PROJECT REPORT

Contributory Factors of Hearing Handicap in Individuals with Sensorineural Hearing loss and Auditory Neuropathy Spectrum Disorder (ANSD).

AIISH Research Fund Project No. SH/CDN/ARF-59/ 2016 - 2017

Authors
Prof. Ajith Kumar U (PI)
Dr. Hemanth N (Co-PI)

Sanction No. SH/CDN/ARF-59/ 2016 - 2017

Personnel	Ms. Sindhu P Research Officer
Total Fund	Rs. **4,54,000**
Project duration	12 months
Principal Investigator:	Prof. Ajith Kumar U Professor of Audiology, Department of Audiology All India Institute of Speech and Hearing Mysuru– 570 006, Karnataka, India
Co-Investigator:	Dr. Hemanth N Reader in Audiology, Department of Audiology All India Institute of Speech and Hearing Mysuru– 570 006, Karnataka, India

Acknowledgments

The investigators would like to acknowledge the Director of the All India Institute of Speech and Hearing for being pivotal in granting the funds for the study. We would like to acknowledge the HOD, Department of Audiology for allowing us to use the resources from the department for testing. We also would like to extend our appreciation to the accounts section for providing support in maintaining the accounts. Our heartfelt gratitude is also extended to all the participants for their kind cooperation.

List of Figures

List of Tables

Abstract

Objectives: The study aimed to investigate a) how the speech perception in noise, psychoacoustic skills, hearing handicap and quality of life in ANSD differed from SNHL; and b) contributory factors of hearing handicap in ANSD and SNHL. **Design:** A total of 84 participants were recruited in the study. The clinical participants were grouped into two based on site of pathology. Forty-nine participants were suffered from SNHL (mean age = 35.92) and the remaining 35 participants were diagnosed as ANSD (mean age = 26 years). Each group was further sub-grouped based on degree of hearing loss viz. mild, moderately severe and severe. SNR 50 and psychoacoustic skills (difference limen frequency and temporal modulation transfer function) were performed at participant's most comfortable level. In addition, each participant was administered with HHIA and QOL questionnaires. **Results:** A significant higher SNR was required to obtain 50 % speech recognition in mild-subgroup of ANSD than SNHL. In SNHL, to achieve SNR 50 a higher SNR was required as a function of increased degree of hearing loss. Whereas, in ANSD other than mild degree of hearing loss, SNR 50 was not achieved even at the initial SNR was set at 30 dB. In frequency discrimination, a significant larger DLF was observed in ANSD than SNHL participants. In TMTF, mild sub-group of ANSD participants took a significant higher modulation detection threshold than mild SNHL for 8 Hz and 64 Hz frequency rates. However, in moderately severe and severe sub-groups of ANSD there was no measurable modulation detection threshold for each of the frequency rates. The subscale of quality of life was equally affected in both groups. Hearing handicap was reduced with increase in degree of hearing loss in SNHL group. Though, hearing handicap in ANSD remained same irrespective of degree of hearing loss, a significant increase in hearing handicap was observed in individuals with ANSD than SNHL. The hearing handicap was related negatively with QOL and positively with SNR 50 in SNHL participants. However, in ANSD, none of the contributory factors under the study were related to hearing handicap. **Conclusion**. The mild degree of impairment caused due to auditory neural pathology was similar to or more than the severe degree of cochlear origin on psychoacoustic tasks, speech in noise task and hearing handicap. The hearing handicap was significantly affected if site of pathology is at the auditory neural level than cochlear origin.

Chapter 1

Introduction

Sensorineural hearing loss (SNHL) is a type of hearing loss in which the root cause lies in the inner ear or cochlea. Auditory neuropathy spectrum disorder is a type of SNHL and has unique audiological findings such as most often raising pattern of audiogram, normal middle ear status with either absent or elevated reflexes, robust (Otoacoustic emission) OAEs and absent (Auditory brainstem response) ABR. A few literature review on prevalence of ANSD reported a late onset ANSD is very high in the Indian population (Jijo and Yathiraj 2012; Kumar & Jayaram, 2006) compared to that of western population(Berlin et al., 2010; Starr, Sininger, & Pratt, 2000). A sudden onset of hearing loss in ANSD at later part of their life can affect speech understanding ability which results in communication breakdown. Thus, it is pertained to quantify the hearing handicap in them.

1.1 Hearing handicap and Hearing loss

Perceived hearing handicap from mild hearing loss revealed large intersubject variability (Newman, Jacobson, Hug, & Sandridge, 1997). Similar to the previous study Stewart, Pankiw, Lehman, and Simpson (2002) investigated the hearing handicap index on 232 individuals who exposed to noise. The results revealed that HHIA score varied significantly as a function of high frequency hearing loss. In yet another study by Iwasaki et al. (2013) who also reported that mild correlation was found between hearing handicap and those individuals with SNHL who had average hearing loss of 67 dB. Contrary to the previous studies Ventry and Weinstein (1982) documented hearing handicap from different degree of hearing loss (mild to severe) in older adults from their developed hearing handicap inventory. It was observed that hearing handicap increases with degree of hearing loss. Where as in ANSD, the hearing handicap was obtained from a total of 50 participants who had hearing loss ranged from mild to severe degree. The result revealed no significant differences between degrees of hearing loss on hearing handicap. In considering irrespective of degree of hearing loss in ANSD a total score on hearing handicap revealed an about 32 % of them had mild to moderate hearing handicap and 68 % had a significant hearing handicap (Prabhu, 2017). To conclude equivocal results are observed in hearing handicap and degree of hearing loss in SNHL. However, in ANSD, majority of them had a significant hearing handicap irrespective of degree of hearing loss.

1.2 Hearing handicap and Speech recognition threshold

Hearing handicap was underestimated with respect to the speech recognition threshold in individuals with SNHL (Robinson et al, 1984). A few studies Alhanbali, Dawes, Lloyd, and Munro (2018) and Pedersen and Rosenhall (1991) reported a mild relationship between speech recognition and hearing handicap. In a recent study by Lima, Mantello, and Anastasio (2016) who investigated the hearing handicap and the recognition threshold of sentences in quiet and in noise from the cohort of ASND clients. Hearing Handicap Inventory for Adults (HHIA) was administered on 47 participants aged mean value of 47 years who had moderate degree of hearing loss. The hearing handicap before hearing aid adaptation demonstrated that all responses were attributed to the "always" option on both the emotional and social subscales. This corresponded to a severe degree of hearing handicap (100 points). In a similar line of study by Prabhu (2017) who investigated relation between hearing handicap and speech perception in quiet condition from ANSD subjects. The results revealed that the hearing handicap was predicted by speech identification scores (SIS). The poor score in SIS had significant effect on social handicap of HHIA which was speculated to have a communication problem (Prabhu, 2017). To conclude the relationship between hearing handicap and speech understanding in SNHL showed modest relation. Whereas, ANSD participants reported a significant hearing handicap irrespective of scores in SIS.

Relationship between these behavioral measures (PTA and speech understanding) and hearing handicap found to have shown equivocal results upon individuals with SNHL but fair relationship between them in individuals with ANSD. It could be due to subjective variability and or procedural variations. In subjective variability, the clients recruited in a few studies were confined to a single group and in other studies a groups were framed based on degree of hearing loss. In addition, the age and type of hearing loss differed from one study to another study. In case of procedural variability, utilization of target as a speech stimulus for assessing speech understanding and its correlation with hearing handicap has wide variability. A few studies have used word which has redundancy less compared to sentences. Definitely repeating words and relating it with hearing handicap accounts no relation due to far representation in reality. Thus, researchers have used low predictive and high predictive sentences to correlate with hearing handicap. A modest relation was observed between understanding sentences as a target stimulus with hearing handicap. This modest correlation could be due to noise employed to mix with target speech varies from speech shaped noise to broad band noise. In addition, in generating SNR whether noise was added to a fixed level of speech or speech was added to a fixed level of noise. The method of generating SNR in understanding speech has an effect on hearing handicap as the speech perception has deleterious effect when noise was added to a fixed level of speech. Thus, controlling the above mentioned variables in the present study accurately determine the relationship between behavioral measures and hearing handicap in SNHL and ANSD.

1.3 Psychoacoustic measures

Psychoacoustics is the perceptual effect of neurophysiological activities of the cochlea and auditory nervous system in brain. Hearing loss caused due to damage in either cochlea or auditory nerve distorts the signal and this distorted signal reaches the brain unable to capture the subtle psychoacoustic cues for interpretation of speech which leads to communication breakdown. Temporal modulation transfer function is a psychoacoustic task which assesses temporal resolution. It measures the thresholds for detecting changes in the amplitude of a sound a function of rapidity of the changes. A few studies have reported that client with cochlear hearing loss often showed reduced temporal resolution (Bacon & Gleitman, 1992; Bacon & Viemeister, 1985). In contrary to the previous studies a few researchers Moore, Shailer, and Schooneveldt (1992) and Bacon and Gleitman (1992) have reported that if the sensation level of stimulus and bandwidth of the stimuli were controlled then SNHL subjects often perform as well as, or even better than normal individuals. Whereas in participants of ANSD showed less sensitive to detect modulation amplitude and its threshold worsen as a function of modulation rate (Pottackal Mathai & Yathiraj, 2013).

Difference limen frequency (DLF) is another psychoacoustic test which assesses the ability to detect the smallest change in frequency between the two tones. Moore and Peters (1992) and Simon and Yund (1993) have reported that DLF is adversely affected in cochlear hearing loss who reported two findings a) DLF could be same for the two ears when absolute thresholds were different b) DLF could be different for the two ears when absolute thresholds were same. Goldstein (1977) documented larger DLF in cochlear hearing loss than normal hearing subjects suggesting the loss of neural synchrony in the auditory nerve. Even in ANSD cases an abnormal frequency discrimination was observed below 4 kHz but normal discrimination ability was observed above 4 kHz (Zeng et al, 2005).

Need for the study

The ability to detect the inherent amplitude fluctuation in an ongoing speech alludes temporal resolution skill is essential to under speech (Bacon & Gleitman, 1992; Bacon & Viemeister, 1985). Furthermore frequency resolution ability is another accompying factor for speech perception. A minimum change discern by the ear in the pitch of a sound reflects frequency resolution assessed by difference limen in frequency (Goldstein, 1977). Identifying subtle cues in a rapidly changing of ongoing speech requires good score on psychoacoustic measure. Due to damage in the cochlea or at nerve the difficulty in understanding speech can be exacerbated when listening speech in noise contains limited to available amplitude' or spectral fluctuations where impaired temporal (Pottackal Mathai & Yathiraj, 2013 and spectral (Simon & Yund, 1993) auditory system unable to capture it. Thus, there is a direct relationship between reduced speech perception score and the impaired psychoacoustic skills. Another fact is that there a modest relationship between speech perception skills and handicap. Thus, an attempt is made at liking psychoacoustic results and speech perception skills to understand the subjective handicap and quality of life. The present study is focused to determine how behavioral skills, psychoacoustic skills, quality of life and hearing handicap differed from ANSD and SNHL subjects. Further, relationship between hearing handicap and each of the psychoacoustic skills, behavior skills and quality of life were ascertained in two groups of study participants.

1.4 Aim of the study

The aim of the study was to determine a probable attributing factors of hearing handicap from speech perception, psychoacoustic and in individuals with SNHL and ANSD.

1.5. Objectives of the study

1. To compare speech perception in noise (SNR 50) from individuals with SNHL and ANSD
2. To compare temporal modulation detection thresholds (TMTF) and difference limen of frequency (DLF) in individuals with SNHL and ANSD.
3. To compare hearing handicap inventory for adults between individuals with SNHL and ANSD.
4. To compare World Health Organization Quality of Life (WHO –QOL) between individuals with SNHL and ANSD.
5. To investigate the relation between hearing handicap and attributing factors (hearing loss, SNR 50, TMTF, DLF and QOL).

Chapter 2

Method

A comparative with correlational research designs was utilized to study the hearing handicap index from possible contributory factors. A total of 84 participants were recruited in the study. The clinical participants were grouped into two based on site of pathology. Group I included participants with confirmed cochlear hearing loss. A total of 49 participants were recruited in the study. These participants were sub-grouped into three based on degree of hearing loss: mild (n=10, mean age =35 years, age range = 19 – 50 years, mean threshold =34 dB, Male =6 and Female= 4), moderately severe (n=32, mean age = 38 years, age range =15-62 years , mean threshold =56 dB, Male =16 and Female= 16) and severe (n=7, mean age =45 years, age range = 19- 60 years , mean threshold = 80 dB, Male =4 and Female= 3). Participants of each sub-group of the SNHL had normal middle ear status indicated by type 'A' tympanogram with elevated reflexes (Ipsi and contra) at 500 Hz to 4 kHz (in octave) or absent reflexes based on hearing loss, absent TEOAEs. To rule out RCP a less than 0.8 ms latency shift in ABR for the two repetition rates (11.1/sec and 90.1/ sec) was included in those patients on whom ABR was measurable. Carhart and Raymond (1957) method of tone decay test was adapted to rule out RCP in those individuals on whom ABR was absent. Those study participants who heard the tone for one complete minute without change in loudness was considered for the study. Group II included 35 individuals with confirmed Auditory Neuropathy Spectrum Disorder. Whereas, those clinical participants of Group II who have had normal middle ear status indicated by type 'A' tympanogram with absent reflexes (Ipsi and contra), present TEOAEs or DPOAEs and absent ABR were recruited. Further, ANSD group was sub grouped into three based on degree of hearing loss mild (n=19, mean age = 25 years, age range = 49-49 years, mean threshold = 30 dB, Male =7 and Female= 12), moderately severe (n=11, mean age = 24 years, age range = 17–40 years, mean threshold = 60 dB, Male =3 and Female= 8) and severe (n=5, mean age = 33 years, age range = 19–51 years, mean threshold = 76 dB, Male=3 and Female=2). All the study participants were native speakers of Kannada and none of them had any complaint of psychological problems, neurological and systemic illness.

**DPOAEs were administered to those individuals for whom TEOAEs were absent*

2.1. Test Environment

Tests were carried out in a sound treated double room situation. The noise levels at frequencies from 250 to 8 kHz were within the permissible limits as per ANSI (S3.1; 1991).

2.2. Instrumentation

The following instruments and speech materials were used.

1. A calibrated diagnostic two channel audiometer with head phones (TDH-39) was used to measure the hearing sensitivity, speech identification scores. Bone vibrator (B-71) was used to obtain bone conduction thresholds. Loud speaker was used to obtain SNR 50**,** difference limen frequency (DLF) and temporal modulation transfer function (TMTF).
2. A calibrated immittance meter was used to test tympanometry and acoustic reflexometry.
3. The otodynamics ILO V6 was used to record oto-acoustic emissions (OAEs) to evaluate the status of the outer hair cell functioning.

4. Personal laptop was used to play the recorded standardized sentences to obtain SNR 50 and the stimuli for TMTF and DLF.
5. Aux viewer version 1.3.13 (The Audacity Team, MA, USA, 2011) software was used to prepare stimuli for SNR 50.
6. Maximum Likelihood Procedure code and Matlab software 7.9 (The Math Works, Inc., MA, USA, 2009) was used to present the stimulus for DLF and TMTF.

2.3. Speech materials

1. Phonemically balanced (PB) word lists in Kannada developed by Yathiraj and Vijayalakshmi (2005) was used to obtain open set speech identification score.
2. A standardized four lists of Kannada sentences developed by Geetha, Kumar, Manjula, and Pavan (2014) were used as a stimuli to obtain SNR 50.

2.4. Questionnaires

1. The Kannada version of the Hearing Handicap Inventory for Adults (Parthasarathy & Mathai, 2017) was used to assess the degree of hearing handicap
2. The Kannada version of the World Health Organisation – Quality of Life BRIEF version was used to assess the quality of life (Prabha, 2002).

2.5. Data collection

The procedure of data collection included quantitative and qualitative tests. The quantitative tests included behavioural tests and psychoacoustic tests. Behavioural tests included pure tone audiometry, speech perception in noise (SNR 50). Psychophysical tests included DLF and TMTF. In qualitative tests, hearing handicap inventory and quality of life were assessed.

2.5.1. Behavioural tests

2.5.1.1. Pure tone audiometry: The pure tone thresholds for air conduction at octave frequencies from 250 Hz to 8 kHz were obtained using +10 and -5 dB procedure as specified by Carhart and Jerger (1959). The bone conduction thresholds from 250 Hz to 4 kHz were identified using similar procedure.

2.5.1.2. SNR 50: Speech shaped noise (SSN) having spectrum similar to that of standardized sentence was prepared. The procedure of generating speech shaped noise is given by Shetty and Mendhakar (2015), where SSN was generated with a simple FIR filter matching the speaker spectrum for the target speech. Four lists of standardized Kannada sentence were used which were phonetically and phonemically balanced. Each list comprised of ten sentences and each sentence comprised of five target words. For each sentence, root mean square (RMS) was identified and then noise was mixed with the sentence at desired SNR. The first two lists of ten sentences were mixed with speech shaped noise at different signal to noise ratios ranged from +30 dB to -6 dB SNR in 2 dB step size. A pilot study was performed with the aim to determine the range of SNRs to account measurable scores of speech. It was found that a measurable speech in the presence was observed in the range of 30 dB to -6 dB SNR. The onset of noise was started 500 ms before the onset of each sentence and continued for 500 ms after the offset of the sentence. To avoid unintended effect of noise an early onset and late offset of noise with respect to speech was created. A smooth ramp (rise and fall time) was made to the noise using cosine function to avoid unintended effects. The following formula was used to add noise to each sentence. Similarly, to the other two lists of sentences noise was added at different SNRs (as specified earlier) using the similar procedure.

$$\boldsymbol{SNR} = \mathbf{wave}(\text{filename})@\,\mathbf{rms}\ >>\mathbf{500} + \boldsymbol{ramp}\,(\boldsymbol{wave}\,("\boldsymbol{noise}")@\,\boldsymbol{rms}, \mathbf{20})$$

Ten sentences embedded at different SNRs were randomized. Each sentence was presented through loudspeakers at the participant's most comfortable level (range of 70 dB to 90 dB). The participants were instructed to repeat the sentence heard. The SNR level at which the testing started (L) and number of correctly recognized target words in each sentence were noted down. The total number of target words from all sentences were added (T). Also, the total number of words per decrement (W) and SNR decrement step size in each sentence (d) were noted down. The obtained values were substituted to the given equation adapted by Spearman-Karber to determine SNR 50 % (Wadley, 1952). The below equation was used to calculate the SNR 50.

50 point = L+ (0.5*d) – d (T)/ W

2.5.2. Psychophysical tasks:

The maximum likelihood procedure (MLP) was used to estimate the thresholds for DLF and TMTF. The MLP estimates the threshold by assessing the psychometric functions in every trial. The laptop loaded with MLP was connected to an audiometer. The output of the audiometer was delivered through loud speakers located at 0° azimuth at participant's most comfortable level. To have realistic environment in listening we presented the stimuli of various test through loudspeakers.

2.5.2.1. Temporal Modulation Transfer Function: The TMTF stimulus developed by Lorenzi, Dumont, and Fullgrabe (2000) was adopted. A 1000 ms white noise was sinusoidal modulated at 8 Hz, 64 Hz and 128 Hz modulation frequency. These frequencies were selected to include both low and high modulation frequencies. The modulation depth of each frequency modulates (fm) from 0 dB to -30 dB. The maximum amplitude modulation used was 0 dB (100 %) and the minimum was -30 dB (0 %).

A three interval forced choice method was used in which two were white noise and target stimulus was amplitude modulated sinusoidal signal. These three blocks of stimuli were presented in sequence. The target stimulus can occur at any of the three blocks and its occurrence was randomized. Each participant was instructed to indicate the target stimulus. Initially, the target stimulus had 100% modulation (0 dB) was presented. The modulation depth was gradually decreased once the participant identified the modulated signal. A step size of 4 dB was reduced if the client gives positive response and if no response then 4 dB was increased. The 4 dB step size was replaced by 2 dB step size after two reversals. Testing was stopped either a total of eight reversals were achieved or 99 trials were completed. The last three reversals were averaged to obtain the temporal modulation transfer function. This procedure was repeated for each frequency modulated signal.

The modulation detection threshold (MDT) was obtained in dB in terms of the following equation. A method adopted by Zeng, Liang, Hoang, and Peh (2009) was utilized to calculate peak modulation sensitivity. The peak modulation sensitivity is the lowest modulation depth (in dB) required to identify the modulation from unmodulated white noise. The peak modulation sensitivity was calculated for each frequency modulation.

MDT = 20 log 10 m, where m is the modulation detection threshold in %.

2.5.2.1. Difference Limen Frequency: The stimulus developed by Micheyl, Delhommeau, Perrot, and Oxenham (2006) was adopted to assess DLF. DLF was measured for tones of frequencies 500 Hz, 1000Hz, 2000Hz and 4000Hz (standard frequencies). DLF is defined as the minimum frequency required to differentiate between two tones which are closely spaced in terms of frequencies was assessed. The minimum and the maximum frequency deviation was 0.1 and 200 Hz respectively. For individuals with ANSD, a practice trial of frequency difference of about 1000 Hz was given to help them understand the task.

Three blocks of duration 250 ms each were presented. Out of the three blocks, two of them were the standard stimuli and the other was the variable stimulus. The standard stimulus was a pure tone at standard frequency and the variable stimulus was a pure tone of frequency higher than the standard frequency. Each participant was instructed to indicate the variable stimulus. The value which corresponded to the 79.4% point of psychometric function was the obtained DLF. DLF was obtained in Hertz.

2.5.3. Administration of Questionnaires: Clinician administered the two questionnaires and it was rephrased if the client fails to understand the inference of the question.

2.5.3.1. HHIA The Kannada version of Hearing Handicap Inventory for Adults (HHIA) (Parthasarathy & Mathai, 2017) was used. The questionnaire consists of emotional and social questions. A 13 questions were belong to emotional aspects and 12 questions on social aspects which constitutes to a total of 25 questions. The scores of the degree of handicap in the social and emotional life of an individual were obtained. Each question was rated on a three-point rating scale 'yes' as 4, 'sometimes' as 2, and 'no' as 0. The maximum overall score is 100. The maximum number of points for social and emotional subsections is 48 and 52 respectively. A score of 0 implies no handicap while a score of 100 implies total handicap. A score ranging from 0-16% indicates no handicap, a score of 18-42% indicate Mild-Moderate Handicap. A score of above 44% indicates a significant Handicap.

2.5.3.2. Quality of Life. The Kannada version of the World Health Organisation – Quality of Life BREIF version (Prabha, 2002) was used to assess the quality of life. The questionnaire included 26 questions. Each question was rated on a five-point rating scale and the score ranged from 1 to 5. It has six domains namely quality of life (maximum scoring =10) health (maximum scoring=20), physical (maximum scoring=15), psychological (maximum scoring = 30), environmental (maximum scoring = 10) and social (maximum scoring = 10) containing 2, 4, 3,6, 2, 1 questions, respectively. Two questions are on rating the quality of life and regarding the satisfaction about health. In the questionnaire, one of the questions in the social domain did not seem apt to the Indian context. Hence the question was replaced according to the recommendation by International Electro Technical Commission (IEC). The question about satisfaction about sex life was replaced with the relationship with neighbours. The participants were instructed to select an option from 1 to 5 for each of the questions. The scores of quality of life, health and total scores for each of the domains were calculated.

Data analysis

1. A Kruskal Wallis test was performed between subgroups of each of the ANSD and SNHL groups on SNR50, DLF (each frequency), TMTF (each frequency), HHIA and QOL. If significant difference was noted between sub-groups in any of the dependent variables than a Mann- Whitney U test was used as a post hoc to find out the sub-groups which had caused a significant difference.
2. To assess differences between groups (SNHL and ANSD) in each of the dependent variable, a Kruskal Wallis test was performed. If significant difference was noted between groups, then a Mann- Whitney U test was used as a post hoc to find the groups which had caused a significant difference on each of the dependent variable.
3. A Mann- Whitney U test was administered to assess the severity of mild sub-group of SNHL compared to which subgroups of ANSD on each of the dependent variables.
4. A signed rank Spearman correlation was performed to find the relationship between hearing handicap and contributory factory, which was carried out separately for SNHL and ANSD.

Chapter 3

Results

The aim of the study was to investigate the contributory factors of hearing handicap in individuals with sensorineural hearing loss and Auditory Neuropathy Spectrum Disorder (ANSD). The performances in the SNR 50, psychoacoustic tests and questionnaires (HHIA and QOL) obtained from subgroups of each group were subjected to Statistical Package for Social Science (SPSS version-21). An appropriate statistical analyses were performed to investigate the aim of the study.

3.1. Comparison of SNR 50 from individuals with SNHL and ANSD

To achieve 50 recognition, the SNR required was less in mild hearing loss than moderately severe followed by severe degree of SNHL group (Table-1). A Kruskal Wallis test showed a significant difference between sub-groups for SNR 50 in SNHL ($\chi^2(2)$ =8.242 p=0.016). Further, a post hoc Mann- Whitney U test was carried out to check in which sub-groups of SNHL had caused a significant difference on SNR 50. The mild sub-group of SNHL required significantly lesser SNR to achieve SNR 50 than moderately severe (U= 74, Z= -2.546, p= 0.011) and severe sub-groups (U=12, Z= -2.253, p= 0.024). Though the SNR required to achieve 50 % recognition was lesser in moderately severe than severe subgroup, failed to reach significant difference (U= 83, Z= -1.064, p= 0.287). In case of ANSD, a measurable SNR 50 was obtained from 13 /19 participants of mild sub-group. the median SNR required to achieve 50 % recognition in them was 9.5 dB. However, no measurable SNR 50 was obtained from either moderately severe or severe sub-groups of ANSD (Table-1).

Table 1 Median and SD of scores of SNR 50 in SNHL and ANSD

Sub-groups	Mild		Moderately severe		Severe	
	Median (range)	SD	Median (range)	SD	Median (range)	SD
SNHL	-1 (10)	3.86	3 (23.5)	4.28	4 (32)	14.93
ANSD	9.5 (28.90)	10.61	NA	0	NA	0

NA – Not achieved

Moderately severe and severe subgroups of ANSD get the disability certificate based on degree of hearing loss according to the revised PWD act (2016). Thus, mild subgroup of ANSD was compared with each of the subgroups of SNHL on SNR 50 using the Mann-Whitney U test. These comparisons were performed to know the severity of impairment in SNR 50 in mild sub-group of ANSD compared to which subgroups of SNHL. It was observed that mild sub-group of ANSD (median=9.5) required a significantly higher SNR to achieve 50 % speech recognition than mild (median =-1; U= 9.50, Z= -3.94, p= 0.000) and moderately severe (median = 3; U= 97.50, Z= -4.03, p= 0.000) subgroups of ANSD. In addition, through mild sub-group of ANSD (median = 9.5) required higher SNR to achieve 50 % recognition than severe (median = 4; U= 54.50, Z= -0.72, p= 0.49), it failed to reach significant.

3.2. Comparison of difference limen of frequency and modulation detection thresholds in individuals with SNHL and ANSD.

The median and SD of DLF at each frequency from sub-groups of SNHL and ANSD are tabulated in Table-2 and Table-3, respectively. A Kruskal Wallis test was carried out to check for differences within the sub-groups on frequency resolution in each frequency. It was found that in the SNHL group, there were no differences between the subgroups on DLF at 500Hz (χ^2 (2) =2.62, p=0.270), 1000Hz (χ^2 (2) =3.141, p=0.208), 2000Hz (χ^2 (2) =1.26, p=0.53), 4000Hz (χ^2 (2) =2.22, p=0.328). Similarly, for the ANSD group, there were no significant differences between subgroups on DLF at 500 Hz (χ^2 (2) =5.29, p=0.071), at 1000 Hz at (χ^2 (2) =8.022, p=0.051), 2000 Hz (χ^2 (2) =1.938, p=0.379), at 4000 Hz (χ^2 (2) =2.672, p=0.263).

Table 2 Median and SD of scores of DLF in SNHL

Sub-groups	Mild		Moderately severe		Severe	
Frequency (Hz)	Median (range)	SD	Median (range)	SD	Median (range)	SD
500	36.93 (80.04)	30.28	63.86 (135.58)	134.07	45.2 (193.14)	115.14
1000	57.68 (146.24)	44.61	85.26 (130.99)	87.22	26.97(182.64)	322.86
2000	126.01(283.59)	91.59	156.99(258.45)	126.84	71.39 (109.8)	256.15
4000	139.21 (172.10)	51.21	195.83 (150.76)	202.71	215.65 (289.07)	301.19

Table 3 Median and SD of scores of DLF in ANSD

Sub-groups	Mild		Moderately severe		Severe	
Domains	Median (range)	SD	Median (range)	SD	Median (range)	SD
500	79.54 (233.17)	61.61	105.42 (415.38)	169.17	143.91 (498.88)	197.19
1000	119.4 (471.04)	106.03	254.5 (831.84)	244.44	253.5 (163.52)	63.77
2000	174.59 (534.79)	112.36	240.24 (555.85)	158.58	179.84 (410.10)	194.76
4000	202.35 (609.70)	175.53	308.64 (897.66)	297.09	389.55 (248.06)	104.64

Further a Mann- Whitney U test revealed a significantly better frequency resolution in SNHL than ANSD on DLF at 500Hz (U= 523.5, Z= -3.139, p= 0.002), 1000Hz (U= 448.50, Z= -3.809, p= 0.000), 2000Hz (U= 642.5, Z= -2.076, p= 0.038), and 4000 Hz (U= 553.5, Z= -2.872, p= 0.004).

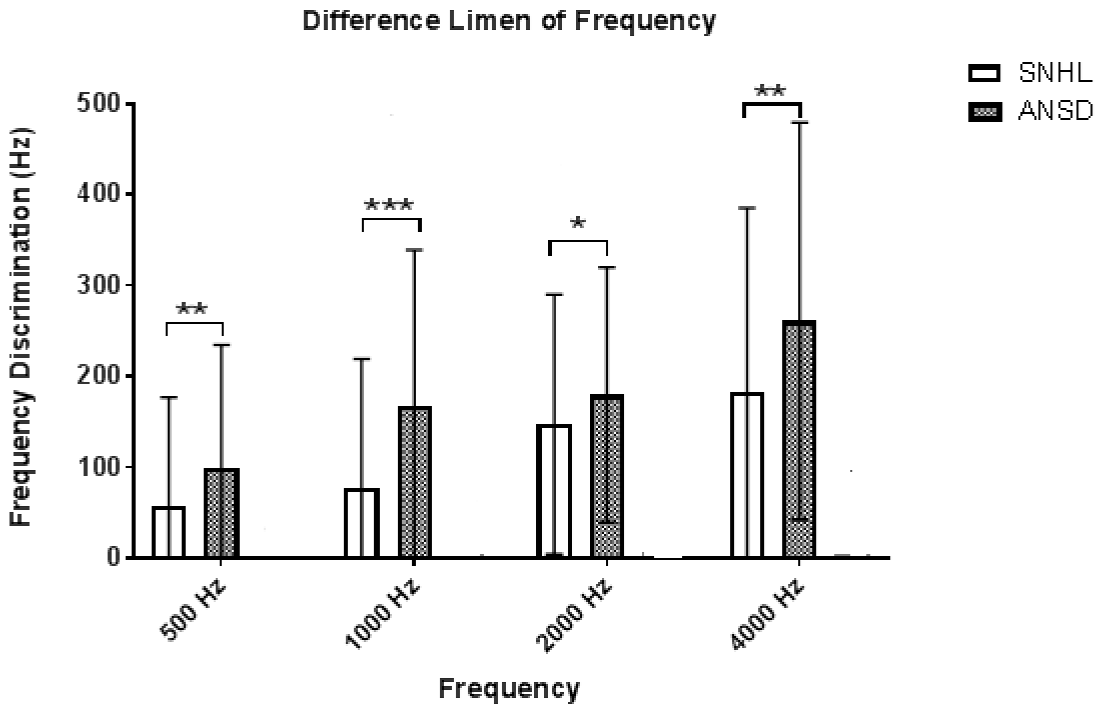

Figure 1 - Comparison of DLF in SNHL and ANSD individuals

Further mild subgroup of ANSD was compared with each of the sub-groups of SNHL on DLF for each primary tone. A Mann-Whitney U test result revealed that mild subgroup of ANSD required a significantly larger DLF for 500 Hz than each of the mild (U=42.00, Z= -2.43, p= 0.014), moderately severe (U= 14.00, Z=-2.88, p=0.003) and severe (U=3.00, Z= -2.69, p=0.005) subgroups of SNHL. In addition, a significantly larger DLF was observed in mild ANSD for 1 kHz than mild (U= 32.50, Z= -2.86, p=0.003), moderately severe (U=7.00, Z=-3.38, p=0.000) and severe (U=1.000, Z= -2.93, p=0.001) sub-groups of SNHL. Further, a significantly larger DLF was required by the sub-group of ANSD for 2 kHz than mild (U=69.00, Z=-1.193, p=0.027), moderately severe (U=26.00, Z=-2.64, p=0.043) and severe (U=17.00, Z=-0.98, p=0.371) subgroups of SNHL. Similar result was observed for 4 kHz as the mild group of ANSD required larger DLF to discriminate the primary tone from its variable tones than mild (U=42.00, Z=-2.43, p=0.014), moderately severe (U=16.00, Z= -0.006, p=0.005) and severe (U=2.00, Z=-2.81, p=0.003) subgroups of SNHL. It infers that frequency resolution in each of the frequencies in mild sub-group of ANSD was affected more than severe subgroup of SNHL. It alludes that moderately severe and severe subgroups of ANSD having a significant frequency resolution impairment than mild ANSD. It is obvious that other subgroups of ANSD (moderately severe and severe) definitely have frequency resolution impairment than severe subgroup of SNHL.

To sum up, the individuals with ANSD required significantly higher difference in frequency to differentiate two tones compared to those with SNHL (Figure-1). In addition, frequency resolution in mild ANSD was affected more than severe subgroup of SNHL.

Temporal Modulation Transfer Function: The median scores and SD on TMTF in individuals with SNHL and ANSD are tabulated in Table 4 and 5, respectively. Kruskal Wallis test was used to check for the difference between sub-groups on scores of TMTF for each frequency. Though the temporal resolution was better in mild sub-group than moderately severe followed by severe sub-groups of SNHL, it failed to cause significant differences on scores of TMTF at 8Hz (χ^2 (2) =3.529, p=0.129), 64 Hz (χ^2(2) =2.81, p=0.245), and 128 Hz (χ^2(2) =3.65, p=0.161). Unlike the SNHL group, there was a measurable score on temporal resolution only at 8 Hz and 64 Hz in mild sub-groups of ANSD.

Table 4 Median and SD of scores of TMTF in SNHL

Sub-groups	Mild		Moderately severe		Severe	
Modulation frequency (Hz)	Median (range)	SD	Median (range)	SD	Median (range)	SD
8	-14.7 (10.20)	3.73	-13.35 (17.10)	3.91	-11.85 (15.45)	6.52
64	-8.55(8.10)	2.77	-8.25 (14.55)	3.92	-5.55 (11.25)	3.95
128	-5.4(11. 40)	3.27	-4.56 (12.15)	3.39	-1.35 (8.40)	3.01

Table 5 Median and SD of scores of TMTF in ANSD

Sub-groups	Mild		Moderately severe		Severe	
Modulation frequency (Hz)	Median (range)	SD	Median (range)	SD	Median (range)	SD
8	-8.85 (19.65)	5.12	NA	-	NA	-
64	-2.25 (15.95)	4.62	NA	-	NA	-
128	NA	-	NA	-	NA	-

Further mild subgroup of ANSD was compared with each of the sub-groups of SNHL on modulation detection threshold at 8 Hz and 6 4 Hz. A Mann-Whitney U test result revealed that mild subgroup of ANSD required a significantly higher modulation detection threshold for 8 Hz modulation frequency than each of the mild (U= 4.50, Z= -2.27, p= 0.021), moderately severe (U= 4, Z= -3.90, p= 0.000) and severe (U=4.00, Z= -2.58, p= 0.010) subgroups of SNHL. Similarly, a significant higher modulation detection threshold was observed in mild ANSD for 64 Hz modulation frequency than mild (U= 42.50, Z= -2.41, p= 0.014), moderately severe (U= 3.00, Z= -4.18, p= 0.000) and severe (U= 3.00, Z= -2.70, p= 0.005) sub-groups of SNHL. It infers that the temporal resolution in each of the frequencies in mild ANSD was affected more than severe subgroup of SNHL.

3.3. Comparison of hearing handicap inventory in adults with SNHL and ANSD.

From Table-6 it is observed that the severity of hearing handicap was mild to moderate degree in mild sub-group of SNHL. Whereas, hearing handicap was significantly affected in moderately severe and severe sub-groups of SNHL. In addition, scores on social and emotional domains were reduced with increase in degree of hearing loss. This was true in each domain of hearing handicap inventory. A Kruskal Wallis test was administered to compare the severity of hearing handicap between sub-groups of SNHL group. The results revealed no differences between the sub groups on the scores of social domain of HHIA (χ^2 (2) = 3.49, p=0.175), emotional domain of HHIA (χ^2(2) =1.497, p=0.473) and total score of HHIA (χ^2(2) =2.757, p=0.252).

Table 6 Median and SD of scores of HHIA in SNHL

Sub-groups	Mild		Moderately severe		Severe	
Domains	Median (range)	SD	Median (range)	SD	Median (range)	SD
Social	17 (36)	13.59	26 (42)	12.5	32 (30)	12.61
Emotional	18 (44)	14.83	26 (38)	12.07	28 (42)	15.99
Total	36 (78)	27.38	56 (78)	23.51	54 (68)	27.29

From Table-7, it is observed that hearing handicap is significantly affected irrespective of degree of hearing loss. In addition, social domain of HHIA and total score of HHIA were affected more in severe subgroup than mild subgroup followed by moderate-severe subgroup of ANSD. Whereas, emotional domain of HHIA was same across sub-groups of ANSD. A Kruskal Wallis test revealed no difference between sub-groups on score of social domain of HHIA (χ^2 (2) = 2.40, p=0.301) and total score of HHIA (χ^2(2) =0.682, p=0.711).

Table 7 Median and SD of scores of HHIA in ANSD

Sub-groups	Mild		Moderately severe		Severe	
Domains	Median (range)	SD	Median (range)	SD	Median (range)	SD
Social	34 (44)	10.39	32 (26)	8.54	40 (14)	5.76
Emotional	34 (38)	11.24	34 (42)	12.83	34 (24)	9.95
Total	68 (78)	20.09	60 (68)	20.38	72 (30)	11.22

The scores in each domain of HHIA obtained between sub-groups were combined in each of the groups as there were no significant differences in them. This was done to compare the scores of each domain of HHIA between SNHL and ANSD. A Mann-Whitney U test result revealed a significantly higher severity of hearing handicap in ANSD than SNHL (χ^2 (1) = 6.347, p=0.012) (Figure-2). This was true in each domain of HHIA, that is, social domain (χ^2 (1) = 7.842, p=0.005) and emotional domain (χ^2 (1) = 4.249, p=0.039).

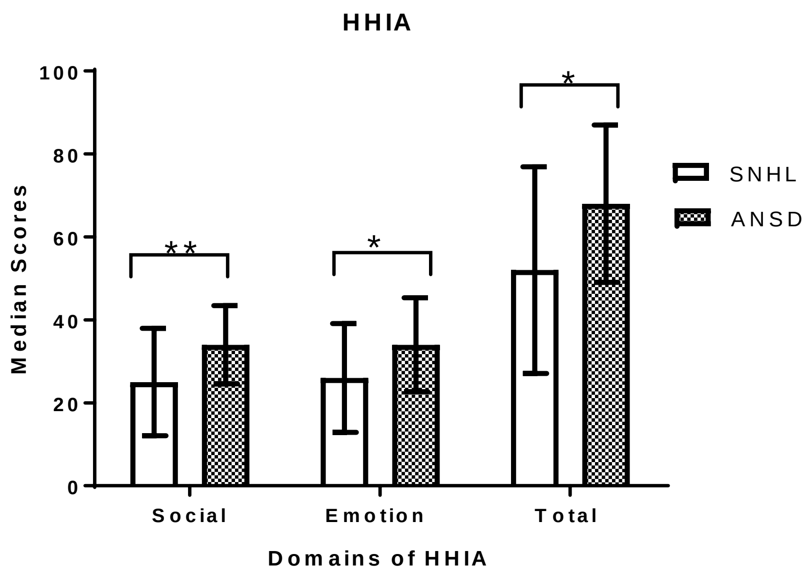

Figure 2 Comparison of scores of each domain of HHIA in SNHL and ANSD

Further, mild subgroup of ANSD was compared with each of the subgroups of SNHL on total hearing handicap index using the Mann-Whitney U test. These comparisons were performed to know the total severity of handicap in mild sub-group of ANSD compared to which subgroups of SNHL. The mild sub-group (median =68) of ANSD showed a significant higher hearing handicap than mild (median=36; U=45.50, Z= -2.27, p=0.021) and moderately severe (median =56; U= 225.50, Z= -1.67, p= 0.049) subgroups of SNHL. In addition, though the total hearing handicap in mild subgroup of ANSD (median=68) had higher score on total hearing handicap than severe sub-group of SNHL (median =54), it failed to reach significant (U= 55.50, Z= -0.63, p= 0.534) (Figure 2). Furthermore, though the each component in hearing handicap score was more in the moderately severe subgroup of ANSD than each of the subgroups of SNHL, failed to reach significant. A similar result was observed when hearing handicap sores was compared between severe subgroup of ANSD with the each subgroup of SNHL.

3.4. Comparison of World Health Organization Quality of Life (WHO –QOL) between individuals with SNHL and ANSD.

A Kruskal Wallis test was performed between sub-groups of SNHL on scores of each of the domains on quality of life. The results revealed no significant difference between subgroups of SNHL on quality of life ($\chi^2(2)$ =0.838, p=0.658), health ($\chi^2(2)$ =0.014, p=0.993), physical ($\chi^2(2)$ =0.091, p=0.955), psychological ($\chi^2(2)$ =0.243, p=0.885), environmental ($\chi^2(2)$ = 1.72, p=0.422), social ($\chi^2(2)$ =1.623, p=0.444), and total QOL ($\chi^2(2)$ =0.743, p=0.690) (Table-8). Further, the results of Kruskal Wallis test revealed no significant differences between sub-groups of ANSD on scores of quality of life ($\chi^2(2)$ =0.468, p=0.792), health ($\chi^2(2)$ = 4.212, p=0.122), physical ($\chi^2(2)$ =2.16, p=0.340), psychological ($\chi^2(2)$ =2.383, p=0.304), environmental ($\chi^2(2)$ = 0.082, p=0.960), social ($\chi^2(2)$ =0.006, p=0.997), total QOL ($\chi^2(2)$ =0.130, p=0.937) (Table-9).

Table 8 Median and SD of scores of QOL in SNHL

Sub-groups	Mild		Moderately severe		Severe	
Domains	Median (range)	SD	Median (range)	SD	Median (range)	SD
Quality of Life	3 (3)	1.19	3 (4)	1.02	4 (2)	0.78
Health	3 (3)	0.91	3 (4)	1.08	3 (2)	0.89
Physical	25.5 (20)	6.21	25 (28)	6.44	22 (15)	5.24
Psychological	19 (15)	4.06	20 (16)	4.26	19 (7)	2.42
Environmental	24.5 (16)	4.88	29 (25)	5.79	23 (14)	5.52
Social	12 (10)	2.90	12 (11)	3.17	9 (9)	2.92
Total	85 (63)	18.29	82 (71)	17.51417	79 (35)	14.17409

Table 9 Median and SD of scores of QOL in ANSD

Sub-groups	Mild		Moderately severe		Severe	
Domains	Median (range)	SD	Median (range)	SD	Median (range)	SD
Quality of Life	3 (4)	1.24	3 (3)	1.00	2 (1)	0.54
Health	3 (3)	1.02	3 (2)	0.70	2 (2)	0.89
Physical	25 (19)	5.97	26 (14)	4.88	26 (11)	4.15
Psychological	18 (19)	4.85	20 (8)	2.80	16 (11)	4.15
Environmental	26 (24)	6.15	25 (21)	6.78	27 (6)	2.70
Social	9(11)	3.38	10 (9)	2.79	10 (8)	3.20
Total	87 (69)	18.81	83 (47)	15.92	85 (33)	13.30

The scores in each domain of quality of life obtained between sub-groups were combined as there were no significant differences in them. Further, quality of life was compared between SNHL and ANSD groups. The quality of life was affected more in ANSD than SNHL (Figure-3), which was found significant (χ^2 (1) = 4.454, p=0.035). In addition, though each domain of quality of life was affected more in ANSD than SNHL, it failed to reach significant in health (χ^2(1) = 0.075, p=0.785), physical (χ^2(1) = .238, p=0.626), psychological (χ^2(1) = 0.238, p=0.626), environmental (χ^2(1) = 0.644, p=0.422), social (χ^2(1) = 2.899, p=0.089) and total score of quality of life (χ^2(1) = 0.486, p=0.486).

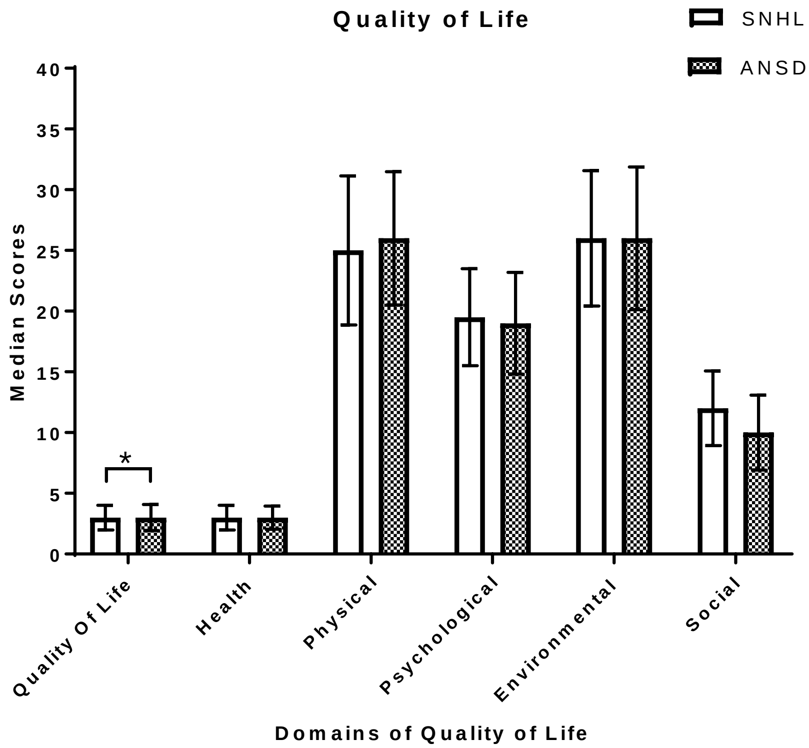

Figure 3 Comparison of scores of domains of QOL in SNHL and ANSD

Mild subgroup of ANSD was compared with each subgroup of SNHL on total score of quality of life using the Mann-Whitney U test. These comparisons were performed to know the severity of quality of life in mild sub-group of ANSD compared to which subgroups of SNHL. Though the quality of life was worse in mild sub-group of ANSD than each of the sub-groups of SNHL, failed to reach significant. A similar result was observed when total score of quality of life was compared between moderately severe/ severe and each subgroup of SNHL.

3.5. Relationship between hearing handicap and attributing factors.

The contributory factors such as hearing thresholds, speech perception in quiet, SNR 50, modulation detection thresholds, difference limen of frequency, communication handicap and quality of life in individuals with SNHL and ANSD were utilized to correlate with hearing handicap. This relationship was performed separately for SNHL and ANSD. A Spearman's sign rank correlation coefficient was performed between hearing handicap scores and contributory factors. In individuals with SNHL, a significant mild degree of positive correlation was found between total hearing handicap scores and SNR 50 (Table-10). In addition, a significant mild degree of negative correlation was found between total hearing handicap and total score of quality of life. However, no correlation was found between total hearing handicap scores and average of pure tone averages, DLF and TMTF scores.

Table 10 Correlation between attributing factors and hearing handicap in SNHL

Attributing factors	R	P
PTA- average	.259	.069
SNR50	**.327***	**.022**
TMTF8	.084	.562
TMTF64	.008	.957
TMTF128	-.079	.585
DLF500	.102	.480
DLF1K	-.002	.989
DLF2K	-.052	.722
DLF4K	.062	.670
Total QOL	**-.382****	**.006**

In individuals with ANSD, no correlation was found between hearing handicap and any of the attributing factors (average of pure tone averages, SNR 50, DLF and TMTF scores). However, there was a significant mild degree of negative correlation between total handicap scores and total quality of life. Table 11 represents the correlation values and corresponding p values of each of the contributory factors with the hearing handicap.

Table 11 Correlation between contributory factors and hearing handicap in ANSD

Attributing factors	R	P
PTA- average	-.024	.892
SNR50	-.073	.676
TMTF8	.157	.368
TMTF64	.148	.397
TMTF128	-.017	.921
DLF500	.243	.160
DLF1K	.171	.325
DLF2K	-.104	.551
DLF4K	.010	.957
Total QOL	-0.365	0.31

3.5. Summary of the results

1. Mild subgroup of ANSD participants required significantly higher SNR to achieve 50 % recognition of speech than mild subgroup of SNHL. However, there was no measurable SNR for 50 % recognition in moderately severe and severe sub-groups of ANSD. In addition, the severity of mild ANSD sub-group has the speech perception impairment similar to that of severe sub-group of SNHL.
2. Larger DLF was required as a function of frequency. This was true for each of the sub-groups of SNHL and ANSD. A significantly larger DLF was required in ANSD than SNHL for each frequency. In addition, the severity of impairment in discriminating frequency in mild subgroup of ANSD was similar to severe sub-group of SNHL.

3. In TMTF there was no measurable modulation detection threshold for moderately severe and severe groups of ANSD in each of the modulation rates. Whereas, mild sub-group of ANSD required higher modulation detection threshold than mild sub-group of SNHL at 8 Hz and 64 Hz, respectively. In addition, temporal resolution impairment in mild sub-group of ANSD was significantly higher than each of the sub-groups of SNHL.
4. Hearing handicap was significantly affected in ANSD than SNHL. A severity of hearing handicap in any sub-group of ANSD was significantly affected than severe sub-group of SNHL.
5. Quality of life was equally affected in both SNHL and ANSD groups. A severity of quality of life in any sub-group of ANSD was significantly affected than severe sub-group of SNHL.
6. In SNHL group, the SNR 50 was positively related and QOL was negatively related to hearing handicap. Speech perception and quality of life were the contributory factors for hearing handicap in SNHL group. Whereas, in ANSD, none of the factors are related to hearing handicap.

Chapter 4

Discussion

In sensorineural hearing loss to obtain 50 % speech recognition in noise required higher SNR as a function of degree of hearing loss. It indicates that SNHL hearing impaired individuals exhibits greater susceptibility to noise with increase in degree of hearing loss (Li et al. (2015) and thus required higher SNRs to understand speech, suggesting secondary distortion due to impaired temporal and spectral resolution (Stach, 1991). Temporal processing abilities are same among different degree of hearing loss in each of the frequencies. The sampled population of SNHL who suffers from temporal resolution impairment unable to capture moment to moment fluctuation of amplitude. Furthermore, irrespective of degree of hearing loss the auditory filters are widened due to loss of receptor cells and loosing basilar membrane stiffness which reflects the larger delta 'f' in DLF. It is quite obvious that lesser degree of hearing loss individuals utilizes contextual cues differently than higher degree of hearing loss, due to that fact that the distortion of the incoming speech. Thus, it is reasonable to assume that with increase in degree of hearing loss requires high SNRs to get the contextual cues in the sentences. Yet another speculation is that with increase in degree of hearing loss there is a high chance of bias towards understanding the message correctly but mistrust what is being heard leading to dilemma causes impediment in understanding sentences. A mistrust is seen in all degree of hearing loss but it is most often with increased severity of hearing loss. Furthermore, processing of intonation and prosodic features in sentence are required to understand speech (Kozhevnikov & Chistovich, 1965). These features changes rapidly over time in an ongoing speech and one should capture these cues swiftly for understanding speech. Psychoacoustic measures assesses the ability of the person to detect the smallest change in either frequency, time or intensity and it has direct relation with perception of speech. It was observed that with increase in severity of hearing loss the DLF and TMTF are affected more in higher degree of hearing loss than their counterpart. Thus, even with increase in SNRs the sampled population of moderately severe and severe subjects of SNHL partly capture the features of intonation and prosody consists of vowel pitch, duration, spectrum and intensity of speech signal in the sentences. The combination of temporal impairment as a function of severity of hearing loss (Florentine, & Buns, 1984) and alteration of temporal characteristics of sentences by speech shaped noise degraded the recognition (Dirks et al, 1982) even with increase in SNRs as a function of hearing loss. The result of the study is in consonance with the research study of Stach, (1991) who reported that speech perception abilities are in proportion with their pure tone hearing loss. This is not true in case of ANSD participants. The SNR-50 was achieved at higher SNR in mild-subgroup of ANSD than SNHL. There was no measurable SNR 50 in moderately severe and severe sub-groups of ANSD when SNR was set at 30 dB SNR in speech recognition test. The results of the present study are in consonance with the previous studies Starr, Picton, Sininger, Hood, and Berlin (1996) who reported a bare minimum score or no measurable speech perception despite an ample audibility of sound. The temporal processing in ANSD reflected in TMTF is impaired irrespective of degree of hearing loss for low modulation frequency. However, no measurable temporal modulation detection at 128 Hz. The main characteristics of auditory neuropathy is a significant temporal impairment, who are unable to capture the modulation depth of envelope in sentences and introduces spurious modulations, which obscures the relevant speech modulations (Narne, 2013). Furthermore, ANSD subjects unable to detect the spatial changes in the excitation pattern along the basilar membrane (Sek & Moore, 1995) due to leakage of signal to neighboring fibers. Complete or partial loss of myelin in auditory nerve have significant effect in the generation and propagation of action potentials. Demyelination has been found to result in an increase in membrane capacitance and a decrease in membrane resistance, leading to delayed excitation, a reduction in the velocity of action potentials propagation (McDonald & Sears, 1970). This has been found to results in emphatic transmission between fibers, with one active fiber setting off discharges in adjacent fibers (Starr, Picton, & Kim, 2001).

Frequency discrimination and temporal resolution cues are the basis for speech understanding in noise. In both SNHL and ANSD subjects required a larger DLF as a function of increased primary frequency tones and degree of hearing loss in each primary tone. The ANSD participants required a larger DLF than SNHL due to the impaired in phase locking ability for discriminating low frequency primary tones (Winter & Palmer, 1990) and altered spatial changes in the excitation pattern along the basilar membrane for discriminating high frequency primary tone (Sek & Moore, 1995). Thus it was observed that the severity of impairment in discriminating frequency for mild subgroup of ANSD was similar to that of 'severe' sub-group of SNHL. Further, except at 128 Hz, the detection threshold at 8 Hz and 64 Hz in mild sub-groups of ANSD was higher than SNHL. In addition, if the severity of neural impairment increased above mild degree there was no measurable detection threshold for irrespective of modulation rate of frequencies. This is because of impairment in timing and synchronicity in firing of neurons in the auditory nerve fibers which unable participants of ANSD to code high rates of modulations. Thus, it was observed that temporal resolution impairment in mild sub-group of ANSD was significantly higher than each of the sub-groups of SNHL. It can be inferred that impairment in psychoacoustic tasks reflected in speech perception in noise too.

Both ANSD and SNHL participants finds difficult to understand speech in noise, thus, social isolation, decline in social activities and an emotional distress make them rate 'Not at all' and 'some what' in each subscale of QOL. Thus, irrespective of degree of hearing loss and site of pathology the QOL is equally affected. This is because the participants of the study might have perceived their social skills which induces a reduced self- esteem. In addition, hearing loss and poor coping strategies while communication contribute to have impaired quality of life. In a routine life an exchange of information with others is an important aspect of everyday life, can be impaired in individuals with hearing loss due to hearing handicap.

The emotional and social skills of HHIA in ANSD were significantly affected than SNHL. This could be due to sudden onset of hearing loss in ANSD made them to undergo a stress which unable to communicate as they were doing well previously. The benefit received from hearing aid ranged from 'little' to 'no' for ANSD subjects. Unlike ANSD, hearing aids lessen the hearing handicap once it is fitted with SNHL subjects. It is well established fact that aided speech perception ability is best if the hearing loss is less and vice versa. Thus, the hearing handicap reduced with lesser degree of hearing loss. Whereas, in ANSD, due to lack of rehabilitation management strategy a functionality was reduced which impacted the everyday life, causing loneliness, social isolation, dependence, and frustration and communication impairment. Thus, a severity of hearing handicap in mild sub-group of ANSD was similar to of 'severe' sub-group of SNHL.

The participants of SNHL showed a significant increase in hearing handicap in those subjects who took higher SNR in dB required for 50 % speech recognition and rated low in quality of life. Individuals with SNHL decipher the meaning of sentence in higher signal to noise ratio because of audibility of speech over the noise. Unfortunately, in a daily listening scenario they may not have experience always an optimum signal to noise ratio to lessen their hearing handicap and quality of life. Thus, the sampled population of SNHL subject rated increased hearing handicap and reduced QoL in those individuals who wanted higher SNR to recognize 50 % speech.

Furthermore in ANSD, the hearing handicap has no relation with the test measures that were taken up in the present study (TMTF, DLF, SNR 50 and QoL). It purports that hearing handicap is equally affected irrespective of scores in the measured test from the samples of ANSD participants. This is because they tend to compare the present listening problem (ie., unable to talk over phone, unable to speak in group conversation, in the work environment or in the place they reside they may feel: embarrassment, irritable, alone, uncomfortable depressed, nervous; difficulty in listening to: whisper sounds, TV, family members, and neighbors) with their listening abilities prior to the hearing loss.

5. Conclusion

Speech perception in noise, psychoacoustic skills, hearing handicap and QOL were significantly affected in ANSD than SNHL groups. In addition, the severity of mild sub-group of ANSD was similar to those participants of severe sub-group of SNHL in each of the behavioral skills, psychoacoustic skills, hearing handicap and QOL assessed. Further, hearing handicap in SNHL was attributed by SNR 50 and quality of life. Whereas, in ANSD, the hearing handicap are not related to any of the attributor factors undertaken in the study.

6. Implication of the study

This study provides insight of how much the mild ANSD subject suffer against their counterpart who have sensory impairment. The finding purports that 'mild' ANSD subjects have listening impairment similar to that of 'severe' degree of SNHL subjects.

7. Limitation of the study

In sampled of each group we unable to categorize their hearing handicap or QOL based on the scores of test measured in the present study. This is because the sampled population rated same degree of hearing handicap or QOL irrespective of degree of hearing loss, temporal impairment and speech perception ability in noise.

8. Reference

Alhanbali, S., Dawes, P., Lloyd, S., & Munro, K. J. (2018). Hearing Handicap and Speech Recognition Correlate With Self-Reported Listening Effort and Fatigue. *Ear Hear, 39*(3), 470-474. doi: 10.1097/aud.0000000000000515

Bacon, S. P., & Gleitman, R. M. (1992). Modulation detection in subjects with relatively flat hearing losses. *J Speech Hear Res, 35*(3), 642-653.

Bacon, S. P., & Viemeister, N. F. (1985). Temporal modulation transfer functions in normal-hearing and hearing-impaired listeners. *Audiology, 24*(2), 117-134.

Baer, T., Moore, B.C.J., Kluk, K. (2002) Effects of lowpass filtering on the intelligibility of speech in noise for people with and without dead regions at high frequencies. *Journal of the Acoustical Society of America*, **112**, 1133–1144.

Berlin, C. I., Hood, L. J., Morlet, T., Wilensky, D., Li, L., Mattingly, K. R., . . . Frisch, S. A. (2010). Multi-site diagnosis and management of 260 patients with auditory neuropathy/dys-synchrony (auditory neuropathy spectrum disorder). *Int J Audiol, 49*(1), 30-43. doi: 10.3109/14992020903160892.

Carhart, R., & Jerger, J. F. 1959. Preferred method for clinical determination of pure-tone thresholds. Journal of Speech Hearing Disorder, 24, 330.

Carhart, Raymond (1957). "Clinical Determination of Abnormal Auditory Adaptation". A.M.A. archives of otolaryngology, 65 (1), pp. 32–39.

Dirks DD, Morgan DE, Dubno JR. (1982) . A procedure for quantifying the effects of noise on speech recognition. J Speech Hear Disord 47 :114-123.

Florentine M, Buns S. (1984) . Temporal gap detection in sensorineural and simulated hearing impairments. J Speech Hear Res 27 :449-455.

Geetha, C., Kumar, K., Manjula, P., & Pavan, M. (2014). Development and standardisation of the sentence identification test in the Kannada language. *J Hear Sci, 4*(1), 18-26.

Goldstein, J. (1977). Auditory-nerve spike intervals as an adequate basis for aural frequency measurement. *Psychophysics and physiology of hearing*.

Goldsworthy, R,L., Delhorne, L, A., Braida, L, D., and Reed, C, M (2013). Psychoacoustic and Phoneme Identification Measures in Cochlear-Implant and Normal-Hearing Listeners. Trends Amplif. 17(1): 27–44. doi: 10.1177/1084713813477244.

Iwasaki, S., Sano, H., Nishio, S., Takumi, Y., Okamoto, M., Usami, S., & Ogawa, K. (2013). Hearing handicap in adults with unilateral deafness and bilateral hearing loss. *Otol Neurotol, 34*(4), 644-649. doi: 10.1097/MAO.0b013e318287f1fe

Jijo, P., & Yathiraj, A. (2012). Audiological characteristics and duration of the disorder in individuals with auditory neuropathy spectrum disorder (ANSD)–a retrospective study. *J Indian Speech Hear Assoc, 26*(1), 17-26.

Kozhevnikov VA, Chistovich LA. (1965). Speech: Articulation and Perception. [Translated by the Joint Publications Research Service (Washington, DC: No. JPRS 30543)].

Kumar, U. A., & Jayaram, M. M. (2006). Prevalence and audiological characteristics in individuals with auditory neuropathy/auditory dys-synchrony. *Int J Audiol, 45*(6), 360-366. doi: 10.1080/14992020600624893

Li, B., Hou, L., Xu, L., Wang, H., Yang, G., Yin, S., & Feng, Y. (2015). Effects of steep high-frequency hearing loss on speech recognition using temporal fine structure in low-frequency region. *Hear Res, 326*, 66-74.

Lima, A. P., Mantello, E. B., & Anastasio, A. R. (2016). Monitoring the Hearing Handicap and the Recognition Threshold of Sentences of a Patient with Unilateral Auditory Neuropathy Spectrum Disorder with Use of a Hearing Aid. *Int Arch Otorhinolaryngol, 20*(2), 185-188. doi: 10.1055/s-0034-1397338

Lorenzi, C., Dumont, A., & Fullgrabe, C. (2000). Use of temporal envelope cues by children with developmental dyslexia. *J Speech Lang Hear Res, 43*(6), 1367-1379.

Micheyl, C., Delhommeau, K., Perrot, X., & Oxenham, A. J. (2006). Influence of musical and psychoacoustical training on pitch discrimination. *Hear Res, 219*(1-2), 36-47. doi: 10.1016/j.heares.2006.05.004

Moore BCJ. (2007). Cochlear Hearing Loss: Physiological, Psychological and Technical Issues, Second Edition. Second edition, John Wiley & Sons, England. **Pages 42- 44.**

Moore, B. C., & Peters, R. W. (1992). Pitch discrimination and phase sensitivity in young and elderly subjects and its relationship to frequency selectivity. *J Acoust Soc Am, 91*(5), 2881-2893.

Moore, B. C., Shailer, M. J., & Schooneveldt, G. P. (1992). Temporal modulation transfer functions for band-limited noise in subjects with cochlear hearing loss. *Br J Audiol, 26*(4), 229-237.

Narne VK (2013) Temporal Processing and Speech Perception in Noise by Listeners with Auditory Neuropathy. PLoS ONE 8(2): e55995. https://doi.org/10.1371/journal.pone.0055995

Newman, C. W., Jacobson, G. P., Hug, G. A., & Sandridge, S. A. (1997). Perceived hearing handicap of patients with unilateral or mild hearing loss. *Ann Otol Rhinol Laryngol, 106*(3), 210-214. doi: 10.1177/000348949710600305

Parthasarathy, S., & Mathai, J. P. (2017). Translation of hearing handicap inventory (adults and elderly) to Kannada. *Journal of Indian Speech Language & Hearing Association, 31*(1), 5.

Pedersen, K., & Rosenhall, U. (1991). Correlations between self-assessed hearing handicap and standard audiometric tests in elderly persons. *Scand Audiol, 20*(2), 109-116.

Pottackal Mathai, J., & Yathiraj, A. (2013). Effect of temporal modification and vowel context on speech perception in individuals with auditory neuropathy spectrum disorder (ANSD). *Hearing, Balance and Communication, 11*(4), 198-207.

Prabha C (2002). Scoring and coding for the WHO QOL instrument in Kannada. Mental Health: evidence and research, Department of Mental health and substance dependence, WHO, Geneva.

Prabhu, P. (2017). Evaluation of Hearing Handicap in Adults with Auditory Neuropathy Spectrum Disorder. *J Int Adv Otol, 13*(2), 226-229.

Sek, A., & Moore, B. C. (1995). Frequency discrimination as a function of frequency, measured in several ways. *J Acoust Soc Am, 97*(4), 2479-2486.

Shetty, H. N., & Mendhakar, A. (2015). Development of phrase recognition test in Kannada language. *Journal of Indian Speech Language & Hearing Association, 29*(2), 21.

Simon, H. J., & Yund, E. W. (1993). Frequency discrimination in listeners with sensorineural hearing loss. *Ear Hear, 14*(3), 190-201.

Starr, A., Picton, T. W., Sininger, Y., Hood, L. J., & Berlin, C. I. (1996). Auditory neuropathy. *Brain, 119 (Pt 3)*, 741-753.

Starr, A., Sininger, Y. S., & Pratt, H. (2000). The varieties of auditory neuropathy. *J Basic Clin Physiol Pharmacol, 11*(3), 215-230.

Stach BA, Loiselle LH, Jerger J. (1991) . Special hearing aid considerations in elderly patients with auditory processing disorders. Ear Hear 12(Suppl):131S-1378.

Stewart, M., Pankiw, R., Lehman, M. E., & Simpson, T. H. (2002). Hearing loss and hearing handicap in users of recreational firearms. *J Am Acad Audiol, 13*(3), 160-168.

Ventry, I. M., & Weinstein, B. E. (1982). The hearing handicap inventory for the elderly: a new tool. *Ear and hearing, 3*(3), 128-134.

Wadley, F. (1952). Probit Analysis: A Statistical Treatment of the Sigmoid Response Curve. DJ Finney. New York-London: Cambridge Univ. Press, 1952. 318 pp. $7.00: American Association for the Advancement of Science.

Winter, I. M., & Palmer, A. R. (1990). Responses of single units in the anteroventral cochlear nucleus of the guinea pig. *Hear Res, 44*(2-3), 161-178.

Yathiraj, A., & Vijayalakshmi, C. (2005). Phonemically balanced wordlist in Kannada. *University of Mysore*.

Zeng, Y., Liang, Y.-C., Hoang, A. T., & Peh, E. C. (2009). *Reliability of spectrum sensing under noise and interference uncertainty.* Paper presented at the Communications Workshops, 2009. ICC Workshops 2009. IEEE International Conference on.