EFFECT OF ENHANCED SIGNAL ON LISTENING EFFORT IN OLDER ADULTS WITH AND WITHOUT HEARING LOSS

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(Audiology)

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May-2019

CERTIFICATE

This is to certify that this dissertation entitled **'Effect of enhanced signal on listening effort in older adults with and without hearing loss'** is a bonafide work submitted in part-fulfillment for degree of Master of Science (Audiology) of the student Registration Number: 17AUD013. 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 of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **'Effect of enhanced signal on listening effort in older adults with and without hearing loss'** has been prepared under my supervision and guidance. It is also 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 **'Effect of enhanced signal on listening effort in older adults with and without 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, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Abstract

Objective: Purpose of the study was to know the effect of enhanced signal on listening effort in hearing impaired older adults**. Study sample:** Nineteen normal hearing older individuals and nineteen hearing impaired older adults were participated in the study using purposive sampling approach. **Method:** A comparative study research design was utilized to investigate the listening effort measured in enhanced and unprocessed conditions at different SNRs from older adults with and without hearing loss. Deep band modulation strategy was used to enhance the signal. Listening effort was measured using dual task paradigm where primary task and secondary task includes repeat and recall, respectively. **Results:** It was found that no difference in listening between enhanced and unprocessed conditions, in each of the SNRs. As expected, a significant difference in listening effort was found between older adult with and without hearing loss, in each of the SNRs. **Conclusion:** Enhanced speech did not lessen the listening effort in older adults with and without hearing loss.

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Chapter 1

Introduction

According to this framework of effortful in understanding the speech, listening requires the effective processing of the auditory and cognitive system. In individuals with hearing loss, the distortion of signal by background noise and distortion caused due to damage in the cochlea of older adults limits access to cognition in understanding speech than individuals without hearing loss, potentially impacting the ease of communication (Hornsby, 2013). The distorted input from cochlea reaches the central auditory system from older adults who have hearing loss. The cognitive system allocates the 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 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 knowledge of the situation to understand the speech before allocating the cognitive resource in quiet and at different SNRs.

Turner and Souza (1994) examined the age-related effect on the target stimulus at different SNRs. Younger adults had maximum performance obtained at +8dB SNR that was comparable with older adults. Older adults have difficulty in speech perception in noise. They compensate by understanding the knowledge on the situation over the deterioration of peripheral sensory function that declines with age. In the absence of contextual cues, the lost information is due to transmission factor such as noise and or reverberation; the older adults with a hearing loss find it hard to retrieve the information. Gordon-Salant and Fitzgibbons (1993) examined the speech recognition of sentences that were distorted by a temporal envelope in the presence of noise. Older adults failed to understand distorted sentences, especially in lower SNR. Festen and Plomp (1990) conducted a study on recognition of speech at different SNRs. It concludes that older adults with hearing loss participants required higher SNR to perform the same as that of normal hearing participants. Speech recognition difference between normal and hearing impaired was ranged from 2 to 5 dB in speech-shaped noise, and 7 to 15 d B in single competing talker, time-reversed talker or an amplitude modulated noise.

A speech enhancement approaches are used to improve speech perception in noise on individuals with temporal impairment. Narne (2008) studied the effect of temporal envelope enhancement strategy on auditory neuropathy spectrum disorder who suffers from temporal impairment. Participants are grouped based on their peak modulation detection threshold using temporal modulation transfer function. The grouping had a different level of severity (mild, moderate. Severe), participants with lowest peak modulation detection threshold are categorized as mild and highest as severe. They speculated that temporal processing might lead to poor performance. They compared the perception of unprocessed and enhanced speech in study participants. Speech perception Improved in ANSD individuals. Hemanth and Akshay 2015 conducted another study in a similar line) who utilized deep band modulation to enhance speech. They measured speech perceptions in processed and unprocessed conditions for older adults who had temporal asynchrony. Deep band modulation (DBM) is one among the speech enhanced algorithms which use the principle of compression and expansion schema with increased depth of modulation. This algorithm was used to enhance the speech to assess speech perception in older adults at different SNRs. It reveals that unprocessed speech was less benefitted than enhanced speech. That enhancement compensates temporal asynchrony in them, and energetically masking by noise was less for the higher amplitude of the temporal envelope which can easily access the cognitive resource effectively in listening to the speech effortlessly. In particular, when the signal is enhanced by 15 dB the arousal activation and it is attended intentionally and eliminated the noise at different SNRs. Crucially, it remains unexplained that when enhanced speech within and between older adults with and without hearing loss how to meet the allocation of cognitive capacity during the listening task, even when the demands of the listening task have not exceeded a person's maximum capacity. Thus, it hypothesized that the enhancement of speech might reduce the listening effort in the older adult with hearing impaired.

1.1. Need for the study

Older adults with hearing loss suffer from impaired perception because of wider auditory filters and reduced temporal resolution. A distorted input from the damaged peripheral auditory system is processed where bottom-up processing unable to segregate speech from noise and consequently tax the top-down processing of the central system. If a noise alters the temporal content of speech and obscures its modulation than a significant impairment of bottom-up processing makes the available cognitive resource to mediate for understanding speech. During this process, there is a high chance of cognitive system putting a lot of effort in listening, if the conversation continues over some time. In the recent past, speech enhancement strategies are used effectively to understand speech in adverse listening condition. It enhances the temporal envelope by increasing the modulation depth thereby compensate the temporal asynchrony of older adults. The enhanced temporal envelope attribute to increased accessibility of envelope cues who suffer from temporal asynchrony seen in older adults. Also, the enhanced modulation depth in the speech where less energetically masked by noise can augment in better perception. Thus, segregation of noise is done through the speech which is enhanced acoustically and also compensates a temporal asynchrony of an older adult can easily access the available cognitive resource thereby reduces the listening effort.

1.2. Aim: To investigate the effect of enhancement on listening effort in older adults with and without hearing impaired.

1.3. Objectives of the Study

1. To compare the scores of primary and secondary tasks of listening effort between unprocessed and processed condition at different SNRs from study participants.
2. To compare the scores of primary and secondary tasks of listening effort between control and clinical groups in unprocessed and processed conditions at different SNRs.

Chapter 2

Review of Literature

Speech is considered to be a complex dynamic signal which fluctuates with amplitude and frequency over time (Jenstand & Souza, 2007). Intact peripheral and central the auditory processing system encodes speech at the auditory cortex in using their effective cognitive mechanism. This process is an ineffective especially older adult with hearing loss due to internal and external factors. The internal factors include unable to process the subtle temporal and fine structure cues available over momentary fluctuation especially at low amplitude of external noise. Speech understanding n noise is difficult in older adults. Aging in adults reduce the hearing ability and increases effort in the comprehension of speech especially in noise (e.g., CHABA, 1988).Thus, enhanced speech with higher amplitude temporal cues is less energetically masked. The available temporal cues are accessed by the cognitive system to use the resource in understanding the speech effectively. Thus it is hypothesized that listening subtle temporal cues over noise accessed by the cognitive system may reduce the listening effort in the participants of older adults with and without hearing loss. In this purview, a thorough review of the following headings is done.

2.1. Cognition and hearing loss

2.2. Speech perception in noise in older adults

2.3. Listening effort

2.4. Temporal enhancement

2.1. Cognition and hearing loss

Hearing loss in older adults affects the speech understanding ability. Several factors potentially contribute to the older listener's difficulty in understanding speech. The principal factor associated with acquired changes in the peripheral auditory system, including loss of hair cells, a tissue of the stria vascular, and neural cells. In particular, loss of strial tissue appears to be a consequence of the aging process and results in a decrease in the end cochlear potential (Mills et al., 2006). Tun ,McCoy and Wingfeild, (2009) studied hearing loss in older adults and its interaction with cognitive performance. Their findings revealed that decline in many aspects like cognitive functioning less memory for new information which in turn affects processing, working memory capacity, the decline in sensory acuity, frequency, and temporal resolution. Thus older individuals experience a lot of effortful in comprehension and memory in everyday life. Souza (2007) conducted a study to see the speech recognition in older listeners with hearing loss; noises used were steady noise and twelve talker babble in connected speech test (CST). From noises were those were taken from CST recordings both the presented at -2, +2, +6, and +10 dB SNR and result revealed that reduced score observed in multi-talker babble than the steady state on recognition of speech. It could be an imbalance in allocating the cognitive resource. To attend the stimulus a lot of cognitive resources was spent and remaining resource utilized to retrieve the remembered stimuli in understating the string of words to understand the meaning out of it. Pichora-Fuller et al., (2016) proposed Framework for understanding effortful listening (FUEL) (Figure 2.1). 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. Level of arousal was controlled by 1) the demands imposed by the activities 2) input out related demands include source, transmission, listener, message and contextual factors.

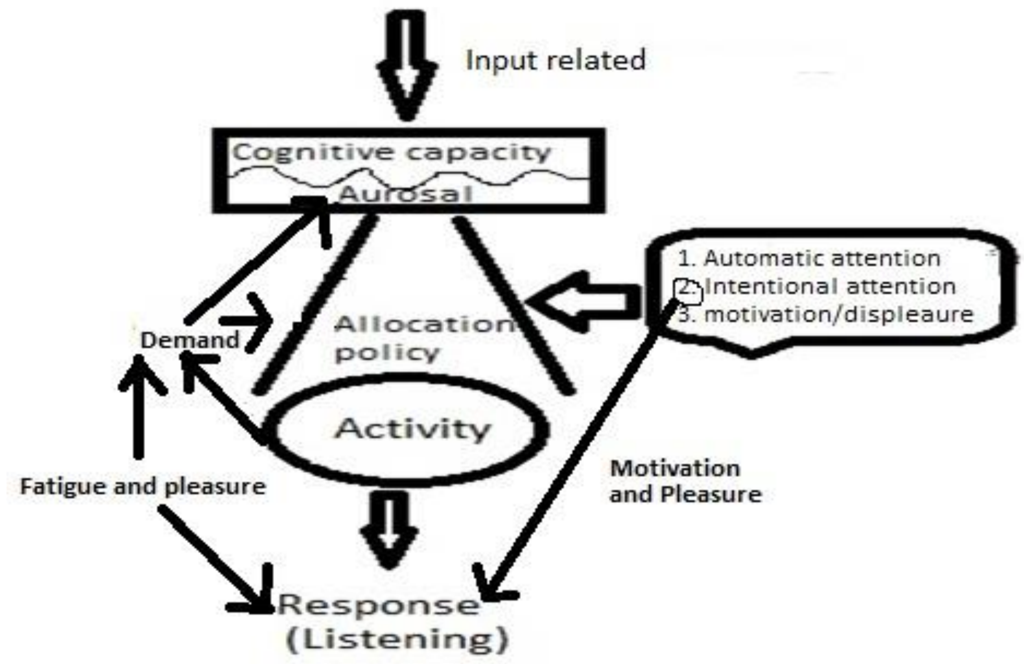

Figure-2. 1 Framework for understanding the listening effort

The cognitive capacity is diverse among individuals. Either automotive attention or intentional attentions are 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. Accentuated input speech in the presence of noise with familiar vocabulary was delivered. The peripheral and central auditory system processes the signals. The arousal in cognitive capacity allocates resource to eliminate the noise, and available resource is used to put the words in memory and use the episodic memory to retrieve the words in memory to understand the heard information. 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 numbers of activities are examined to see the influence 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 a roll backed. The allocation process stops in the cognitive resource, where the heard sounds are not interpreted through the auditory system processes the sounds leading to just hearing a sound.

According to this framework of effortful in understanding the speech, listening requires the effective processing of the auditory and cognitive system. The distorted input from cochlea reaches the central auditory system from older adults who have hearing loss. The cognitive system allocates the more resource to fill the misperceived information, rehearsals the heard words in memory and recalled in understand the information. If the noise in the environment is high, then more of the cognitive resource is allocated to eliminate the noise, and available resource is utilized to rehearse and recalls the heard words to retrieve the message. In a situation where demand is high then on that time, neuroeconomics calculation takes place to evaluate the cost-benefit analysis. If the listener is not motivated and displeasure and receives less reward for what is being listened then the cognitive system stops allocating the resource. Sometime listeners may take knowledge of the situation to understand the speech before allocating the cognitive resource. It indicates that older adults may have declined cognitive processing and accentuates, even more, when there is a hearing loss in them.

2.2. Speech perception in noise seen in older adults

Older adults will have difficulty in speech perception in noise. They should compensate for the deterioration of peripheral sensory function that declines with age. Older adults make use of redundant cues to understand speech (top-down approach). Zamratol- Mukari, Wahat, and Mazlan (2014) studied the effect of aging and speech perception in noise was. They used hearing in noise test (HINT) to find reception threshold for sentences in four conditions (i.e., in quiet, noise from the front, noise from right, noise from the left). All the conditions reveal age-related decline. This study indicates that when hearing thresholds were affected, cognitive function and auditory processing are important in speech perception performance in noise. Carvalho , Gonsalez, and Iorio (2017) studied speech perception in noise on elderly participants who had different levels of educational background and cognition score. Result revealed there was a correlation between cognitive function and education level on speech perception in noise. Depressive symptoms, cognitive performance, and level of education influence the speech perception in noise. Better the cognitive level and level of education better the communicative performance in noise. Gordon-Salant and Fitzgibbons (1993) examined the speech recognition of sentences which has distorted temporal envelope in the presence of noise. Older adults failed to understand distorted sentences in lower SNR.

The distorted signal was more worsen when two or more combination of distortion. Turner and Souza (1994) examined the age-related effect on target stimulus given at different SNRs. Maximum performance was comparable to younger adults at +8dB SNR. In cochlear hearing loss Festen and Plomp (1990) conducted a study on recognition of speech at different SNRs. Normal hearing participants performed same as that of older adults with hearing loss at higher SNR. Speech recognition difference between normal and hearing impaired was ranged from 2 to 5dB in speech-shaped noise and 7 to 15dB in single competing talker, time-reversed talker or an amplitude modulated noise.

To summarize, it showed that having a normal hearing threshold in older adults is not associated with normal speech perception in noisy environments as good as normal young people. Processing of speech items in noise require more cognitive resources for rehearsal or encoding the previous items to encode the speech finally (Rabbitt, 1991).

2.3. Listening effort

Listening to the incoming acoustic information is important in communication. In advanced age, sensory acuity reduces and suprathreshold sensory processing. These older adults put an effort to listen in noisy condition. Listening effort is known as an extent to the allocation of cognitive resources for speech perception (Hicks & Tharpe, 2002). Listeners experience greater effort in a difficult situation than quiet situation (Gordon-Salant & Fitzgibbons, 1997). The age-related listening effort revealed that older adults expend more listening effort than younger adults and older adults with and without hearing loss expend same listening effort to understand the speech in both speech and nonspeech type of noise (Desjardins and Doherty, 2012). Ward, Shen, Souza, and Grieco-Calub (2017) conducted a study on age-related differences in listening effort during degraded speech recognition. They used a dual-task paradigm that consists of a primary speech recognition task and a secondary visual monitoring task. They used Speech recognition with processed noise band vocoding. The primary findings from this study are as follows: (1) Both younger adults (YA) and older adults (OA) experienced declines in secondary-task accuracy with increased spectral degradation of the primary task; (2) OA experienced greater declines in secondary-task performance than YA (3) age-related differences in executive control significantly accounted for a portion of the observed differences in listening effort between YA and OA. Older adults were slower and less accurate than younger adults on the visual monitoring task when performed in isolation, which paralleled age-related differences in standardized scores of executive control. In a similar line of study by Sarampalis, Kalluri, Edwards, and Hafter (2009), who measured listening effort using two dual-task experiments at different SNRs on older adults with hearing loss. The results suggest that extracting speech at low SNRs reduces the listener's abilities to rehearse heard material and to respond quickly to complex visual stimuli in background noise. Listening task in noise will affect speech understandability as well as words or phrases to be remembered. Peters et al. (1996) studied speech recognition using spectral and temporal dips in the presence of noise. They used three different noises in which temporal dip resulted as a major cue to understand the speech in younger adults, but the older adults showed reduced scores. It refers that 'dip listening' was affected in older adults, that means they were unable to use the temporal cue properly at different SNRs. Brannstrom, Karlsson, Waechter, and Kastberg (2018) examined the listening effort with order effect and core executive functions. The results revealed that correct response, response time, immediate and delayed auditory comprehension were affected below 10dB SNR in the presence of multi-talker babble noise. It concludes that the order effect was present in which the previous competing noise exposure affects the target signal in the listening task. Listening in degraded speech is a challenging task which requires cognitive resources (Peelle, 2018).

To summarize, a listening effort is more in older adults than younger in noise. Presence of noise affects speech understanding ability due to an imbalance in the allocation of cognitive resource in extracting the speech buried in noise.

2.4. Temporal enhancement

Speech temporal enhancement strategies can resolve the problems faced by older adults to understand speech. Turner, Souza and Forget (1995) studied the perception of nonsense speech syllables in unprocessed and processed condition. The processed signal includes broadband noise modulated by an envelope of a broadband speech signal, high pass, and low pass noises modulated by an envelope of high pass and low pass speech signal and combined two channel signals which comprised of low and high modulated signals. Each of these stimuli presented at the most comfortable level for hearing impaired and normal individuals. Hearing impaired individuals performed poorer than the normal individual. This shows that hearing-impaired individuals have a problem in utilizing the temporal dips in the presence of noise. Wiinberg, Zaar, and Dau (2018) studied envelope expansion in consonant perception. Multiband nonlinear expansion of temporal envelope fluctuations between 10 and 20 Hz: (a) ‘‘idealized’’ envelope expansion of the speech before adding the stationary background noise, (b) envelope expansion of the noisy speech, and (c) envelope expansion of only those time-frequency segments of the noisy speech that exhibited signal-to-noise ratios (SNRs) above 10 dB. Consonant perception test using CV nonsense syllables was conducted in these three conditions from normal and hearing impaired. The SNR based envelope expansion found to be more beneficial in recognition of CV nonsense syllables than the other two methods. Shannon, Gang Zeng, and wygonski (1998) studied the speech recognition with the altered spectral distribution of envelope cues. Speech materials passed through four band pass filters (analysis bands). The envelope from each speech band modulated a band-limited noise (carrier bands). Carrier bands were manipulated independently to alter the spectral distribution of envelope cues. The results revealed that, in each of the four bands, the frequency alignment of the analysis bands and carrier bands were critical for good performance. Another study by Vanaja, (2012) investigated the effect of expansion/ compression schema to enhance the temporal envelope in words on individuals with auditory neuropathy. The results revealed that the identification score was best when the temporal envelope of the consonant portion in the word was enhanced. In yet another study Hemanth and Akshay (2015) studied the envelope enhancement on older adults. The results revealed that lessened temporal impairment in older adults when the deep band modulation (DBM) strategy used to enhance phrases. In DBM strategy duration and amplitude, increased modulation depth which results in a less energetic mask by noise. Thus speech output from DBM helps to access the content of speech from the impaired auditory system.

Spectral and or temporal envelope cues in speech after enhancement accessed by the auditory system may allow the cognitive resource to allocate effectively to understand the speech in noise. It hypothesized that speech having higher amplitude temporal enhancement shows less energetically masking by noise which helps to access the cognitive system. Eventually, a balance allocation of a cognitive resource may lessen the speech understanding difficulty in noise.

Chapter 3

Method

A comparative research design was used to investigate the effect of enhanced speech on listening effort in older adults with and without hearing impairment. Listening effort measured older adults in unprocessed and deep band modulation conditions.

3.1. Participants

`We recruited a total of 38 participants. There were two groups of participants a) control and clinical. Control group comprised of nineteen participants within the age ranged from 50 to 70 years (mean = 57 and SD = 5.05). 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 nineteen hearing impaired participants were involved in the clinical group. (Mean = 57.7 and SD = 5.24). Those participants who had bilateral mild to moderate sensorineural sloping hearing loss with hearing ability was ≤ 30 dB HL from 0.25 kHz to 2 kHz (in octave) and ≤ 55dB to ≤ 65dB from 4 kHz to 8 kHz(in octave). Figure-3.1 shows the audiogram of control and the clinical group. The speech identification scores (SIS) were ≥ 70% (Dirks & Wilson 1969). 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. Those participants, who are a native speaker of Kannada and had normal cognitive scores in mini-mental state examination (Folstein, Folstein, & McHugh, 1975) was involved.

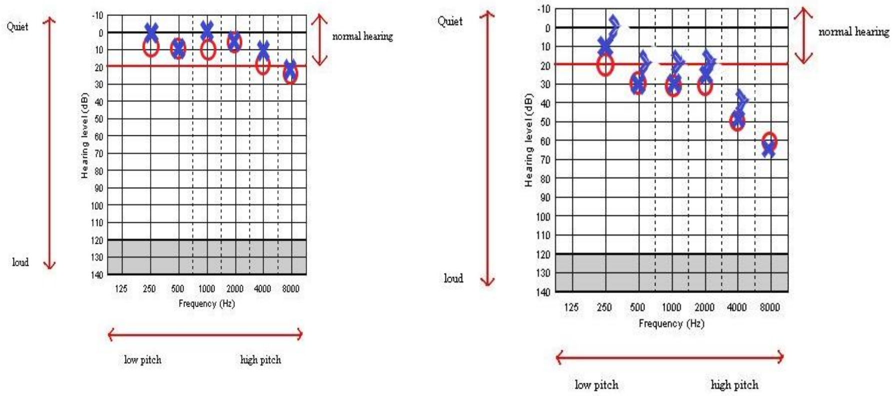

Figure-3. 1 Showing the audiogram of control (Left panel) and clinical group (Right Panel)

3.2. Equipment

1. Diagnostic audiometer Inventis piano with TDH headphone was used to assess air conduction and speech identification scores (SIS). The bone vibrator was used to assess the bone conduction threshold

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

3. Praat software (version 6.0.39) was used to prepare deep band modulated sentences.

4. A personal laptop loaded with the software comprised of listening effort was used to present the stimuli and document the response. The headphone (Sennheiser HDA 200) 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

3.4.1. Deep band modulation: A standardized Kannada sentences developed by Geetha et al. (2014) was used to prepare deep band modulated version of sentences by increasing modulation depth. Speech enhancement procedure developed by Nagarajan et al. (1998) was adopted to enhance the speech. Each sentence was loaded in the Praat software (version 6.0.39), the deep band modulated was selected. Every sentence was filtered by 20 order Butterworth filters. The middle frequencies from these twenty filters are logarithmically spaced between a 100 Hz and 10 kHz. An envelope extracted from the output of every narrowband channel (i.e., Hilbert transform computed through Fast Fourier Transform) within each narrowband filtered channel envelope with cut-off frequencies between 3 -30 Hz (Narne, 2013) prepared through a second order Butterworth filter. The processed Hilbert envelope was then recombined with the initial temporal fine structure. Before adding the 15 dB gain was provided within a frequency range of 1–4 kHz for every channel to generate the deep band modulated sentence.

3.4.2 Listening effort

Preparation of stimuli

A total of 12 lists used which are standardized Kannada sentences developed by Geetha et al. (2014). Five four multi talkers babble (2 male 2 female) from the standardized Kannada sentences and five multi talkers' babbles from the enhanced version of standardized Kannada sentences were generated. The procedure for generating noise is given elsewhere (Shetty and Subbanna, 2015). Twenty Kannada sentences embedded with four multi-talker noises at 0 dB SNR. Twenty sentences, 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. A similar procedure was carried out for 2 dB SNR and 4 dB SNR, respectively. In a block, an interstimulus interval period was set at 3000 milliseconds and inter-block interval period was provided as 10000 milliseconds. Figure-3.2 shows the preparation of stimuli for listening effort. In each condition, there were five blocks (4 sentences in each) in each SNR. Order of stimulus presentation (5 blocks* 3 SNRs = 15 blocks) was randomized and non-counterbalanced across participants. The entire procedure was repeated to prepare the stimuli in deep band modulation condition to measure the listening effort.

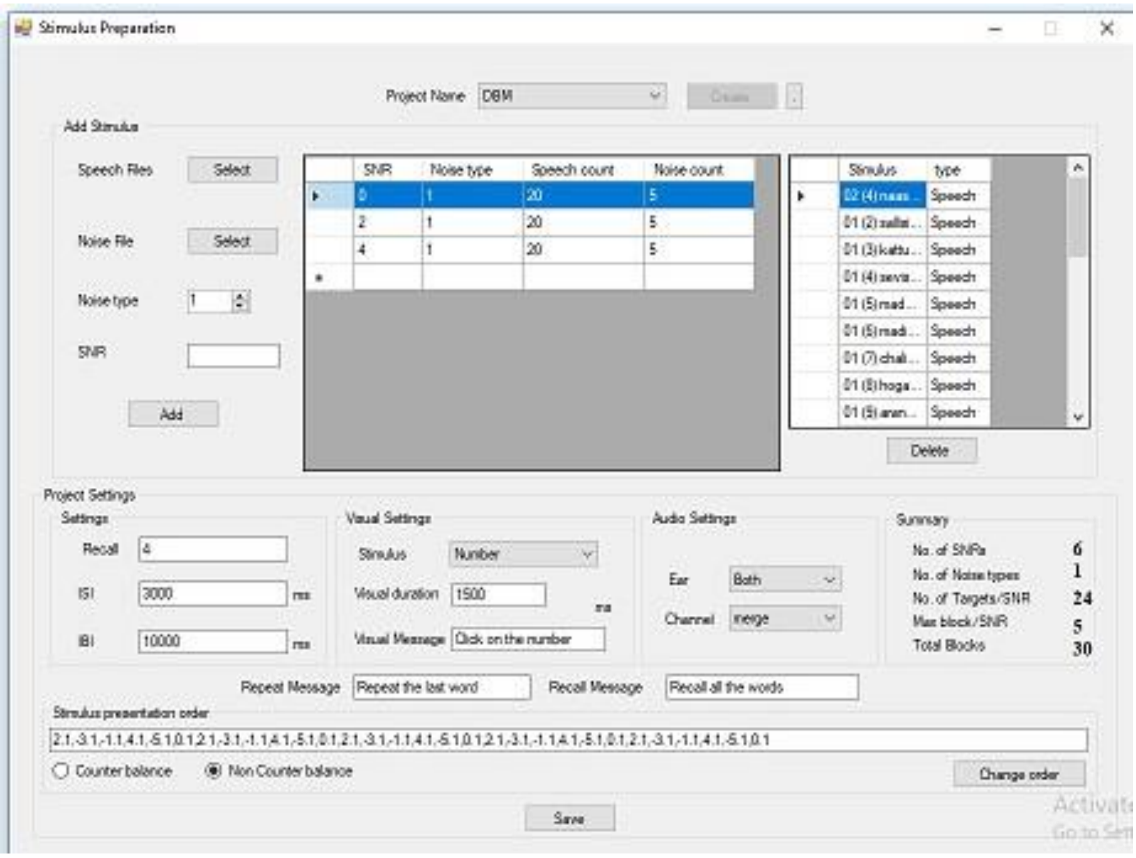

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Figure-3. 2 Preparation of stimuli for listening effort.

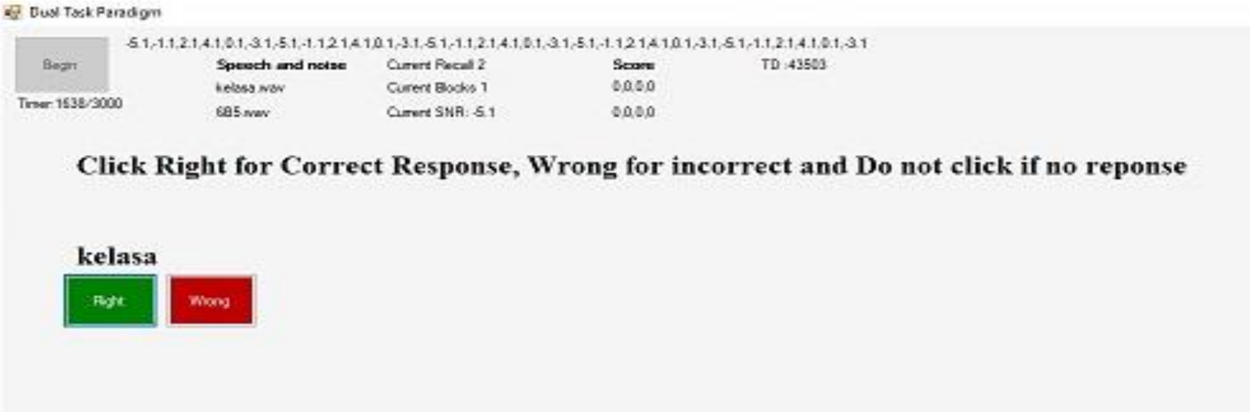
3.5. Test procedure:

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. 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 and listen carefully to the whole sentence. After hearing the sentence, you should repeat the last word of the heard sentence. After every four sentences, the deep sound will be presented. You need to recall the remembered last word of sentences.

The listening effort for each of the unprocessed and deep band modulated conditions was performed randomly across participants. 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 beep sound was presented, and the listeners had to recall as many words as they could, verbally and in the order they preferred. They were encouraged to guess if they are uncertain. A similar procedure was performed in deep band modulated condition. Figure-3 represents the listening effort platform to present the stimuli for a) primary task and b) secondary task. 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 a 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

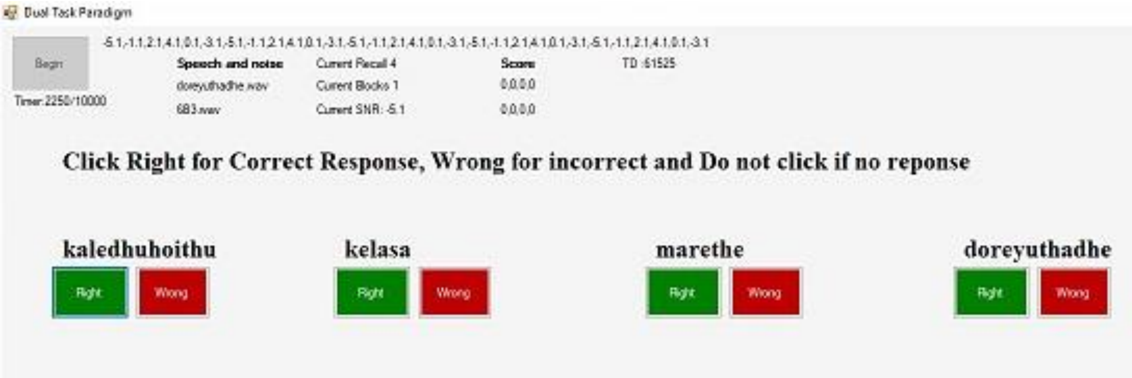


Figure-3. 3 In (A) repeat task is shown and in (B) recall task is shown.

3.6. Scoring

In listening effort, repetition of last word in the primary task was awarded a score of 1,-1, 0 for correct, incorrect and no response respectively. There were four sentences in each of the five blocks accounting to the maximum score of 20 in each SNR. In 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. It 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 formula used for the following in each SNR = sum of recall scores of all blocks/ number of blocks

3.7. Analyses

1. The data of primary task of listening effort measured in unprocessed and processed condition at different SNRs from older adult participants with and without hearing loss were subjected to two way repeated measure ANOVA with between-subject factors as groups.

2. To know the effect of conditions on primary of listening effort a paired sample t-test was administered in each of the experiment condition.

3. Further, to investigate the effect of group on primary tasks of listening effort an independent samples t-test was administered.

A similar test was administered for the secondary task of listening effort under each of the objectives

Chapter 4

Results

The present study was aimed to investigate the effect of enhancement (processed) on listening effort in individuals with older adults with (clinical group) and without (control group) hearing loss. The data of primary and secondary tasks of listening effort in unprocessed and processed conditions at different SNRs from study participants were subjected to statistical package for social sciences (SPSS) (version 21)software.

4.1. Listening effort between unprocessed and processed conditions.

4.1.1. Primary Task

To evaluate the effect of unprocessed and processed conditions on scores of primary tasks (repeat) in listening effort at each of SNRs from the study participants, performed a two way (2 conditions* 3 SNRs) repeated measure ANOVA with between-subject factors as groups. The results revealed as expected that repeat score reduced as a function of reduced SNRs (0 dB SNR, + 2 dB SNR and 4 dB SNR) and these differences reached a significant difference in the main effect of SNRs [$F (2, 72) = 145.91$ $p = 0.001$]. Although the repeated score was higher in unprocessed condition than processed condition, this difference failed to reach significantly in the main effect of the condition [$F (1, 36) = 0.787$, $p = 0.387$]. Also, participants of the control group had scored significantly higher on the repeated score than the clinical group [$F (1, 36) = 25.02$, $p = 0.001$]. Further, an interaction effects of conditions * groups [$F (1, 36) = 0.30$, $p = 0.58$], SNRs *conditions [$F (2, 72) = 2.17$ $p = 0.12$], SNRs *groups [$F (2, 72) = 1.23$, $p = 0.29$], and SNRs *conditions* groups [F (2, 72) = 0.73, p = 0.484] were found no significant difference on repeated score.

Though there were no main effect and interaction effect of condition and group on a repeated score, a significant main and interaction effect of SNRs and repeated score observed in the group. Thus, a paired samples t-test was performed to see if there any difference is present between conditions on the repeated score of listening effort in each of the SNRs separately for control and clinical groups. In control group, the results showed that repeated score was higher in unprocessed condition than processed condition, this difference failed to reach significant at 0 dB SNR (t (18) = 0.42 ,p = 0.67), +2 dB SNR (t (18) = 0.87 ,p = 0.39) and +4 dB SNR (t (18)= -0.24,p = 0.80) (Figure - 4.1).

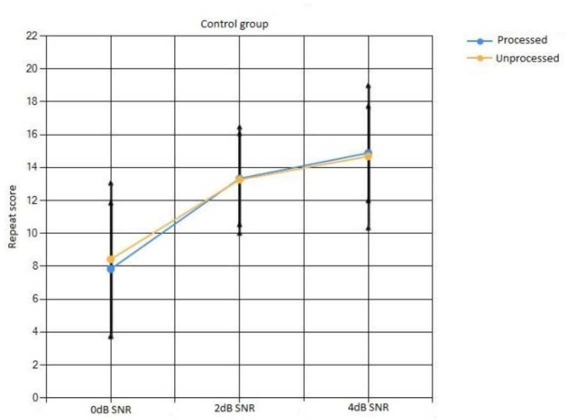


Figure-4. 1 Mean and standard deviation of the score on the primary task in unprocessed and processed condition from the participants of the control group at each SNR.

In clinical group, although the repeated score in unprocessed condition is higher than processed condition at 0 dB SNR (t (18) = 2.38, p = 0.02), +2 dB SNR (t

(18) = 0.87, p = 0.39) and +4 dB SNR (t (18) = -0.24, p = 0.80), these difference failed to reach significant (Figure-4.2).

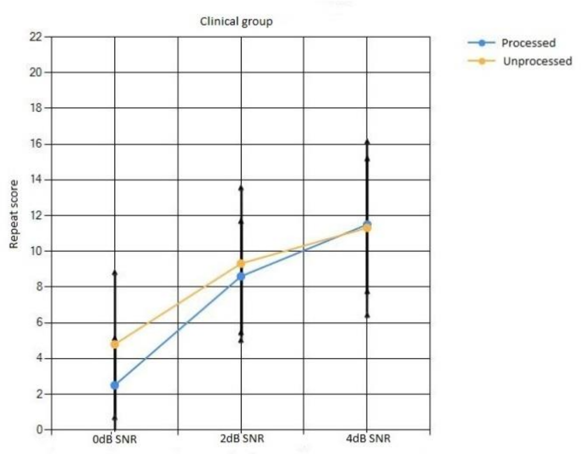


Figure-4. 2 Mean and standard deviation of a score on the primary task in unprocessed and processed condition from the participants of the clinical group at each SNR.

4.1.2. Secondary task

A two way repeated measure ANOVA (2 conditions* 3 SNRs) with between-subject factor as groups were performed to investigate the effect of conditions on scores of the secondary task. The results revealed that the recall scores reduced as a function of reduced SNRs. these difference reached a significant in the main effect of SNRs [F (2, 72) = 173.01, p = 0.001].Although the score on recall was higher in processed condition than unprocessed condition, this difference failed to significant [F (1, 36) = 0.00, p = 1.00] in the main effect of condition. Also, the main effect of group on scores of recall reached no significant difference though it was better in the control group than clinical group[F (1, 36) = 43.59, p = 1.00].Further an interaction effect on SNRs *groups[F (2, 72) = 2.34, p = 0.10], conditions * groups [F (1, 36) = 1.63, p = 0.20] and SNRs *conditions *groups[F (2, 72) = 1.92 ,p = 0.27] were found no significant difference on scores of recall.

Although there were no main effect and interaction effect of condition and group on recall scores, a significant main effect of SNRs and group was observed on the recalled score. Thus, a paired samples t-test was performed to see if any there any difference is present on recall score in each of the SNRs separately for control and clinical groups. In control group, the result showed that recall score was higher in processed condition than unprocessed condition, this difference reached a significant at + 4dB SNR (t (18) = -1.80, p = 0.08). However, the scores of recall for unprocessed and processed conditions were same at 2dB SNR and 0dB SNR (Figure- 4.3).

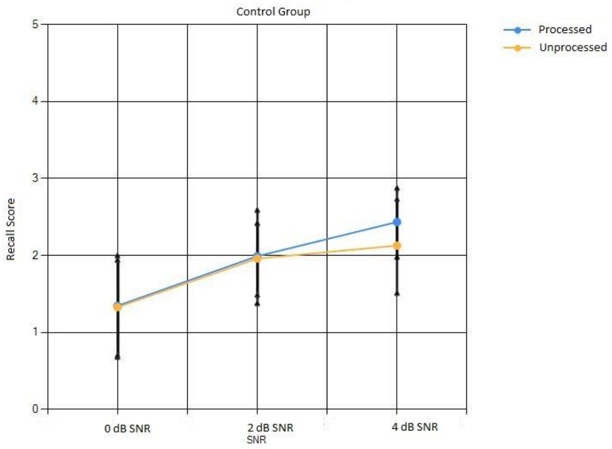


Figure-4. 3 Mean and standard deviation of a score on a secondary task in unprocessed and processed condition from the participants of the control group at each SNR

In clinical group the results of paired samples t test showed that the score on recall found no significant difference between conditions at 0 dB SNR ($t\ (18) = 1.78$, $p = 0.09$), +2 dB SNR ($t\ (18) = 0.18$, $p = 0.85$) and +4 dB SNR ($t\ (18) = 1.25$, $p = 0.22$), though the score of recall was high in processed condition than unprocessed condition (Figure -4.4).

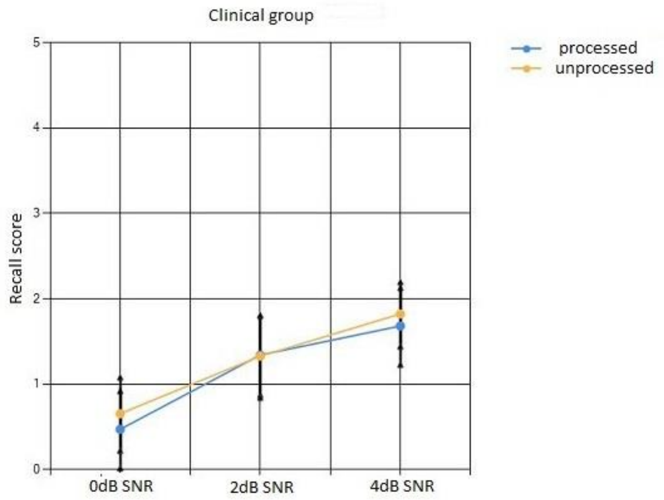


Figure-4. 4 Mean and standard deviation of a score on the secondary task in unprocessed and processed condition from the participants of the clinical group at each SNR.

4.2 Listening effort between control and clinical groups

4.2.1 Primary Task

To compare between control and clinical groups on repeated score an independent samples t-test was performed in each condition at different SNRs. The results revealed that a higher repeat score was observed in control group than clinical group in unprocessed condition, which was found significant difference at 0 dB SNR ($t(36) = 2.48$, $p = 0.01$), +2 dB SNR ($t(36) = 3.13$, $p = 0.003$) and +4 dB SNR ($t(36) = 2.19$, $p = 0.03$) (Figure 4.5)

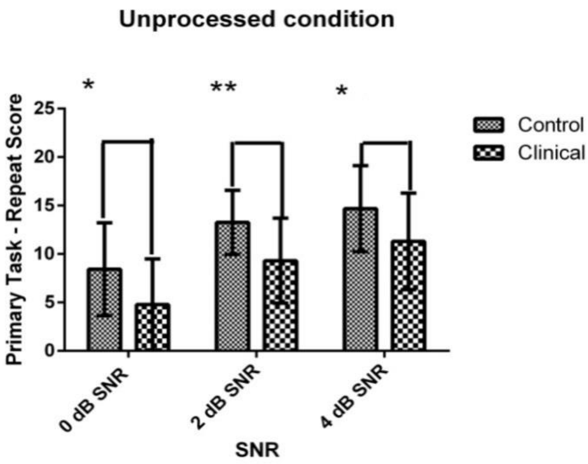


Figure-4. 5 Mean and SD of repeat score in unprocessed condition between control and clinical groups in each of the SNRs

Further, in processed condition, a significant difference was found between groups, where a higher score was observed in control group than clinical group at 0 dB SNR (t (36)=4.77 ,p=0.001), +2 dB SNR (t (36)=4.80 ,p=0.001)and +4 dB SNR (t (36)=2.74 ,p=0.009) (Figure-4.6).

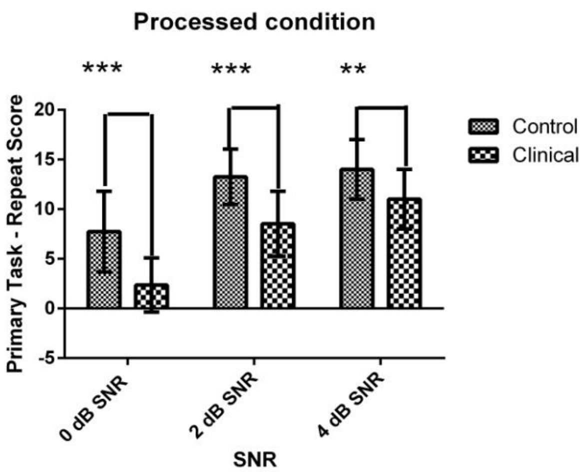


Figure-4. 6 Mean and SD of repeat score in processed condition between control and clinical groups in each of the SNRs

4.2.2 Secondary task

To compare between control and clinical groups on scores of recall an independent sample t-test was performed in each condition at different SNRs. The results revealed that a significantly higher recall score was observed in control group than clinical group in unprocessed condition at 0 dB SNR (t (36) = 3.79, p = 0.001), +2 dB SNR (t (36) = 3.99, p = 0.001) and +4 dB SNR (t (36) = 1.80, p =0.007) shown in (Figure 4.7).

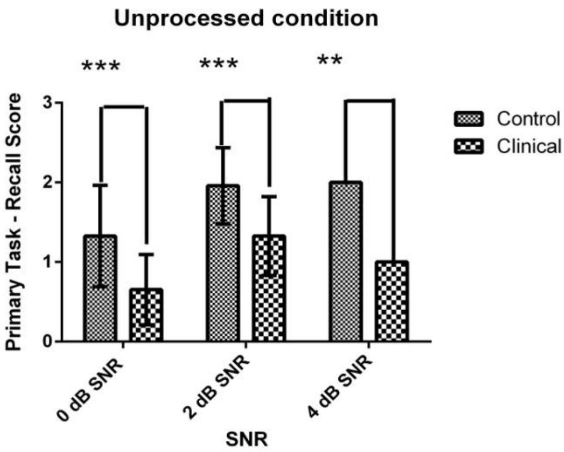


Figure-4. 7 Mean and SD of recall score in unprocessed condition between control and clinical groups in each of the SNRs

Further, higher score was observed in control group than clinical group in processed condition, a significant difference was found between groups on recalled score, this difference reached significant at 0 dB SNR (t (36) = 4.95 ,p = 0.001) +2 dB SNR (t (36) = 3.96 ,p = 0.001) and +4dB SNR (t (36) = 5.23 ,p = 0.001).

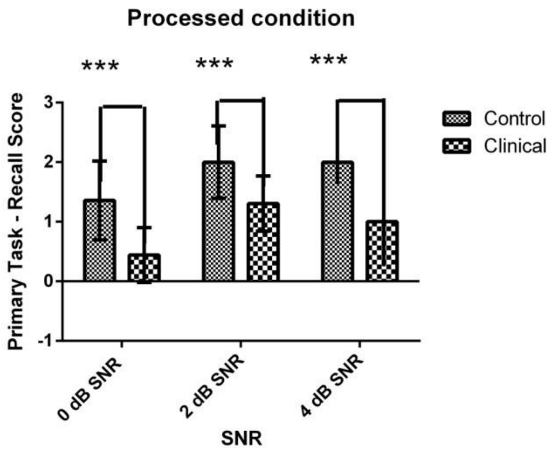


Figure-4. 8 Mean and SD of recall score in processed condition between control and clinical groups in each of the SNRs

To summarize, the scores on primary and secondary tasks of listening effort were unchanged when presented sentences are either processed or unprocessed at each of the SNRs in both control and clinical groups. Also, it reveals that participants of the control group performed significantly better on scores of primary and secondary tasks of listening effort than the clinical group at each of the SNRs.

Chapter 5

Discussion

The goal of the study was to investigate the contributions of enhanced speech on listening effect in older adults with and without hearing loss. 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 the repeated word. It was true in unprocessed and speech enhanced conditions. Results failed to show a significant difference between unprocessed and speech enhanced conditions on listening effort measured irrespective of SNRs in each group (older adults with and without hearing loss). The target stimuli used was high predictive sentences presented with four talkers babbles at different SNRs (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. However, the words in sentences are familiar and semantic context related. When normal and enhanced sentences were presented in noise, the available cognitive capacity was activated by intentional attention. Though the sentences are enhanced by 15 dB gain, the message factors such as familiar words in a sentence, semantic context, and high predictable sentences does not tax the available maximum cognitive capacity at higher SNRs (2 dB SNR and 4 dB SNR). The cognitive capacity allocates the resource to eliminate the noise easily, and the available resource is utilized to recall repeated words. However, in reduced SNRs (0 dB SNR), either in processed and unprocessed conditions, 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 was used to recall the repeated words. Thus, a primary (early) and recency (most immediate) words being recalled leaving the asymptote words (between early and most immediate). During the test process, the demand evaluates for cognitive capacity. As the message factors are easy to perform the task, though the listening does not fetch any rewards for their listening the participants are motivated to maintain the same cognitive capacity to allocate the resource effectively to repeat and recall the last word of heard normal and enhanced sentences. Thus, the alternative hypothesis is rejected as the enhanced speech did not lessen the effort in listening to the sentence in the presence of noise at different SNRs.

Also, as expected results showed a significant difference between control (older adults with normal hearing) and clinical group (older adults with hearing loss) on listening effort, irrespective of unprocessed and processed conditions. It is because the distorted input from cochlea reaches the central auditory system in the older adults who have hearing loss. The cognitive system allocates the more resource to fill the misperceived information due to noise, and the only limited amount of cognitive capacity might have left over to do rehearsals and recall the last words of heard sentences in their memory. 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 than an older adult with normal hearing, hearing impaired 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 alternative hypothesis is accepted as the older adults with hearing loss put effortful listening at reduced SNRs than older adults having normal hearing.

Chapter 6

Summary and conclusion

The older adults have temporal impairment with advanced in age and it is exaggerated with hearing loss. The auditory and cognitive system works hard to understand speech due to distorted input from damaged cochlea. In the presence of noise, the cognitive system allocates the resource effectively to understand the speech. It is hypothesized that if the speech is enhanced than its high amplitudes are less energetically masked such that effort utilized in listening reduces. The purpose of the study was to know the effect of enhanced signal on hearing impaired older adults using listening effort. The objectives of this study includes 1.To compare the scores of primary and secondary tasks of listening effort between unprocessed and processed condition at different SNRs from study participants. 2. To compare the scores of primary and secondary tasks of listening effort between control and clinical groups in unprocessed and processed conditions at different SNRs. A total of 38 participants were included in present study. Nineteen participants who had bilateral SNHL hearing loss (clinical) and another 19 participants had age matched normal hearing (control) were recruited. Listening effort was measured using dual task paradigm on both groups in processed and unprocessed condition at each SNR (0 dB SNR, 2 dB SNR and 4 dB SNR).It was found that no difference in listening between enhanced and unprocessed conditions, in each of the SNRs. As expected, a significant difference in listening effort was found between older adult with and without hearing loss, in each of the SNRs. The participants of each group have allocated same cognitive resource in enhanced and normal conditions. This is because the four talker babble was informationally masked caused maximum interference such that listening effort was leveled in normal and enhanced conditions. To conclude, enhanced speech did not lessen the listening effort in older adults with and without hearing loss

Implication of the study

Older adults are experience mental effort in everyday life. Listening effort measures demand on capacity in noisy condition. There is a need of public awareness and education about mental effort, motivation to use maximum capacity of cognitive resource. This assists inclusion of listening effort as a measure in test battery. It is important in evaluating the outcome and assessing intervention.

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