Listening effort in individuals with noise induced hearing loss

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This Dissertation is presented as part of the requirements for the

award of the Degree of Master of Science

University of Mysore, Mysore

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CERTIFICATE

This is to certify that this dissertation entitled **"Listening effort in individuals with noise induced hearing loss"** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student Registration Number: 17AUD040. This has been carried out under the guidance of the faculty of the 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 **"Listening effort in individuals with noise induced hearing loss"** 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 **"Listening effort in individuals with noise induced hearing loss"** is the result of my own study under the guidance of Dr. Hemanth N, Reader 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.

Mysore **Registration No: 17AUD040**

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Acknowledgment

"Feeling gratitude and not expressing it is like wrapping a present and not giving it." "There is always something to be thankful for." "Not what we say about our knowledge we gain, but how we use them, is the true measure of our thanksgiving."

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Abstract

Objective: The study aims to investigate the listening effort in individuals with noise induced hearing loss. The objectives was to compare the scores on primary and secondary tasks of listening effort at each of the SNRs between NIHL group and age matched normal hearing control group. Further, self- assessment effort assessment scale was correlated with the recall score of listening effort. **Method:** A comparative research design was utilized to investigate the listening effort at each SNRs between normals and noise induced hearing individuals. A total of 40 participants took part in this research. Participant comprised of 20 normal hearing individuals and 20 noise induced hearing individuals from the age range of 40 to 60 years. The target sentences in dual task paradigm was presented at participant's MCL which was used to assess the listening effort at different (-1, 0, 2, 4) SNRs. In addition, the self-rated effort assessment scale was used. **Result:** A one repeated measure ANOVA (one factor with four SNRs) with between subject factor as groups (control and clinical groups) was performed separately for primary and secondary tasks of listening effort. The results revealed a significant main effect of SNRs and group on listening effort. Further, an interaction effect of SNR*group caused significant effect on listening effort. Results showed NIHL group performed significantly poorer in both the tasks (primary and secondary tasks of listening effort) than the normal group. Further, as expected, listening effort increased with reduced in SNRs. In addition, there was a significant moderate negative relation between self-rating listening effort scale and recall score of listening effort. **Conclusion:** The noise induced hearing loss subjects put effortful listening at reduced SNRs than age matched normal hearing group.

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Chapter 1

Introduction

Hearing is an essential sense of human beings. It is one of the channels through which we communicate and interact with society. Unfortunately, multiple factors can affect the hearing of an individual. The most common factor which can hurt our hearing is noise. Noise can have a profound impact on the effectiveness of communication. Noise by definition is any undesired sound, and by extension, noise is any unwanted disturbance within a useful frequency band. Noise may be continuous, intermittent, impulsive or explosive. Loud noise not only causes damage to hearing but it is known to adversely affect work performance in the industry causing annoyance, sleep disturbance, psychological distress, and physiologic changes (includes changes in heart rate, changes in blood pressure, decrease sodium level in blood).

Consequences of hearing the loss in factory workers directly impact on interference with speech communication due to a prolonged period of noise exposure. NIHL is the second most common form of the sensorineural hearing deficit, after presbycusis. NIHL is a sensorineural hearing deficit that begins at the higher frequencies (3 kHz to 6 kHz) and spreads in other bands of frequencies gradually as a result of chronic exposure to excessive sound levels. Studies have shown that noise levels of more than 85 dB cause an acquired NIHL. It is usually bilateral symmetrical hearing loss and affecting high frequencies first than spreads to low frequency. High-frequency loss results loss of clarity in speech perception and then interfere with daily activities as hearing loss progresses (Nandi, 2008). Noise causes temporal processing deficits over long term exposure. Kumar et al. (2012) measured TMTF (temporal modulation transfer function) and assessed speech recognition in multi-talker babble at -5 dB on train drivers who had the normal hearing ability. It found that temporal processing skills were reduced in individuals who have exposed to noise. Also, speech recognition scores were significantly poorer in noise in those who are exposed to noise than who are not. It infers that temporal processing impairment contributed to the poor performance in speech perception.

A distortion of signal by background noise and another source of distortion caused due to damage in the cochlea by noise exposure limits access to cognition in understanding speech than individuals without hearing loss, potentially impacting the ease of communication. The distorted input from cochlea reaches the central auditory system. The cognitive system allocates more resource to eliminate the noise and remaining available resources are used to fill the misperceived information (episodic memory) and or rehearsals the heard words in memory and finally recalls to understand the information. In a situation where demand is high (noise and reverberation conditions) then on that time, neuroeconomics calculation takes place to evaluate the cost-benefit analysis. I listened to what reward shall I get, and this feedback allows the listener to undergo (dis)pleasure or (de) motives to listen further by reallocating the cognitive resource. Sometime listeners may sense from the knowledge of the situation to understand the speech before allocating the cognitive resource in quiet and at different SNRs. Dudek et al, (1991) show the effect of noise on cognitive processes in NIHL participants. They have used simple reaction time test (SRT), choice reaction time test (CHRT) and Stroop's tests at two different noise levels 75 dBA and 95 dBA. The results revealed a significant interaction effect of noise and individual noise sensitivity on time reaction and the number of errors. In a similar line of experiment Irgens et al, (2018) evaluated cognitive performance using visual attention test and its processing speed. The results of the study state that high noise exposure levels during work impair reaction time. The capacity of mental resources is allocated to perform tasks, that there are individual differences in maximum capacity, and that the amount of capacity allocated to tasks increases as the tasks become more difficult or demanding (Wingfield, 2016). When there is decreased hearing sensitivity or in adverse listening condition (background noise), the perceptual effort required to recognize speech consumes cognitive resources. When effortful listening consumes these resources, a limited and or insufficient cognitive resources are available for encoding the retrieved words in memory for comprehending the information (Wingfield et al. 2006). What remains unexplained is how the allocation of cognitive capacity during listening may be modulated when speech is presented in noise in NIHL individuals, even when the demands of the listening task do not exceed a person's maximum capacity. Thus, it is hypothesized that temporal impairment in NIHL can have a significant effect on listening effort.

1.1 Need for the study

Individuals who exposed to noise over some time develop temporal processing impairment in addition to hearing loss which has a deleterious effect on speech recognition. Kumar et al (2012) found temporal processing impairment in the noise exposure group than control normal hearing group although hearing ability in both groups were almost matched to 25 dB HL. Temporal processing impairment in them has caused reduced speech recognition scores in noise. As we know that speech communication takes place often in a noisy environment. If the speech intensity level is less than noise than top-down processing mediates to understand the speech for communication. This is because peripheral masking and distorted input from the damaged auditory system makes the listeners use their available cognitive resources. There is a dearth of literature on how much effort a noise-induced hearing loss subject puts in to understand speech when it is masked by noise often in everyday communication. Thus, the listening effort is investigated in noise-induced hearing loss subjects.

1.2 Aim of the study

To investigate listening effort in individuals with noise-induced hearing loss

1.3 Objectives of the study

- To compare the scores on primary and secondary tasks of listening effort between normal and NIHL groups at each of the SNRs.
- To correlate the recall score of listening effort with self-rating scores on listening effort.

Chapter 2

Review of literature

The impact of noise upon the auditory system has become a major problem in today's highly technological society. Occupational hearing loss can be defined as a partial or complete hearing loss in one or both the ears as a result of an individual's employment (Nandi & Dhatrak, 2008). It includes acoustic trauma which results in sudden changes in hearing resulting from a single exposure to a sudden burst of sound kirchner et al, (2003) and noise-induced hearing loss (NIHL). The degree of hearing loss may range from mild to profound. NIHL depends on an individual’s susceptibility, amount and duration of noise exposure. Initially, the hearing loss appears at 4 kHz due to the largest energy of sound reaches cochlea because of the resonance frequency of ear-canal and middle ear. Eventually, the hearing loss spreads in the frequencies below and above the 4 kHz notch leading to trough-shaped configuration or sloping hearing loss (Schwetz, Doppler, Schewezik, & Wellesxhik, 1980). The psychophysical evidence indicates that the presence of cochlear loss causes impairment in temporal processing abilities. Temporal processing encompasses a wide range of auditory skills including temporal resolution or temporal discrimination, masking, temporal integration, and temporal ordering, as well as localization and pitch perception (ASHA, 1996). The temporal aspects of the stimulus are crucial for normal perception and understanding speech in quiet and adverse listening conditions. Studies have shown that individuals with cochlear hearing loss perform poorly on tasks of temporal processing (Moore, 2007). The noise exposure has adverse effects on cognitive performances, and the magnitude of these depends on the duration and intensity of the noise and also cognitive task performances. Cognitive science research suggests that the noise might reduce worker productivity of the individuals by impairing the cognitive functions, such as attention and working memory (Szalma & Hancock, 2011). Noise can also disturb the man's work, sleep, and communication. Also, noise adversely affects the tasks that involve memory and problem solving (Woodhead, 1964). The speech perception skills in NIHL individuals are adversely affected by the presence of multiple babble. This is due to the changes in the central auditory system due to prolonged exposure to occupational noise. This indicates that the individuals with NIHL may require more effort in listening especially to understand the speech in noise compared to normal hearing listeners. A hearing-impaired listener might not be able to hear every single word in a sentence. Consequently, the more mental effort may be required to identify the relationship between the different items in the sentence, guess misheard words. The increased listening effort might benefit hearing-impaired individuals in terms of understanding speech in challenging listening situations (Downs 1982; Hick & Tharpe 2002; Zekveld et al. 2011; Hornsby 2013).

2.1 Audiological characteristics in NIHL

Due to noise exposure, there are two functional consequences to hearing: **TTS** (Temporary Threshold Shift) and **PTS** (Permanent Threshold Shift) (Plontke and Tubingen, 2004). TTS refers to a transient sensorineural hearing loss lasting for hours to a few days. Hearing thresholds are depressed until the metabolic activity in the cochlea recovers. Hence before audiometric testing subjects should be out of the noise for at least 24 hours if not 48 hours to avoid the effect of TTS on hearing (Bohne & Harding, 1999). NIHL cause damage to the outer hair cells of the cochlea resulting in a reduction of the amplification ability of the cochlea (Reshef, Attias, & Furst, 1993). Shortly after a damaging exposure, the cells and the tissues of the inner ear are in a dynamic state of injury, degeneration, and repair. This has termed as the acute phase of noise damage. WHO estimates that 10% of the world population is exposed to sound pressure levels that could potentially cause noise-induced hearing loss. In about half of these people, auditory damage can attribute to exposure to excessive noise (Oishi & Schacht, 2011). The Permanent threshold shift predicted by the duration of noise exposure, frequency of wearing noise protectors and especially by the initial TTS at 4 kHz. Using 14 dB TTS as a cut-off had 82% sensitivity and 53% specificity to predict 20 dB or higher levels of NIHL and TTS at 4 kHz is a significant predictor of long-term NIHL, as measured by PTS at 4 kHz or the average PTS for 2–4 kHz (Moshammer, 2014). The National Institute for Occupational Safety and Health (NIOSH) recommends that workers not be exposed to more than 85 dBA for more than 8 hours per day (NIOSH, 1998). They used electrophysiological measures one hundred and twenty-six subjects (76 females and 50 males) to see the effects of noise exposure and the subjects had a wide range of lifetime noise exposure. Exposure to noise adversely affects speech discrimination. Sheikh et al, (2017) evaluated speech discrimination in noise from occupational high-frequency hearing loss subjects. It is found that frequencies above 3 kHz are important for understanding speech, especially in background noise. In those NIHL patients who have had hearing loss at 3 kHz face a serious problem in speech discrimination and localization abilities (Moore, 2016). To summarise, the noise-induced hearing loss found to have mild to severe hearing loss with either sloping or trough-shaped configuration. The serious consequence found in speech recognition abilities irrespective of configuration and degree of hearing loss

2.2 Speech perception in noise and NIHL

Speech recognition ability assessed in train drivers in whom hearing sensitivity was normal (Kumar et al, 2017). A total of 118 participants who exposed to continuous noise of more than 8 hours of 80 dBA. Speech recognition assessed in multi-talker babble presented at -5 dB SNR. Results revealed a significant main effect of subjects group on the speech scores, and they also found that the ability to identify the speaker in the presence of noise was poor in individuals with NIHL than the control group. They concluded that long-term noise might have a persistent effect on brain function and behavior, even though the peripheral hearing sensitivity is within the normal range. In a similar line of study Keller et al, (2017) investigated the speech intelligibility in the presence of noise in navy command. A total of 32 navy command with age ranged from 28 to 44 yrs were recruited. They conduct the modified rhyme test at different SNRs. At reduced SNRs, the score in rhyme test reduced. They concluded that noise could have a significant negative impact, especially in a dynamic and high-stress environment. In yet another study by Skinner, (1980) who conducted speech recognition test in noise on participants of NIHL with high-frequency hearing loss.They used SPIN in the field and word identification. They compared the scores from both tests from NIHL with normal individuals. Results show that subjects with noise-induced hearing loss got poor scores for both the tests. Liden (1957) reported that NIHL individuals scored 20 to 30% poorer than the control group in speech intelligibility task using phonetically balanced words and monosyllabic words. Also, there was a good correlation between PTA and Speech recognition scores. Further, a higher intensity level was required to match the scores of the control group. Quist et al, (1978) investigated the hearing loss at 2 kHz on speech recognition ability. A total of 20 NIHL participants with or without loss at 2 kHz were examined using speech audiometry with a three-digit test, bisyllabic and monosyllabic PB word lists in silence and at noise with a masking effect of 44 dB and 68 dB at 1 kHz. Results showed that the subjects with up to 20 dB hearing loss at 2 kHz had almost the same speech comprehension in noise as normal hearing subjects. Whereas subjects with hearing loss greater than 20 dB at 2 kHz had increasing discrimination loss at increasing noise levels. NIHL individuals needed a better signal-to-noise ratio than normal-hearing persons. To summaries, speech processing abilities in individuals with NIHL poorer than the normal individuals in quiet and at noise conditions.

2.3. Cognition and NIHL

The available capacity fluctuates with arousal. The "allocation policy," which governs how much of the available capacity will be supplied to which activities. The allocation policy "is controlled by four factors: 1) automatic attention and 2) intentional attention 2) The evaluation of demands 3) fatigue, low arousal displeasure may influence the evaluation of performance 4) motivation and displeasure. Two sets of factors control the level of arousal: 1) the demands imposed by the activities 2) input out related demands include source, transmission, listener, message and contextual factors.

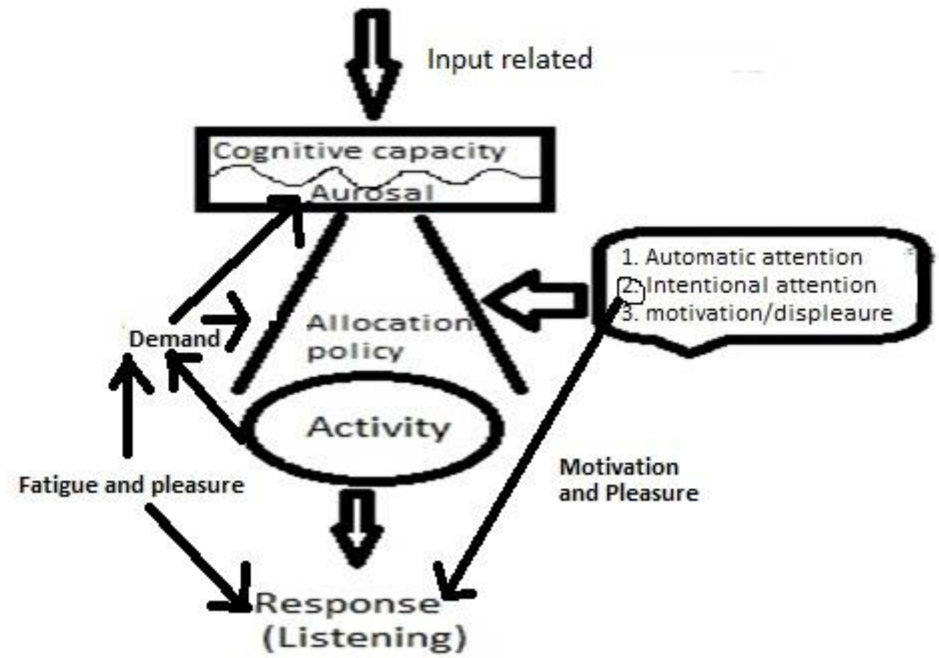


Figure-2.1. Framework for understanding the listening effort

Pichora-Fuller et al (2016) explained the framework for understanding the effortful listening Figure-2.1. The cognitive is diverse among individuals. Either automotive attention or intentional attention is given then cognitive capacity is allocated to do possible activity for listening. The cognitive and auditory systems work together along with psychological and social factor for the perception of speech. Basic vocabulary and accentuated input speech delivered in the presence of noise. The peripheral and central auditory system process the signals. The arousal in cognitive capacity allocate resource to eliminate the noise, and available resource is used to put the words in memory and or use the episodic memory to retrieve the words in memory to understand what is heard. The intentional attention is individual driven if the person is pleasure or motivated to listen then with the available cognitive capacity was allocated to understand the speech. If the situation is demanded (noise or reverberation), then cognitive capacity is reallocated to extend its resource for listening. The number of activities is evaluated which is influenced by performance and reward in listening (neuroeconomics) gives contingent feedback to allocate the resource for understanding the speech and over some time system undergo fatigue. The listening situation does not have any rewards or demotivated/ displeasure then gradually intentional attention is rollbacked. The allocation process in a cognitive resource is stopped, where the heard sounds are not interpreted through the auditory system process the sounds leading to just hearing a sound.

A distortion of signal by background noise and another source of distortion caused due to damage in the cochlea by noise exposure limits access to cognition in understanding speech than individuals without hearing loss, potentially impacting the ease of communication. The distorted input from cochlea reaches the central auditory system. The cognitive system allocates more resource to eliminate the noise and remaining available resources are used to fill the misperceived information (episodic memory) and or rehearsals the heard words in memory and finally recalls to understand the information. In a situation where demand is high (noise and reverberation conditions) then on that time, neuroeconomics calculation takes place to evaluate the cost-benefit analysis. If listened to what reward shall I get, and this feedback allows the listener to undergo (dis)pleasure or (de) motives to listen further by reallocating the cognitive resource. Sometime listeners may sense from the knowledge of the situation to understand the speech before allocating the cognitive resource in quiet and at different SNRs.

Kumar et al (2012) measured TMTF (temporal modulation transfer function) and assessed speech recognition in multi-talker babble at -5 dB on train drivers who had the normal hearing ability. It found that temporal processing skills were reduced in individuals who have exposed to noise. Also, speech recognition scores were significantly poorer in noise in those who are exposed to noise than who are not. It infers temporal processing impairment unable to access the cognitive system to function effectively in allocating the resources to eliminate the noise and retrieving the stored information from memory to comprehend the speech signal. During this process, the cognitive system tries hard to retrieve the information in noise such that listening becomes more effortful. Irgens et al, (2018) evaluated cognitive performance using visual attention test and response time. The results of the study state that high noise exposure levels during work impair reaction time and they didn't found any association between noise exposure and test errors. Dudek et al, (1991) measured the effects of noise on information processing in perceptual and memory tasks, as well as time reaction to perceptual stimuli on 18 individuals. They used performance simple and choice reaction time test and Stroop's test at three levels and heart rate in information processing test. They found that noise has no effects on information processing and time reaction to perceptual stimuli. They concluded that noise as a separate factor does not influence task performance. However, noise affects the heart rate. They found that selecting a more cognitively challenging test with longer test duration might have changed the outcome. Ljungberg and Neely, (2007) measured the cognitive performances on 134 participants after noise exposure and vibration. They were used attention task and rating scale to measure alertness. They found that performances of the attention task degraded after vibration and noise exposure and rating scale for alertness shows higher scores after vibration and noise exposure. This is due to the speed-accuracy trade-off when vibration and noise presented. Subjects worked faster at the cost of precision after being exposed to noise and vibration. Noise can also affect the attention despite normal hearing sensitivity; this shown in the study done by Bressler et al, (2017) measured the cognitive processing in veterans with blast exposure. Fourteen individuals were included in the study; 12 had a normal to near normal range hearing sensitivity. They have used attention task and envelope following responses (EFRS) to measure the cognitive processing and neural coding. Results show that EFRS were similar between blast-exposed and non-Blast exposed group, but Blast-exposed subjects performed substantially worse than non-blast controls in an auditory selective attention task. These show that the noise has a substantial effect on cognitive processing.

To conclude the capacity of mental resources are allocated to perform tasks, that there are individual differences in maximum capacity, and that the amount of capacity allocated to tasks increases as the tasks become more difficult or demanding (Wingfield, 2016). When there is decreased hearing sensitivity or in adverse listening condition (background noise), the perceptual effort required to recognize speech consumes cognitive resources. When effortful listening consumes these resources, a limited and or insufficient cognitive resources are available for encoding the retrieved words in memory for comprehending the information (Wingfield et al. 2006). What remains unexplained is how the allocation of cognitive capacity during listening may be modulated when speech is presented in noise in NIHL individuals, even when the demands of the listening task do not exceed a person's maximum capacity. Thus, it is hypothesized that temporal impairment in NIHL can have a significant effect on listening effort.

Chapter 3

Method

The present study aimed to evaluate the listening effort in individuals with noise-induced hearing loss using a comparative research design.

3.1. Participants

We recruited a total of 40 individuals with age ranged from 40 to 60 years. The participants grouped into control and clinical group Figure-3.1. Control group comprised of twenty participants within the age range from 40 to 60 years (mean=53.75, SD=5.07). All the participants had a hearing sensitivity ≤ 15 dB HL in each of the frequencies from 0.25 kHz to 2 kHz (in octave) and threshold of ≤ 20 to 25 dB HL in 4 kHz to 8 kHz. An age-matched 20 hearing impaired participants (mean=55.05, SD= 3.78) were involved in the clinical group. All the participants had a bilateral mild hearing loss. The participants exposed to industry noise of above 90 dB (A) with a minimum period of 5 years with at least eight hours of work. All participants had normal middle ear status indicated by ‘A' type of tympanogram. The ipsi and contra- reflexes from 0.25 kHz to 4 kHz (in octave) were present in the control group. In clinical cases reflexes are either present or absent in those specified frequencies concerning the degree of hearing loss. All participants were a native speaker of Kannada and no history of systemic illness.

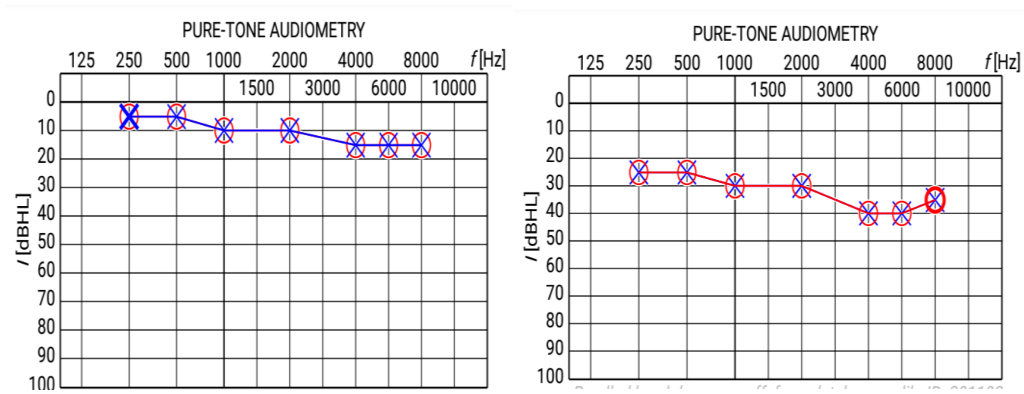


Figure -3.1. Showing the audiogram of control (Left panel) and clinical group (Right Panel)

3.2 Instruments

1. Diagnostic audiometer Inventis piano with TDH headphone was used to assess air conduction. A bone vibrator B-71 was used to evaluate the bone conduction threshold

2. Middle ear analyzer (GSI Tympstar version 2) was used to assess the middle ear status.

3. A personal laptop (Intel Core i3 processor) loaded with the software comprised of listening effort was used to present the stimuli and document the response. The calibrated (Sennheiser HD 206) headphone was used to present the stimuli of listening effort.

3.3 Test Environment

All the testing was carried out in a sound-treated room with a permissible noise level recommended by ANSI S3.1; 1991.

3.4 Preparation of stimuli

The standardized Kannada sentence lists developed by Geetha et al, (2013) was used as the target test sentences in a dual-task paradigm to measure the listening effort. The test material consists of 24 lists and each list comprised of ten sentences, which are phonemically balanced and semantically and semantically correct. We have used eight lists to assess listening effort at different SNRs. A five-four multi talker's babble (2 male two female) from the standardized Kannada sentences were generated. The procedure for generating noise is given elsewhere (Hemanth, 2015). Twenty Kannada sentences were embedded with four multi-talker noises at -1 dB SNR. Twenty sentences were grouped into five blocks where each block comprised of four sentences. In each of the blocks, the five multitaskers babble were randomly added to the twenty sentences. In a neighborhood, an interstimulus interval period was set at 3000 milliseconds and inter-block interval period was provided as 10000 milliseconds Figure-3.2. A similar procedure was carried out for 0 dB SNR, 2 dB SNR, and 4 dB SNR. In each condition, there were five blocks (4 sentences in each) in each SNR and a total of 20 sentences in each SNR. Order of stimulus presentation (5 blocks* 4 SNRs = 20 blocks) was randomized and non-counterbalanced across participants.

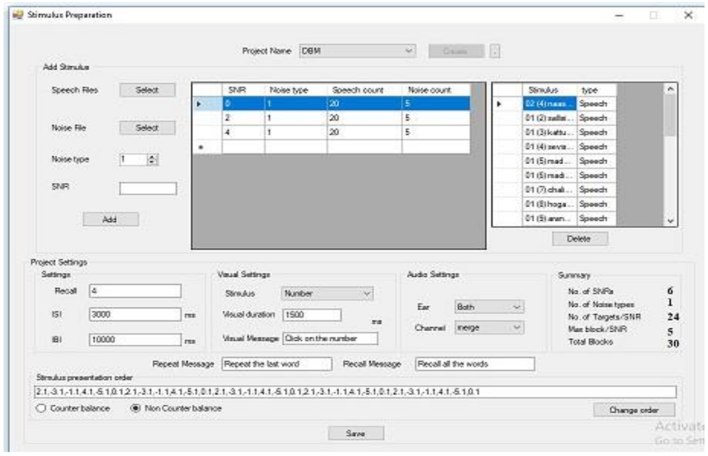


Figure- 3.2 Preparation of stimuli for listening effort.

3.5 Listening effort procedure

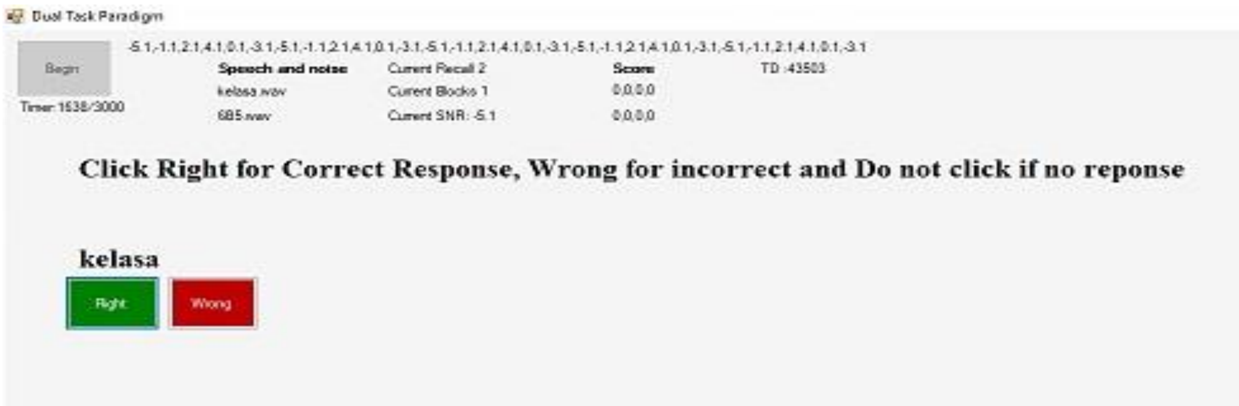
The procedure of the dual task paradigm developed by Pichora-Fuller et al. (1995) was adopted. The listening task comprised of primary and secondary tasks Figure-3.3. In the primary task, the last word of the heard sentence should be repeated. In the recall task, the repeated last words of four sentences should be recalled in free order as soon as hearing through beep sounds.

Instruction: You should avoid noise (babble) and listen carefully to the whole sentence. Soon after hearing the sentence you should repeat the last word of the heard sentence. After every four sentences, the beep sound was presented. You need to recall the remembered last word of four sentences.

The level of the noise was fixed, and sentence level was increased to generate each of the desired SNRs. The loaded stimuli in the software were delivered in both ears at participant's MCL through the headphone. After the presentation of each sentence, each participant was asked to repeat the last word. After every four sentences, a pure tone of

200ms was presented, and the listeners had to recall as many words as they could. They were encouraged to guess if they are uncertain. In the primary task, the response was counted as correct when the repeated word was the same as that of the presented word. Whereas in the secondary task the responses were deemed to be correct when they are same as that of the words reported previously, and indeed, there will be no scores provided if there were ‘no response' or incorrectly repeated.

A. Primary task



B. Secondary Task

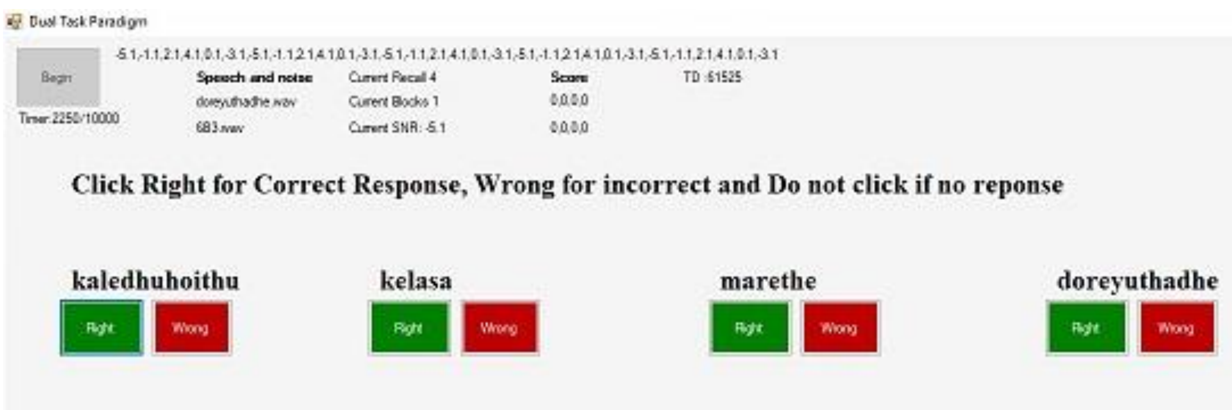


Figure-3.3 (A) primary task and (B) secondary task of listening effort.

3.6 Scoring

In listening effort, repetition of the last word in the primary task was awarded a score of 1 for correct, -1 for incorrect and 0 for no response respectively. There were four sentences in each of the five blocks accounting to the maximum score of 20 in each SNR. In the recall, a score of one was awarded when recalled the repeated last word of the sentence. A score of four was provided if they recall all the last words of four sentences with or without order. This was true for each block at each of the SNRs. Total scoring pattern includes two types of scores a) Repeat scores b) Recall scores. In repeat scores, the correct response from each of the blocks pertained to each SNR were summed. To calculate the recall score, the following formula was used.

Recall scores in each SNR = sum of recall scores of all blocks/ number of blocks

3.7 Effort Assessment Scale (EAS) questionnaire

The effort assessment scale was used in the present study developed by Alhanbali et al. (2017). It contains six items and the responses are provided on a visual analog scale from 0 to 10 where 0 indicates "no effort" and 10 indicates the "lots of effort." The participants are required to rate each item from 0 to 10 that represents the level of effort they experience. The total score of EAS was calculated by adding the score of each of the six items to give a score between 0 and 60, with higher scores indicating more effort.

3.8. Analyses

The data of listening effort from noise-induced hearing loss participants and age-matched normal hearing participants measured at different SNRs. The data of listening effort at different SNRs from study participants were subjected to repeated measure

ANOVA with between-subject factors as groups. Also, a post hoc independent samples t-test was administered to see in which SNRs the effort in listening reached significant between groups. Further, a Spearman correlation coefficient was performed to determine the relationship between effort assessment scale and recall scores of listening effort.

Chapter 4

Results

The present study aimed to investigate the listening effort in individuals with noise-induced hearing loss. The scores on primary and secondary tasks of listening effort obtained from control (normal hearing) and clinical (NIHL) groups were subjected to statistical analysis using SPSS software version 21.

4.1 Comparison of scores on primary and secondary tasks of listening effort between control and clinical groups at each of the SNRs.

4.1.1. Primary task

A repeated measure ANOVA (SNRs having four levels) with between-subject factor as groups was performed on the primary task (repeat scores). The result revealed that a main effect was observed in SNR [F (3, 114) = 222.43, p= 0.001] and groups [F (1, 38) = 870.72, p= 0.001] on scores of primary task. Further, a significant interaction effect SNR* group was found [F (3, 114) = 7.73, p = 0.001] on score of primary task. Further, a post hoc analysis was performed to investigate in which SNRs a significant difference between groups was found on a score of the primary task. An independent samples test was performed separately between groups at each of the SNRs. The results revealed that score on primary task was significantly poorer in clinical group than control group in -1 dB SNR (t (38) = 3.66, p= 0.001), 0 dB SNR (t (38) = 4.94, p= 0.001), and 2 dB SNR (t (38) = 2.82, p= 0.008). At 4 dB SNR, although the score on primary task was poorer in the clinical group than the control group, this difference failed to reach significant (t (38) = 0.521, p= 0.60) Figure-4.1.

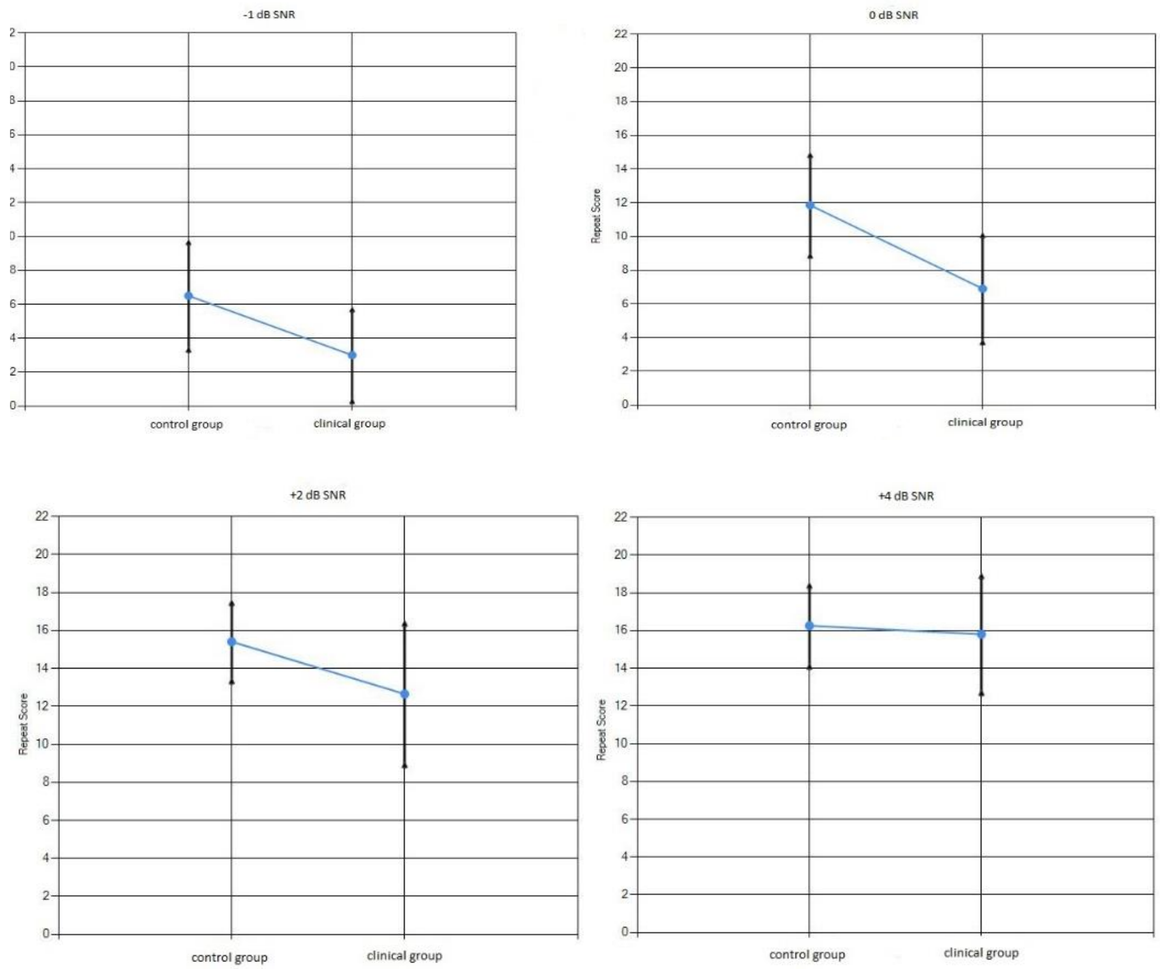


Figure 4.1: Repeat scores of the primary task for the control and clinical group at each of the SNRs

4.1.2. Secondary task

A repeated measure ANOVA with groups as within-subject factor was carried out on the secondary task and it was found that there a significant main effect on SNR [F (3, 114) = 118.434, p= 0.001] and groups [F (1, 38) = 751.300, p= 0.001], also there was a significant interaction effect SNR* group [F (3, 114) = 5.541, p = 0.001]. Post hoc analysis was carried out to establish the SNR at which the significant difference between the groups was observed on scores of the secondary task. An independent sample t-test was carried out between the groups at each SNR on scores of the secondary task. The results revealed that the scores of control group in secondary task was significantly poorer than clinical group at 0 dB SNR ($t(38) = 6.76$, $p = 0.001$), +2 dB SNR ($t(38) = 7.44$, $p = 0.001$), and +4 dB SNR ($t(38) = 3.90$, $p = 0.001$). Although the scores in the secondary task of the control group were poorer than the clinical group at -1dB SNR, it did not reach statistical significance ($t(38) = 2.23$, $p = 0.032$) Figure-4.2.

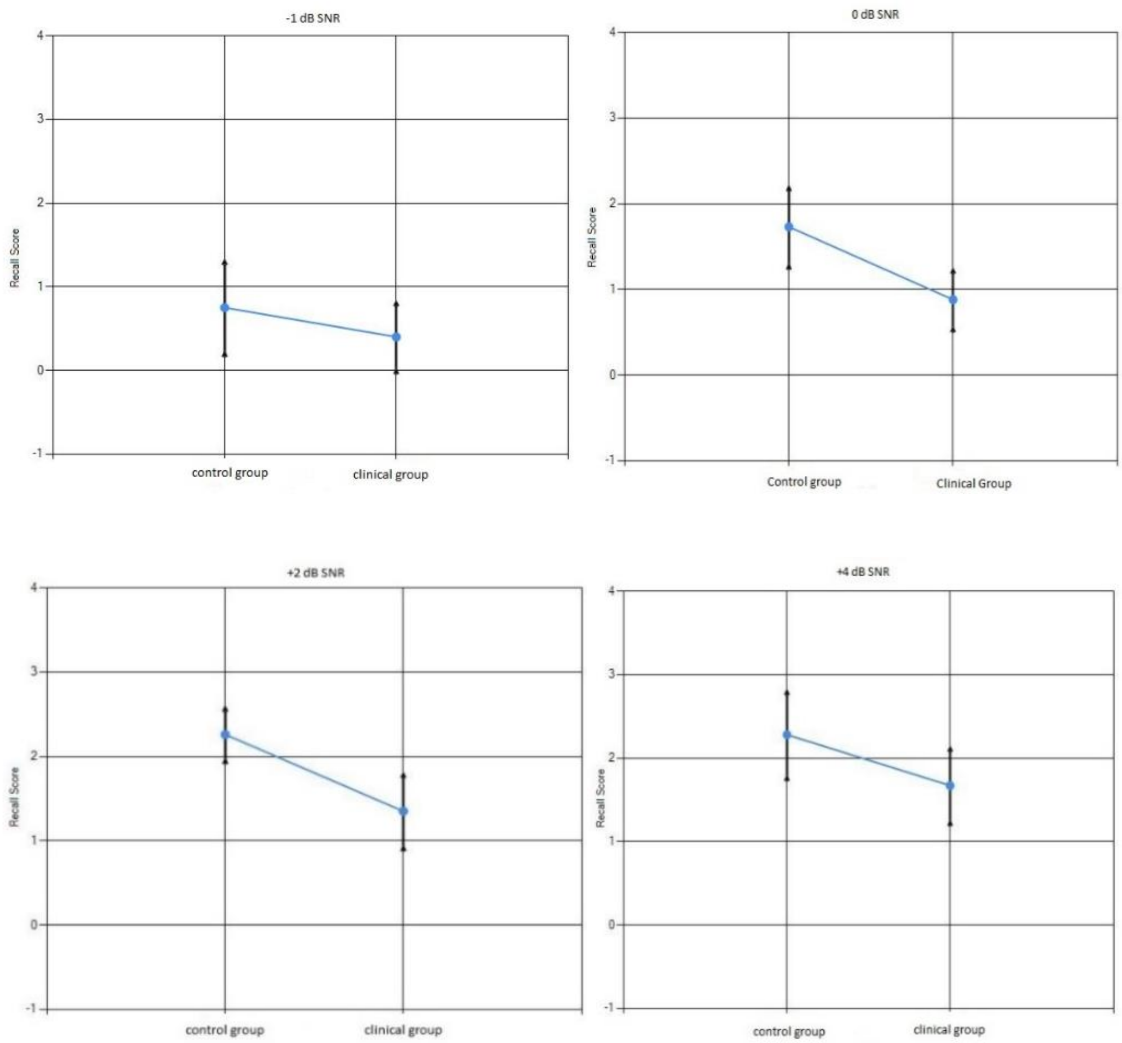


Figure 4.2: Recall scores of the secondary task for control and clinical group at each of the SNRs.

4.2. Correlation of recall score of listening effort and self-rating scores on listening effort

The recall scores of listening effort and a self-rating score of EAS on listening effort subjected to Spearman correlation Figure-4.3. A result revealed a significant moderate negative relation between recall score of listening effort and a self-rating score of EAS on listening effort. It infers that the recall scores reduced with increase in self-rating score of EAS on listening effort.

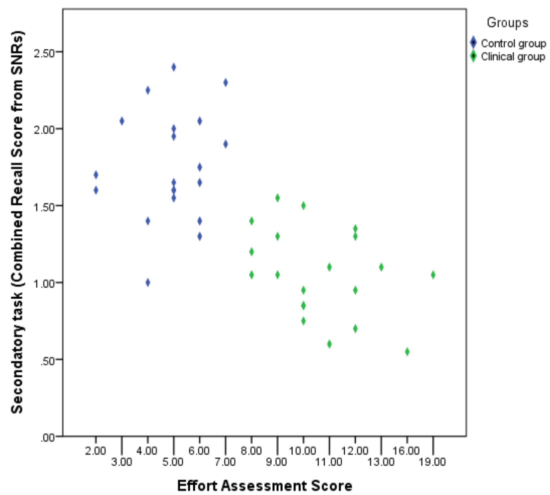


Figure 4.3: The score of secondary task versus effort assessment score for control and clinical group.

To summaries, except at 4 dB SNR, the participants of the clinical group performed weaker than the control group on scores of primary and secondary tasks in each of the SNRs. Also, recall scores reduced with increase in self-rating score of EAS on listening effort.

Chapter 5

Discussion

The goal of the study was to investigate the listening effort in individuals with noise-induced hearing loss, and the age-matched normal hearing group. The performance of the primary task (repeat score) tells us the effort the listeners put in on the secondary task (recall). As expected when SNRs reduced the repeat score reduced and listeners have to put a lot of effort to recall what they repeated. This was true in NIHL participants and normal hearing participants. Results showed a significant difference between NIHL and normal hearing participants on listening effort measured irrespective of SNRs. The target stimuli used was high predictive sentences presented with four talkers babbles at different SNRs (-1 dB SNR, 0 dB SNR, 2 dB SNR and 4 dB SNR). Subtle cues important for speech recognition are lost by the transmission factor due to noise. Although, the words in sentences are familiar and semantic context related to the distorted input from damage cochlea reaches the central auditory system. When sentences presented in noise, the available cognitive capacity was activated by intentional attention. The cognitive ability allocated the resource to eliminate the noise, and the available resource is utilized to recall repeated words. However, in reduced SNRs (and -1 dB SNR and 0 dB SNR), the cognitive capacity allocates the maximum resource to extract the target words in a sentence as there is a likely chance of information masking (four-talker babble) and limited remaining resource used to recall the repeated words. Thus, a primary (early) and recency (most immediate) words being recalled leaving the asymptote words (between early and quickest). In a situation where demand is high especially at reduced SNRs, a neuroeconomics calculation takes place to evaluate the cost-benefit analysis. Since the cochlear distortion due to hearing loss is high in NIHL participants than their age-matched counterpart taxes the maximum cognitive capacity in allocating the resource. Thus, in evaluating the demand on capacity during the task, feedback from the cognitive system shows displeasure and receives no reward for their task induces low motivation. The influence of feedback evaluation allocates the cognitive resource where the intentional attention fluctuates during the task leading to more effort in listening. Thus, the correlation analysis revealed a significant moderate negative relation between recall score of listening effort and a self-rating score of EAS on listening effort. It infers that the recall scores reduced with increase in self-rating score of EAS on listening effort. The alternative hypothesis is accepted as the noise-induced hearing loss subjects put effortful listening at reduced SNRs than the age-matched normal hearing group.

Chapter 6

Summary and Conclusion

Older adults with hearing loss have temporal processing impairment. The distorted input from damaged cochlea and in addition, a subtle cue (temporal and or spectral) buried in noise tax the cognitive system. This this regard an attempt has been made to evaluate how NIHL and normal hearing participants allocate cognitive resource was studied using listening effort task. Objective of the study is to compare the scores on primary and secondary tasks of listening effort at each of the SNRs between NIHL group and age matched normal hearing control group. Further, self- assessment effort assessment scale was correlated with the recall score of listening effort. A comparative research design was utilized to investigate the listening effort at each SNRs between normals and noise induced hearing individuals. A total of 40 participants took part in this research. Participant comprised of 20 normal hearing individuals and 20 noise induced hearing individuals from the age range of 40 to 60 years. The target sentences in dual task paradigm was presented at participant's MCL which was used to assess the listening effort at different (-1, 0, 2, 4) SNRs. In addition, the self-rated effort assessment scale was used. A one repeated measure ANOVA (one factor with four SNRs) with between subject factor as groups (control and clinical groups) was performed separately for primary and secondary tasks of listening effort. The results revealed a significant main effect of SNRs and group on listening effort. Further, an interaction effect of SNR*group caused significant effect on listening effort. Results showed NIHL group performed significantly poorer in both the tasks (primary and secondary tasks of listening effort) than the normal group. Further, as expected, listening effort increased with reduced in SNRs. In addition, there was a significant moderate negative relation between self-rating listening effort scale and recall score of listening effort. In NIHL, the cognitive system takes the maximum resources to extract the target words in sentences of lower SNRs and limited remaining resource was used to recall the repeated words. The noise induced hearing loss subjects put more effortful listening than normal hearing subjects at reduced SNRs.

Clinical implication

The results of the study may shed a light on how the bottom up and top down processing interacts each other to access the available cognitive resources to recognize speech especially, at different SNRs.

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