e) Recognition of sentences between group-I and group-II in normal rate and in 35 % compressed rate processed in each strategy, in different SNRs. The findings in each objective are discussed in the reports of previous research and partly speculated by viewing the spectrogram.

The one short pre-test, post-test only repeated measure design was adopted. A total of twenty two participants were involved in the present study, in which 12 participants comprised of older adults having normal hearing sensitivity and 10 participants of older adults having a bilateral sensorineural hearing loss. Two sets of 12 lists in each normal and 35 % compressed rate of sentences were prepared from standardized Kannada sentences. The 12 lists of the normal rate of sentences were made into 3 sets comprised of 4 lists. The first set of all four lists was processed through linear hearing aid. Except the list-1 of linear processed sentences, the speech spectrum-shaped noise were mixed in + 10 dB SNR, + 5 dB SNR, and + 3 SNR to the List-2, List-3 and List-4, respectively. Similarly, the second of 4 lists was processed through the fast compression time constant and noise was mixed at different SNRs. In addition, the third set of 4 lists of the normal rate of sentences was processed through the slow release time constant and mixed with noise at different SNRs. Further, the same procedure was utilized to process the 3 sets of 4 lists in each of 35 % compressed rate of sentences. These processed sentences were presented at a participant MCL level through the headphone bilaterally in random order. The correct recognition of each sentence under different experimental conditions was awarded a mark one.

It is evident from the present study that irrespective of the strategies the sentence recognition scores were reduced as a function of lesser signal to noise ratios (SNRs), but these differences did not cause significant differences in Group I and in group II. It infers that sentence recognition for the normal rate of sentences almost similar in varied SNRs, processed in each strategy upon older adult with and without hearing loss. In addition, there were no differences in the sentence recognition between strategies in each SNR. It suggests that older adults with and without hearing loss have well divide attention skills and inhibit the irrelavent information, though the cues in sentences were obscured by noise.

At 35 % compressed rate, the sentence recognition scores were deteriorated in each strategy as a function of SNRs. This is because in time compressed sentences the sub-phonemic cues reduced and alter the temporal cue, which led to an unfamiliar sound pattern through the spectral cues are preserved. However, in the presence of noise, sentence recognition scores are worsened, as it masks the weaker consonants, reduces the modulation depth and alters the spectral cues. In addition, the available gaps between gaps were filled with noise. Thus, sentences in 35 % compressed rate processed by any strategies did not help in recognition. This is because the combined effect of rate and noise reduced the overall intelligibility, clarity and pleasantness. Further, distortions caused by compressed rate and noise unable the impaired physiological auditory system to access the available cues to interpret the meaning of the heard sentences.

Further, the sentence recognition scores were poorer in different experimental conditions in the older adults having hearing loss than participants having normal hearing sensitivity. It infers that the combined effect of physiological impairment and the alteration of cues by either noise and or speaking rate did not negate by any of the strategies. It suggests that processing strategy which enhances the acoustic cues optimally even in the presence of noise is warranted.

IMPLICATION OF STUDY

This study represents the extent of difficulty faced by older adults on the recognition of sentences in the presence of noise and variable rate of speakers. It also helps the audiologist to set the optimum compression release time in hearing aid users who are exposed to noise. The extent of benefit and or reduction in sentence recognition of individual and interactive effects of environmental factors such as noise and rate of speech processed by compression release time (shorter and longer) provides the information to the naïve hearing aid user at the time of purchasing the hearing aid.

Reference

Amos, N., & Humes. (2007). Contribution of high frequencies to speech recognition in quiet and noise in listeners with varying degrees of high frequency sensor neural hearing loss. *Journal of Speech Language and Hearing Research,* 50(4), 813-834.

Anderson, S., & Schwoch, W. T. (2013). Reversal of age- related neural timing delays with training. *Proceedings of National Academy of Science,*, *110*(11), 4357-4362.

Bao, J., Kevin., & Ohlemiller, K. (2010). Age-related loss of spiral ganglion neurons. *Hearing Research*, *264*(1-2), 357-362.

Borden, G. J., & Harris, K. S. (1980). *Speech science primer: Physiology, acoustics, and perception of speech*. Baltimore: Williams & Wilkins.

Brungart, D. (2001). Informational and energetic masking effects in the perception of two simultaneous talkers. *Jouranal of the Acoust Society of America*, 109(3), 1101-1109.

Bryan, J., Luszcz, M. A., & Pointer, S (1999). Measurement executive function: Considerations of detecting adult age differences. *Journal of Clinical and Experimental Neuropsychology*. 22(1), 40 - 55.

Carhart, J., & Jarger, G. (1969). Preferred method of clinical determination of pure tone thresholds. *Journal of Speech Language and Hearing Disorders*. 24, 330-345.

Cohen, I. (2003). Noise spectrum estimate in adverse environments: improved minima controlled recursive averaging. *Speech and Audio Processing*, 11(5), 466 - 475.

Cruickshanks, K. J., Nash, S. D., Zhan, W., Tsai, M. Y., Klein, R., Chappell, R., Nieto, F. J., Klein, B. E., Schubert, C. R., Dalton, D. S., & Tweed, T. S. (1998). Long-term assessment of systemic inflammation and the cumulative incidence of age-related hearinimpairment in the epidemiology of hearing loss study. *Journal of Gerontology,* 69(2), 207 - 214.

Dirks, D. D., & Wilson, R.A. (1969). Binaural Hearing of Speech for Aided and Unaided Conditions. *Journal Speech and Hearing Research*, 12, 650-664.

Drullman, R. (1995). Temporal Envelope and Fine Structure Cues for Speech Intelligibility. *Journal of Acoustic Society of America*, 97(1), 585-592.

Dubno, J. R., Dirks, D. D., & Morgan, D. E. (1984). Effects of age and mild hearing loss on speech recognition in noise. *Journal of the Acoustic Society of America*, 76, 87ï 96.

Dubno, J., Lee, F., Matthews, L., & Mills, J. (1997). Age-related and gender-related changes in monaural speech recognition. *Journal of Speech Language and Hearing Research,* 40, 444-452.

Feldman, R. M., & Reger, S. N. (1967). Relations among hearing, reaction time, and age. *Journal of Speech and Hearing Research*, 10(3), 479 - 495.

Fitzgibbons, P. J., & Gordon-Salant, S.(1995). Age effect on duration discrimination with simple and complex stimuli. *Journal of Acoustic Society of America*. 98(6), 3140 - 3150.

Geetha, C., Sharath, K.S. (2013). Development and standardization of sentences test in Kannada language for adults. Departmental project, AIISH.

Gordon-Salant, S., & Fitzgibbons, P. J. (1993). Temporal facters and speech recognition performance in younger and elderly listeners. *Journal of Speech and Hearing Research,* 36(6), 1276- 1285.

Gordon-Salant, S. (1987). Age-related differences in speech recognition performance as a function of test format and paradigm. *Ear & Hearing*, 8(5), 277-282.

Gordon-Salant, S. (2005). Hearing loss and aging: new research findings and clinical implications. *Journal of Rehabilitation Research and Development*, 42 (4), 9-24.

Gordon-Salant, S., & Fitgibbons, P. J. (2001). Sources of age related recognition difficulty for time- compressed speech. *Journal of Speech Language & Hearing Research, 44, 709-719.*

Gordon-Salante, S., & Fitzgibbons, P. J. (2004). Effect of stimuls and noise rate variability on speech perception by younger and older adults. *Journal of the Acoustic society of America*, 115(4), 1808 - 1817.

Gordon-Salante, S., & Fitzgibbons, P. J.(1997). Selected cognitive factors and speech recognition performance among younger and elderly listeners. *Journal of Speech Language and Hearing Research*, 40 (2), 423 - 431.

Harris, R. W., & Reitz, M. L.(1985). Effects of room reverberation in noise on speech discrimination by the elderly. *Audiology*, 24(5), 319 - 324.

Hasher, L., Zacks, R., Stoltzfus, E. & Rypma, B. (1988). Age and inhibition. *Journal of Experimental Psychology: Learning Memory and Cognition*, 17(1), 163-169.

Helfer, K. S., & Wilber, L. A. (1990). Hearing loss, aging, and speech perception in reverberation and noise. *Journal of Speech Hearing and Research*, 33 (1), 149-155.

Hickok, G., & Poeppel, D. (2000). Towards a functional neuroanatomy of speech perception. *Trends in Cognitive Sciences*, 4(4), 131- 138.

Hickson, L. & Byrne, D. (1997). Consonant perception in quiet: effect of increasing the consonant-vowel ratio with compression amplification. *Journal of American Academy of Audiology*, 8(5), 322- 332.

Hickson, N., & Thyer, L. (2003). Acoustic Analysis of Speech through a Hearing Aid: Perceptual Effects of Changes with Two-Channel Compression. *Journal of American Academy of Audiology*, 14(8), 414-426.

Hogan, C. A., & Turner, C. W. (1998). High frequency ability: benefits hearing-impaired listerners. *Journal of Acoustic Sociaty of America*, 104(1), 432 - 441.

Hopkins, K., & Moore, B. C. J. (2011). The effect of age and cochlear hearing loss on temporal fine structure sensitivity, frequency selectivity, and speech reception in noise. *Journal of Acoustic Society of America.* 130, 334- 352.

Hornsby, B. W. Y., Johnson, E. E., & Picou, E. (2011). Effects of Degree and Configuration of Hearing Loss on the Contribution of High- and Low-Frequency

Speech Information to Bilateral Speech Understanding. *Ear & Hearing*, 32, 543ï 555.

Houtgast, T., & Steeneken, H. J. M. (1985). A review of the MTF concept in room acoustics and its use for estimating speech intelligibility in auditoria. *Journal of the Acoustical Soceity of America*, 77, 1069 - 1081.

Humes, L. (1999). Dimensions of hearing aid outcome. *Journal of American Academy of Audiology*, 10(1), 26-39.

Humes, L. E., Burk, M. H., Coughlin, M. P., Busey, T. A & Strauser, L. E (2007). Auditory speech recognition and visual text recognition in younger and older adults: similarities and differences between modalities and the effects of presentation rate. *Journal of Speech, Language and Hearing Research*, 50 (2), 283 - 303.

Jenstad, L. M., & Souza.E., (2005). Quantifying the effect of compression hearing aid release time on speech acoustics & intelligibility. *Journal of Speech Languageand Hearing Research*, 48 (3), 651-667.

Jenstad, L. M., & Souza, E. P. (2007). Temporal Envelope Changes of Compression and Speech Rate: Combined Effects on Recognition for Older Adults. *Journal of Speech Language and Hearing Research*, 50,1123-1138.

Laplante-Lévesque, A., Hickson, L., & Worrall, L.(2013). Stages of change in adults with acquired hearing impairment seeking help for the first time: application of the transtheoretical model in audiologic rehabilitation. *Ear & Hearing*, 34(4), 447-457.

Mazziotta, J., Phelps, M., Carson, R. & Kuhl, D. (1982). Tomographic mapping of human cerebral metabolism: sensory deprivation. *Annlus of Neurology*, 12(5), 35-44.

Mills, J., Richard, A., Schmiedt, & Kulish, L. (1990). Age-related changes in auditory potentials of mongolian gerbil. *Hearing Research,* 46,(3), 201ï 210.

Mills, J., Schmiedt, R. , Schulte, B., & Dubno, J. (2006). *Age-Related Hearing Loss: A Loss of Voltage not Hair Cells. Seminars in Hearing,* 27(4), 228-236.

Moore, B., Glasberg, B., Shailer, M., Watson , N. & Harris, S. (1990). Auditory filter shapes at 8 and 10 kHz. *Journal of the Acoustical Society of America.* 88(1), 141-148.

Neuman, A. C., Bakkea, M. H., Hellman, S., & Levitt, H. (1995). Effect of release time in compression hearing aids: Paired-comparison judgments of quality. *Journal of the Acoustical Society of America,* 96(3), 3182-3187.

Neuman, A., Bakke, M., Mackersie, C., Hellman, S., & Levitt, H. (1998). The effect of compression ratio and release time on the categorical rating of sound quality. *Journal of the Acoustical Society of America*, 103, 2273-2281.

Ohde , R., & Stevens, K. (1983). Effect of burst amplitude on the perception of stop consonant place of articulation. *Journal of Acoustic Society of America*, 74 (3), 706-714.

Philips, S. L., Richter, S. J., & McPherson, D. (2009).Voiced initial consonants perception deficits in older listeners with hearing loss and good and poor word recognition. *Journal of Speech Language and Hearing Research,* 52, 118-129.

Pichora - Fuller, M. K., Schneider, B. A., & Daneman, M. (1995). How younger and older adults listen to and remember speech in noise. *Journal of the Acoustical Society of America*, 97 (1), 593 - 608.

Pichora - Fuller, K. M. (2003). Processing speed and timing in aging adults: psychoacoustics, speech perception, and comprehension. *International Journal of Audiology* 42(s), 59-67.

Pittman, A. L., & Stelmachowicz, P.G. (2003). Hearing loss in children and adults: audiometric configuration, asymmetry and progression. *Ear & Hearing*, 24(3), 198-205.

Port, D. K (1983). Time - varying features as correlation of place of articulation in stop consonants. *Journal of the Acoustical Society of America*, 77, 322- 343.

Port, D. K, & Neel, T, (2003). Vowel space characteristics and vowel identification accuracy. *Journal of Speech Language and Hearing Research*, 51, 574-585.

Salthouse, T. A. (1982). Duration estimates of two information processing components. *Acta Psychologcia,* 52(3), 213-226.

Salthouse, T. A. (1996). The processing speed theory of adult age differences in cognition. *Psychological review*, 103 (3), 403-416.

Schulte, B. A., & Schmiedt, R. A. (1992). Lateral wall Na, K-ATPase and endochlear potential decline with decline age in quiet ï reared gerbils. *Hearing Research*, 61, 35-46.

Sommers, S. M. (1997). Stimulus variability and spoken word recognition. II. The effect of age and hearing impairment. *Journal of Acoustical Society of America*. 101, 2278- 2292.

Stein, B. E., & London, D. (1996). Enhancement of perceived visual intensity by Auditory stimuli: A Psycophysical Analysis. *Journal of Cognitive Neuroscience*, 8(6), 497-506.

Summers, V., & Molis, M. R. (2004). Speech recognition in fluctuating and continues maskers: effect of hearing loss and presentation levels. *Journal of Speech Language and Hearing Research*, 47(2), 245- 256.

Tremblay, K. L., Billings, C.S., & Rohila, N. (2004). Speech evoked cortical potentials: Effects of age and stimulus presentation rate. *Journal of American Academy of Audiology,* 15 (3), 226-237.

Tun, P., O'Kane, G., & Wingfield, A. (2002). Distraction by competing speech in young and older adult listeners. *Psychology Aging*, 17 (3), 453-467.

Van Tasell, D. J., Soli, S. D., Kirby, V M., & Widlin, G. P. (1987). Speech waveform envelope cues for consonant recognition. *Journal of the Acoustical Society of America*, 82, 1152-1161.

Van Tasell, D., Soli, S., Kirby, V., & Widin, G. (1987). Speech waveform envelope cues for consonant recognition. *Journal of the Acoustical Society of America ,*82(4), 1152-1161.

Weatherley, C. C., WorrallL, E. W., & Hickson, L. M. (1997). The effect of hearing impairment on the vocal characteristics of older people. *Folia Phoniatria and Logopedics*, 49(2), 53-62.

Wingfield, A., Poon, W. L., Lombardi, L., & Lowe, D. (1985). Speed of processing in aging: effect of speech rate, linguistic structure, and processing time. *Journal of Gerontology*, 40(5), 579 - 585.

Wingfield, A., McCoy, S. L., Peelle, J. E, Tun, P. A., & Cox, L.C. (2006). Effect of adult aging and hearing loss of comprehension of rapid speech varying in syntactic complexity. *Journal of American Academy of Audiology*, 17 (7), 487-497.