SENTENCE PERCEPTION ABILITIES IN PRESENCE OF NOISE AMONG HEARING AID USERS

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गुरुर्ब्रह्मा गुरुर्विष्णु र्गुरुर्देवो *महेश्वरः ।*

गुरु *साक्षात परब्रह्मा तस्मै श्री गुरवे नमः ॥*

Dedicated to my
guide and my
parents

CERTIFICATE

This is to certify that this dissertation entitled **"Sentence perception abilities in presence of noise among the hearing aid users"** bonafide work submitted in part fulfillment for the degree of Master of science (Audiology) of the student (Registration No: 16AUD013). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award or any other diploma or degree.

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CERTIFICATE

This is to certify that this dissertation entitled **“Sentence perception abilities in presence of noise among the hearing aid users”** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier to any other university for the award or any other Diploma or Degree.

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DECLARATION

I hereby declare that this dissertation entitled **"Sentence perception abilities in presence of noise among the hearing aid users"** is the result of my own study under the guidance of **Dr. Prawin Kumar,** Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Manasagangothri, Mysuru and has not been submitted earlier to any other university for the award or any other Diploma or Degree.

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INTRODUCTION

"Although it is true that mere detection of a sound does not ensure its recognition, it is even more true that without detection the probability of corrected identification are greatly diminished"

David Poscoe

"The flood of sound, noise and voices which suddenly break into the conscious of the person who has not heard them for years is very much like the first impact of direct sunlight on a person who has lived in dungeon.

Sidney Blackstone

Normal hearing sensitivity is usually inferred when hearing sensitivity as determined by the acquisition of absolute threshold response is "excellent" and is observed to be within normal and acceptable auditory limit. When hearing sensitivity is excellent the first assumption is that an auditory system under scrutiny is free of disease (Sahley & Musiek,.). That is from the outer ear to cerebral cortex the assumption is that for any given sample of listener whose auditory system have been characterized as exhibiting excellent sensitivity the same listeners are said to have auditory system that are functioning optimally. Hearing is a sensory activity which enables us to communicate with the other individuals, share the feeling and thoughts, warns from danger and entertained by music and laughter. Loss of hearing isolates the individual from the society and gives rise to frustration. Extraction of speech from the background noise or any other competing voice is essential for understanding the communication. Hearing loss makes this process more difficult which in turns hamper the effective communication. Speech communication in daily life does not use single words and one ear but occurs at semantic level of the sentence involving both ears, and not in a surrounding free from interference but practically always in ambient noise. The listener receives constantly a mixture of interference and signal, the latter in the form of sentences.

Thresholds obtained by using pure tones have long been used by audiologist as the gold standard for measuring hearing sensitivity (Lins et al., 1996). These tests are important in determining hearing sensitivity at specific frequencies, but they are often inadequate when it comes to predicting speech understanding, especially in noise. Pure-tone thresholds primarily reflect the mechanical amplification of quiet sounds provided by the outer hair cells (Moore, 2007). Thus the audiogram is primarily a reflection of pure hearing sensitivity (Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004). In contrast, it is the inner hair cells that are responsible for sending most of the auditory signals to the brain, and if there is inner hair cell damage, individuals typically suffer more from a loss of clarity than a loss of sensitivity (Moore, 2007).

Speech perception is vital to the communication process and hence its assessment in the audiometric testing is indispensable for successful audiologic rehabilitation (McArdle & Wilson, 2008; Mueller, 2001; Wilson, Carnell, & Cleghorn, 2007). Tests of speech perception employ a variety of stimuli like non-sense syllables, monosyllabic words, bisyllabic words and sentences (Tyler, 1994). The advantages of sentence test are: (i) they can provide insight regarding an individual’s performance in more realistic communication scenarios; (ii) they are considered to be valid indicators of intelligibility and give better representation of verbal communication (Tyler, 1994) (iii) they provide better accuracy and effectiveness in measuring speech reception thresholds due to steeper intelligibility functions of sentence level materials in comparison to testing using single words (Zokoll et al., 2013); (iv) they contain contextual cues and are expected to have better predictive validity compared to words; (v) they assesses co-articulation as well as temporal aspects of speech; and (iv) they have face validity as ‘natural’ and ‘meaningful’ stimuli for assessing auditory function (Miller, Heise, & Lichten, 1951).

For individuals with normal hearing, speech recognition in fluctuating background such as a single competing voice is generally superior to performance in unmodulated competing sound at the same overall presentation level. For listeners with sensorineural hearing impairment, recognition performance is much more similar in fluctuating and steady-state background. In literature, it has been reported that hearing aid users faces lot of difficulty in perceiving speech in presence of background sounds (Bentler, Palmer, & Mueller, 2006; Brooks, Hallam, & Mellor, 2001; Hickson & Worrall, 2003). Hearing aid does not give complete satisfaction to the users in difficult listening situations since hearing aid also amplifies the background signal or noises. These unwanted amplified signals lead sometimes pain, discomfort, annoyance or distraction. Whenever noise is present and audible, it affects the signal-to-noise ratio (Nilsson, Soli, & Sullivan, 1994). In behavioral measures, the effect of the signal level of noise is well understood by performance of the individuals with hearing impairment. It is observed that as signal levels become audible the performance becomes better, than as signal levels begin to exceed 60-70 dB SPL, modest decrements in performance are seen and are thought to be due to spread of masking in the cochlea at higher levels (Billings, McMillan, Penman, & Gille, 2013; Billings, Tremblay, Stecker, & Tolin, 2009).

Speech perception in quiet and noise in normal hearing individuals

The skills to perceive speech in noisy situations are highly variable from individual to individual. Perception of speech in the presence of competing noise is a challenging listening situation even for individual with normal hearing. A consistent challenge in field of spoken word recognition in noise is identifying the underlying sources of individual difference in speech perception skills. Speech perception in noise depends on correct understanding by the listener, whether in terms of discrimination, identification, recognition, or comprehension. The ability of speech perception in noisy interfering needs the listener to devote significant processing requires resource to encode highly detailed information in the speech signal. In highly challengeable listening situation, identification of vowel is generally conserved and confirmed the special functional role of consonant during lexical recognition. While vowel played central role in word detection step that precedes the word identification step in noisy competing situation, consonants seems essentially used to identify the lexical item. When speech signals are embedded in background noise, normal hearing individual are often able to take advantage of temporary improvement in signal-to-noise ratio (SNR). This improvement occurs because the normal hearing individual can take a help from temporal, spectral and spatial auditory cues as well as the integration of multi-sensory information. It happens because the signal is fluctuating, which makes it easier for the listener to hear the message in between when the speech level is greater than noise.

Individuals experience more difficulty in following the conversation and perceiving the speech in presence of background noise and in group situation. Individuals with normal hearing even have a wide range of variation in their speech intelligibility under ideal speaking and listening condition across different talkers (Black & Haagench, 1963; Bond & Moore, 1994; Hood & Poole, 1980). The normal hearing listeners are sensitive to talker variability and speech perception and word recognition. Score decreases with increasing talker variability in the test materials like male versus female (Mullennix, Pisoni, & Martin, 1989; Nygaard & Pisoni, 1998; Nygaard, Sommers, & Pisoni, 1994). For normal hearing listeners, moderate presentation levels are sufficient for all portions of a speech signal to be audible. Thus, for these listeners, there would be no reason to expect improvement in speech recognition at high levels based on increased signal audibility.

Several authors reported speech-reception thresholds for normal hearing listeners are at fixed noise levels ranging from 25 to 85 dBA (Drullman, Festen, & Plomp, 1994; French & Steinberg, 1947; Speaks, Karmen, & Benitez, 1967; Studebaker, Sherbecoe, McDaniel, & Gwaltney, 1999). Rollover was observed for both fluctuating and continuous maskers when noise levels increased from 70 to 85 dBA, and speech levels rose above 71.5dBA. In addition, they reported that the greater rollover in fluctuating than in continuous noise. This finding could indicate that one aspect of rollover is a reduced ability to benefit from masker fluctuations at high presentation levels. Normal hearing individual does not face any difficulty in understanding speech in quiet as long as the speech is clearly audible and intelligible whereas speech perception abilities in noisy and reverberant or any other adverse listening condition is very difficult for normal hearing people

Speech perception in hearing impaired in quiet and noise

Hearing loss is defined relative to the lowest SPL(dBA) that normal hearing person can hear. Hearing loss is divided in 3 categories out of which sensory neural hearing loss is most common. Sensory neural hearing loss occurs when there is a lesion in the inner ear or VIII cranial nerve. Hearing loss can range from minimal to profound hearing loss. Individuals with hearing loss requires on average 10–12 dB higher SNR to obtain 50% correct performance in word identification, whereas individuals with normal hearing reach 50% correct at signal-to-noise ratios of 2–6 dB (Mcardle, Wilson & Burks, 2005). Loss of primary auditory nerve fibers that affect how the speech signal is encoded in the auditory nerve, further contributing to the loss of clarity which is majorly affected as the physiology of hair cells gets damaged. However, this loss of clarity is not reflected in the audiogram. Pure tone audiometry evaluates individuals hearing sensitivity and speech perception in quiet, but does not obtain speech perception in noise as part of their routine battery (Magnusson, 1995)**.** Whenever noise is present and audible, it affects the signal-to-noise ratio (Nilsson et al., 1994) In all the factors, types of competing noise play a major role in determining the extent of difficulty in speech perception (Cainer, James, & Rajan, 2008; Peters, Moore, & Baer, 1998; Pichora-Fuller & Souza, 2003; Schneider, Daneman, & Pichora-Fuller, 2002; P. E. Souza & Turner, 1994). The difficulty in speech perception leads to develop isolation from the society with advancement of age (Chia et al., 2007; Dalton et al.,2003). Hence, it is important to start effective rehabilitation programs to prevent aging persons from missing out on social events. In literature different authors have used different approach to evaluate declining effect of age on speech perception irrespective of hearing loss. Speech perception has been studied in different age groups individuals with different degree of peripheral hearing loss. The effect of age was segregated from the effect of hearing loss using different statistical procedure (Barrenäs & Wikström, 2000) or correlations (Van Rooij & Plomp, 1990; Van Rooij, Plomp, &

Orlebeke, 1989). Speech perception can be affected due to peripheral hearing loss, type of background noise, reduced temporal processing abilities due to advancing age and reduced spectral resolution (Füllgrabe, Moore, & Stone, 2014; He, Horwitz, Dubno, & Mills, 1999; Schoof & Rosen, 2014; Takahashi & Bacon, 1992). Speech perception abilities in normal hearing individuals and in older individuals with hearing impairment having normal cognitive abilities also suffers in understanding of speech in adverse listening conditions.

Study done by several authors on normal hearing individuals as well as on individuals with hearing loss in presence of noise noticed that hearing impaired individual shows poor speech perception abilities in presence of any types of noise compared to normal hearing adults (Amos & Humes, 1997; Frisina & Frisina, 1997; Karen S Helfer & Wilber, 1990; Humes & Roberts, 1990; Peters et al., 1998; Souza & Turner, 1994; Takahashi & Bacon, 1992; Van Rooij et al., 1989). This outcome is in agreement with a wide range of studies showing that peripheral hearing loss is the main factor limiting speech perception performance in background noises (Krogholt, Christiansen & Oxenham, 2014).

Speech perception through hearing aid in quiet and noise

Depending on the degree of hearing loss and output limits of hearing aid receiver technology, a hearing aid is prescribed to the individuals with hearing loss. Among these individuals with hearing loss, critical high frequency speech information is not available to hearing aid users. Study done by (Monson et al., 2014) reviewed the role of high-frequency energy (5kHz-20 kHz) in speech and singing and discussed the importance of high-frequency energy for sound quality, localization, and speech intelligibility. A number of studies have shown that difficulty perceiving high-frequency speech information can have negative consequences for speech perception (Hogan & Turner, 1998; McCreery et al., 2014;)

Nonlinear frequency compression is a hearing aid processing strategy that is intended to restore the speech frequency cues that would otherwise be unavailable to a listener with hearing loss (Hazan & Simpson, 1998). The frequency spectral information from inaudible-frequency regions to audible-frequency regions, nonlinear frequency compression algorithms helps individuals to use individualized compression ratios and cutoff frequencies based on the user's audiogram (Kluender, 2009). From an acoustic point of view, individuals with steeply sloping high-frequency hearing losses, which are often observed in an older adult population, would be predicted to receive the most benefit from this processing strategy, given that previously inaccessible high frequency cues would be compressed into an audible frequency range (Hopkins & Moore, 2009). Additionally, high frequency cues have been found to be particularly helpful for speech perception when background noise is present (Hornsby, Johnson, & Picou, 2011; Johnsrude et al., 2013; Peters et al., 1998).Even though nonlinear frequency compression is commercially available, there remains conflicting evidence across numerous studies published over the last decade regarding its benefit for adults using a range of outcome measures in simulations or with commercial hearing aids, including consonant recognition in adults (Cox, Alexander, & Gilmore, 1987; Glista et al., 2009; Simpson, Hersbach, & McDermott, 2005) and speech recognition for words and sentences (Hazan & Simpson, 1998; Schramm, Bohnert, & Keilmann, 2010; Wolfe et al., 2015). Studies have investigated the use of nonlinear frequency compression with pediatric population as well, measuring its effects on phoneme discrimination, word- and sentence-level recognition, and subjective preferences (Glista et al. 2009; Wolfe et al. 2011).

Study done by Sarampalis, Kalluri, Edwards and Hafter in year 2009 were measured listening effort with digital noise reduction processing using a dual-task test method for an adult population with hearing thresholds within normal limits. In the primary task, participants reported the final word of a sentence presented in quiet or four-talker babble at different signal to noise ratios. The secondary task was to recall as many of those words as possible from blocks of eight sentences. While the noise reduction algorithm under study did not improve speech recognition, it did improve recall performance at the most difficult SNR tested (−2 dB SNR). The benefit provided by the noise reduction algorithm was hypothesized to decrease the listening effort during the recognition task, possibly freeing cognitive sources within working memory for the recall task. Study done by Desjardins and Doherty (2014) reported use of a dual-task measure that had a primary task of sentence recognition in noise with a different secondary task (visual tracking) to assess the benefits of noise reduction in a commercial hearing aid for listeners with hearing loss. They found that noise reduction helped in reducing the listening effort in the most difficult SNR condition but did not significantly improve sentence recognition in noise performance, which is consistent with the findings of (Sarampalis et al., 2009) study. This finding suggests that although recognition performance did not significantly improve with the use of noise reduction, the secondary recall task was sensitive to a reduction in listening effort.

Some hearing aid algorithms are intended to provide additional audibility to the users, but alterations of the speech signal may also be conceptualized as a form of distortion

(Souza, Arehart, & Neher, 2015). Even though hearing aids do help to improve audibility for a speech signal, they also alter its spectral and temporal characteristics with the use of processing strategies, such as noise reduction or nonlinear frequency compression.

When spectral and temporal characteristics of the interfering noise are predictable and can be clearly characterized, noise reduction can be quite effective at improving the SNR for speech perception though it is more challenging (Anderson, White-Schwoch, Choi, & Kraus, 2013; Helfer & Wilber, 1990; Chang et al. 2007). Assuming that the target signal is speech, interfering signals may be random noise, another talker, or multiple talkers. Currently, the most common methods of noise reduction use some variation of either spectral subtraction or an assessment of SNR in each band followed by gain reduction to separate speech from noise without altering the signal of interest. Studies with adults have shown significant improvements in speech perception when the noise is restricted to a narrow frequency region (Rankovic, 1998; Van Dijkhuizen, Festen, & Plomp, 1991). Study done by (Tye-Murray, Spencer, & Gilbert-Bedia, 1995) evaluated the intelligibility of sentences and non-sense syllables processed by eight different noise reduction algorithms. Stimuli were presented in four different types of noise at 0 and 5 dB SNRs. The only notable finding they reported it was significantly better performance for sentences in one of the eight conditions.

From the above review of literature, it is clearly reflected that individuals with normal hearing as well as individual with hearing loss are having difficulty in speech perception in adverse listening conditions. Their performance is further deteriorated when signal to noise ratio is not favorable level. Individual with hearing impaired do recommended using hearing aids depending on their hearing loss. However, in spite of best hearing aid uses, these technologies could not able to replace the normal functioning of the auditory system in terms of speech perception.

Need for the study

Pure tone audiometry is a measure of individual hearing capability which can measure the individuals audibility (Wilson & McArdle, 2005) but cannot predict the successful useful of amplification (Walden & Walden, 2005) or signal to noise ratio loss. So, it is advisable to go for audiological test which uses speech stimulus Monosyllabic and spondees gives limited information about the speech perception ability as it lacks lexical semantics syntactic redundancies and dynamic cues. Sentences provide information regarding the time domain of everyday speech and can approximate contextual characteristics of conversational speech (Jerger, Speaks & Trammell, 1968). Brinkmann and Richter (1997) stated that the sentences provide additional information on the ability of participant to understand speech in daily life and have proved to be useful tool especially for selection of suitable hearing aids. Hence, there is a need to study the sentence perception among hearing aid users in quiet as well as in noise.

Aim of the study

The aim of the present study was to assess the clinical utility of sentence perception abilities among hearing aid users in presence of noise and compared the performance with quiet condition.

Null Hypothesis

The null hypothesis assumed for the present study was that there is no significant difference in the sentence perception abilities of the hearing aids users in quiet and noise condition.

Objectives of the study

The specific objectives of the study is to find out,

1. Sentence perception abilities of the hearing aids users in quiet condition.
2. Sentence perception abilities of the hearing aids users in presence of the noise.
3. To compare the sentence perception abilities among hearing aids users in quiet and noise condition.

Chapter 2

METHOD

The present study was aimed to compare the sentence perception ability in individual with hearing impairment who was the naïve hearing aid user in two different conditions i.e. in quiet and noise. To accomplished the above aim, the below mentioned method was adopted.

Participants

Twenty-four individuals with hearing impairment (13 males & 11 females) in age range of 30 years to 60 years (mean age 57.12 years) participated in study. All the participants included in the study had either asymmetrical or bilateral symmetrical moderate-to-moderately severe sensorineural hearing impairment with flat configuration. They were either native Hindi/Urdu speakers and fitted with pre-selected digital hearing aids. The above study was single group (subject) design and comparison was done within group subject in two different conditions i.e. quiet and noise (-2 dB SNR) with and without hearing aids. A written/oral informed consent was obtained from all the participants prior to conducting an experiment and explained the procedure.

Inclusion and exclusion criteria

All the participants had normal otoscopic examination which indicates the present status of the tympanic membrane and ear canal. They were having asymmetrical and/or bilateral moderate-to-moderately severe sensorineural hearing impairment (41-70 dB HL) with flat configuration. They had either A/As type tympanogram with absence of acoustic reflexes in both ears indicating status of the middle ear. All the participants had absent Transient Evoked Otoacoustic Emission in both ears. Those participants who had presence of any otological, and neurological problem were excluded from the study based on structured interview.

Test environment:

The pure tone audiometry and speech audiometry were carried out in a double room situation. Immittance evaluation was administered in single room situation. All the room were sound treated complying with American national standard institute guidelines (ANSI S3.1-1991) (ASA 99-1991) for permissible ambient noise level.

Instrumentation:

A calibrated two separate and identical channel advanced feature invents piano diagnostic audiometer with TDH 39 supra aural headphone housed in MX-41/AR ear cushion was used for air-conduction threshold estimation and speech audiometry. The same audiometer with Radio Ear B-71 bone vibrator was used for bone conduction threshold estimation. A calibrated GSI- Tympstar clinical immittance meter was used for tympanometry and reflexometry. A calibrated otoacoustic emission system ILO (version 6) was used to record the TEOAEs using click stimuli. HI-PRO version-2 a universal hardware interface for programming system was used to program the hearing aid. A pre-selected digital behind the ear hearing aid was used for the study.

Procedure

A detailed structure case history was taken before the commencement of audiological evaluation which includes the pure tone audiometry, Speech audiometry, Immittance evaluation (tympanometry & reflexometry) and transient evoked otoacoustic emission. Pure tone threshold was obtained using modified Hughson and Westlake procedure (Carhart & Jerger, 1959) at octave frequencies from 250 Hz to 8000 Hz for air conduction and 250 Hz to 4000 Hz for bone conduction threshold. The bracketing method was adopted for obtaining speech recognition threshold (SRT) using the spondee word list in Hindi developed by Abrol et al. The speech identification score (SIS) was obtained using phonetically balanced (PB) word list at 40 dB (Ref. SRT). Ascending method was used to determine participant's uncomfortable level for speech for both ears. During immittance evaluation, participant was seated comfortably and instructed to avoid swallowing or any other head movement. Tympanometry was carried out with a probe tone frequency of 226 Hz at 85 dB SPL. Tympanogram was obtained by changing the pressure within the ear canal +200 to -400 daPa by using pump speed of 50 dp/s. Ipsilateral and contralateral acoustic reflexes threshold were measured for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz using probe tone frequency of 226 Hz. Transient evoked otoacoustic emissions was recorded using click stimuli and signal-to-noise ratio (SNR), reproducibility was documented. For considering the response present, +3 dB SNR at two consecutive frequencies was cutoff criteria used with above 80% reproducibility for TEOAEs.

Test material

Sentence test for speech recognition in Hindi developed by (Jain, Narne, Singh, Kumar, & Mekhala, 2014) was used for unaided and aided performance with pre-selected digital BTE hearing aids. The developed sentence test was validated on native speaker of Hindi/Urdu and having more than 20 equivalent lists. Each list consisted of 10 sentences. Out of 20 lists, two lists were randomly selected and used for quiet and noise conditions in present study. The order of presentation of list was randomized to avoid the order effect.

Hearing aid fitting and optimization

All the individuals with hearing impairment fitted with pre-selected hearing aids were first time hearing aid user. The test ear of the participant were fitted with the hearing aid and coupled to the ear via ear tip. The programming of the hearing aid was based on the audiometric threshold and NAL-NL1 to normalize the loudness growth (Byrne, Dillon, Ching, Katsch, & Keidser, 2001). Further optimization of hearing aid setting was done and after the initial fit for ensuring the audibility of the ling's sounds and finally the above the program was saved in hearing aid. After programming patients were evaluated wearing hearing aid for the in quiet and noise conditions. The sentences were presented with recorded material routed through the diagnostic calibrated audiometer. The output was channeled using the loudspeaker at 0^0 azimuth at most comfortable level (MCLs). The participants were asked to repeat the complete sentence and PB words in both quiet as well as in the presence of noise. The response was considered correct only if either complete sentence or key words in the sentences were repeated correctly by participant and was not semantically different. Similarly, PB words were also considered correct if repeated correctly. The responses were also audio-recorded for the offline analysis to obtain scores.

Instruction to the participants

The participants were instructed as *"you are going to hear words (PB) and then sentences in Hindi, which will be first in quiet and then in presence of noise conditions respectively. Your task is to hear this word as well as sentence very carefully and try to repeat exactly what you heard. In case it's not clearly heard or understood you can make a guess for word to complete the sentence or pay attention to the key words".*

Scoring:

Each sentence was scored one if correctly repeated and, in each sentence, there were maximum 3 key words. The list 1 and list 2 had total 28 and 29 key words respectively. Each key word was also awarded with score 1 for correct recognition.

Statistical analysis:

The data were tabulated and analyzed using statistical packaged for social sciences (SPSS) software version 21.0. Shapiro-Wilks test of normality was used to find the normal distribution of the data, which shows non-normal distribution of the data ($p > 0.05$). Hence, non-parametric tests were performed to assess for the different parameters. Descriptive statistics was used to obtain mean and standard deviation for the unaided and aided performance in quiet and in presence of noise. Further, Wilcoxon signed rank test was done for the within group comparison for unaided and aided performance for both PB words and sentence perception in quiet and noise.

Chapter 3

RESULTS

To meet the objective of the study, results are tabulated and analyzed using SPSS version 21.0. Normality of the data was tested using shapiro-wilk test, which showed data were not normally distributed and hence non-parametric test was done. The non-parametric test includes Wilcoxon signed rank test for the comparison of the performance in quiet and noise condition for PB words and sentence perception between with and without hearing aids. Descriptive statistics includes mean and standard deviation (SD) for unaided and aided performance in quiet and noise for both monosyllabic word identification (PB Words) and sentence perception.

Monosyllabic word identification in Quiet and noise

Monosyllabic word identification was estimated in naïve hearing aid users with and without hearing aids in both quiet and noise conditions. The mean and standard deviation of the unaided and aided performance using monosyllabic words (PB words) is mentioned below in Table 1. From table 1, it is inferred that the mean word identification scores in unaided condition in quiet as well as in noise is lower (poorer) in comparison to aided condition. Further, it is noticed that the mean scores in the presence of noise i.e. at -2 dB SNR is almost lesser then 50% of the maximum scores in naïve hearing aid users (Figure 1).

Table 1: Mean and Standard deviation of PB word scores in unaided and aided conditions

CONDITION		**QUIET**		**NOISE (-2 DB SNR)**	
	N	Mean (Max. scores = 25)	SD	Mean (Max. scores = 25)	SD
Unaided	24	1.04	2.11	0.00	0.00
Aided	24	21.38	1.34	10.04	2.67

N: Number of participants; SD: Standard deviation; SNR: Signal- to-noise ratio

Wilcoxon signed rank test was done to compare between the unaided and aided performance in quiet as well as in noise condition for monosyllabic word identification. The results revealed statistically significant differences between unaided and aided in quiet (Z= -4.31, $p<0.05$), as well as in noise i.e. at -2 dB SNR (Z= - 4.29, $p<0.05$) for monosyllabic words identification.

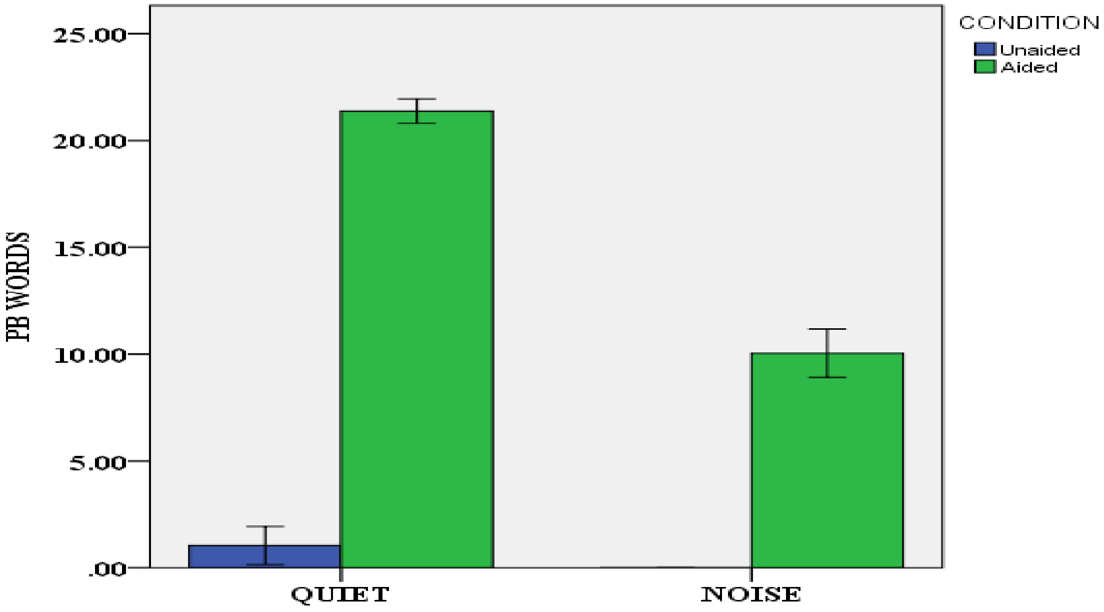

Figure 1: Mean and 95% confidence interval (CI) in quiet and noise (-2 dB SNR) for PB words

Sentence perception in quiet and noise condition

Sentence perception was estimated in naïve hearing aid users with and without hearing aids in both quiet and noise conditions. The scoring of sentence perception is done in two ways i.e. first one is repetition of the complete sentences and second one is correct identification of key words. The mean and standard deviation of the unaided and aided performance using sentence test is mentioned below in Table 2. From table 2, it is inferred that the mean sentence perception scores without hearing aids in quiet as well as in noise is lower (poorer) in comparison to with hearing aid condition. Further, it is noticed that the mean scores in the presence of noise i.e. at -2 dB SNR is almost lesser then 50% of the maximum scores in naïve hearing aid users for both key words identification as well as complete sentence identification (Figure 2 & 3).

Table 2: Mean and standard deviation of sentence perception in quiet and noise condition

SCORES	**CONDITION**		**QUIET**		**NOISE**	
		N	**Mean**	**SD**	**Mean**	**SD**
Sentence scores (Max. Scores= 10)	Unaided	24	0.33	0.81	0.00	0.00
	Aided	24	9.71	1.04	2.92	1.88
Key word scores (Max. Scores = 28)	Unaided	24	1.20	2.28	0.00	0.00
	Aided	24	27.33	2.16	12.29	6.31

N: Number of participants; SD: Standard deviation

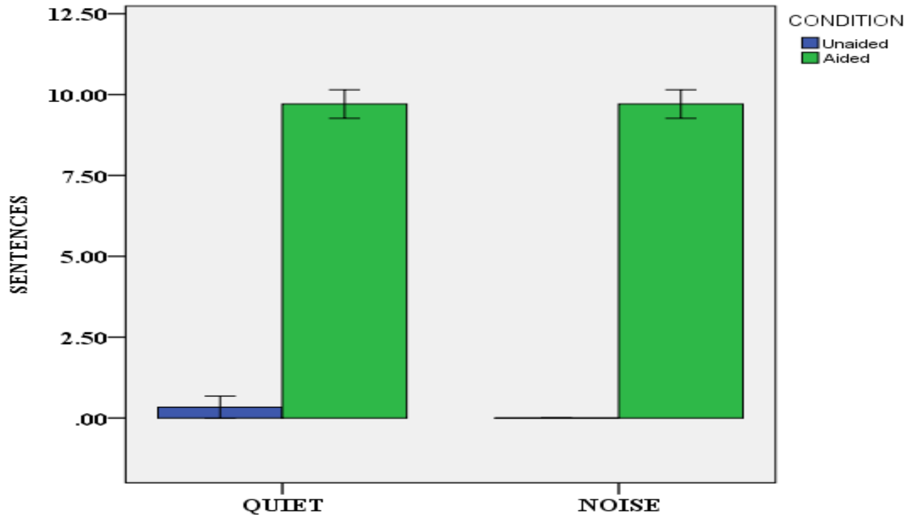

Figure 2: Mean and 95% confidence interval (CI) of sentence perception in quiet and noise with and without hearing aids

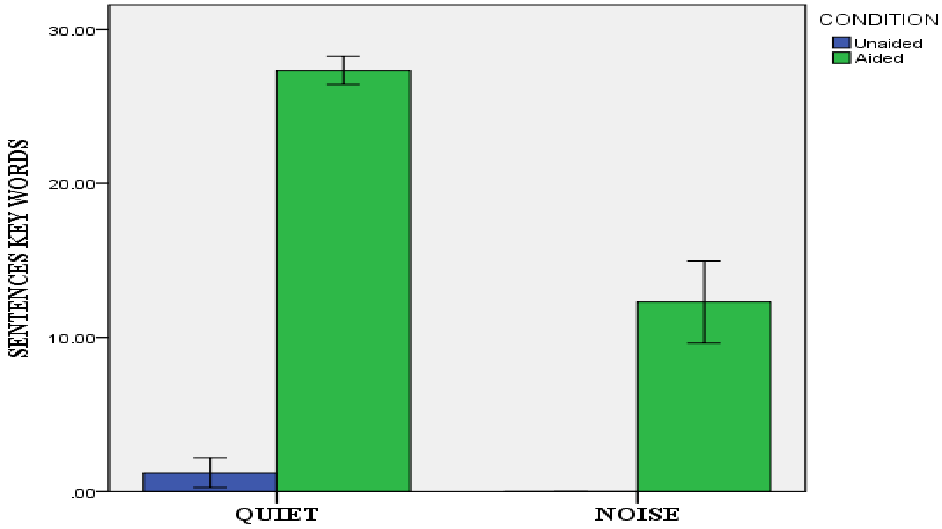

Figure 3: Mean and 95% confidence interval (CI) of sentence perception using key words in quiet and noise with and without hearing aids

Wilcoxon signed rank test was done to compare between unaided and aided condition for both quiet and noise conditions. The results revealed statistically significant difference between unaided and aided performances in quiet (Z= -4.47, $p<0.05$), as well as in noise (Z= -4.22, $p<0.05$) for sentence perception. Further, sentence perception using correctly identification of key words shows statistically significant differences between unaided and aided performance in quiet (Z= -4.41, $p<0.05$) as well as in noise i.e. at -2 dBSNR (Z= -4.20, $p<0.05$). Comparison between quiet and noise in aided conditions only performed using Wilcoxon signed rank test, which revealed statistically significant differences between quiet and noise conditions for monosyllabic word identification (Z = -4.30, $p<0.05$), sentence perception (Z = -4.30, $p<0.05$), and sentence perception using key words (Z = -4.28, $p<0.05$) in naïve hearing aid users.

Chapter 4

DISCUSSION

The purpose of the present study was to assess speech perception (monosyllabic words and sentence) ability in naïve hearing aid users in presence of noise i.e. at -2 dB signal-to-noise ratio (SNR) and quiet condition. The study also compares the aided and unaided scores in noise as well as in quiet for monosyllabic word and sentences.

Monosyllabic word identification ability in quiet and noise

Monosyllabic word identification scores were higher (better) in aided condition compared to unaided condition in quiet as well as in noise in naïve hearing aid users. The present finding is in agreement with the existing literatures (Barr & Roup, 2011;) measured the effect of noise on normal and hearing-impaired individuals having hearing loss mild to moderate hearing loss at different SNR (i.e. 5, 10, 15 dB) with monosyllabic words and they found that noise is mildly disruptive for normal but it more for hearing impaired individuals. (Pekkerinen, Salumivalli & Suopaaj, 1990;) measured the effect on speech perception of noise at (0, 5 and 10dB SNR) and reverberation time (2.1 and 1.6).and compared with quite noise reverberation and noise with reverberation conditions. Results revealed that speech perception was excellent in quiet compare to noise and reverberation condition but it significantly reduced when noise and reverberation was added together. Barrenasmarie-Louise and Wikstrominger (2000) studied the speech recognition in noise in sensorineural hearing-impaired children and compared to normal hearing school going children. Results showed the significant reduction (Poor) of scores in presence of noise compared to normal children. Their findings suggested that speech identification scores in noise correlated strongly with pure tone audiogram. Hearing aids with advanced features provides the noise reduction, adaptive directionality which helps in improvement of SNRs for speech perception. (Hawkins & Yacullo, 1984) reported that the SNR advantage of binaural hearing aid and directional microphones under different level of reverberation in normal and hearing-impaired subjects. Pekkerinen, Salumivalli and Suopaaj (1990) revealed significant binaural advantage (2-3 dB) and directional microphone (3-4dB) advantages in adverse listening condition. This suggests that the SNR is optimized when hearing aid with directional microphone used in daily life environment. (Shanks, Wilson, Larson, & Williams, 2002) were reported speech recognition performance of patients with unaided and aided conditions using linear and compression hearing aids. Their results show significance difference in speech perception with hearing aid as compare to without hearing aids. Study done by Ohlenforst et al in year 2017 assessed the effect of hearing impairment and hearing aid amplification on listening effort. They found that the hearing-impaired individuals put more effort than normal even though the hearing aid provides the gain for speech frequencies region.

Perception of speech in the presence of background noise is a challenging listening situation for individuals with normal hearing as well as those who have hearing impairment (Darwin, 2008). When speech signals are embedded in background noise, individuals with normal hearing are often able to take advantage of temporary improvements in the signal-to-noise ratio (SNR). The above temporary improvements requires the use of temporal, spectral, and spatial auditory cues as well as the integration of multi-sensory information (Billings, Penman, McMillan, & Ellis, 2015). It happens because the signal is fluctuating, which makes it easier for the listener to hear the message in between when the speech level is greater than the noise. Unfortunately, individuals with hearing impairment are not always able to take advantage of these improvements in presence of noise (Adams, Gordon-Hickey, Morlas, & Moore, 2012). Further, background noise, whether it is made up of speech or non-speech sounds, degrades the signal and interferes with important cues. However, Giolas and Epstein (1963) stated that monosyllables provide diagnostic but not prognostic values as, it does not approximate how an individual understand conversational speech. Cox, Alexander and Gilmore (1987) reported no relationship between the monosyllable recognition threshold and hearing aid benefits.

Sentence perception abilities in quiet and noise condition

Sentence perception abilities with hearing aids were better compared to without hearing aids in both quiet and in presence of noise (-2 dB SNR). The scoring was done using both complete sentence identification as well as repetition of key words. Performances were better with both the ways of scoring in aided condition among naïve hearing aid users. Sentence perception helps in assessing both recognition and comprehension in daily life situation. Several studies in literature support the present finding (Hagerman, 1995; Ozimek, Warzybok & Kutzner, 2010; Koloustou, Dimitris, & George, 2017). The studies existing in literature compared the sentence perception in noise and quiet with aided and unaided conditions and they found poorer scores in unaided than aided score in presence of noise. Study done by Seyede faranak emani (2015) compared the word recognition score in presence of wide band noise in healthy individuals at +5 & +10 dB and concluded that the speech recognition scores reduced as SNR increases even in normal hearing individuals. Several authors compared the speech understanding with hearing aid in the noise and without noise and concluded that scores were significantly better with hearing aid but it reduced in presence of noise with aided condition (Mens, 2011; Hazan & Simpson, 1998; (Brooks et al., 2001); (Hällgren, Larsby, Lyxell, & Arlinger, 2005). Sentence perception abilities are having several advantages such as providing insight regarding an individual's performance in more realistic communication scenario; considered to be valid indicators of intelligibility and give better representation of verbal communication; provide better accuracy and effectiveness in measuring speech reception thresholds; contain contextual cues and are expected to have better predictive validity compared to words; helps in assessing co-articulation as well as temporal aspects of speech; and having more face validity as 'natural' and 'meaningful' stimuli for assessing auditory function.

Chapter 5

SUMMARY AND CONCLUSION

Perception of speech in the presence of background noise is a challenging listening situation for individuals with normal hearing as well as those who have hearing impairment. When speech signals are embedded in background noise, individuals with normal hearing are often able to take advantage of temporary improvements in the signal-to-noise ratio. The above temporary improvements require the use of temporal, spectral, and spatial auditory cues as well as the integration of multi-sensory information. It happens because the signal is fluctuating, which makes it easier for the listener to hear the message in between when the speech level is greater than the noise. Unfortunately, individuals with hearing impairment are not always able to take advantage of these improvements in presence of noise.

A total of 24 individuals with moderate-to-moderately severe sensorineural hearing loss with flat configuration in age range of 30-60 years participated in study. All the participant was naïve hearing aid users. After routine audiological evaluation and hearing aid fitment participant underwent word identification test and sentence perception in presence of noise. Present study was carried out in two conditions i.e. in quiet and then in noise with unaided and aided conditions. Test material used was monosyllabic words and sentences. Statistical analysis was done by using SPSS version 21. Non- parametric test such as Wilcoxon signed rank test was done for within group comparison in aided and unaided conditions. The results revealed that there is significant difference in recognition scores in both the listening conditions i.e. quiet and noise. It can be concluded that the because background noise is a real, everyday problem for hearing aid users, the implementation of test measures to estimate the degree of difficulty is beneficial to clinicians in selecting appropriate amplification. A patient's perception of background annoyance and tolerance can affect hearing aid use, we can use speech-in-noise tests as a positive counseling tool to help patients evaluate their expectations and reach their listening potential.

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