TEMPORAL PROCESSING, WORKING MEMORY AND SPEECH PERCEPTION SKILLS IN NORMAL HEARING INDIVIDUALS EXPOSED TO INDUSTRIAL NOISE

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This Dissertation is submitted as a part of fulfilment

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CERTIFICATE

This is to certify that this dissertation entitled **‘Temporal processing, working memory and speech perception skills in normal hearing individuals exposed to industrial noise’** is the bonafide work submitted in part fulfilment for the Degree of Master of Science (Audiology) of the student with Registration No: **16AUD033**. 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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This is to certify that this dissertation entitled **'Temporal processing, working memory and speech perception skills in normal hearing individuals exposed to industrial noise'** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this Master's dissertation entitled **'Temporal processing, working memory and speech perception skills in normal hearing individuals exposed to industrial noise'** is the result of my own study under the guidance of Dr.Ajith Kumar U, Professor of Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

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ABSTRACT

The present study aimed at investigating temporal processing, working memory and speech perception in noise in normal hearing individuals exposed to industrial noise. 15 adult males in the age range of 25 to 40 years exposed to industrial noise participated in the study. Age and gender matched 15 normal hearing adults who are not exposed to industrial noise served as contraol group. All the participants had puretone thresholds within 25 dBHL, ‘A’ type tympanogram and normal acoustic reflexes at 500 and 1000 Hz. Participants in both the groups had clinically normal otoacoustic emissions. Gap detection thresholds (GDT) and temporal modulation transfer functions (TMTF) were assessed to estimate temporal processing. Working memory assessment included forward digit span (FDS), backward digit span (BDS), operation span and reading span. SNR-50 was done to assess speech perception in noise. Individuals who are exposed to noise had significantly poor gap detection threshold and poor modulation detection thresholds compared to normal hearing control group. Furthermore, participants in noise exposed group showed poor performance on working memory measures and also poor SNR-50. The study concludes stating prolonged exposure to industrial noise has an adverse effect on auditory-cognitive system.

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CHAPTER 1

INTRODUCTION

Noise exposure leads to acute loss of afferent nerve terminals and synapses with a temporary threshold shift (Kujawa & Liberman, 2009). A number of recent studies have reported that noise exposure and age can cause permanent loss of synapses between inner hair cells (IHC) and auditory nerve without permanently affecting the hearing thresholds. This type of disorder has been variously termed as cochlear neuropathy, cochlear synatopathy or hidden hearing loss (Bharadwaj et al., 2014; Liberman & Kujawa, 2017; Liberman & Liberman, 2015; Oxenham, 2016). These individuals may have small, but functionally important, neural losses, yet be classified as having audiometrically normal hearing thresholds. Temporal coding measures and noise-exposure history support the notion that neuropathy may be present even in persons with normal hearing thresholds (Bharadwaj, Masud, Mehraei, Verhulst, & Shinn-Cunningham, 2015). Higher levels of recreational noise exposure in young listeners were associated with poorer amplitude modulation detection thresholds at lower sound levels. Researchers applied simple theoretical model, taken from signal detection theory, to provide some predictions for what perceptual effects can have on synapse loss. These predictions as well as empirical evidences suggest that loss of auditory nerve fibers can affect tone detection in quiet and in noise, frequency discrimination, level discrimination, and binaural lateralization tasks even before any reliable change in thresholds could be detected (Oxenham, 2016).

Over a past decade or so there is increased interest among researchers in studying the association between cognitive functions and sensory skills. Humes and his colleagues in series of studies investigated the relationship among peripheral, central auditory processing skills and cognitive skills, specifically working memory

(Humes & Floyd, 2005). Collectively their results indicated that cognitive factors contributed substantially for speech understanding. This association between cognition and speech understanding was stronger in adverse listening conditions and for amplified speech. Furthermore, their observation also supported the hypothesis that age related changes in cognitive functions may be mediated through age related changes in sensory functioning. Relationship between sensory and cognitive function is explained by information degradation hypothesis. According to this poor sensory input or degraded sensory information will result in poor cognitive function.

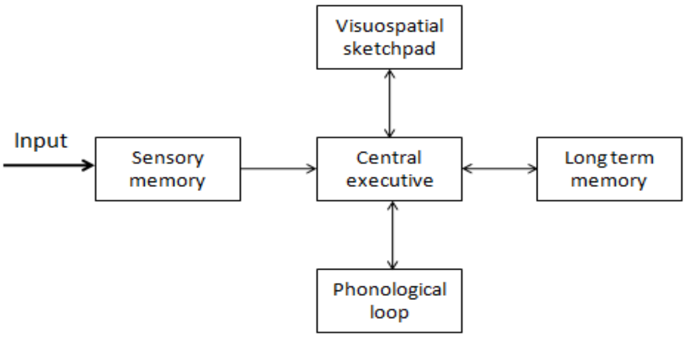

Figure 1.1: The working memory model (Baddeley & Hitch, 1974).

Figure 1.1 describes the working memory system and how subsystems are connected to central executive.

Working memory refers to a cognitive system that allows us to maintain and manipulate information in brain for short periods of time and plays a significant role in many forms of complex cognition such as learning, reasoning, and problem solving and language comprehension. Figure 1.1, shows the working memory model proposed by Baddeley and Hitch (1974). Auditory working memory can be assessed using various tasks like digit span, operation, simple calculation, reading comprehension, visual and spatial processing (Conway et al., 2005). A recent study showed that prolonged noise exposure has a negative effect on reading comprehension in school going children (Clark et al., 2006a). A normal auditory system has the ability to understand, analyse and process information in presence of competing stimuli. The adverse effects of noise on speech discrimination and recognition was proven in studies conducted earlier (Elliott et al., 1979; Finitzo-Hieber & Tillman, 1978).

Need for the study

As noted earlier there is enough evidence to believe that sensory functions have significant influence over cognitive functions, temporal processing and speech perception in noise. Since exposure to industrial noise has adverse effects on auditory system, it is important to investigate the effect of distorted processing skills on temporal, working memory and speech perception abilities as hearing thresholds will be normal or near normal in individuals with hidden hearing loss.

Aim of the Study

The study aims to investigate the temporal processing, working memory and speech perception in noise abilities in persons who exposed to industrial noise.

Objectives of the study

1. To assess the effect of noise exposure on some temporal processing and speech perception skills.
2. To study the effect of prolonged noise exposure on working memory skills.
3. To compare the temporal processing and speech perception skills between individuals who work in noisy environment and normal hearing individuals.

4. To compare the working memory abilities (auditory digit span, operation span and reading span) between individuals who work in noisy environment and normal hearing individuals.

CHAPTER 2

REVIEW OF LITERATURE

Noise is defined as audible acoustic energy (or sound) that is unwanted because it has adverse auditory and non-auditory physiological effects on humans (Kryter, 1972). Recent works suggests that most vulnerable elements in the inner ear are the synapses between hair cells and cochlear nerve terminals that degenerate first in the aging or noise exposure. This primary neural degeneration does not affect hearing thresholds, but likely contributes to problems understanding speech in difficult listening environments (Liberman, Epstein, Cleveland, Wang, & Maison, 2016).

2.1 Effect of noise on temporal processing

Sounds are dynamic in nature. Auditory temporal processing can be defined as the perception of sound within a defined time domain (Musiek et al., 2005). Temporal processing is critical to a wide variety of everyday listening tasks. Speech is characterized by rapid changes in intensity & frequency over time, the accurate processing of these temporal changes is important for perception of speech. Temporal processing encompasses a wide range of auditory skills including temporal resolution (Schow, Seikel, Chermak, & Berent, 2000). The common and reliable method of investigating temporal processing is using gap detection and temporal modulation transfer functions. Gap detection tasks test listeners' abilities to follow rapid changes over time by measuring the shortest interval of silence that is detectable in an otherwise continuous sound; modulation- detection tasks measure how listeners' abilities to perceive rapid fluctuations (or modulation) change as the rate of modulation is varied. All these measures are concerned with the limits of our ability to follow rapid changes and referred to as measures of temporal resolution. The temporal resolution ability is critical to understand speech and this can be measured through gap detection and amplitude modulation detection (Oxenham & Bacon, 2003).

Kumar, Ameenudin and Sangamanatha (2012) recorded temporal processing skills and speech perception in normal hearing train drivers, exposed to occupational engine noise more than 80dBA. A total number of 118 participants comprising of three groups in the age range of 30–40 (*n* = 13), 41–50 (*n* = 9), and 51–60 (*n* = 6) years and their counterparts who are not exposed to occupational noise (*n* = 30 in each age groups) participated in the study. Participants of all the groups had air condition thresholds within 25 dB HL in the octave frequencies between 250 and 8 kHz. Temporal processing was assessed by gap detection, modulation detection and duration pattern tests. Gap detection using 750 ms broadband noise in 28 individuals exposed to railway engine noise was measured. Results did not reveal any significant effect of noise exposure on gap detection thresholds when compared with normals. 500 ms Gaussian noise was sinusoidally amplitude modulated at 8, 20, 60 and 200 Hz modulation frequencies. Modulation detection thresholds were compared between young and older adults. High modulation frequencies (60 & 200 Hz) were affected in older adults compared to young adults.

The study done by Stone and Moore in the year 2014 aimed to assess effect of noise exposure intensity on amplitude modulation detection. Hearing test battery was done for the selection of participants (N= 32). Participants were young (from 18 to 24 years) and older (from 26 to 35 years) who were exposed to high level of noise (HN, i.e. >38 dBA) and low level noise (LN, i.e. <38 dBA) for 3 to 5 years. Puretone audiometry was done from 125 to 8000 Hz including octaves and mid octaves and subjects with puretone thresholds greater than normal range was excluded from the study. Shaped broad band noise was used as the signal. Amplitude modulation detection thresholds were measured for 3, 4 and 6 kHz at 10, 25 and 40 dB SL. 2 alternative forced choice, 3 down 1 up procedure was used. Thresholds were taken from last 6 reversals. Stimuli duration used was 250 ms. The HN had poorer amplitude detection thresholds at 10 dB SL than LN groups at 3 and 4 kHz. At high levels, 25 and 40 dB SL both groups performed similar.

Bharadwaj, Masud, Mehraei, Verhulst and Shinn-Cunningham (2015) aimed to determine if the pattern of individual differences in suprathreshold temporal coding in a cohort of young normal hearing adults is consistent with cochlear neuropathy. 26 subjects aged from 21 to 39 years were recruited for the study. All subjects had pure-tone hearing thresholds within 15 dB hearing level in both ears at octaves between 250 Hz and 8 kHz. Psychophysical tuning curves were measured for a low-intensity probe tone at 10 dBSL through notched-noise method. Amplitude modulation detection thresholds were obtained using 500 Hz broadband noise centred at 4 kHz and modulated at 19 Hz. Envelop following responses was measures in response to 400 ms long bursts of 100 Hz transposed tones with a CF of 4 kHz at 75 dBSPL. The modulation depths were varied. The authors found large individual differences in temporal coding and amplitude modulation detection thresholds. Whereas some participants showed a gradual reduction in the envelop following response magnitude as modulation depth decreases and the rest of the participants showed more precipitous reduction leading to weak EFR responses at shallow modulation depths.

Zhou and Merzenich (2012) took control and noise exposure (NE) rats that were exposed to pulse trains with repetition rates that varied over a significant frequency range. This structured noise was exposed at 65 dB SPL which is below the broadly accepted safety standards. Behavioural tests had a procedural-learning phase followed by a perceptual-testing phase. In temporal rate discrimination tasks the rats were supposed to discriminate pulse train with varying duration from 6.3 p.p.s. to 14.3 pp.s to constant pulse train of duration 520 ms. The average performance of NE rats were lower when compare with control rats. ABR measurement and cortical recording were carried out after they were returned to a normal environment. ABR was recorded using tone pips of different intensities and repetition rates. ABR data recorded from NE rats were within the normal ± 2 standard deviation (SD) boundaries. Microelectrodes were used to record cortical responses, thresholds and latencies recorded at cortical sites in NE rats did not differ from those recorded in control rats. The frequency selectivity was first evaluated for each cortical site by constructing the tuning curve using tone pips with random frequencies and intensities. The tuning curve bandwidths measured was larger for NE than for control rats, indicates that the frequency response selectivity was significantly and systematically degraded with noise exposure. The strong deterioration in cortical processing of acoustic inputs is independent of the modulation rates of structured noises. These results says there can be substantial negative consequences for the auditory system documented at the cortical level, attributable to environmental exposure to structured noises delivered under conditions that do not directly impact hearing sensitivity.

2.2 Effect of noise on cognitive function

Working memory is a system which temporarily stores the information, manipulate and then retrieve it when it is required. Working memory can be assessed by executing higher level cognitive tasks such as digit recall, operation span and reading span.

Exposure of aircraft noise on physiological, motivational and cognitive on children was studied. The participants were boys and girls in the age range of 9 to 10 years. The subjects of experimental group were children attending elementary schools located around an airport. Peak sound levels in these schools were as high as 95dBA. Children from three quiet schools were taken as control group. Reading comprehension, recognition, information recall and conceptual recall were measured. The experimental group performed poorly when compared with controls. Results concluded that prolonged noise exposure has a negative effect on reading comprehension in school going children (Clark et al., 2006b).

Cohen, Evans, Krantz and Stokols (1980) conducted a similar study in which they used longitudinal data to determine whether children adapt to the air craft noise over a period of one year. The results indicated that there was little evidence for adaptation to noise over a period of one year. Noise abatement had small unsatisfactory effect on cognitive performance, children’s ability to listen to their teachers and their social achievement. Noise exposure may also interfere with our other day-to-day activities and cause anxiety, restlessness, stress and sleep disturbances.

2.3 Effect of noise on speech perception

Understanding speech in the adverse conditions is an extremely important and challenging task for the human auditory system (Beattie, Barr, & Roup, 1997). The ability to understand speech in noise depends upon multiple factors such as characteristics of the speech signal, the signal-to-noise ratio, and the listener's degree of hearing impairment.

Kumar et al. in the year 2012 evaluated the speech recognition in presence of multitalkerat -5dB SNR in individuals with normal hearing but exposed to industrial noise. Their results showed that speech recognition scores in the presence of noise were significantly poorer compared to control individuals and it had an association with their poorer temporal processing skills suggesting that processing of suprathreshold temporal cues can be significantly distorted due to noise exposure which may contribute to the difficulties in hearing in adverse listening conditions.

Difference in the temporal processing and speech perception abilities between pre and post exposure conditions could be because of influence of noise exposure on cognitive abilities. Gomes, Martinho and Castelo (1999) studied the effects of occupational noise exposure to low frequency noise on cognition. Subjects were 40 male workers working as aircraft technicians in the age range of 35 to 56 years, exposed to occupational noise of large pressure amplitude (> or =90 dB SPL) and low frequency (≤5500 Hz) LPALF noise for a long time duration (from 13 to 30 years). P300 event-related brain potential elicited with an auditory discrimination task, and the psychological tests were performed to record any change in cognition. Results indicated that there was deterioration in memory but not in attention as a result of long-term exposure to LPALF.

Yeend, Beach, Sharma and Dillon (2017) aimed to investigate effect of noise exposure in auditory processing and speech perception in noise. A total of 122 participants were selected for the study. Puretone audiometric test, tympanometry, acoustic reflexes, otoacoustic emission and medial olivocochlear responses were assessed as screening protocol for the selection of participants. Amplitude modulation detection thresholds were assessed in 3.5 kHz carrier tone modulated sinusoidally at 4 Hz (AM4) with duration of 750 ms and 90 Hz (AM90) with duration of 500 ms.Attention was assessed using three auditory subtests from the Test of Everyday Attention (TEA). The test had several levels of tasks such as Selective attention, Attention Switching etc. Attention, short-term memory and working memory were tested using the Digit Span Forward (DSF) and Digit Span Backward (DSB). The DSF task requires participants to recall digits in the order they are presented while the DSB requires the digits to be recalled in reverse. An Australian-English version of the Reading Span Test was used to assess speech in noise. This condition was chosen because it presents spatially separated background noise and target speech, the most realistic listening scenario of the four listeners conditions. NAL dynamic conversation test was also used to assess speech perception in noise. Pearson correlation coefficient was calculated to find the correlation between noise exposure and auditory processing and speech perception in noise. The results obtained say no significant correlation was found between noise exposure and auditory processing or speech perception in noise.

2.4 Electrophysiological findings in individuals exposed to noise

Attias and Pratt (1985) studied the changes in ABR in individuals exposed to occupational noise >90dBA with normal hearing thresholds. 30 ears were taken up for the study. They recorded ABR using click stimuli of alternating polarity at two repetition rate of 10/sec and 55/sec at 75 dBHL in 16 new industrial workers with normal hearing soon after an exposure to pink noise of 95 dBHL through TDH 39 headphones for 15 minutes accounting for temporary threshold shift. ABR were again recorded for the same individuals when they developed threshold shift. They assessed waveform morphology, absolute latencies for I III and V peak and Inter peak latencies for I-III, III-V and I-V. Results revealed prolongation of wave I, III and V was found and also inter peak latencies values increased as the repetition rate increased from 10/sec to 90/sec. They conclude that ABR with faster repetition rate are sensitive to noise induced changes than lower repetition rate.

Indora, Khaliq and Vaney (2017) assessed the auditory pathway in traffic policemen by means of ABR, MLR and LLR. 35 traffic policemen in the age range from 25 to 40 years with minimum 3 years of field posting were selected along with 35 age matched controls. Participants with any ear related disorders were excluded from the study. All the participants underwent three tests ABR, MLR, and slow vertex response (SVR) or LLR. Absolute peak latencies of waves I, II, III, IV, and V and inter-peak latencies of I-III, III-V, and I-V were determined for ABR along with the amplitudes of waves I and V and their ratio (V/I) for each ear separately. Increase in the latencies of waves I and III of ABR, and prolonged inter peak I-III latencies were observed. Latencies of negative and positive peaks, N_0, P_0, N_a, and P_a were recorded and N_0-$P_{0\ \text{peak to peak}}$ amplitude were analysed for MLR. Absolute peak latencies of negative and positive peaks that are N_1, P_2, and amplitude N_1-$P_{2\ \text{complex}}$ were recorded analysed for LLR. Compared to controls, the MLR and SVR waves showed no significant changes. Authors concluded saying chronic exposure of noise results in delayed conduction in peripheral part of the auditory pathway. That is from auditory nerve up to the level of superior olivary nucleus. And no impairment was determined at the level of sub-cortical, cortical, or the association areas.

2.5 Vestibular findings in individuals exposed to industrial noise

Raghunath, Suting and Maruthy (2012) determined the effect of long term occupational noise exposure on vestibular system. The participants were one experimental group and two control groups. The experimental group consisted of 20 weavers aged from 18 to 32 years. The control group 1 and 2 consisted of 20 people who were as waiters in a restaurant and 20 graduate and post-graduate students of audiology respectively. All subjects had normal hearing sensitivity (hearing thresholds within 15 dB HL) from 250 Hz to 8000 Hz as assessed on a pure tone audiometry. They had normal middle ear function was confirmed with immittance evaluation. Transient-evoked otoacoustic emissions (TEOAEs) were also measured to rule out any outer haircell dysfunctions. The experimental group exposed to occupational noise for more than 10 years. A dizziness questionnaire was administeredwhich studied the presence/ absence of eight symptoms that may be present in an individual with vestibular disorders. There was significant difference between the experimental group and the both the control groups in terms of frequency of vestibular symptoms. However, most of the symptoms were subtle in nature. Tinnitus was significantly more frequent in the group exposed to occupational noise than the 2 control groups. The participants with vestibular symptoms reported that the severity of dizziness increased by the end of working day; the dizziness was relatively relieved during non-working hours, and became worse by overwork or exertion. The authors concluded long term exposure to noise may cause vestibular symptoms before clinically detectable hearing loss.

CHAPTER 3

METHODS

The study aimed to compare the psychophysical abilities, speech perception in noise and working memory in normal hearing individuals with and without noise exposure. Written informed consent was taken from all the participants for willingly participating in the investigation.

3.1 Research design

Research design used was standard group comparison. A between subject design was used to compare the temporal processing, working memory and speech perception in noise among normal hearing (NH) and noise exposure (NE) groups. Within subjects design was used to assess the effect of modulation detection thresholds across frequencies.

3.2 Participants

A total of 30 participants in the age range of 25 to 40 years were selected for the study. Participants were divided into two groups; first group consisted of 15 adult males with normal hearing sensitivity (NH) and second group consisted of 15 adult males who are exposed to industrial noise for at least 5 years (NE). And all the participants had tenth standard as educational qualification.

Participants were selected on the following inclusion criteria.

Air conduction pure tone hearing thresholds of less than 25 dB HL at octave frequencies between 250 Hz to 8000 Hz in both ears (Bernstein & Trahiotis, 2016; Liberman & Kujawa, 2017) and bone conduction thresholds less that 15 dB HL from

500 to 4000 Hz. No history of hearing loss, ear disease, head trauma, ear surgery, speech language problems and usage of ototoxic drugs. These details were noted through a structured interview. Normal functioning of middle ear as indicated by bilateral 'A' or 'As' type of tympanogram(Jerger, 1970) and with acoustic reflex (ipsilateral and contralateral) present at normal sensation levels at 500 Hz and 1000 Hz. Bilateral transient evoked otoacoustic emission (TEOAE) was present in both the ears. Participants in the NE group had minimum 5 years of noise exposure. Noise levels in their working environment were above 70 dBA and all of them reported that they worked in this environment for a minimum of 6 hours a day. All of them used hearing protective devices of different types.

3.3 Instrumentation

A calibrated two channel diagnostic audiometer, MA-53 (MAICO Diagnostics, Germany) equipped with HDA200 headphone (Braunschweig, Germany) was used to estimate the air conduction pure tone thresholds, speech recognition thresholds and speech identification scores and B-71 bone vibrator (Radioear, KIMMETRICS, mithbergs, MD 21783) were used to assess bone conduction thresholds. GrasonStadler Inc. Tympstar system (GSI VAISYS Healthcare, Wisconsin, USA) was used to measure tympanogram and acoustic reflexes. A calibrated otoacoustic emission system, ILO v6 (Otodynamics Ltd., Hatfield, UK) was used to assess OAEs. Working memory assessment was done using Smriti-Shravan software (Kumar & Sandeep, 2013). Temporal processing skills were evaluated using psychoacoustic tool box (Grassi & Soranzo, 2014) implemented in Matlab. Speech perception in noise assessment was done using PC/ laptop connected to HDA200 circumaural headphones. Headphones were calibrated to produce 65 dB SPL output in a KEMAR ear simulator.

3.4 Test Environment

Pure tone audiometry and TEOAE testing were carried out in an acoustically treated and electrically shielded room where the noise levels were within the permissible limits (ANSI S3.1; 1999). All the other experiments were carried out in a quiet room with good illumination, ventilation and minimal visual distraction.

3.5 Stimuli and procedure

3.5.1 Audiological evaluations

Pure tone audiometry: Pure tone audiometry was done from 250 Hz to 8000 Hz in all octave frequencies for air conduction thresholds and from 250 Hz to 4000 Hz for bone conduction thresholds using modified Hughson and Westlake principle (Carhart & Jerger, 1959). A calibrated two channel MA53 diagnostic audiometer was used to track the thresholds.

Tympanometry: The test was carried out with a probe tone frequency of 226 Hz at 85 dBSPL by varying the air pressure in the ear Canal from +200 dapa to -400 dapa. Ipsilateral and contralateral acoustics reflex thresholds were measured for 500 Hz and 1000.

3.5.2 Gap detection thresholds

The test was done through psychoacoustics toolbox implemented in MATLAB (Grassi & Soranzo, 2014).A three interval three alternate forced choice method was used to estimate the minimum gap that the participant can find. Three blocks of broadband noises, with 500 ms duration, were presented binaurally at 65 dBSPL. Of the three two blocks had the standard noise of 500 ms and one block with a gap in the centre of the noise. Participants were asked to find the block which contained the gap. The duration of gap was varied from 20 ms to 0.1 ms.The order and presentation of standard and target stimuli was randomised. The duration of the gap was varied in 5, 2 and 1ms step after each reversals following simple up-down procedure. Average of final 6 reversals was considered for the calculation of gap detection thresholds.

3.5.3 Modulation detection thresholds

Modulation detection thresholds were estimated using simple up-down procedure using psychoacoustic tool box implemented in Matlab(Grassi & Soranzo, 2014). In this, the minimum amplitude modulation necessary to identify amplitude modulated noise from un-modulated white noise was assessed. The testing was done at 65 dBSPL binaurally. A 500 ms broadband noise was sinusoidally amplitude modulated at 8 Hz, 16 Hz, 64 Hz and 128 Hz modulation frequencies. On each trial of three blocks, two blocks had standard unmodulated stimuli and one had sinusoidally amplitude modulated target stimuli. The participants were instructed to identify the modulation and determine which block had the modulated noise. A three interval three alternate forced choice method was used to estimate the minimum modulation depth the participant can find. The order and presentation of standard and target stimuli was randomised. The modulation depth was varied in simple up-down method. Final 6 reversals were taken for the estimation of modulation detection threshold.

3.5.4 Speech perception in noise

The signal to noise ratio (SNR) required for obtaining 50% correct identification of the words in a sentence was measured (SNR-50). FourKannada sentence list developed by Geetha, Pavan and Kumar in the year 2012 was used as target stimulus which has 10 sentences in each list with 4 keywords in each sentence. Eight talker babble taken form Quick SIN Kannada (Avinash, Methi, & Kumar, 2010) was used as competing stimuli. Stimuli were presented at 65 dB SPL. SNR was varied in 2 dB steps from +8 dB SNR to -10 dB SNR sequentially from first to last sentences of the list. The participants were instructed to verbally repeat the target sentences. Score of one was given to each correctly identified key word. The number of correct key words recognized at each SNR was counted. The SNR-50 was calculated using the Spearman-Karber equation as:

$$\text{SNR-50} = I + \tfrac{1}{2}(d) - (d)(\#\text{ correct})/(w)$$

where:

I = the initial presentation level (dB S/B);

d = the attenuation step size (decrement);

w = the number of key words per decrement;

correct = total number of correct key words.

3.5.6Working memory experiments

All the tasks for assessing working memory were carried out using Smriti-Shravan V1.0 software (Kumar & Sandeep, 2013). Presentation of the stimuli and collection of the responses were done adaptively.

Auditory digit span: The digit span test is divided into forward and backward digit span. Here, numbers were presented as clusters in random order and participants had to memorize them in sequence. Presentation of stimuli and collection of responses were done using Smriti-Shravan software. Participants were instructed to click on the numbers in the same order for forward span and in reverse order for backward span. Length of the sequence was increased each time the participant gave correct response and reduced for incorrect responses. Working memory capacity can be calculated as the total number of digits that the person can correctly recall in digit span test. Practice trials were given before string with the actual testing. A total of 6 reversals were presented where first two reversals were discarded and final 4 reversals were taken for the estimation of digit span.

***Operation span**:* Here, participant's ability to remember the target stimuli which was interleaved with a secondary processing task was evaluated. The primary task was to remember the target words in the same sequence and the secondary processing task was to verify the mathematical problem. Each set of stimuli consists of a mathematical operation followed by a word to be remembered [e.g., (10+8)*1=18, true or false? Followed by Kannada bisyllabic word] were the target words. The secondary processing task, i.e., the mathematical operation to be verified had either multiplication or division for the first mathematical operation within the parenthesis. Practice trials were given prior to the testing. Out of total 6 trials, last 4 trials were taken for estimation of scores. Partial credit scores weighted (i.e. each item is scored as a proportion of correctly recalled elements with giving higher weightage is given to the item with higher load) was taken for scoring.

Reading span task: In the reading span task, each part consists of a sentence followed by a target word. Primary task was to memorize the target words in sequence. Secondary task was to verify the statement (e.g., /I:dinabha:rata band iddudarinda namma vidhjalaja teredithu/, true or false? Followed by Kannada bisyllabic words) were the targets were the words and the statement was the distractor. The participant was asked to read the sentence and choose true or false and then memorize the words in sequence. Scoring was done considering partial credit scores (i.e. each item is scored as a proportion of correctly recalled elements with giving higher weightage to the item with higher load).

3.6 Statistical Analyses

The data obtained from the study was subjected to statistical analyses using the Statistical Package for the Social Sciences (IBM SPSS 20.0) software package. Descriptive statistics was carried out to determine the mean, median, range and standard deviation for all the parameters. Assumptions of parametric statistics were established through Shapiro-Wilk test of normality. Independent sample t test was carried out to compare the gap detection threshold, temporal modulation transfer function, forward digit span, backward digit span, operation span, reading span and SNR-50 between normal hearing and noise exposure group. Repeated measures ANOVA was done to analyze the effect of noise exposure on within subject and between subject effects of modulation frequency in TMTF.

CHAPTER 4

RESULTS

The present study aimed at assessing the temporal processing, working memory and speech perception skills in individuals exposed to industrial noise but having normal hearing sensitivity. The study also compared the same skills with that of individuals with normal hearing sensitivity who are not exposed to industrial noise. For this purpose, gap detection thresholds, temporal modulation transfer functions, auditory digit spans (forward and backward), operation span, reading span and speech perception in noise was assessed. The statistical analyses were done using IBM SPSS 20.0 software package. Normal distribution of the data was ensured through Shapiro-Wilk normality test. As the data was normally distributed parametric tests were used for further analyses.

The results of above mentioned tests are mentioned under the following headlines

1. Gap detection thresholds
2. Temporal modulation transfer functions
3. Forward digit span
4. Backward digit span
5. Operation span
6. Reading span
7. Speech perception in noise

4.1 Gap detection thresholds

Table 4.1 and Figure 4.1 show the mean and one standard deviation of the GDT across two groups (NH and NE). Independent samples t-test was carried out to check the significance of difference between NH and NE groups. Results showed that individuals in NH group had significantly better gap detection thresholds compared to individuals in NE group, t (28) =-3.465, p<0.01.Furthermore, from the Figure and Table it can inferred that variance was more in the NE group as evidenced by larger SD compared to NH group

Table 4.1

Mean, median, range and standard deviation for GDT (in ms) across NH and NE group

	Mean	Median	Range	Std. deviation
NH group	0.97	1	0.5 – 1.33	0.21
NE group	2.15	2	1.17 – 6.50	1.3

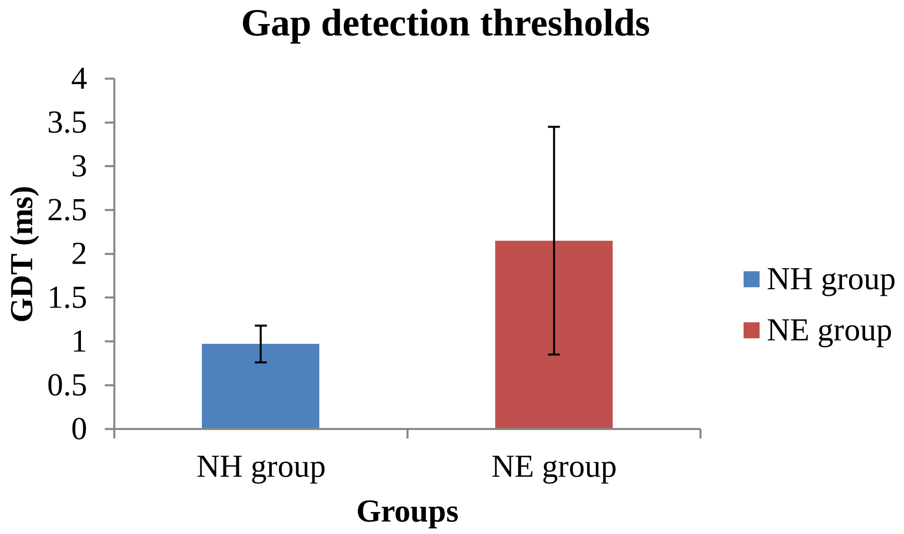

Figure 4.1: Gap detection thresholds for normal hearing and noise exposure group. The x-axis represents groups and y-axis represents gap detection thresholds in ms.

4.2 Temporal modulation transfer functions

Table 4.2 and figure 4.2 shows the mean and one standard deviation of the modulation detection thresholds in two groups (NH and NE). From the Table and Figure it can be seen that individuals in NH group had better modulation detection thresholds compared to NE group. Repeated measures ANOVA revealed a significant (within subject) main effect of the modulation frequency [F (3, 84) = 7.63, $p<0.001$, $\eta_p^2=0.214$], and significant (between subject) main effect of group [F (1, 28) = 505.32, $p<0.001$, $\eta_p^2= 0.947$]. However, there was no significant interaction between modulation frequency and group. Independent t-tests were carried out for each of the frequencies to check the significance of differences in the modulation frequency between the two groups. Results indicated that there were no significant differences in the modulation detection thresholds between the two groups for all modulation frequencies except 128 Hz [$p<0.05$, corrected for multiple comparisons using FDR correction, Benjamini&Yekutieli (2001)].

Table 4.2

Mean median, range and standard deviation of modulation detection threshold (in dB) for NH and NE group.

		Mean	Median	Range	Std. deviation
8 Hz	NH group	-38.04	-40.25	-50.00 to -21.81	9.2
	NE group	-35.77	-36	-47.75 to -27.25	6.06
16 Hz	NH group	-30.14	-32	-44.50 to -05.17	10.28
	NE group	-21	-28.25	-46.25 to 31.25	22.38
64 Hz	NH group	-35.65	-36.25	-55.50 to -14.00	10.56
	NE group	-28.45	-30	-45.25 to -09.00	9.77
128 Hz	NH group	-31.33	-33.5	-38.25 to -13.00	6.99
	NE group	-23.48	-22.5	-36.50 to -14.00	7.99

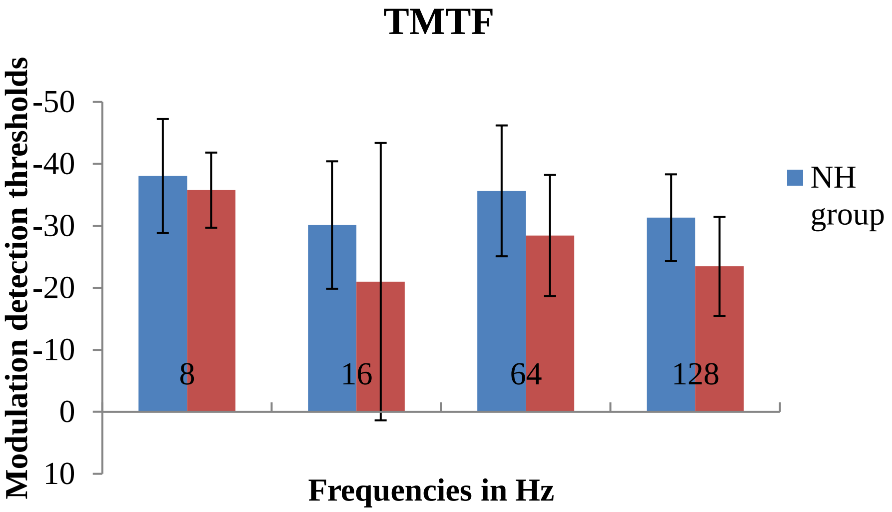

Figure 4.2: TMTF across 8 Hz, 16 Hz, 64 Hz and 128 Hz for NH and NE group.

4.3 Forward digit span

Table 4.3 and figure 4.3 represents mean and one standard deviation of forward digit span scores across NH and NE group. Independent sample t-test was carried out to assess the significance of difference in the forward digit span scores between two groups. Results revealed NH group performed significantly better than the NE group, [t (28) = 3.079, p= 0.005].

Table 4.3

Mean, median, range and standard deviation for forward digit span for NH and NE group

	Mean	Median	Range	Std. deviation
NH group	4.91	5	3 - 7.75	1.25
NE group	3.61	3.75	0.75 - 5	1.05

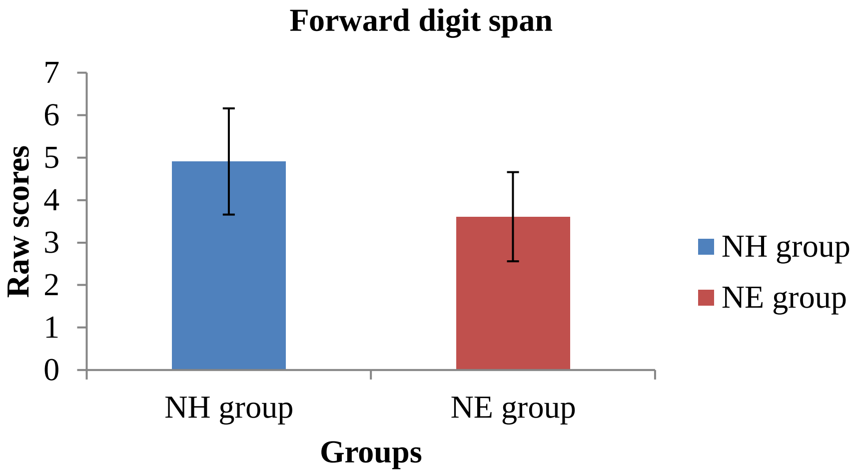

Figure 4.3: Mean scores for forward digit span in NH (normal hearing) and NE (noise exposure) groups. The horizontal axis represents groups and vertical axis represents raw scores for forwards digit span.

4.4 Backward digit span

Table 4.4 and Figure 4.4 depict the mean and one standard deviation of backward digit span scores in NH and NE group. To check the significance of difference in performance between the groups independent samples t-test was done. Results revealed no significant difference between NH group and NE group, [t (28) = 1.845, p= 0.076].

Table 4.4

Mean, median, range and standard deviation for backward digit span for NH and NE group

	Mean	Median	Range	Std. deviation
NH group	3.85	3.5	2 – 6.75	1.41
NE group	3.05	325	0.0 – 6.75	0.9

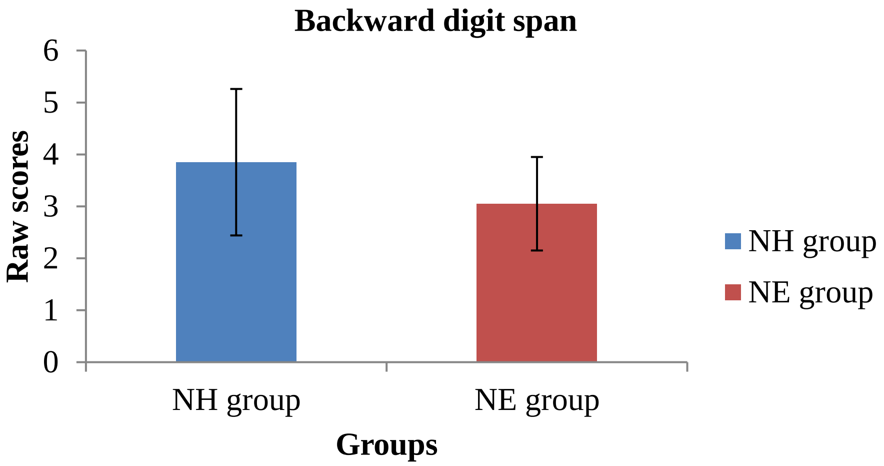

Figure 4.4: Mean scores for backward digit span for NH and NE groups. The x-axis represents both normal hearing and noise exposure groups and the y-axis represents raw scores for backward digit span.

4.5 Operation span

Table 4.5 and figure 4.5 illustrate the mean and standard deviations of partial credit scores across NH and NE group. Independent sample t-test revealed that NH group performed significantly better than NE group[t (28) = 3.179, p= 0.004].

Table 4.5

Mean, median, range and standard deviation for PCSW scores for operation span between NH and noise exposure group

	Mean	Median	Range	Std. deviation
NH group	0.63	0.68	0.25 – 0.91	0.17
NE group	0.40	0.46	0.09 – 0.64	0.25

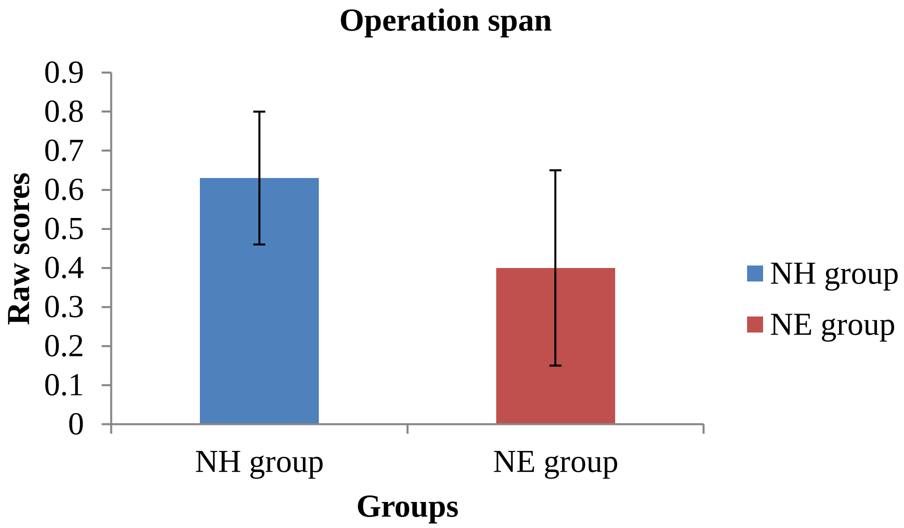

Figure 4.5: Mean scores for operation span in normal hearing group and noise exposure group. Normal hearing (NH) and noise exposure (NE) groups are represented along x-axis and operation span scores represented along y-axis.

4.6 Reading span

Table 4.6 and Figure 4.6 show means and standard deviations for partial credit scores weighted for normal hearing and noise exposure groups. From the Figure 4.6 and Table 6, it can be inferred that reading span scores of NH group is better compared to NE group. Independent samples t test revealed that NH group had significantly better scores compared to NE group [t (28) = 2.488 with p= 0.019].

Table 4.6

Mean, median, range and standard deviation for PCSW scores for reading span between NH and noise exposure group

	Mean	Median	Range	Std. deviation
NH group	0.63	0.68	0.11 - 1	0.17
NE group	0.40	0.46	0.11 – 0.78	0.25

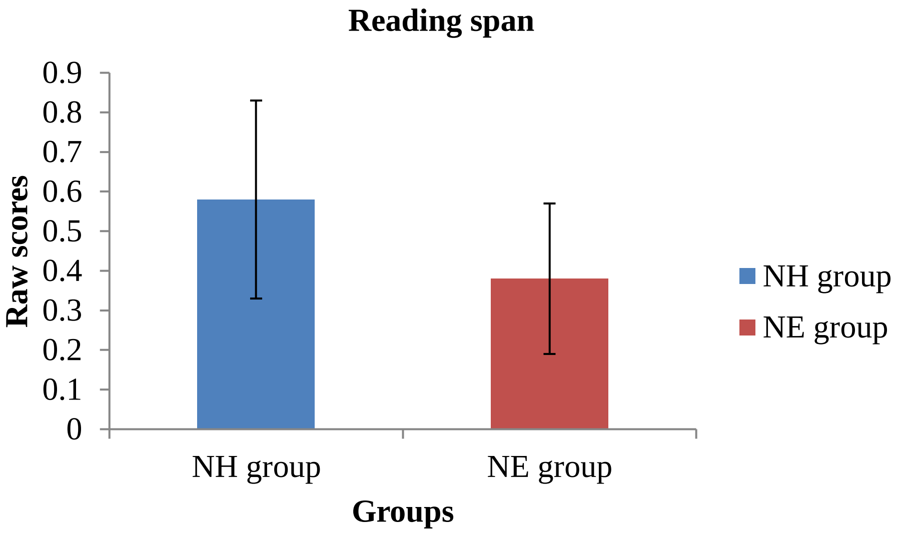

Figure 4.6: Mean and standard deviation of reading span scores between two groups. Groups are represented in x-axis and raw scores are represented in y-axis.

4.7 Speech perception in noise

Table 4.7 and Figure 4.7 depict means and one standard deviation of SNR-50 values in NH and NE groups. An independent sample t test was done to determine the significance of differences in the mean SNR-50 scores between two groups. Results showed that SNR-50 was significantly better in the NH group compared to NE [t (28) = -9.727, p= 0.001].

Table 4.7

Mean, median, range and standard deviation of SNR-50 scores for NH and NE group

	Mean	Median	Range	Std. deviation
NH group	-7.72	-7.75	-8.5 - -7	0.41
NE group	-5.21	-5.87	-6.88 – 6.38	3.24

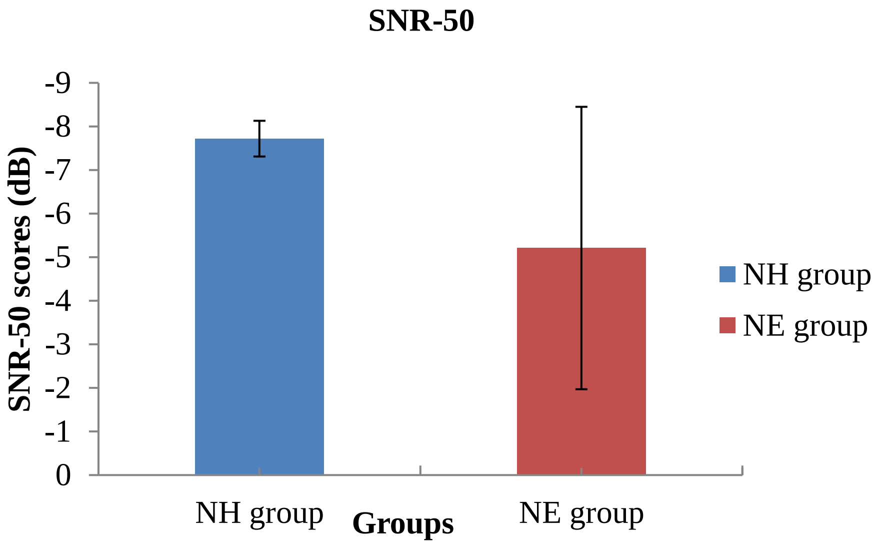

Figure 4.7: Mean SNR-50 scores for NH and NE group with standard deviation. The x-axis represents groups (NH and NE) and y-axis represents SNR-50 scores.

CHAPTER 5

DISCUSSION

Main aim of the current study was to investigate the effect of industrial noise exposure on temporal processing, working memory and speech perception skills in persons working in industrial set ups. Individuals exposed to industrial noise more than 80 dBA with hearing thresholds within 25 dB HL in all octaves from 250 Hz to 8 kHz participated in the study. Gap detection thresholds and temporal modulation transfer functions were determined for assessing temporal processing skills. Gap detection thresholds were significantly elevated in individuals exposed to industrial noise compared to non-noise exposure control group. Modulation detection thresholds were elevated in the noise exposure group only at high modulation frequencies.

Previous studies, both on animals and humans have shown adverse effects of nose on temporal processing skills even in the presence of normal audiometric thresholds. The effect of noise exposure on temporal resolution was estimated in rats by measuring the behavioural gap detection threshold (GDT) by Rybalko and Syka (2005). GDT values showed an increase in thresholds for experimental group which says the noise exposure cause adverse effect on temporal resolutions. Results of gap detection thresholds in the occupational noise exposure and control groups across different age groups demonstrated a significance poorer performance for experimental group (Cohen et al., 1980; Kumar et al., 2012) which is in line with the findings in the current study.

An interesting observation of the current study is that NE group had significantly poorer modulation detection thresholds compared to NH group only at high modulation frequency. Similar results are reported by(Kumar et al., 2012). They Studied gap detection in noise, temporal modulation transfer function at 8, 20, 60 and 100 Hz and speech perception in noise for control and on train drivers who are exposed to noise but having normal hearing sensitivity. Their results revealed that gap detection thresholds did not reveal any significant difference between both the groups. Modulation detection thresholds were impaired for experimental group at high frequencies. The result of the present study is also in consensus with this.

In a study done by Stone and Moore in 2014, Gaussian noise modulation detection thresholds were assessed and the experimental group performed poorly than controls. This pattern was attributed to IHC dysfunction in the experimental group, which would have led to a noisier neural functioning of the signal envelope.Clark et al. (2006) compared cognition abilities in school going children in the age range of 9 to 10 years were taken from different schools that are exposed to aircraft noise. Several working memory tasks like information recall, conceptual recall, recognition and reading comprehension were assessed. The authors concluded that increased aircraft noise exposure at school set ups are significantly related with poor reading comprehension. Animal studies have suggested that noise exposure initially leads to neuropathy mainly for neurons with low spontaneous rates and medium to high thresholds. This leads to the prediction that perceptual deficits should be apparent at medium to high presentation levels (Kujawa & Liberman, 2009; Liberman & Liberman, 2015).

A contradictory results were reported by Vinay and Moore (2010) where they stated sinusoidal amplitude detection were significantly better for the experimental group (individuals using personal music players, i.e. PMPs). A possible reason for the discrepancy is that use of PMPs generally results in lower exposure levels. It may be the case that moderate exposure levels cause mainly OHC dysfunction, leading to improved AM detection, while higher exposure levels lead to IHC dysfunction in addition, leading to poorer AM detection.

Auditory digit span (forward and backward span) task, operation span and reading span tasks were carried out to assess the working memory. NE grouphad significantly poorer working memory compared to non-noise exposure control group. This proves that the noise exposure has adverse effects on working memory abilities. Gomes et al. (1999) determined prolonged occupational exposure to large pressure amplitude and low frequency (LPALF) noise leads to cognitive deterioration. Results indicated that there was deterioration in memory but not in attention as a result of long-term exposure to LPALF. Prolonged noise exposure has a negative effect on reading comprehension and more selective cognitive impairments in school going children. Clark et al. (2006b) studied exposure of aircraft noise on physiological, motivational and cognitive on children. School going children in the age range of 9 to 10 years were selected for the study. Experimental group were children attending elementary schools located near an airport. Peak sound levels in these schools were >95dBA. Children from three quiet schools were taken as control group. Reading comprehension, recognition, information recall and conceptual recall were measured. The experimental group performed poorly when compared with controls and that concludes prolonged noise exposure has a negative effect on reading comprehension in school going children. Haines et al.(2001) investigated if cognitive impairment and stress are attributable to aircraft noise exposure. Control group from the schools where less aircraft noise (16h, <57 dBA) and experimental group where high exposure of aircraft noise (16h, >63 dBA) were selected for the study. Health and cognitive performance were assessed and compared. Results showed impaired reading on difficult stimulus, raised annoyance and household deprivation was significantly higher for experimental group. And they chronic noise exposure is associated with raised noise annoyance in children.

The adverse effects of noise on speech discrimination and recognition was proven in studies conducted earlier (Elliott et al., 1979; Finitzo-Hieber & Tillman, 1978). The adverse relationship between chronic noises with reading is partially attributable to deficits in language acquisition. Children chronically exposed to noise also suffer from impaired speech perception, which, in turn mediates the noise exposure reading deficit link (Evans & Maxwell, 1997).The reduced neuronal activation seen in hidden hearing loss has been explained as a result in degradation of the temporal coding of suprathreshold sounds and deficits in speech discrimination and intelligibility, particularly in a noisy environment. Persons with this type of hearing loss may have difficulties in speech discrimination and temporal processing, particularly in a noisy environment (Wan & Corfas, 2017).

Recent works suggests that hair cells synapses between hair cells and cochlear nerve terminals are most vulnerable elements in the inner ear. It is that degenerate first in the aging or noise exposed ear. This primary neural degeneration does not affect hearing thresholds, but likely contributes to problems understanding speech in difficult listening environments (Liberman, Epstein, Cleveland, Wang, & Maison, 2016).

Based on all the findings mentioned above, the observed deterioration in the temporal processing, working memory and speech processing skills in the noise exposed individuals, with normal hearing sensitivity is probably due to changes in the central auditory system distortions caused due to prolonged exposure to occupational noise.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Higher level of industrial noise has adverse effects on auditory system. This study aimed at investigating temporal processing, working memory and speech perception in noise in individuals with normal hearing exposed to noise. 15 adult males in the age range of 25 to 40 years exposed to industrial noise participated in the study. Age and gender matched 15 normal hearing adults who are not exposed to industrial noise served as contraol group. All the participants had puretone thresholds within 25 dBHL, ‘A’ type tympanogram and normal acoustic reflexes at 500 and 1000 Hz. Participants in both the groups had clinically normal otoacoustic emissions.

Temporal processing was determined by assessing gap detection thresholds (GDT) and modulation detection thresholds. Speech perception in noise was assessed by measuring the SNR-50 using Kannada sentences. Working memory was assessed by measuring auditory digit forward and backward, reading span and operation span tasks. 500 ms broadband noise with a gap in the centre was used as the stimuli for GDT. Each trial had 3 blocks. Participants were instructed to find the block which contains the gap. 500 ms broadband noise was sinusoidally amplitude modulated at 8 Hz, 16 Hz, 64 Hz and 128 Hz modulation frequencies and minimum amplitude modulation necessary to identify amplitude modulated noise from standard un-modulated white noise was assessed. The testing was done using psychoacoustic toolbox implemented in Matlab(Grassi & Soranzo, 2014). Participants were instructed to click on the numbers heard in the same order for FDS and in reverse order for

BDS from a pool of numbers displayed. Operation span was done by asking the individual to solve a mathematical equation followed by a target word, and to memorise and click on those words heard in the same sequence. Reading span was done similarly, instead of equation a sentence was displayed and followed by words. All the working memory tasks were carried out using Smriti-Shravan software (Kumar & Sandeep, 2013). The participants were asked to repeat the sentences heard in speech in noise test where SNR in each sentences were varying in 2dB step.

Results revealed that normal hearing (NH) group performed significantly better than noise exposure group (NE) in gap detection and modulation detection. Performance of NE group was significantly poorer than NH group on forward span, reading span and operation span tasks. NE group had significantly poorer SNR-50 compared to NH group. These findings suggest that noise exposure can result in supra threshold auditory and working memory deficits even before audiometric thresholds are affected.

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