PSYCHOACOUSTIC MEASURES OF TEMPORAL PROCESSING & SPEECH PERCEPTION IN OLDER ADULTS WITH NAIVE HEARING AID USERS OF 4 CHANNEL Vs 12 CHANNEL HEARING AIDS

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CERTIFICATE

This is to certify that this dissertation entitled "**Psychoacoustic measures of temporal processing & speech perception in older adults with naive hearing aid users of 4 channel Vs 12 channel hearing aids**" is a bonafide work submitted as a part for the fulfillment for the degree of Master of Science (Audiology) of the student Registration Number: 17AUD002. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore
May, 2019

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CERTIFICATE

This is to certify that this dissertation entitled "**Psychoacoustic measures of temporal processing & speech perception in older adults with naive hearing aid users of 4 channel Vs 12 channel hearing aids"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **“Psychoacoustic measures of temporal processing & speech perception in older adults with naive hearing aid users of 4 channel Vs 12 channel hearing aids”**is the result of my own study under the guidance of**Dr. Rajalakshmi K**., Professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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I WOULD LOVE TO DEDICATE THIS DISSERTATION TO MY APPA, AMMA AND MATHAN

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நிமிர்ந்த நன்னடை நேர்கொண்ட பார்வையும்,
நிலத்தில் யார்க்கும் அஞ்சாத நெறிகளும்,
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"With upright heart and steadfast look and ideals that are not afraid of anyone in the world- the woman does not falter as she has the possession of wisdom."

-MahakaviBarathiyar

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Abstract

Human auditory system has the ability extract the input signal in terms of spectrally and temporally to discriminate, identify and comprehend the stimulus. Individuals should extract the temporal information from the speech to comprehend it. Ageing causes the structural and functional changes in the peripheral and central auditory system. This will have an effect on auditory processing in older individuals. Hearing aids are the major rehabilitative option for individuals with hearing impairment. This present study checked the speech perception and temporal processing abilities in older naive hearing aid users. 20 older adults (mean age -55. 15) with moderate hearing loss have participate in the study. SIS and SPIN tests for speech perception and GDT, DPT and TMTF tests for temporal processing have carried out in three conditions (unaided Vs aided 4 channel hearing aid Vs aided12 channel hearing aid). Results showed aided scores are better than unaided scores in all the condition. In aided there is no significant difference between aided 4 channel condition and aided 12 channel condition. Speech perception and temporal processing are well correlated in all the tests especially SPIN in speech perception highly correlated with all temporal processing tests than SIS. Hearing aid improves the speech perception and temporal processing in older adults to an extent. High number of channel does not give any impact on speech perception and temporal processing in older adults.

Key words: *Speech perception, temporal processing and hearing aids*.

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Chapter 1

Introduction

Hearing or auditory perception is the ability to perceive sound by detecting vibrations and changes in the pressure of the environment. Hearing is a complex process of picking sounds and attaching meaning to it. The human ear is developed completely at birth and it responds to very slow as well as very loud sounds in a particular frequency range.

The World Health Organization (WHO), 2012 provided an estimate of 360 million (5.3%) people of the world's population suffer from disabling hearing loss. India has a high incidence and prevalence for hearing impairment that is around 63 million people (6.3%). In South- East Asia, the prevalence ranges from 4.6% to 8.8% (WHO, 2012).

Hearing loss refers to diminished ability to hear sounds. Speech perception and communication difficulties can be caused due to hearing loss, whereas in case of adults it can paveway for depression, problems with employment, increase in risk for dementia, withdrawal from community and quality of life also decreases (Davis et al, 2007). The amount of hearing disability completely depends upon the type and degree of hearing loss. In comparison with conductive hearing loss, sensorineural hearing loss is common in adult population (Gatehouse, 2002). The management also differs for different types and degree of hearing loss. The mechanisms underlying speech perception difficulty experienced by adults with High Frequency Sensory Neural Hearing loss (HF SNHL) have yet to be completely determined. Due to loss of audibility, auditory processing of signal in particular frequency region deteriorates (Moore 1996) and poorer supra threshold processing isobserved. For example, due to hearing loss intensity, frequency, and temporal processing dysfunctions are observed in particular frequency region. These processing disorders might not be limited to particular frequency region with respect to cochlear hearing loss but it might spread to adjacent regions as well. The off-channel impact of cochlear lesions on signal processing has been indicated in both intensity and frequency coding (Nelson &Freyman 1986; Florentine et al. 1993; Simon &Yund 1993; Schroder et al. 1994; Wang et al. 1996) and has also been confirmed in a recent study using an animal model in which gap detection thresholds, as measured in evoked potential, were found to be elevated in the low-frequency region after a cochlear lesion was created in high frequencies by noise trauma (Yin et al. 2008).

Drullman et al, (1994) found that temporal modulations were essential for accurate speech perception in normal hearing (NH) listeners, whereas several studies have suggested that word and sentence recognition performances are both positively correlated with temporal resolution in hearing-impaired subjects especially in the presence of background noise (Tyler et al. 1982; Grasberg& Moore 1989). However, contradictory reports exist (Strouse et al. 1998). These disparate findings probably result from differences in both the experimental paradigm used for measuring gap detection and the actual measures of speech understanding used. Because both temporal processing and speech perception in noise are influenced by many factors, such as age, hearing loss configuration, and stimulus signal parameters, the relationship between speech understanding in noise and temporal processing needs to be re-evaluated in an experiment in which these parameters are controlled.

Hearing impaired older adults showed poor speech perception in reverberation and noisy conditions even though they have mild peripheral hearing loss. The amount of distortion increases when the age increases, the elderly individuals showed poor performance in the speech perception task than young and normal listeners. (Harris & Reitz, 1985; Nabelek, 1988; Nabelek& Robinson, 1982). There is strong correlation between peripheral hearing loss and the speech perception, when the hearing lossincreases speech perception decreases in both quiet and noise condition. (Helfer& Wilber, 1990)

Hearing aids improve the speech intelligibility of persons with hearing impairment. In quiet environment there is no difference observed for speech intelligibility in linear and compression hearing aids at most comfortable level (MCL). Wide Dynamic Range Compression (WDRC) hearing aids help at lower levels in quiet environment (Dillon, 1996). WDRC hearing aids showed better speech intelligibility in both quiet and noisy environment comparing to linear hearing aids. (Jenstad, Seewald, Cornelisse, Shantz 1999).

Hearing impaired listeners show poorer performance in Temporal Modulation Transfer Function (TMTF) test which assess the temporal processing, comparing to normal listeners (Bacon &Viemeister 1985). Fast-acting WDRC was found to reduce the ability to detect slow envelope fluctuations in hearing aid users (Wiinberg et al, 2015). Hearing impaired listeners showed poor temporal processing ability in Gap Detection Test (GDT) and showed enlarged threshold in GDT (Florentine et al, 1988).

Need for the study:

Literature has accounted the presence of poor temporal processing in hearing impaired persons when compared to normal hearing individuals. Older adults showed poor speech perception in adverse listening condition compared to young adults. Age and hearing loss impairs the speech perception. WDRC hearing aids show better speech intelligibility than linear hearing aids (Jenstad et al, 1999). Hearing impaired persons show enlarged gap detection in Gap Detection Threshold (GDT) and less sensitive in Temporal Modulation Transfer Function (TMTF). Hearing aid user's show reduced Spectro Temporal Modulation (STM) sensitivity (Bernstein et al 2016). Fast-acting WDRC was found to reduce the ability to detect slow envelope fluctuations (Wiinberg et al, 2015).

Hearing aid plays a major role in improving audibility of the persons with hearing impairment. Hearing aid has different signal processing techniques including different channels and frequency bands. Temporal processing and speech perception could be influenced by various channels and number of channels in a hearing aid. So, there is a need to assess the temporal processing and speech perception in different channels of hearing aids.

Aim of the study:

Objective 1: To record psychophysical measures (speech perception and temporal processing) in unaided and aided (4 channel and 12 channel) in older naïve hearing aid users.

Objective 2: To find the correlation between temporal processing and speech perception in unaided and aided (4 channel and 12 channel) conditions.

Chapter 2

Review of Literature

Over the decades attempts have been made to investigate the speech perception and temporal processing abilities of older adults using hearing aids. Speech perception is a specialized aspect of a general human ability, the ability to seek and recognize patterns. These patterns are in acoustic form, used as cues to perceive speech. Temporal processing is one of the parts in auditory processing, which gives information about the coding of time related changes in the auditory input (ASHA 1996).

Speech perception in older adults

Humes(1996) reviewed speech understanding difficulties in elderly. He stated variation in the amount of sensorineural hearing loss leads to individual variation in speech understating in elder individuals. Elder individualsshowed good correlation between the amount of hearing loss and speech identification scores in quiet, noise and reverberation condition (Humes and Roberts, 1990). However, Elder individualsperformed poorer than normal young adults in auditory discrimination tasks. Christopherson and Humes (1992) further divided the elder individuals into two groups as young-old (63-74 years) and old-old (75-83 years) and found no age related differences between both the groups.However,both the group performed equallypoorer than young normal adult group in auditory discrimination task.

Fitzgibbons and Gordon-Salant (1996) stated older adults showed poor understanding of fast speech; this leads to the hypothesis that the ability to process rapid acoustic information reduces due to ageing. Older adults showed decrement in performance when the complexity of the target stimulus increases that is not observed in young adults. Deficit in processing temporal characteristics of the stimuli leads to reduced understanding of rapid speech in elderly.

Gordon-Salant (2005) reviewed hearing loss and auditory processing problem in older individuals. Older individuals who have hearing loss through presbycusis usually get speech understanding difficulty in adverse listening environment than quiet. Age related speech understanding deficits are observed when 0 dB SNR or near to that. Significant age related changes of speech recognition performance observed in elderly males comparing to females (Dubno et al, 1997).

Schneider et al(2005) stated speech comprehension tend decreases when the rate of speech is faster in older adults than younger adults. Revised- Speech Perception in Noise (R-SPIN) scores revealed older adults require high SNR to understand the speech than young adults. Both low context and high context condition older adults showed poor performance than young adults. Performance of older adults depends on the age and signal rate. Sentences that are in faster rate leads to reduced performance.

Shrivatsav et al (2006) used spectral shaped and raised level CUNY Nonsense syllable test (CUNY NST) in older adults. Older adults showed better performance (increased speech identification scores) in spectrally shaped stimulus compared to that of non-shaped stimulus. Older adults performed poorer when there is a competing singal. In the presence of competing signal selective attention and divided attention tasks were given to the older adults. Selective attention scores are better than divided attention scores for older adults.

Humes (2007) reviewed the role of audibility and cognitive factors involved in older adult's speech perception. He stated audibility is the primary contributor for speech understanding difficulties in older adults. Presbycusis leads to poor speech understanding ability in high frequency speech sounds. Decreased high frequency bandwidth in Hearing in Noise Test (HINT) observed in older adults than young adults. Older adults require greater SNR than young adults. (Lee and Humes, 1993; Nilsson et al., 1994). Increasing presentation level does not eliminate the difficulty of the inaudibility of high frequency sounds. Loss of audibility and the reduced dynamic range leads to reduced speech understanding in older adults (Dubno and Schaefer, 1995).

Temporal processing in older adults

Takahashi and Bacon (1992) studied modulation detection and speech understanding in noise in elderly. They performed sinusoidal modulation detection (SAM) with broad band noise and speech understanding in with and without back ground sinusoidal modulated noise (with various SNRs). Older subjects showed poor modulation detection threshold in high modulation frequencies than younger subjects. Percentage of correct scores increased when SNR increases. In unfavorable SNR condition scores are better in modulated condition than unmodulated condition. Older adults with mild hearing loss showed decreased performance in speech understanding in noise than younger subjects.

Fitzgibbons and Gordon-Salant (1996) examined the hypothesis that elderly listeners have impaired temporal processing. Only few elderly listeners showed abnormal gap detection threshold; most of the elderly listeners showed normal gap detection threshold that is independent of individual's hearing loss (Moore et al, 1992). Schneider et al (1994) stated elderly listeners gap detection scores are twice as poorer that of younger listeners. Elderly listeners showed reduced scores in amplitude modulation detection than younger listeners (Takahashi and Bacon, 1992). Reduced difference limens in duration were observed in elderly listeners than younger listeners, irrespective of hearing loss and stimulus frequency.

Strouse et al (1998) examined temporal resolution in older adults with different sensation levels. Older adults showed poor gap detection threshold than younger adults. Both speech perception and temporal processing scores were decreased in older adults. Authors have concluded that aging plays a major role in the temporal processing than hearing loss.

Fitzgibbons and Salant (1998) studied temporal ordering in older adults. They examined the hypothesis that younger listener's temporal ordering performances are better than older listeners and temporal discrimination task will be easier than identification task for older listeners. In the entire tasks older group performed poorer than younger group. But poorer scores were obtained when the task complexity increased. Both discrimination of complex pitch patterns and identification of fast stimuli presentation obtained least scores. Hearing loss has a minimal role in temporal ordering.

Schneider and Fuller (2001) reviewed temporal processing changes implied on speech perception. Temporal processing is important to code the temporal fine structure of speech. Older adults showed difficulty in perceiving short sounds. Age related changes are noted both in gap detection and speech perception in noise. Gap detection test in temporal resolution and speech perception in noise (SPIN), degraded speech with reverberation and signal with fast rate of speech tests are correlated well.

Souza and Boike (2006) examined the temporal envelope information in different frequency channel conditions (1 channel, 2 channel, 4 channel, 8 channel and multichannel). Nonsense syllables perception task was carried out by the participants. They have observed both normal hearing and hearing impaired listeners performed equally in 1 channel condition and the performances increased for both the groups when there is increased number of channels. In all conditions the older adults performed poorer than young adults. They concluded that increasing age leads to difficulty in perceiving temporal envelope cues in speech.

Moore (2009) examined temporal fine structure properties in individuals with normal hearing and hearing loss. He used nonsense syllables with low pass filter 1.5 kHz because absolute thresholds in the frequencies below 1.5 kHz were below 20 dB in both the groups. Normal hearing individuals performed better than hearing impaired individuals even though their thresholds were within 20 dB. So he concluded that individuals with hearing impairment lose temporal envelope processing ability.

Shetty (2016) reviewed the hypothesis that older adults have reduced temporal processing. Older adults face difficulty in understanding speech at higher rates, adverse conditions like noise and reverberation. Deep band modulation strategy (DBM) enhances the temporal modulation and helps in temporal processing. A 15 dB enhancement of temporal envelope in 3 to 30 Hz avoids the masking of consonants by vowels. He suggested incorporating DBM in rehabilitative devices to improve temporal processing.

Hearing aid's role in speech perception and temporal processing

Yund and Buckles (1994) studied speech perception in various signal to noise ratios (SNRs) with linear amplification hearing aids (LAHA) and multichannel (8 frequency band) compression hearing aids (MCCHA). SNR was varied from -5 to +15 dB. MCCHAs got better performance when there is unfavorable SNR condition than in LAHA. Less number of subjects benefitted from LAHAs. Individuals with less hearing impairment benefitted more from multichannel hearing aids. So they have concluded that individuals with mild to moderate hearing loss get good benefit in speech discrimination in adverse condition with multichannel hearing aids.

Nordrum(2006) stated that there is an increased performance in hearing in noise test with a multichannel hearing aid than linear amplification.

Stecker(2006) studied the syllable identification training to improve the speech perception in older naïve hearing aid users and experienced hearing aid users. Nonsense syllable test (NST) was performed with participants. He found that experienced users show better performance than naïve users. He also reported that perceptual training is a promising tool to get better speech perception in older naïve and experienced hearing aid users.

Jenstad and Souza (2007) examined compression and speech rate effect on older adult's speech recognition. Wide dynamic range compression (WDRC) hearing aids alter the temporal envelope cues of speech. Envelope difference index (EDI) quantifies the temporal envelope on compression. Higher rate of speech leads to increased EDI, increased distortion and reduced speech discrimination performance. They have concluded that older adults use redundant cues in normal rate of speech to compensate negative effects of WDRC but still they face difficulty in higher rate of speech.

Lavie et al (2015) studied the plasticity of auditory system for older adults after hearing aid usage. They have studied whether hearing aids improve unaided performances of dichotic listening and speech in noise. After 4 weeks of binaural amplification, scores improved in dichotic test and speech identification in noise test than baseline evaluation in older adults. This improvement was not observed in control group who did not get amplification devices. Authors concluded that usage of hearing aids can change the auditory processing in older adults.

Fast-acting WDRC was found to reduce the ability to detect slow envelope fluctuations in hearing aid users (Wiinberg et al, 2015).

Literature has accounted the abnormal auditory processing in older adults in terms of both speech perception and temporal processing. Similarly, impact of hearing loss on auditory processing has been accounted. But there are very few studies to repot the effect of hearing aid's benefit on temporal processing, speech perception and correlation of both. Hence, there is a need to study temporal processing and speech perception in hearing aids and whether the number of channels in hearing aids really matter for auditory processing.

Chapter 3

Method

The present study aimed to record the psycho acoustical measures of speech perception and temporal processing in three different conditions (unaided, aided 4 channel hearing aid and aided 12 channel hearing aid) and to see the correlation between the speech perception and temporal processing in different conditions. The study used experimental within subject design in order to investigate the objectives of the study. To achieve the aim of the study, the following methods were taken. Ethical guidelines for bio behavioral research at All India Institute of Speech and Hearing (Venkatesan, 2009) were followed during the study.

3.1 Participants:

The present study included twenty participants (35 ears) with post-lingual moderate flat sensorineural hearing impairment with an age range of 41-70 years (Mean Age = 55.15). Among the twenty participants 15 had bilateral moderate sensorineural hearing loss and 5 had asymmetrical hearing loss; from those 5 individuals, moderate hearing loss ear was included for the study. All the participants fulfilled the following criteria:

Inclusion criteria

- Participants with unilateral/bilateral flat sensorineural hearing loss were selected for the study. The configuration was considered flat if the difference was not more than 10 dB HL at every octave from 250 Hz to 8000 Hz (Kennedy, Levitt, Neuman, & Weiss, 1998).

- Speech identification scores was not less than 70%,
- ‘A’ or ‘As’ type of tympanogram with acoustic reflex thresholds which were appropriate to the degree of hearing loss at 500 Hz to 4000 Hz,
- All the participants were naïve hearing aid users fitted with a WDRC digital hearing aid with an option for DNR and directionality, and
- All of them had Kannada language as their mother tongue.

Exclusion criteria

- Participants with otologic disorders, neurological involvement and psychological related problems were excluded from the study. Case history was taken to confirm the details on the above aspects.

Instrumentation and Test set up

- A calibrated dual channel diagnostic audiometer, Inventis piano, was used for routine audiological evaluation as well as for the actual experiment using TDH 39 supra aural head phones housed in MX-41 AR cushion and Radio Ear B-71 bone vibrator for routine audiological evaluation
- Two hi-fi (FBT) sound field speakers located at 1 meter distance at 45° angle for routine evaluation and for the actual experiment.
- GSI-Tympstar middle ear analyzer was used to assess the functioning of the middle ear, tympanometry and acoustic reflex.
- The personal computer with windows 10 configuration was used to program the hearing aids which were connected to Hi-PRO (an interface)

with the help of NOAH-4.6 software. Suitable cable for programming along with the program software given by that particular hearing aid company was used to program the hearing aid.

- A personal laptop with windows 10 configuration was connected to the audiometer auxiliary input to present the target stimuli for speech perception in noise.
- All the testing, both for selecting participants and experimental purpose were conducted in a sound treated air conditioned double room set-up. The noise level in the testing room was maintained within the permissible limits (ANSI, 1999).

Hearing aid programming and fitting

The 4 channel and 12 channel behind the ear hearing aids were used in this present study. Hearing aids were programmed based on NAL–NL1 Prescriptive formula using the computer with the NOAH-4.6 software according to the audiometric thresholds of the individual and First fit was applied. The default compression, directionality and noise reduction settings were kept constant. The gain setting of the hearing aid was modified according to the requirement of the participants. Optimization of ling 6 sounds was performed through the speakers at a distance of 1 meter for each participant. A routine hearing aid evaluation using the audiometer was carried out by asking five questions and finding out SIS at 40 dB HL.

Test Stimuli

- Phonemically balanced wordlist in Kannada (Yathiraj&Vijayalakshmi, 2005) were used for SIS
- Phonemically balanced word lists in Kannada (Manjulaet al., 2015) were used for SPIN.
- Recorded material was presented at comfortable level to assess the SIS and SPIN.

Procedure

Measurement of speech perception:

- Speech Identification Scores (SIS) was assessed by phonemically balanced wordlist in Kannada (Yathiraj&Vijayalakshmi, 2005) at the comfortable level (40 dB SL).
- Speech Perception in Noise (SPIN) was assessed in the list of phonemically balanced word lists in Kannada (Manjulaet al., 2015) with +10 dB SNR.
- Stimuli were played from the CD player which was presented through a calibrated loudspeaker placed at (45^0) degree azimuth and at distance of 1 meter.
- The participants were instructed to repeat the words. The mode of scoring was live by the experimenter in both SPIN and SIS assessment.
- Tests were done in 3 conditions: unaided and aided (4 channel hearing aid and 12 channel hearing aid)

- The aided scores were measured using single blinded procedure, participants were not aware of the type of hearing aid.

Measurement of temporal processing

Gap Detection Threshold

- Gap detection test was carried out using Maximum Likelihood Procedure (MLP) tool box which implements a MLP in MATLAB (Soranzo & Grassi, 2014).
- 3AFC (Alternative Force Choice Method) to track the threshold.
- Stimulus used to track the threshold of gap detection was presented at comfortable level (40 dB SL) with reference to the pure tone average of the participant.
- Stimuli consisted of a band of 750ms Gaussian noise with 0.5ms cosine ramps at the beginning and end of the gap. The standard stimulus presented to the listener was a 750ms Gaussian noise with no gaps, whereas the variable stimuli had a gap in its temporal center. Two down/one up adaptive procedure (2D1U) was used to determine thresholds of the participants.
- Participants were instructed to press the number keys (1, 2 or 3) in response to the variable stimulus containing the gap. The gap size increased with every incorrect response and decreased with two correct responses. Initially practice trials were given to individuals and the actual set of 10 trials were given to get appropriate responses.
- Stimulus was presented to each ear and GDT was measured separately for each ear.

Duration pattern test:

- The duration pattern test was administered in the manner described by Gouri and Manjula (2003).
- A 1000 Hz pure tone with two different durations (i.e., short (S) 250 msec and long (L) 500 msec) separated by a 250 ms gap was used to generate Six different combinations of three tones (eg. LLS, LSL, LSS, SSL, SLS and SLL) was used as a stimuli.
- Initially practice trials (5) were given before the actual test started, the participants were instructed to verbally repeat the sequence of three tone of varying durations in the sequence heard. Reversals of sequence were considered as an incorrect response.
- Scoring for DPT was taken as percentage (no of correct items divided by total no. of items X 100).

Temporal-Modulation Transfer Function (TMTF)

- It is a sinusoidal amplitude modulation (SAM) noise discrimination task. A 500ms Gaussian noise is sinusoidally amplitude modulated at 20Hz, 200Hz. Experiment was done at 8Hz and 128Hz.
- The depth of the modulation is expressed as 20log (m), where m is a modulation index that ranges from 0.0 (no modulation) to 1.0 (full modulation).
- 3AFC (Alternative Force Choice) method used to run the task; participants were given 10 trials to get used to the task. Two down/one up adaptive procedure (2D1U) was used to determine modulation thresholds.

- The participants had to identify interval that contained the modulated noise. Noises had two 10ms raised cosine ramps at onset and offset.
- TMTF test was done at comfortable level (40 dB SL).
- The threshold is the modulation depth (in dB).This test assesses the temporal resolution of envelope.

Chapter 4

Results

The current study aimed to assess the speech perception and temporal processing abilities of older naïve hearing aid users. In this study a total of 35 ears from 20 individuals with moderate hearing loss and who were naïve users of hearing aid, were evaluated with test of speech perception (SIS and SPIN) along with the test for temporal processing abilities using psycho acoustical measures such as the GDT, DPT and TMTF. The data obtained were tabulated and analyzed statistically using Statistical Package for the Social Science (SPSS) software packaging version 21.

All the data at first were subjected to descriptive statistical analysis where Mean, Median and Standard Deviation were computed and are depicted in the table 4.1 below and graphically represented in the Figure 4.1 below.

Table 4.1 Overall Mean, Median and Standard deviation across all the measures across three conditions

Tests	Unaided			Aided 4			Aided12		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
SIS	86.63	4.54	88.00	93.09	3.981	92.00	94.57	3.41	96.00
SPIN	63.83	11.86	64.00	66.74	11.67	68.00	67.54	12.33	68.00
GDT	10.21	8.50	7.35	8.57	6.19	5.86	9.74	8.16	6.45
DPT	64.57	16.46	68.00	65.49	19.57	68.00	66.86	18.90	68.00
TMTF[1]	-10.5	6.2	-8.1	-10.5	5.9	-9.5	-12.5	13.1	-8.3
TMTF[2]	-2.7	2.3	-1.2	-3.5	2.4	-2.4	-3.4	2.5	-2.5

Note: TMTF[1] - TMTF 8 Hz TMTF[2] – TMTF 128 Hz

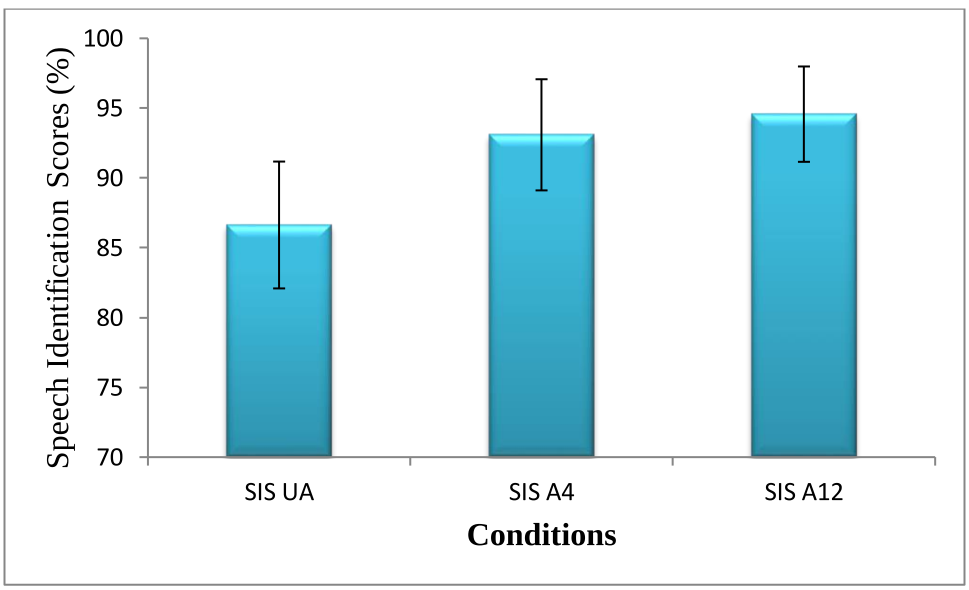

Figure 4.1(a): Mean and standard deviation of the SIS Scores

The Figure 4.1(a) depicts the Mean SIS score across three condition. From the figure it is evident that the mean scores of aided condition found to be better than the unaided condition and among the aided condition the aided performance of 12 channel hearing aid found to be better than the 4 channel aided condition.

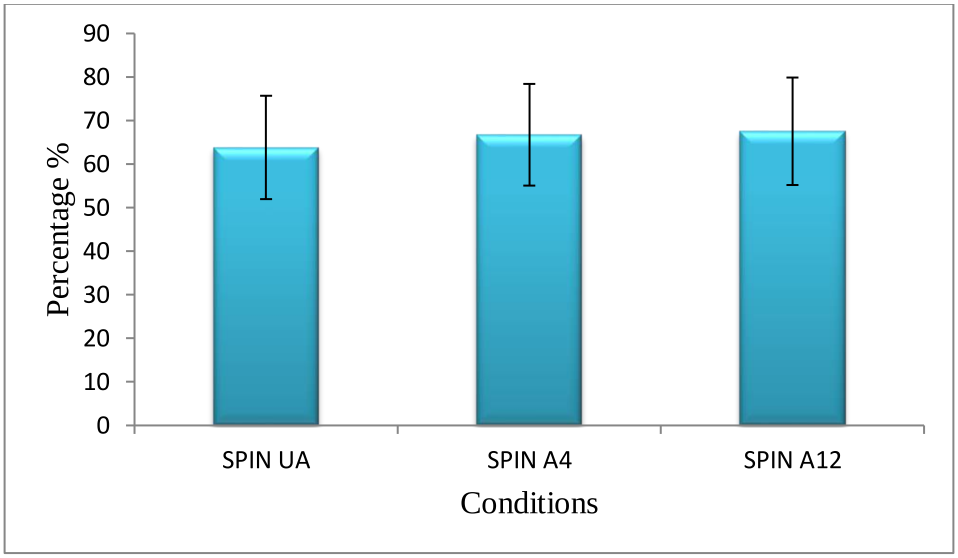

Figure 4.1(b): Mean and standard deviation of the SPIN Scores

From the Figure 4.1 (b) it is evident that the Mean SPIN scores of both the aided conditions is found to be better compared to the unaided condition and among the Aided conditions the performance of both the 4 channel hearing aid and 12 channel hearing aid is similar in performance.

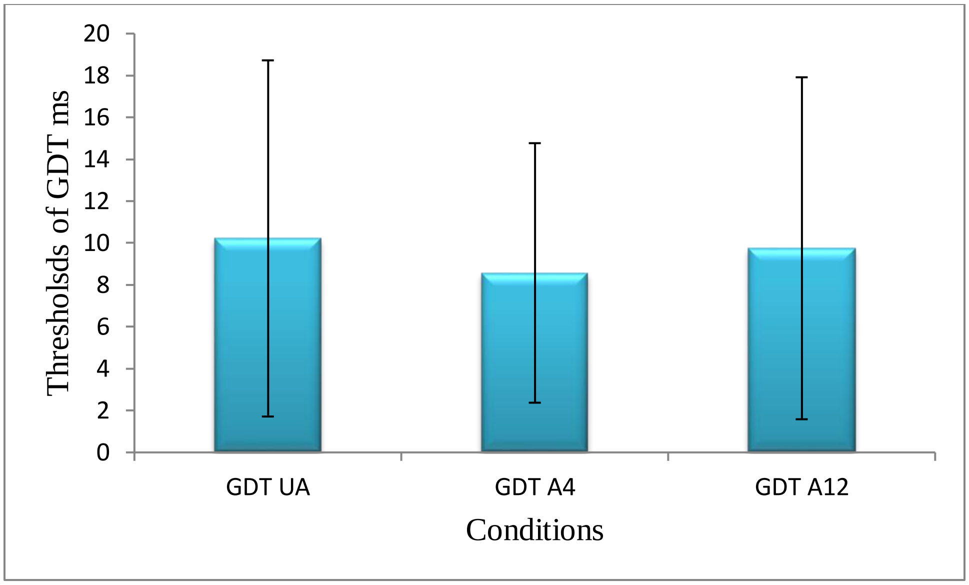

Figure 4.1(c): Mean and standard deviation of the GDT measures

From the Figure 4.1 (c) the thresholds of GDT found to be deviant from the norms in all three conditions however among all the three the aided 4 condition is found to be slightly better in performance.

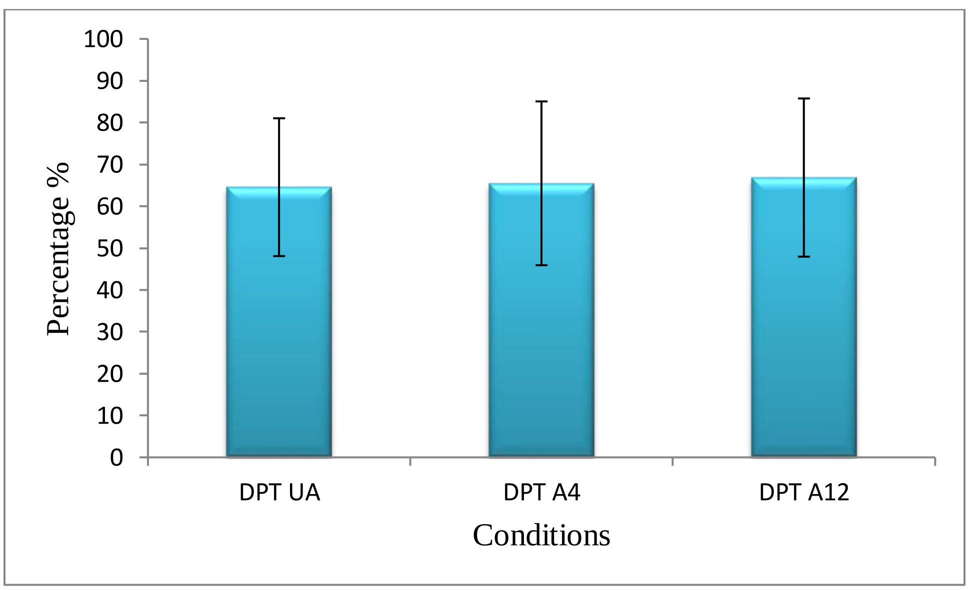

Figure 4.1(d): Mean and standard deviation of the DPT measures

From Figure 4.1 (d) it is evident that there is no much difference seen between aided and unaided performance in DPT.

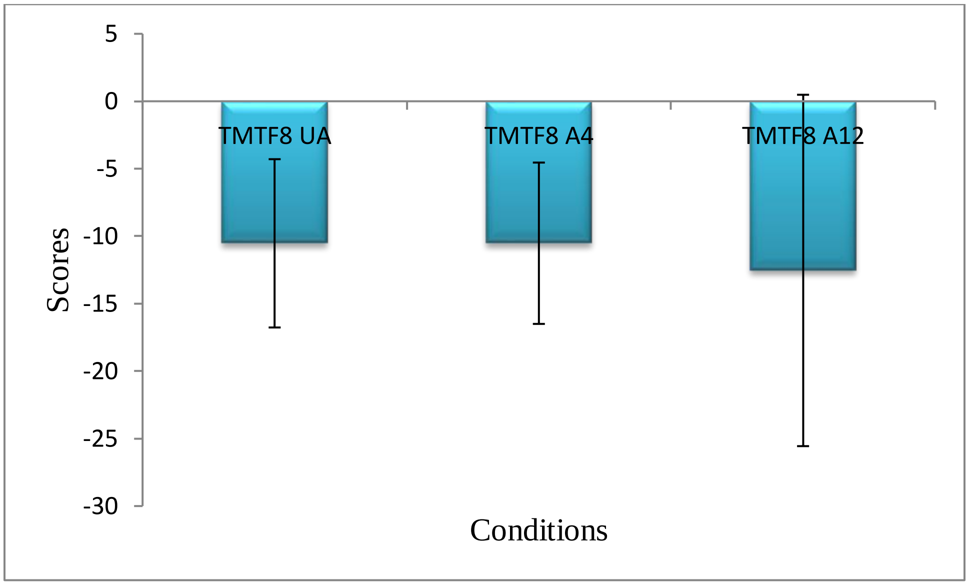

Figure 4.1(e): Mean and standard deviation of the TMTF measures at 8 Hz

From figure 4.1 (e) is it evident that the mean 12 channel hearing aid aided condition scores were found to be slightly better than that of both the 4 channel hearing aid aided condition and the unaided condition.

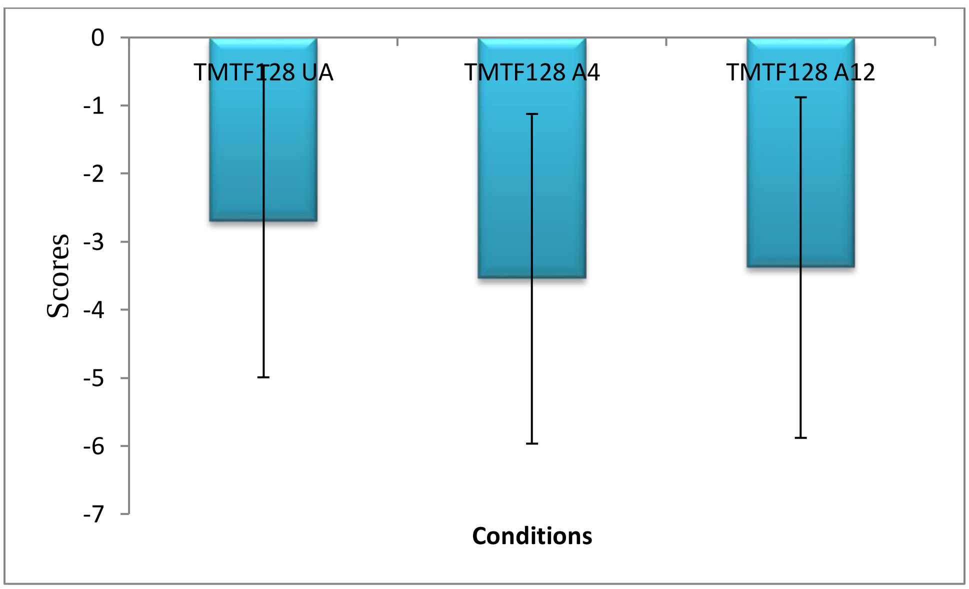

Figure 4.1(f): Mean and standard deviation of the TMTF measures at 128 Hz

From the figure 4.1 (f) is it evident that the mean aided scores of both the 4 channel hearing aid and the 12 channel hearing found be better in performance than the unaided condition and however among both the 4 channel and 12 channel hearing aid condition there is no much difference.

All the data after the descriptive analysis were subjected to the test of normality using ShaphiroWilk's test of normality. The data were not normally distributed as the level of significance found be less than 0.05 ($p<0.05$). Hence all the data were subjected to non-parametric inferential statistics based on the two objectives.

4.1 To check difference between the performances across three conditions in both measure of speech perception and temporal resolution:

To evaluate the first objective, the data were subjected to find comparison across the three conditions. Friedman test was carried out for each of the measure and the values are depicted in the table 4.2.

Table 4.2: To check comparison across all the three test condition across all the measures of speech perception and temporal processing abilities.

TEST MEASURES	χ^2
SIS	56.838**
SPIN	27.315**
GDT	22.338**
DPT	14.843**
TMTF 8Hz	7.664*
TMTF 128 Hz	47.314**

Note: ** (p<0.01), *(p<0.05).

From table 4.2, it is evident that there is significant differences observed across all the test conditions in all the test measures and hence all the test measures were subjected to pair wise comparison across the test condition individually. For that Wilcoxon signed rank test was done and depicted in the table below:

Table 4.3: To compare between the conditions on Speech Identification scores

	UA	**A4**	**A12**
UA		5.020**	5.135**
A4			2.993**
A12			

Note: ** (p<0.001), *(p<0.05), UA- Unaided, A4 – Aided 4 channel hearing aid, A12- Aided12 channel hearing aid condition

From table 4.3 it is evident that across all the three conditions a highly significant differences was observed in the scores of speech identification measures.

Table 4.4: To compare between the conditions on Speech Perception in Noise scores

	UA	**A4**	**A12**
UA		4.003**	4.070**
A4			1.460*
A12			

Note: ** (p<0.001), *(p<0.05), UA- Unaided, A4 – Aided 4 channel hearing aid, A12- Aided12 channel hearing aid condition

From the table 4.4 it is evident that across the aided and unaided condition there is a high statistical significance across both the aided conditions.

Table 4.5: To compare between the conditions on the thresholds of gap detection

	UA	**A4**	**A12**
UA		2.916**	2.010*
A4			1.787
A12			

Note: ** (p<0.001), *(p<0.05), UA- Unaided, A4 – Aided 4 channel hearing aid, A12- Aided12 channel hearing aid condition

From the table 4.5 it is evident that there a high significance found between the aided 4 and unaided condition and statistical difference between the unaided and aided 12 condition. However, there is no significant difference observed between both the aided conditions.

Table 4.6: To compare between the conditions on the thresholds of Duration pattern measures

	UA	**A4**	**A12**
UA		1.307*	2.424*
A4			2.294*
A12			

Note: ** (p<0.001), *(p<0.05), UA- Unaided, A4 – Aided 4 channel hearing aid, A12- Aided12 channel hearing aid condition

From the table 4.6 the measure of duration pattern revealed a statistical difference across all the three conditions assessed.

Table 4.7: To compare between the conditions on the measure of temporal modulation transfer function at 8 Hz modulation stimuli

	UA	**A4**	**A12**
UA		1.065	0.598
A4			1.894
A12			

Note: ** (p<0.001), *(p<0.05), UA- Unaided, A4 – Aided 4 channel hearing aid, A12- Aided12 channel hearing aid condition

From the table 4.7 it is evident that at a 8Hz modulation stimulus there is no significant difference observed across all the three conditions of temporal abilities.

Table 4.8: To compare between the conditions on the measure of temporal modulation transfer function at 128 Hz modulation stimuli

	UA	**A4**	**A12**
UA		5.160**	4.497**
A4			1.702
A12			

Note: ** (p<0.001), *(p<0.05), UA- Unaided, A4 – Aided 4 channel hearing aid, A12- Aided12 channel hearing aid condition

From the table 4.8, it can be observed that for the temporal modulation at 128 Hz stimuli there is a high statistical difference between the aided and unaided condition. However, there is no statistical difference observed between both the aided conditions.

4.2 To check whether there is any correlation between the measure of speech perception and the temporal processing abilities on older naïve hearing aid users

To address this objective of the study a non-parametric spearman's correlation test was done to check the correlation between the measure of speech perception and temporal abilities. The data of spearman's correlation are depicted inthe table 4.9 below.

Table 4.9: Correlation between the measure of speech perception and temporal processing abilities

	GDT UA	GDT A4	GDT A12	DPT UA	DPT A4	DPT A12	TMTF8 UA	TMTF8 A4	TMTF8 A12	TMTF 128 UA	TMTF 126 A4	TMTF 128 A12
SIS UA	-0.206	-0.193	-0.190	0.272	0.303	0.288**	-0.431**	-0.447*	-0.380*	-0.413*	-0.419	-0.434
SIS A4	-0.300	-0.363*	-0.284	0.438**	0.468**	0.430	-0.520**	-0.525**	-0.307**	-0.350*	-0.406	-0.377*
SIS A12	-0.230	-0.261	-0.175	0.203	0.220**	0.214**	-0.400	-0.332	-0.158	-0.120	-0.196	-0.226
SPIN UA	-0.724**	-0.719**	-0.735**	0.831**	0.795*	0.820**	-0.550	-0.671	-0.476**	-0.709**	-0.724**	-0.624**
SPIN A4	-0.775**	-0.780**	-0.797**	0.896**	0.860*	0.877**	0-.597	-0.731**	-0.561	-0.781**	-0.802**	-0.704**
SPIN A12	-0.800**	-0.766**	-0.800**	0.926**	0.880*	0.896*	-0.513	-0.658**	-0.500**	-0.814	-0.835**	-0.748**

Note: ** (p<0.001), *(p<0.05), UA- Unaided, A4 – Aided 4 channel hearing aid, A12- Aided12 channel hearing aid condition

From the data table 4.9 depicts the correlation of speech perception and temporal processing.

Correlation analysis revealedmeasures of speech perception and temporal processing abilities found to have a good correlation.Among the speech perception measures the SPIN measures found to have a good correlation with the measure of temporal processing abilities than that of the SIS measure of speech perception.

Chapter 5

Discussion

The purpose of the current study was to record the psycho acoustic measures of speech perception and temporal processing abilities in three different conditions; unaided, aided 4 channel hearing aid and aided 12 channel hearing aid and to see the correlation between the speech perception and the temporal processing abilities in those conditions in older individuals. To assess speech perception abilities SIS and SPIN tests were carried out and for the temporal perception GDT, DPT and TMTF tests were carried out. The results of the present study show that all the conditions are significantly different from one another. All the tests showed aided performances to be better than unaided performances except TMTF at 8 Hz. Among aided 4 channels and 12 channels there is no significant difference observed. In correlation analysis SPIN has correlated well with all the temporal processing tests than SIS (quiet).

The current study follows the same pattern of research work by Yund and Buckles (1995)stating that the Speech discrimination performance increases with increase in number of channels on phoneme discrimination scores when consonant confusion analysis was carried out. Jenstad et al (1999) state that the speech intelligibility is better in wide dynamic range compression hearing aid than linear hearing aids. In this study the speech identification scores (SIS) are significantly better in aided condition than the unaided condition with the aided 12 condition being better in performance than the aided 4 condition. Speech discrimination in noise test scores is better with hearing aid than without hearing aid condition. Hearing aids help to improve speech perception in adverse condition (Mangold et al, 1990). The results of the current study are also in agreement with the same pattern that is aided (both 4 channel and 12 channel hearing aid) performances are better than unaided condition. Significant differences are observed in these two conditions.

Older adults with minimal hearing loss performed poorer than younger hearing impairment in speech perception in noise task. Older adult with minimal hearing loss showed marked difficulty in understanding speech in adverse conditions like noise and reverberation (Helfer and Wilber, 1990). Number of channels did not have an effect on signal to noise ratios. Speech identification in noise test scores are better in multichannel compression hearing aids when there is unfavorable SNR than favorable SNR (Yund and Buckles, 1995). Subjects with flat hearing loss showed no difference between linear hearing aid and multichannel compression hearing aid in speech perception (De Gennaro et al, 1986). In the current study SPIN scores revealed that there is difference between unaided and aided condition. A less significant difference was observed in aided condition (between aided 4 channel Vs aided 12 channel) but the mean scores of aided 4 and aided 12 were equal. When the severity of the hearing loss increases the linear hearing aid performed better than multichannel compression hearing aid. Better performance in multichannel compression hearing aid observed when the hearing loss severity decreases (Barfod, 1978).Negative effects of speech perception noted when there is high compression ratio. Severity of hearing impairment increases very high compression ratios required in all the channels of hearing aid. This leads to the negative effect on speech perception. So the subject will lose some of the auditory information below threshold (Crain and Yund, 1993; Plomp, 1994; Yund and Crain, 1994).

The number of channel in the hearing aid and the independent amplitude compression of nonlinear hearing aid have an effect of speech intelligibility. "Amplitude frequency response should carefully tailor to the level and spectrum of sound so that the speech components are optimally audible over a frequency range". So the spectro-temporal contrast should be preserved for the speech intelligibility that lacks in multichannel automatic gain compression hearing aids (Yund& Buckles, 1995). Benefits for speech in background noise condition are less with hearing aid which has large number of channels. Benefits observed up to 8 numbers of channels. A increase in number of channels more thaneight leads to decrement in the spectro temporal contrast in the speech. (Bustamante &Braida 1987; Braida et al., 1981). The current study showed less difference between 4 channel and 12 channel hearing aids. But the significant differences observed between unaided and aided condition.

Individual with hearing impairment showed enlarged GDT than individual with normal hearing (Florentine and Buss, 1984). "Temporal processing depends on both analysis of time pattern occurring with each frequency channel and comparison of the time patterns across channels" (Moore, 1995). In broadband noise condition larger gap detection threshold observed in individuals with hearing impairment because audibility range decreases due to high frequency hearing loss (Buss & Florentine 1985; Florentine & Buss , 1984; Salvi & Arehole, 1984). Enlarged gap detection threshold was observed even for individuals with flat hearing loss in the current study with reference to Fakruddin and Rajalakshmi (2006) mean scores of older adults with hearing loss. Individuals with cochlear hearing loss usually have recruitment and a reduction of peripheral compressive nonlinearity; due to this enlarged gap detection threshold is observed in individuals with cochlear hearing loss (Jesdeadt et al., 1976; Moore &Glasberg1988).

The current study shows that the significant difference was observed between unaided and aided condition (both 4 channel and 12 channel hearing aid) in gap detection threshold. Nonlinear compression hearing aid improves the temporal resolution of the hearing impaired listener. But there is no significant difference observed within the hearing aids (aided 4 channel and 12 channels). Hearing aid benefits observed till 8 numbers of channels, more than 8 channels leads to reduction in the spectro temporal contrast in the speech signal. In the current study gap detection test mean scores showed no difference between the aided 4 channels and aided 12 channel conditions.

Older individuals performed more poorly than younger individuals in pattern perception task. Hearing loss had a minimal role in pattern perception. Older individuals with normal hearing also showed poorer performances than younger individuals. In pattern perception age has more importance than the hearing impairment (Fitzgibbons & Salant, 1998). The current study shows there is a significant difference observed in all the three conditions (unaided Vs aided 4 channel hearing aid Vs aided 12 channel hearing aid). Mean scores of DPT are almost equal for all the conditions. Hearing aids take care of audibility part in pattern perception so, no improvement observed in the aided condition.

In TMTF 8 Hz and 128 Hz, mean scores of 8 Hz is better than 128 Hz in the present study. The ability to detect the modulation at high rates is limited by the temporal resolution of the ear in hearing impaired individuals (Bacon & Veimeister, 1995; Lamore et al, 1984). This is because hearing impaired individuals mostly have high frequency hearing loss than in low frequency and the broad band noise is low pass filtered, so deviation is observed in the high frequencies (Bacon & Veimeister, 1995). Individuals with flat hearing loss detected modulation equally with normal hearing individuals (Bacon & Gleitman, 1992). But in the current study individuals with flat hearing loss performed better in low modulation frequency rates than high modulation frequency. Disruption in the cochlear hair cells lessens the ability of sharp frequency tuning. Because of wider auditory filter in the disordered cochlea tunes the low frequency better which is wider than the high frequency (Tussell, 1993).

Nonlinear hearing aid users showed reduced TMTF threshold due to WDRC. This indicates reduced temporal resolution in hearing impaired individuals is not modified by the WDRC (Winberg et al., 2015). The results of the present study support the findings of previous study. TMTF thresholds did not significantly change in all the conditions (unaided Vs aided 4 channel hearing aid Vs aided 12 channel hearing aid). Nonlinear hearing aid with varying the channels does not help to improve the modulation detection.

Nonlinear compression attenuates the envelope cues in the modulation transfer function (MTF). This amount of decrement is based on compression ratio and the number of channels. So the speech intelligibility is better in single channel hearing aid because spectral contrast of the speech is well preserved in single channel hearing aids (Plomp, 1988). The current study shows no significant difference between aided (both 4 channel and 12 channel hearing aid) and unaided condition in low modulation rate (8 Hz). But in high modulation rate (128 Hz), significant difference is observed between unaided and aided condition but there is no difference observed within aided condition (within 4 and 8 channel hearing aid). Attenuation of envelope variation due to compression is smaller for high modulation frequencies and larger for low modulation frequencies (Plomp, 1988). This finding is supporting the finding in the current study, thatat low modulation frequencies no difference was observed between aided and unaided condition but not with a high modulation frequency (128 Hz).

In the current study, correlation analysis revealed there is a good correlation between speech perception and temporal processing abilities. In speech perception, the SPIN test highly correlated with all the temporal processing tests than that of SIS. “Poor temporal resolution leads to increased confusion of consonant perception. There is high correlation observed between gap detection threshold and the consonant perception than vowel perception. In consonant perception, perception of fricative and plosive depends on the slope of hearing loss and the minimum gap detection ability. So, the reduced temporal resolution leads to difficulty in perception of plosive detection (Dreschler, 1989).

Spectro-temporal modulation (STM) sensitivity is the predictor of speech perception in noise for hearing aid users. Here, STM detection has shown significant proportion to the speech perception in noise test in hearing impaired individuals. STM sensitivity is a critical predictor of speech recognition threshold (SRT); reduced STM and the SRT in noise observed in older hearing aid users. “This is due to inability to process the temporal fine structure information and to detect the dynamic spectra of the sound (Bernstein, 2016)”. The current study followed the same pattern; SPIN in speech perception and the TMTF in temporal processing are highly correlated than all other tests. Both SPIN and TMTF are very sensitive to assess the auditory processing and it is affected by age and hearing loss.

The current study exhibited that the older adults with hearing impairment have poor auditory processing. Both speech perception and temporal processing scores are equally affected due to the age and hearing impairment. Nonlinear hearing aids help to improve the auditory processing to an extent. Higher number of channels in hearing aids did not show any noticeable improvement in the processing. Literature has documented that if the number of channels in the hearing aid increases to more than 8 channels there is deterioration in the speech perception abilities due to poor temporal coding. Speech perception and temporal processing are highly correlated in all the conditions.

Chapter 6

Summary and Conclusion

Aging causes structural and functional changes in the peripheral and central auditory system. Peripheral hearing loss leads to attenuation and distortion of input signal. Aging also affects the speech perception and temporal processing of the individuals. Hearing aids are the important feasible rehabilitative option for older hearing impaired individuals. There is scarcity of literature on the hearing aid benefits on auditory processing of older hearing impaired individuals. Modern hearing aid technology tremendously has improved with many features and technology within the hearing aid. One of the main components is channels of the hearing aid. Does the number of channels have an effect on speech perception and temporal processing of older hearing impaired individuals? So, there is a need to assess the hearing aid benefit over speech perception and temporal processing in older hearing impaired individuals.

Thecurrent study aimed to record the psychoacoustic measures of speech perception and temporal processing in three conditions (unaided, aided 4 channels and aided 12 channels hearing aid) and to see the correlation of speech perception and temporal processing in all three conditions. 20 older adults with flat moderate hearing loss have participated in the study. SIS and SPIN tests assessed speech perception; GDT, DPT & TMTF tests were performed to assess the temporal processing. All recorded materials were presented through the audiometer and the signal presented through the sound field system at 45^0angle and one meter of distance from the participant. The collected data was analyzed through Statistical

Package for the Social Science (SPSS) software packaging version 21. The results of present study revealed,

a) Aided mean scores are better than unaided scores in all the tests.
b) There is no significant difference between aided 4 channel hearing aid condition and aided 12 channel hearing aid condition in all the tests except SIS in quiet.
c) Score of speech perception and temporal processing very well correlated in all the conditions.
d) SPIN as a speech perception test, highly correlated with all the temporal processing tests than SIS.

Hearing aids delivers benefits to improve speech perception in both quiet and noisy conditions and temporal processing to an extent. There is no improvement observed with higher number of channel condition; literature has accounted that higher number channel losses the spectro temporal contrast of the speech and make confusion in understanding. Both speech perception and temporal processing are well correlated in all the conditions. It supports the hypothesis that an individual should extract the temporal information from the speech to perceive it.

Implications

1. The study helped to add to the knowledge on the speech perception and temporal processing ability of older adults in aided and unaided conditions.
2. Apart from this the study also revealed the correlation between speech perception and temporal processing in naïve hearing aid users.

3. The results of the present study can help in the selection of hearing aids based on their temporal processing and speech perception scores of the older individuals with sensorineural hearing loss.

Limitations

1. Control group was not considered for comparing the data.
2. Test was carried out through loud speakers.
3. Due to lack of normative data deviance of the test scores was not measured.

Future Directions

1. In future the study can be carried out with experienced hearing aid users.
2. Processing training can be given with the help of hearing aid to individuals who have peripheral hearing loss with processing disorders.

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