THE RELATIONSHIP BETWEEN SOME ASPECTS OF TEMPORAL PROCESSING AND SPEECH IN NOISE SCORES IN OLDER ADULTS WITH NORMAL HEARING

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17AUD035

This Dissertation is submitted as a part-fulfilment

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University of Mysore, Mysore

All India Institute of Speech and Hearing

Manasagangothri Mysore – 570006

May 2019

CERTIFICATE

This is to certify that this dissertation entitled **‘The relationship between some aspects of temporal processing and speech in noise in older adults with normal hearing’**is the bonafide work submitted in part fulfilment for the Degree of Master of Science (Audiology) of the student with Registration No: **17AUD035**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **‘The relationship between some aspects of temporal processing and speech in noise in older adults with normal hearing’**is bonafide work submitted as a part for the fulfilment for the degree of Masters of Science (Audiology) of the student with Registration No: **17ADU035**. This 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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May, 2019

DECLARATION

This is to certify that this Master's dissertation entitled **'The relationship between some aspects of temporal processing and speech in noise in older adults with normal hearing'** is the result of my own study under the guidance of Dr. Animesh Barman, Professor in 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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Dedicated to my Almighty, my pillars,
my inspiration, my support system

My MAA, PAPA and DIDI

For All Your Love and Blessings

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Abstract

The major important part of everyday communication is speech. Elderly persons experience problems in understanding speech, especially in adverse conditions like in presence of noise or reverberation. To perceive speech in noise effectively, several auditory skills like temporal processing come into play to extract the key features in the input. The utilization of the temporal processing skill is highly variable in older individuals with normal hearing sensitivity, and may lead to variations in the perception of speech in noise. The present study was taken up to explore these variations in temporal resolution ability and the use of these features and abilities for predicting speech perception in noise. The study consisted of 60 ears of 30 native Kannada speaking adults in the age range of 50-70 years, divided into two groups 50-60 years and 60-70 years. They were assessed on their temporal resolution skills using behavioural measure of across channel gap detection test and electrophysiological measure of ABR at different intensities of 80 and 50 dB nHL for repetition rates of 11.1 and 90.1/s. Speech perception in noise was assessed at 0 and -5 dB SNR. The results of the study showed that wave V latency related parameters were the most sensitive to manipulation of repetition rate and intensity. Repetition rate effects were larger at lower intensity and intensity effects were larger at higher repetition rate, suggesting that ABRs to clicks at higher repetition rates could be more sensitive by using a lower intensity. There was a negative correlation between across channelgap detection test and speech perception in noise scores, with the magnitude of the correlation increasing with the decrease in the SNR. There was also a negative correlation between speech in noise scores and interpeak latency of wave I-V as well as duration of wave V in the high intensity- high repetition rate condition. A positive correlation was obtained between speech in noise scores and wave I latency shift at a lower repetition rate. Interpeak latencies between waves I-III was the most sensitive to age related group differences in the study. The results suggest that certain parameters of ABR could be useful in understanding how aging affects speech perception in noise and temporal processing.

Key words: Temporal processing, across channel gap detection test, ABR, speech perception in noise, Normal hearing individuals.

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Chapter I

Introduction

The major important part of everyday communication is speech. It is characterised by spectral components that are rapidly changing in terms of spectral and temporal characteristics. The spectral component and temporal characteristicsadd to the redundancy of speech and are important for perception of speech.

Temporal envelope that changes in amplitude and frequency of sound overtime perceived by humans. It is the slow modulations associated with the syllabic and phonetic content in speech, which, are more important for speech perception rather spectral content (Drullman, 1995; Shannon, Zeng, Kamath, Wygonski&Ekelid, 1995). The temporal modulations of the target speech reduces as the noise fills in the peaks and troughs of the temporal waveform of the speech signal (Drullman, 1995), hence making perception in noise more difficult. In noisy environment, precise temporal processing is essential for listening well (Snell &Frisina, 2000; Gor´don-Salant& Fitzgibbons, 1993;Dubno, Dirks & Morgan, 1984). A general decline in the speed of behaviour is one of the most ubiquitous and significant characteristics of mature organisms (Birren& Fisher, 1995). Other than humans, other mammals also show age-related slowing (Salthouse, 1982) and it is reported to be mediated primarily by the central nervous system rather than peripheral factors (Salthouse, 1991).

Elderly persons experience problems in understanding speech, especially when confronted with adverse listening conditions such as background noise and everyday sound-reverberating environments (CHABA, 1988). Older adults with normal hearing perform poorly on behavioural tasks (Modulation detection, Envelope-Interaural time difference discrimination, Envelope-following responses, binaural masked detection and tone lateralization at suprathreshold levels, which require accurate temporal cueing

(Ruggles, Bharadwaj & Shinn-Cunningham, 2012; Grose &Mamo, 2010; Strelcyk&Dau, 2009). This could be due to the reduction in the number of auditory nerve fibres, with rapid decline in the synapses and the auditory nerve terminal, and slower degeneration of the cell bodies as function of aging (Sergenyenko,Lall, Liberman &Kujawa, 2013). However, a few study reported that there was no change in auditory thresholds even when large portions of the nerves were sacrificed (Lobarinas, Salvi & Ding, 2013; Schuknecht &Woellner, 1955).

The temporal perception ability of the auditory system degrades with age, irrespective of preserved hearing(Ruggles et. al., 2012; Fitzgibbons & Gordon-Salant, 2010; Snell, Mapes, Hickman &Frisina, 2002; Snell &Frisina, 2000). As, temporal coding plays a major role in the perception of speech and any deficit in temporal coding would lead to communication difficulties in noise (Bharadwaj et. al., 2015). Also, the low spontaneous rate fibres are important for listening in noise (Costalupes, Young & Gibson, 1984) these are more vulnerable to aging (Schmiedt, Mills & Boettcher, 1996).

The most common way of investigating temporal resolution is by means of gap detection, which offers insight in the auditory perception (Philips, 1999) and would also help to understand the speech perception ability of individuals (Makashay, Theodoroff& Leek, 2013; Papakonstantinou, Strelcyk&Dau,2011; Helfer& Vargo, 2009; Summers, Philips & Smith, 2004).

Gap detection threshold is the shortest interval of silence a listener can detect (Gelfand, 2009). This test requires the listener to identify the just noticeable interruption in otherwise a continuous stimulus. Conventionally, the listener is presented with a pair of stimuli out of which one has a gap. The smallest gap the listener is able to identify is considered the gap detection threshold (GDT). The stimulus with gap is the test stimulus and the other forms the standard stimulus.

Gap detection threshold can be obtained using two paradigms of gap detection threshold which is within channel GDT and across channel GDT. The WC GDT requires activation of neurons within in a single neural channel. Whereas, comparison of the timing of the neural activity with respect to the offset in one neuronal channel and onset in a completely different neuronal channel happens in AC GDT (Formby, Gerber, Sherlock &Magder, 1998; Grose, Hall, Buss & Hatch, 2001). Hence, it is thought that within channel GDT (WC GDT) is easier than across channel GDT (AC GDT). It is also reported that across channel GDT has a better relationship with speech perception in noise than within channel GDT because of the physiology involved (Elangovan& Stuart, 2008; Walker, Brown, Scarff, Watson, Muir & Phillips, 2011). However, the AC GDT is affected by various extraneous variables like attention, interest, procedural differences and understanding of the procedures etc.

Physiological tests which are less affected by extraneous variables could be an alternate test/s which can be used to assess temporal processing in any age group population, as they do not require individual active participation. Auditory Brainstem Response (ABR) is an onset response, occurring within the first 10-15ms of the stimulus presentation can be used an objective tool to assess temporal process. ABR is a highly sensitive tool to measure the integrity of the auditory system till the auditory brainstem, due to its replicability and temporal precision. The responses depend directly on the temporal synchronization of the activity of the neurons within an anatomical region (Jacobson, 1985). The morphology of the waves are dependent on the temporal course of the generation and the transmission of the neuronal activity and also the synchrony of the underlying activity related electrical potential.

Mehraei et al. (2016) showed that those who have difficulty in understanding speech in noise had an increase in the latency of wave V in noise. Also, reduction in amplitude of wave I of ABR at suprathreshold levels (>70 dBnHL), but no apparent change in the wave V amplitude among individuals with noise exposure, with normal hearing (Stamper & Johnson, 2015). There is an increase in the latency of the peaks with the increase in the repetition rate in normal hearing individuals (Burkard & Sims, 2001; Burkard &Hecox, 1983, 1987). Additionally, there is a variability in individual abilities of auditory function (Kidd, Watson &Gygi, 2007) and a large variation specifically in the temporal coding (Ruggles, Bharadwaj & Shinn-Cunningham, 2011; Bharadwaj et al., 2015). Hence, its impact needs to be assessed.

Need for the Study

In daily life, speech communication often takes place in a noisy environment. Most common complaint, of older individuals, even from person with good hearing sensitivity, is that they experience more difficulty in understanding speech in the noisy situations, (Working Group on Speech Understanding and Aging, 1988). Age-related deterioration in any of peripheral, central and/or cognitive processes could lead to this decreased capacity of understanding. The frequency and temporal-resolving power of the ear are the two abilities which are most likely to affect speech understanding in noise. There are reports of reduction in the number of auditory nerve fibres, with rapid decline in the synapses and the auditory nerve terminal, and slower degeneration of the cell bodies as function of aging (Sergenyenko,Lall, Liberman &Kujawa, 2013). Degeneration of neural structure at the different level of auditory system likely to affect temporal processingsignificantly. Thus, this all highlights the necessity to assess the normal variation in temporal processing and its relationship with the speech perception ability in elderly population especially in noise.

In the present study, Auditory Brainstem Responses (ABR) along with across channel Gap Detection Test (GDT) was carried out to assess the temporal resolution. A listener resolves naturally occurring brief dips in the intensity of interfering noise i.e. temporal resolution is one of the way which aids in speech understanding. Gap detection is one of the most commonly used and well-studied test to obtain temporal resolution. Assessing temporal acuity skills across auditory channels would certainly be beneficial in exploring temporal resolution skills in older individuals with normal hearing sensitivity (Gordon-Salant& Fitzgibbons, 1999; Fitzgibbons & Gordan-Salant, 1994; Salthouse, 1985). So, AC GDT was taken to assess temporal resolution in the current study.

ABR is preferred, because, it is easy to administer, and not influenced by subjective factors like attention, state of arousal etc., so preferred as tool for assessing temporal resolution abilities. It is a highly sensitive tool to measure the integrity of the auditory brainstem, due to its replicability and temporal precision. The responses depend directly on the temporal synchronization of the activity of the neurons within an anatomical region (Jacobson, 1985).

In the current study it was also aimed to assess the temporal coding abilities and check for a correlation with the speech perception in noise. If a good correlation and comparison is seen, then ABR can be used as an objective measure to assess the temporal processing in individuals with normal hearing and help in predicting their speech perception ability. This can be further used to check the temporal processing in toddlers and predict the development of speech perception ability in them.

Earlier studies show a strong correlation between temporal processing and speech perception abilities in normal hearing elderly individuals (Summers et al. 2012; Walker et al. 2011; Helfer& Vargo, 2009; Gordon-Salant&Fitzgibbons, 1993). In Indian scenario no studies were conducted comparing across channel temporal acuity skills and ABR parameters with speech perception skills.

Furthermore, if a good correlation is found between AC GDT and SPIN scores and also ABR parameters and SPIN scores then ABR can be used as an alternate tool to predict speech perception ability in all the population as it does not require active participation of subjects.

Aim of the Study

To see the relationship between the temporal processing ability using ABR and across channel GDT and speech perception in noise in older adults with normal hearing.

Objectives of the Study

1. To know the variation of temporal coding in older adults with normal hearing sensitivity.
2. To compare the GDT scores, SPIN at different SNRs and different temporal parameters of ABR at different repetition rates and different intensity levels between the subgroups.
3. To find out the relationship between SPIN at different SNRs and GDT scores in older adults (within group).
4. To find the relationship between SPIN at different SNRs and different temporal parameters of ABR at different repetition rates in older adults (within group).
5. To find the relationship between SPIN at different SNRs and different temporal parameters of ABR at different intensity levels in older adults (within group).

Chapter II

Review of Literature

Communication in everyday situation involves listening in adverse conditions like in presence of noise or reverberation. A reduced ability to understand speech in adverse condition like background noise, or reverberating rooms is a typical complaint of older adults even when they have ‘normal hearing sensitivity’. There is need to evaluated the reasons and the mechanisms underlying for such difficulty. The problem occurs at which level, that is, peripheral, cochlear, neural or central is not defined.

Several auditory processes for involved for extracting auditory input to understand speech perception in noise. These processes are highly variable across individuals (Kidd, Watson &Gygi, 2007). One such auditory process is temporal processing and it gives information regarding the coding of the time related changes in the auditory input. Thus, precise temporal processing is essential for listening well, especially in noisy environments (Snell &Frisina, 2000; Gor´don-Salant& Fitzgibbons, 1993; Dubno, Dirks & Morgan, 1984).

In older individuals temporal processing deteriorate as age increases (Lister et al, 2002). There is loss of cochlear nerve fibres and low spontaneous rate fibres due to aging (Sergeyenko et al. 2013). There is also deficits in neural coding of temporal fine structure (Clinard& Cotter, 2015 andClinard& Tremblay, 2013) and speech envelop (Gossens et al. 2016 and Tlumak et al. 2015). Reduction in the number of auditory nerve fibres, with rapid decline in the synapses and the auditory nerve terminal, and slower degeneration of the cell bodies as function of aging (Sergenyenko,Lall, Liberman &Kujawa, 2013). However, a few studies reported that there was no change in auditory thresholds even when large portions of the nerves were sacrificed (Lobarinas, Salvi & Ding, 2013; Schuknecht &Woellner, 1955).

In this study, temporal processing is assessed behaviourally using gap detection test and neural coding through auditory brainstem response and its correlation is seen with the scores of speech perception in noise. Information has been gathered from literature and has been discussed below.

2.1 Assessing temporal processing abilities using Gap Detection Test (GDT)

Gap detection test assesses the temporal resolving power of the auditory system, i.e., the ability to follow rapid changes over time. It is defined as the shortest time over which the ear can discriminate two signals (Gelfand & Gelfand, 2004). Temporal resolution is important for speech perception in noise (Dubno, Horwitz, & Ahlstrom, 2003; Oxenham& Bacon, 2003; Peters, Moore, & Baer, 1998).

GDT is known to have been affected by different stimulus parameters, like, stimulus bandwidth (Snell, Ison&Frisina, 1994; Eddins, Hall & Grose, 1992), stimulus duration (He, Horwitz, Dubo& Mills, 1999; Schneider &Hamstra, 1999), monotic, diotic, or dichotic presentation modes (Lister & Roberts, 2005; He et al., 1999, Gordon-Salant& Fitzgibbons, 1999), and the spectral similarity of the stimuli before and after the gap (Lister, Besing&Koehnke, 2002; Oxenham, 2000). Temporal acuity skills can be assessed across channels condition using narrow band noise (NBN AC) of different centre frequencies before (lead marker) and after (lag marker) the silence period. NBN is more flexible than BBN. Within channel GDT (GDT WC) is easier than across channel GDT (Lister & Roberts, 2005; Grose et al., 2001), as WC GDT requires activation of neurons within in a single neural channel, whereas, AC GDT requires comparison of the timing of the neural activity with respect to the offset in one neuronal channel and onset in a completely different neuronal channel (Grose et al, 2001; Formby et al., 1998). So, the AC and WC gaps are served by different temporal processing mechanisms. Thus, AC GDT gives information of specific frequency regions as well as greater control of audibility.

Hess, Blumsack, Ross and Brock (2012) evaluated WC and AC GDT across intensities using the ATTR software. The study was done on 50 subjects with normal hearing sensitivity, with the stimulus as NBN, centered at 1000 Hz and 2000 Hz. The results showed that, for both conditions, GDT decreased with increasing stimulus intensity, and large improvement was not seen for stimulus intensities above 20 dB SL. It was also observed that the variability was larger in the NBN-AC condition. This finding was accounted by reasons similar to the explanation given by Lister et al. (2011).

In a study by Lister and Roberts (2005), GDTs for fixed-frequency (WC GDT) and frequency-disparate markers (AC GDT) were measured for 3 groups of listeners: young with normal hearing sensitivity (YNH), older with normal hearing sensitivity (ONH), and older with sensorineural hearing loss (OIH). They found largest GDTs for frequency-disparate markers. Also, they found larger GDTs for ONH and OIH than YNH. They explained listener age and hearing loss influences temporal resolution for frequency-disparate condition that inturn is important for the resolution of timing cues in speech.

Phillips and Smith (2004) studied on the correlation between the WC and AC GDT. The study was done on 95 subjects with normal hearing sensitivity, and the stimulus used was NBN centered at 1000 Hz and 4000 Hz, and for AC GDT, the leading marker was 4000 Hz and the trailing marker was 1000 Hz. Results showed that the gap detection thresholds were lower for the WC GDT than AC GDT. It was also seen that the thresholds were highly correlated between the two WC GDT (1000 Hz and 4000 Hz), and the thresholds were weakly correlated between the AC and WC GDT, that is, AC gap detection thresholds cannot be predicted by the WC gap detection thresholds and vice versa, suggesting different mechanism and pathways for AC and WC GDT. The mechanism underlying this phenomenon is similar to the explanation given by Lister et al. (2011).

Lister, Besing and Koehnke (2002) measured temporal discrimination using gap discrimination paradigm for three groups of individuals with normal hearing i.e. ⩽25 dB HL from 250 to 6000 Hz and dB⩽30 dB HL at 8000 Hz. Silent gaps were placed between 1/4-octave bands of noise centered at one of six frequencies. The center frequency of the leading marker was fixed at 2000 Hz, and the center frequency of the trailing marker varied randomly, so that pairing of noise band markers is done. Gap duration discrimination was significantly poorer for older listeners compared to other groups. The more frequency-disparate stimuli (2000-Hz leading marker followed by a 500-Hz trailing marker) give more age differences than for the fixed-frequency stimuli (2000-Hz lead and 2000-Hz trail). The gap duration difference limens of the older listeners increased more rapidly with frequency disparity than those of the other listeners suggesting temporal mechanisms deteriorate with age and stimulus complexity.

2.2 Speech Perception in Noise (SPIN)

Perception of speech in the presence of noise is considered a multi-step process, including sensory processing and then matching utterances which are present in the signal to their correct phonological, lexical and semantic representations (Lecumberri, Cooke & Cutler, 2010; Norris & McQueen, 2008 McClelland & Elman, 1986). Speech perception in noise testing is affected by several parameters such as signal-to-noise ratio

(Bradlow& Alexander, 2007; Van Engen &Bradlow, 2007; Rogers et al., 2006), type of masker that is present (Lecumberri et al., 2010), attentional allocation (Cooke, 2006). Also, the presentation level of the signal and the masker, hearing loss, age and so on.

Wong, Ettlinger, Sheppard, Gunasekera and Dhar (2010) studied the neuroanatomical characteristics and speech perception in noise in older adults. They took 14 younger and 15 older right-handed native speakers of American English who had neurological deficits but better scores than normal in cognitive tests and also they had normal hearing sensitivity. QuickSIN test was done and they found younger performing better than the older individuals. They explained this by saying not only peripheral but central nervous system contributes to perceive speech in noise. The declination in the volume and cortical thickness of the prefrontal cortex during aging is a factor for decreased score in older individuals. They found that a larger prefrontal cortex volume may compensate for declining peripheral hearing.

Shojaei, Ashayeri, Jafari, Dast and Kamali (2016) studied effect of signal to noise ratio on the speech perception ability of older adults. There were 25 elderly individuals with normal hearing thresholds in both ears for the study and SPIN scores were obtained at three SNRs in presence of ipsilateral white noise. Results revealed by decreasing signal level and increasing competing noise i.e. different SNRs reduces the speech perception ability among elderly individuals. Also for maintaining normal speech perception in challenging situations elderly people requires compensatory strategies.

Masked speech perception across the adult lifespan: Impact of age and hearing impairment was studied by Goossens, Vercammen, Wouters and Wieringen (2017). They performed open-set sentence identification in 3 groups of 6 participants each: younger (20-30 years), middle-aged (50-60 years) and older-cohort (70-80 years), having normal audiometric thresholds uptoatleast 4 kHz and elevated thresholds. Stationary and amplitude modulated speech-weighted noise was taken as energetic maskers with informational masking by unintelligible speech. The results revealed even with normal hearing thresholds, masked speech perception declines by middle-aged and further more on to older adults. It is mediated because of deficiencies in temporal masking and central executive functions.

Due to increase in speech perception deteriorates in quiet as well as noise. The poor speech perception scores is because of auditory system dysfunction in the brainstem or auditory cortex independent of a peripheral sensitivity loss (Gordon-Salant& Fitzgibbons, 1993; Humes& Christopherson, 1991). There also could be loss of cochlear nerve fibres and low spontaneous rate fibres due to aging (Sergeyenko et al.2013). Temporal envelope rather than spectral information is important to perceive speech in quiet (Drullman, 1995; Shannon et al. 1995). There is decrease in depth of temporal modulation of the envelope of speech with increase in noise leads to poorer speech perception. Also, with the increase in the intensity of the masker, ‘listening in dips’ becomes more difficult and SPIN scores reduce further (Cooke, 2006).

2.3 Auditory Brainstem Response (ABR)

Auditory Brainstem Response (ABR) is a non-invasive tool which represents the neural electrophysiological activity at the level of brainstem. The responses obtained are affected by several stimulus related factors like the intensity, repetition rate, polarity, type of stimulus and subject related factors like age, gender, head size and so on. The review of literature has found an effect of intensity and repetition rate on ABR. These are two stimulus parameters considered in the present study to assess the temporal processing using ABR.

In a study by Martini, Comacchio and Magnavita (1991) ABR was elicited using clicks of rarefraction polarity with 21.1/s rate at 75 dB nHL on 36 elderly individuals with normal hearing sensitivity. They were divided in two groups i.e. group I (58 to 65 years) and group II (66 to 76 years). The ABR latencies increased with increase in age and there was statistically significant shift indicating peripheral mechanism producing a partial delay and desynchronization of normal discharge.

Costa, Benna, Bianco, Ferrero and Bergamasco (1991) recorded ABR with unfiltered clicks with alternating polarity using TDH 39 headphones. They investigated the age effects in 154 (72 males and 82 females) normal hearing subjects. They found age related prolongation of wave I more pronounced than other waves. The IPL values do not increase with increasing age. This indicated the central part of the acoustic pathway is less, or late, involved in aging.

Allison, Wood and Goff (1983) obtained ABR in 286 normal hearing subjects in the age range of 4 to 95 years. Peak latencies of all components significantly increase in latency with age. Interpeak latencies showed significant differences in relation to age.

Jerger and Hall (1980) measured ABR in 182 male and 137 female subjects having normal hearing sensitivity for only 98 subjects. There was slight effect on latency and amplitude of wave V from 25 to 55 years, the latency increased about 0.2ms and amplitude of wave V decreased about 10%.

Beagley and Sheldrake (1978) elicited ABR to clicks at 60 dB, 70 dB and 80 dB from a group of 70 normally hearing subjects. They also varied the repetition rate. From second to eighth decade participants were divided having 10 subjects in each decade. The age range was 14 to 79 years. The results revealed increased latencies and reduced amplitudes with increase in age. As there was slower rate (10/s) it gave clearer responses than rapid rates. The reason they gave for these findings were lack of synchrony and increased tissue impedance.

Rowe (1978) studied the variability in auditory brainstem responses in 25 young adults in the age range of 17-33 years and 25 older adults in the age range of 51-74 years. The click stimulus was delivered at the repetition rates of 10/sec and 30/sec at intensity of 60 dB nHL and 30/sec at 30 dB nHL. The responses were studied across different intensities and stimulation rates. It was seen that there was high intra and inter subject variability. It was noted that waves I, III and V were constant and replicable. It was observed that the peak latencies increased with increase in stimulation rate and decrease in intensity. Interpeak latencies were unaffected by intensity changes. Wave I-III increases with increase in stimulus rate and increase in age while wave III-V is not affected by any change in parameters or age. This was justified due to dysynchrony of neurons as the stimulation rate increases. The author has also concluded that wave amplitude alone is not a reliable measure of normality.

2.4 Speech Perception in Noise and Temporal Resolution

In a study by Vermeire et al. (2015) temporal resolution was assessed using GIN test and LIST test was used to investigate sentence understanding in noise. There were 21 young and 33 older normal hearing adults. Results revealed significantly worse temporal resolution and poor sentences understanding in older adults than younger. Temporal resolution correlates with hearing, not age, while speech understanding correlates more with age than hearing. The reported that with advancing age, both temporal resolution and speech understanding in noise significantly deteriorates.

Walker et al. (2011) explored the temporal processing abilities using within channel and across channel gap detection test, sequential and overlapping temporal order judgements tests and its relationship with reading performance in 38 children with LD in the age range of 11-14 years and 38 age matched typically developing children. Phonological Awareness Quotient Subtest, the reading subtest of the Wide-Ranging Achievement Test-3, and short versions of the Olson Phonological and Olson Orthographic subtests were used to assess the language and reading skills of the participants. The results revealed significant correlation between temporal tasks of across channel gap detection test, overlapping order judgements test and reading performance.

Helfer and Vargo (2009) measured the temporal processing using gap in noise (GIN) test and speech understanding abilities in the presence of steady state noise and competing speech, with and without perceived spatial separation of the target speech and masker. They took 12 younger and middle-aged females each with normal hearing sensitivity. The results showed that the speech understanding ability in the presence of a spatially coincident spatial masker of the middle-aged women was poorer than the young women. This was strongly correlated with the scores of the GIN test, and not to the pure tone thresholds. The authors have suggested a strong relationship between temporal processing and speech perception abilities, especially in competing speech situations.

Strelcyk and Dau (2009) assessed frequency selectivity, temporal fine-structure (TFS) processing, and speech reception among 6 normal hearing (NH) listeners, 10 sensorineural hearing-impaired (HI) listener with similar high-frequency losses and 2 listeners with obscure dysfunction (OD). Binaural masked detection, tone lateralization, and monaural frequency modulation detection was done to see TFS processing at low frequency regions of normal hearing. Lateralization and FM detection thresholds were measured in quiet and in background noise. Speech reception thresholds were obtained for full-spectrum and low pass-filtered sentences with different interferers. Frequency selectivity, TFS processing, and speech reception were performed poorly by both the HI and the OD listeners than NH. TFS-processing performance was correlated with speech reception in a two-talker background and lateralized noise, but not in amplitude-modulated noise. The results provide constraints for future models of impaired auditory signal processing.

Elangovan and Stuart (2008) checked for the relationship between voice onset time (VOT) of consonants and gap detection thresholds (GDT) in 18 native English-speaking adults with normal hearing sensitivity. Gap detection threshold were obtained for within channel and across channel gap detection tests. To measure VOT, the stimulus used was a continuum from /ba/ to /pa/. Results exhibited differences in the GDT obtained from the two test paradigms, and the VOT phonetic boundary had a significant positive correlation with the across channel GDT and not for within channel GDT.

Snell and Frisina (2000) found a relationship between gap threshold and spondee-to-babble noise thresholds in older subjects. They found no correlation between spondee-in-babble thresholds and gap detection thresholds in older adults while it was present in younger adults. They stated age-related changes in temporal acuity may begin long before age-related changes in word recognition.

2.5 Speech Perception in Noise and Auditory Brainstem Response

Speech perception degrades in the presence of noise, and this has been attributed to the reduction of the neural synchrony in noise (Russo et al., 2004; Burkard and Sims, 2002 and Halls, 1992). Most of the studies have explored the correlation between SPIN and frequency following response for a speech stimulus in quiet and in presence of noise.

Study by Bramhall, Ong, Ko and Parker (2015) measures speech perception in quiet using NU-6word lists and in background noise using QuickSIN. ABR was elicited using 4000 Hz tone burst, at 80 dB nHL for a repetition rate of 13.3/sec, on young adults with PTA within 45 dB HL. They found reduced ABR wave I amplitudes are related to increased age, also with decreased speech-in-noise performance, but not correlated to speech perception in quiet.

Lipson (2012) studied the relationship between speech perception in noise with R-spaced noise and speech evoked ABR in quiet and in pink noise at +10 dB SNR. The speech evoked ABR was elicited in mono and binaural conditions. The results showed with poor speech perception in noise, the sustained spectral portion of the $F_o$was affected. They have concluded that there is a link between poor SPIN and encoding of fundamental and low frequencies of speech, especially due to the phase locking capacities of the neurons at the level of brainstem.

A study by Papakonstantinou, Strelcyk and Dau (2011) investigated temporal processing behaviorally by means of psychoacoustical frequency discrimination, binaural masked detection and amplitude modulation (AM) detection and objectively by auditory brainstem responses (ABRs) to clicks and broadband rising chirps to see their relation to the ability of speech understanding in noise by determining SRTs for Danish sentences in speech shaped noise. They found that chirp evoked ABR had correlation between wave V thresholds, sentence recognition in noise and temporal resolution measures. Hence, they concluded that temporal resolution abilities measured through behavioral and electrophysiological tests can predict the ability for perception of speech in noise.

King, Warrier, Hayes and Kraus (2002) recorded ABR to both click and formant transition portion of speech syllable /da/, in normal (NL) children and children diagnosed with a learning problem (LP). There were no latency differences between both groups for click but it was present for syllable /da/. They found a correlation between just noticeable differences for speech and FFR, but not with click evoked ABR. They have also attributed these findings to neural synchrony and its importance in perceiving speech in adverse conditions. These authors have emphasized on the importance of neural coding with respect to time at the level of brainstem for the perception of speech in noise.

Chapter III

Methods

The current experiment was taken up to investigate the temporal processing ability using across channel gap detection test, electrophysiological test i.e. auditory evoked brainstem response and correlate the data obtained for behavioural and electrophysiological tests with speech in noise scores in older adults with normal hearing. The objective was to assess the relationship between some aspects of temporal processing using these tests.

Participants:

The study was conducted in 30 older individuals of age ranging from 50-70 years, which were further divided among 2 groups. Group I with age range of 50-60 years (mean age: 54.8 years) and group II with age range of 60-70 years (mean age: 64 years). Both the group consisted of 15 participants each. All participants were native speakers of Kannada and consisted of 16 males and 14 females. Both the ears of each participant were assessed, and all the tests were done in monaural condition.

Subject selection criteria:

All the subjects were selected based on the following criteria.

- Otoscopy observation revealed normal external ear canal and tympanic membrane with cone of light present.
- Pure tone thresholds were within 25 dBHL (ANSI S3.6-1996; WHO, 2008) in octave frequencies of 250Hz, 500Hz, 1000Hz, 2000Hz, and 4000Hz in both ears.

- Normal middle ear functioning was confirmed based on the type ‘A’ tympanogram and presence of both ipsilateral and contralateral acoustic reflexes in both ears.
- Transient evoked otoacoustic emissions were present in all the participants.
- No history of noise exposure or long duration exposure to music which was ascertained by a structured interview.
- Presence or history of neurological, otological or any associated problems at the time of assessment was ruled out.

Instrumentation:

The following instruments were used in the present study:

- For pure tone threshold estimation, speech audiometry and speech in noise scores was assessed using, a two-channel diagnostic audiometer, Inventis Piano calibrated with the transducers TDH-39P headphones and Radio ear B-71 bone vibrator.

- A calibrated middle ear analyzer, GSI-Tympstar (Grasen-Stadler Incorporation, USA) was used for tympanometry and to obtain acoustic reflex thresholds.

- ILO V-6 Clinical OAE Software (Otodynamics Ltd., UK) was used to measure and analyze TEOAEs.

- Lenovo Yoga 520 laptop loaded with Psycon V 2.18 experimental software was used to present the stimulus for across channel Gap Detection Test and the stimulus was delivered through TDH-39P headphones.

- Intelligent Hearing Systems (IHS SmartEP windows, USB v4.0) with ER-3A insert earphones was used to record the auditory brainstem responses.

Testing environment:

All the tests were conducted in an acoustically treated room. The permissible noise level of the room was as per ANSI/ASA S3.1-1999 (R2013) standards.

Procedure:

The standard diagnostic test battery was done to check for ‘normal hearing sensitivity’ in both ears of all the participants.

Basic audiological evaluation:

- A detailed case history was obtained from all the participants to ensure that they met the selection criteria of the present study. It was made sure that none of the participants were exposed to noise or music for long durations. They also had no history or presence of neurological and otological disorders at the time of assessment.
- Through modified Hughson and Westlake procedure (Carhart &Jerger, 1959), the air conduction and bone conduction pure tone thresholds were obtained. It was assessed at octave frequencies, from 250 to 8000 Hz for air conduction and 250 to 4000 Hz for bone conduction.
- Tympanometry was performed for the probe tone frequency of 226 Hz, with pressure varying from +200 daPa to -400 daPa. The ipsilateral and contralateral reflexes were obtained at pure tone frequencies of 500, 1000, 2000 and 4000 Hz.
- Transient evoked otoacoustic emissions were obtained for nonlinear click stimuli presented at around 75 dB SPL. TEOAE was considered to be present if the SNR was more than 6 dB SPL in at least three consecutive octave band frequencies,

with reproducibility greater than 50% (Wagner, Heppelmann, Vonthein& Zenner, 2008).

The tests administered to achieve the objectives of the study are given below.

Speech Perception in Noise (SPIN):

The SPIN scores were obtained using phonemically balanced words and noise developed by Manjula, Antony, Kumar and Geetha (2015). For the present study, 4 word lists were used out of 21 lists, with 25 PB words in each list.

The test was preceded with familiarization of the procedure using 15 words presented at 0 dB SNR. The test consisted of presentation of the stimuli at the most comfortable level, monoaurally at two different SNRs: -5 dB and 0 dB. Different word lists were used across SNRs for every individual and each SNR condition was randomized. The stimuli were played on a personal computer and delivered through TDH-39P headphones of a calibrated audiometer, Inventis Piano. The task was to repeat all the words perceived. Every correct response was assigned a score of ‘1’, and ‘0’ for every incorrect or no response. The maximum score of 25 could be achieved on the correct repetition of the 25 words in a list. The raw scores were recorded in the present study for the analysis.

Gap Detection Test (GDT):

The Gap Detection Threshold was estimated using an across channel paradigm which was performed in Psycon v2.18 experimental software. The software was designed to run on a personal Lenovo laptop.

The stimuli used for the across channel paradigm was two narrow band noise (NBN) with the center frequency of 1000 Hz and 2000 Hz. The 1000Hz was the lead marker, and the latter i.e. 2000Hz was the lag marker. The rise time of lead marker and fall time of lag marker was 30ms. The duration of the lead marker was 300ms and it did not change across the trials. However, the lag marker was varied from 250ms onwards so as to eliminate duration as a cue for identifying the gap. The overall stimulus duration was kept constant within trials, by varying the duration of the lag marker. The standard or the reference stimulus had a constant gap duration, whereas the test stimulus had variable gap duration. Ramping of 1ms was used prior to and post the gap. The reference stimulus had gap duration of 1ms to reduce the spectral splatter. The initial gap duration was set to 50ms and it was varied with respect to the subject's response. The standard and target blocks are presented in random order. The listener's task is to choose the target interval. If the listener selected two correct intervals in a row, the gap duration was decreased. If the listener selected the incorrect answer once, the gap duration was increased.

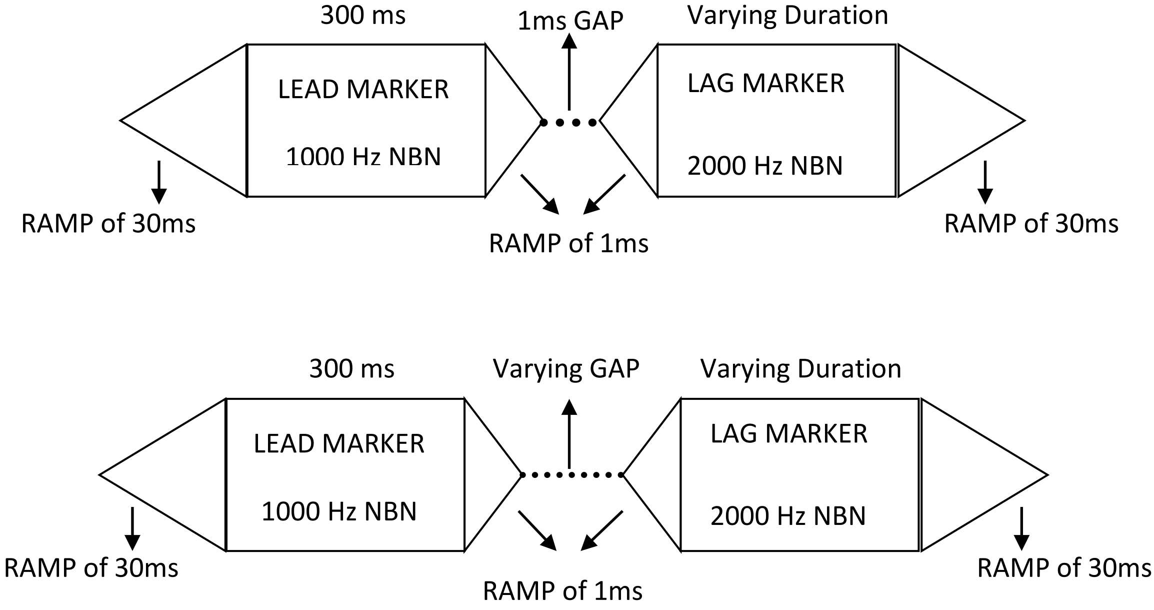

Figure 3.1 Schematic representation of the stimulus used for testing.

This is the common, two-down, one-up stepping rule, which gives the hit rate of 70.7% (Levitt, 1971). The step sizes were 7ms and 2ms above and near the threshold respectively. The GDT was assessed for both the ears, independently for every participant at most comfortable level.

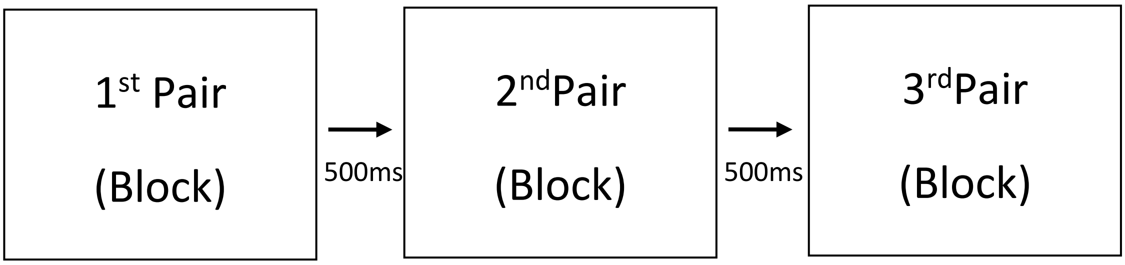

Figure 3.2 Response screen with the three alternatives.

For each condition, an adaptive three interval, three-alternative, forced-choice psychophysical paradigm was used. The participants were presented with three blocks of stimuli with a time interval of 500ms between them. Randomization of placement of the block having gap among 3 blocks of stimuli was done. The listeners were seated in a quiet room facing the laptop wearing earphones connected to the laptop. They were instructed to select the interval having different gapamong all three. The next trial began after 1000ms interval, following the response. The test was terminated after 6 reversals. The gap detection threshold was calculated by obtaining the mean of the gap size of the last six reversals. The same procedure was administered thrice for each ear, and the across channel GDT value considered was the best GDT value among the last two trials. GDT values for each ear were noted for the analysis.

Auditory Brainstem Response (ABR):

A single channel click evoked ABR was recorded at two intensities of 80 and 50 dB nHL and two repetition rates of 11.1/s and 90.1/s. Each condition had 1500 sweeps, which was replicated. The recording was done with the negative electrode at the test ear mastoid, positive electrode at the vertex position and the ground electrode at the opposite ear mastoid. The ABR was measured for both the ears independently, in every participant. The protocol used to record ABR is given below:

Table 3.1

Parameters used to record ABR

STIMULUS PARAMETER	SPECIFICATION	ACQUISITION PARAMETER	SPECIFICATION
Transducer	Insert earphone (ER-3A)	Electrode sites	Non-inverting-Vertex Inverting-Mastoid of the test ear Ground-Mastoid of the opposite ear
Type of Stimulus	Click	Filter settings	100 - 3000 Hz Notch – None
Duration of stimulus	0.1 ms	Analysis time	15 ms
Stimulus Intensity	80 and 50 dB nHL	Number of sweeps	1500
Repetition rate	11.1 and 90.1/ sec	Number of channels	One
Polarity	Rarefaction	Amplification	1,00,000

Waveform Analysis:

The waves were marked on the averaged waveform of the two responses in every condition. The waveforms were analysed by two audiologists and the experimenter. The waves were marked where two out of the three audiologists agreed upon.

The following parameters were noted and used for analysis:

- Absolute latencies obtained at 80 dB nHL and 50 dB nHL for 11.1/s and 90.1/s, respectively.
- Inter peak latencies, that is, the latency difference between wave I-III, wave III-V and wave I-V.
- The slope of the wave V, which is the amplitude from the peak to the trough divided by the peak-trough duration of wave V, were analyzed with respect to each intensity and repetition rate.
- The latency shift, with different repetition rates for waves I, III and V, at 80dBnHL was analyzed. As most individuals did not get wave I and III at 90.1/s at lower intensity, that is why 50 dB nHL was not considered.
- The latency shift, with different intensities for wave I, III and V at 11.1/s and 90.1/s
- Duration of wave V, which is the duration from end of wave III to the end of wave V was considered and analyzed.

Analysis

Gap detection threshold, SPIN scores and values of the different parameters of ABR were analysed for every individual to check for significant difference across the conditions in each of the three tests. Correlational analysis was carried out to explore the relationship between SPIN scores and temporal resolution tests of GDT (behavioural measure) and temporal aspects of ABR (electrophysiological measure) to arrive at the objectives of the study.

Chapter IV

Results

` The current experiment focused to understand how the temporal information is processed in the elderly individual's ears with normal functioning. Also, to see the relationship between some aspects of temporal processing with speech in noise scores. The behavioural temporal processing was obtained using across channel gap detection test and physiological temporal processing ability was assessed using auditory evoked brainstem response and correlated with speech in noise scores obtained at 0 dB and -5 dB SNRs. The data was obtained from 60 ears of 30 normal hearing older individuals. They were divided into two groups; 50-60 years (Group I) and 60-70 years (Group II) having 15 participants in each group. The analysis was carried out using Statistical Package for Social Sciences (SPSS, v20) software. Descriptive analysis was done to obtain the mean, standard deviation, median and the minimum and maximum value. Inferential statistics were used to check for statistical significance of differences and correlations and comparison between the groups.

4.1. Test of Normality

To check whether the data followed normal distribution, Shapiro-Wilks test was performed. The results showed that many measures of data were normally distributed. AC GDT values in the age group of 50-60 years were not normally distributed while it was normally distributed for the 60-70 years age group. Hence for further analysis, non-parametric tests were used for between group comparisons.

For the SPIN scores at 0 dB SNR and -5 dB SNR and the different parameters of ABR, the data was normally distributed for both the groups. Hence, for further analysis, parametric tests were used.

4.2. Descriptive Analysis

The mean, standard deviation and median was calculated for all test scores i.e. AC GDT obtained for group I (50-60 years) and group II (60-70 years) and also for SPIN scores obtained at 0 dB and -5 dB SNRs and different parameters of ABR in both the groups.

4.2.1 Across Channel Gap Detection Test

Across Channel (AC) GDT values for each ear was tabulated and descriptive analysis was carried out. The mean AC GDT values was found to be 66.66 (Standard Deviation: 35.17) for younger age group and 83.86 (Standard Deviation: 36.02) for older age group, respectively. The Q_1, median, Q_3, maximum and minimum for AC GDT values are given in following table 4.1 and these values along with the outliers are shown in the boxplot Figure 4.1.

Table 4.1

The Q_1, median, Q_3, minimum and maximum values for AC GDT for both the groups.

AC GDT values	Q_1	Median	Q_3	Minimum	Maximum
50-60 years	42.75	61.5	90.25	20	19.5
60-70years	61.12	83.5	112.25	161	168

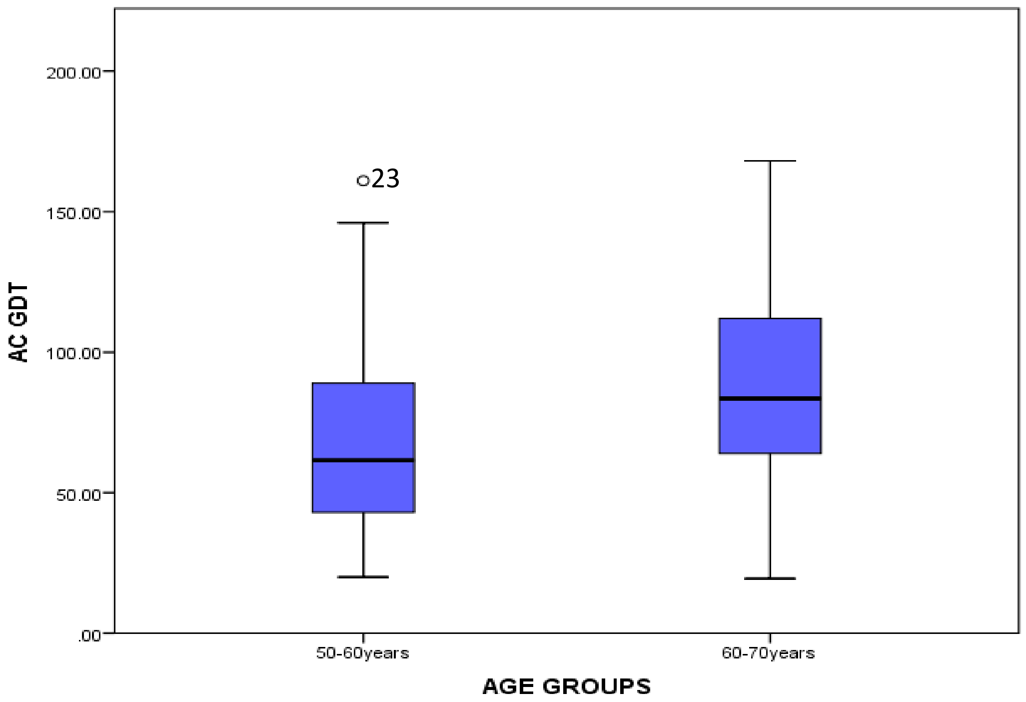

Figure 4.1 Median AC GDT values, quartile values and outlier (open circle) for both the groups.

In the given boxplot the box represents the inter-quartile range with the Q_1, medianand Q_3 values. The open circle depicts that there is one outlier in group I (50-60 years). The figure also reveals that the AC GDT scores were better for younger group compared to older group. There was large variability among the scores in both the groups.

Inferential statistics was done using Mann-Whitney test as the AC GDT data was not normally distributed, to compare the AC GDT scores across the groups. The results revealed a significant difference of AC GDT values (U= 302.5, $p<0.05$) obtained between the groups.

4.2.2 Speech perception in noise

The SPIN scores i.e. number of correctly repeated words obtained at 0 dB SNR and -5 dB SNR were tabulated and descriptive analysis was carried out for the same. The mean and standard deviation values are shown in Table 4.2 and the median and quartile values are depicted in Figure 4.2.

Table 4.2

Mean, Standard Deviation, minimum and maximum values for SPIN scores across SNRs in both groups

	Group I (50-60 years)		Group II (60-70 years)	
Test Statistics/ SNR condition	0 dB SNR	-5 dB SNR	0 dB SNR	-5 dB SNR
Mean	15.83	11.66	12.7	8.56
SD	2.65	3.19	4.24	3.41
Minimum	10	6	4	2
Maximum	20	18	20	17

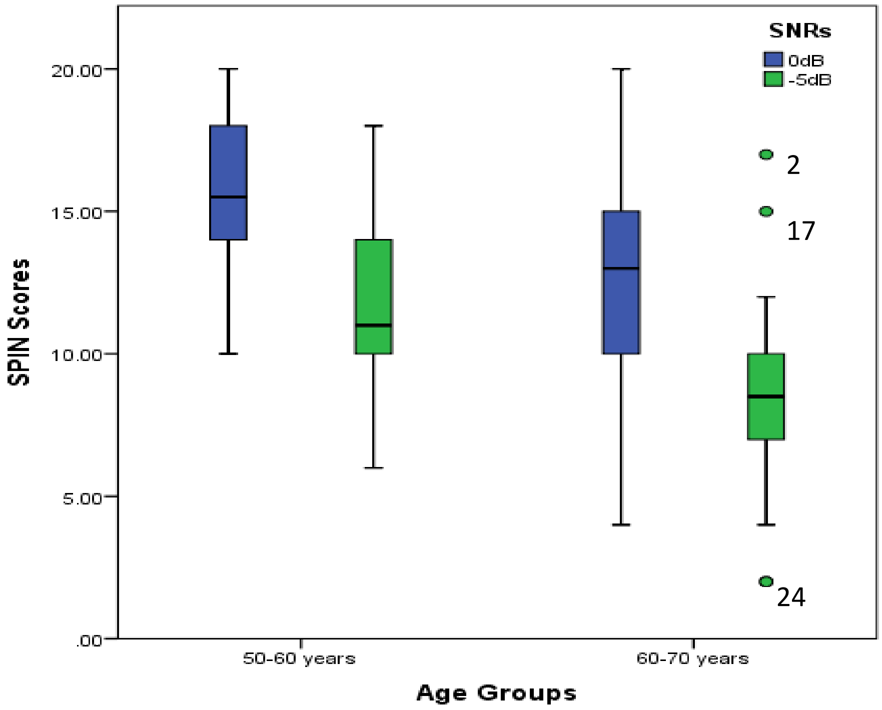

Figure 4.2. Median, quartile values and outliers (closed circles) of SPIN scores obtained at 0dB and -5dB SNR across the groups.

From the Figure 4.2, it can be observed that the median of SPIN scores at 0dB SNR and -5dB SNR for both the groups are 15.5 and 13.00 for 50-60 years and 11.00 and 8.5 for 60-70 years. It can be seen that there are 3 outliers for SPIN score obtained at -5 dB SNR in group II only, one having very low SPIN scores and two outliers having very high SPIN scores almost equivalent to 50-60 years age group at 0dB SNR. There was a trend for the mean SPIN scores to be poorer in the older age group at both SNRs. Within each age group, scores were better for the higher SNR condition.

Mixed ANOVA was done with age groups as the between subject condition and SNRs as within subject condition. It revealed a main effect of both age group [F(1, 58) = 272.883, p<0.01, ŋp^2= 0.189] and SNRs [F (1, 58)= 13.514, p<0.01, ŋp^2= 0.825], with no significant interaction effect between age groups and SNRs [F(1, 58)=0.004, p>0.05, ŋp^2=0.000]. The younger group hence had significantly better scores than the older group. Also, performance was significantly better at 0 dB SNR when compared to -5 dB SNR in both the age groups.

4.2.3 Auditory Brainstem Responses

ABR was evaluated for click stimuli. Responses were obtained at the intensities of 80 dB nHL and 50 dB nHL, and at the repetition rates of 11.1/sec and 90.1 /sec. The following parameters of ABR were analysed:

- Latency of wave I, wave III and wave V at each intensity and repetition rate.
- Inter peak latencies, that is, the latency difference between wave I-III, III-V and I-V at each intensity and repetition rate.
- The Latency shift, with different repetition rates for waves I, III and V, at 80 dB nHL. As most of the individuals did not get have wave I and III at 90.1/s repetition rate at lower intensity, that’s why 50 dB nHL was not considered.

- The Latency shift, with different intensities for waves I, III and V, at 11.1/s and 90.1/s, separately.
- Duration of wave V, which is the duration from end of wave III to the end of wave V.
- The slope of the wave V, which is the amplitude from the peak of wave V to the trough divided by the peak-trough duration, with respect to the intensity level and repetition rate.

Descriptive and inferential statistics was done for each parameter both within and across groups.

4.2.3.1 Latency of wave I, III and wave V at different repetition rates and intensities

The latency of wave I, III and wave V across the repetition rates of 11.1/s and 90.1/s at the two intensities of 80 dB nHL and 50 dB nHL was tabulated. Descriptive analysis was carried out.

Wave I

The mean absolute latency of wave I across repetition rates and intensities is given in Figure 4.3.

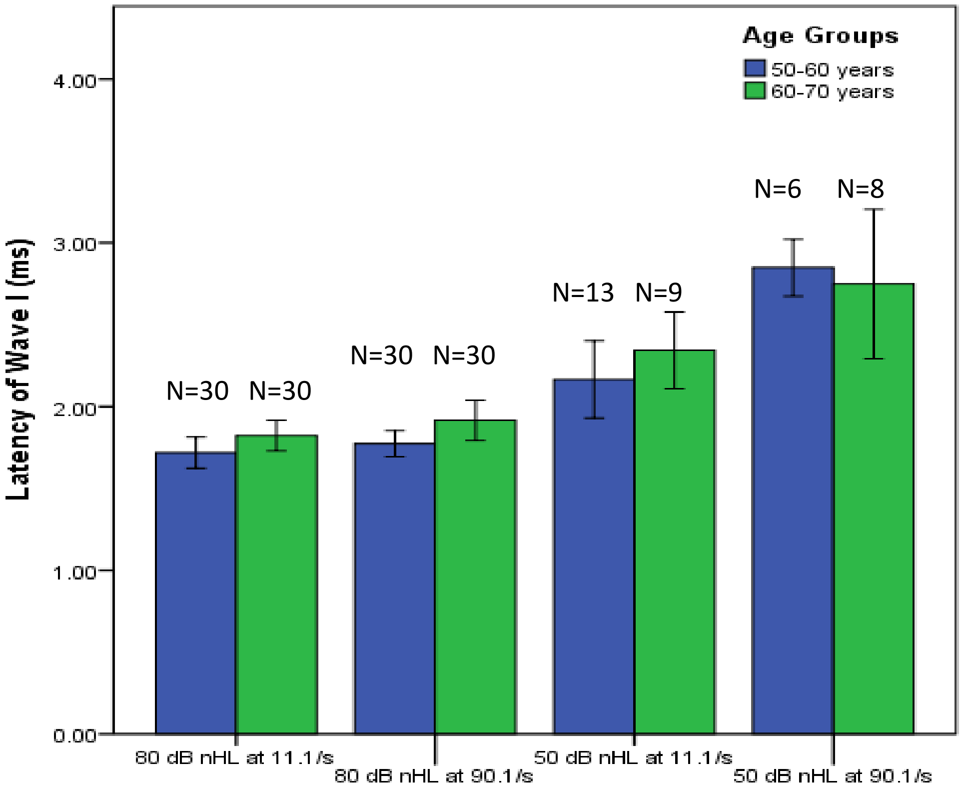

Figure 4.3. Mean latency of wave I at different intensities and repetition rates. The error bars represent two standard errors from the mean.

Figure 4.3 shows the latency shift due to repetition rate was lower for higher intensity and higher for lower intensity. The latencies were shorter at 80 dB nHL compared to 50 dB nHL and also for 11.1/s repetition rate than 90.1/s i.e. there is an increase in the latency of wave I with the increase in repetition rate and decrease in intensity. The results are similar between the groups at all conditions.

Mixed ANOVA was done with repetition rates as within subject conditions and age groups as the between subject condition. The latency of wave I at 50 dB nHL was not taken as the presence of wave I at lower intensity and higher repetition rate is very less among older individuals. The test revealed a main effect of repetition rate [F(1, 58)= 12.805, p<0.01, ŋp^2=0.751], but no main effect of groups [F(1, 58)= 0.292, p>0.05, ŋp^2=0.032]. There was no significant interaction effect between repetition rates and age group [F(1, 58)= 0.065, p>0.05, ŋp^2=0.021]

Wave III

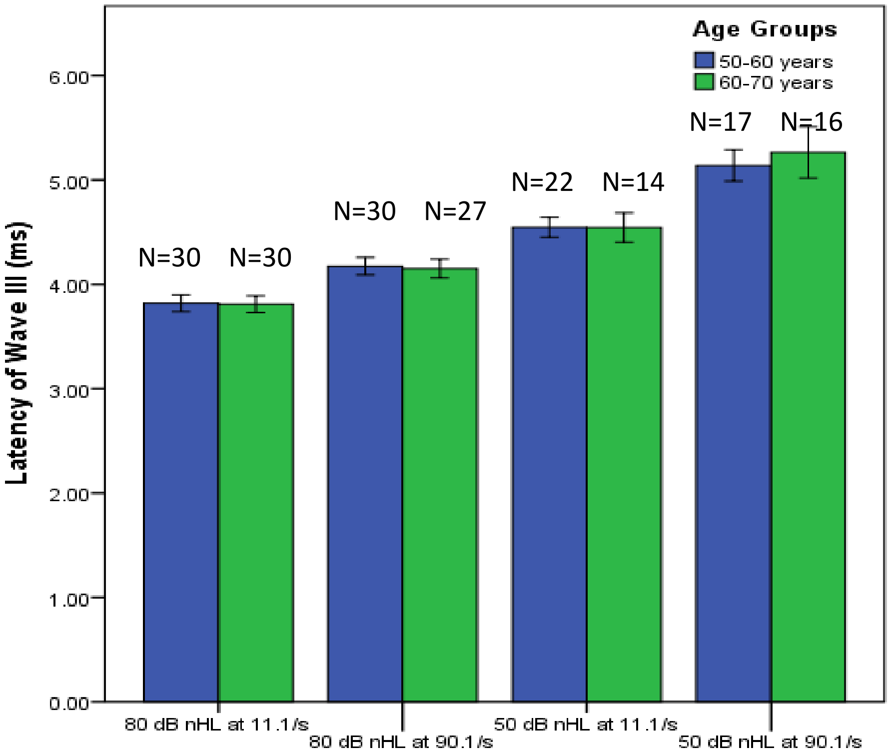

Figure 4.4. Mean latency of wave III at different intensities and repetition rates. The error bars represent two standard errors from the mean.

The figure shows that there is an increase in the latency of wave III with the increase in repetition rate and decrease in intensity. It also shows that the values are similar between the groups across the intensities (50dBnHL and 80dBnHL) and repetition rates (11.1/s and 90.1/s).

Mixed ANOVA was done with intensity level and repetition rates as within subject conditions and age groups as the between subject condition. It revealed a main effect of intensity [F(1, 23)= 359.307, p<0.01, ŋp^2=0.940] and repetition rate [F(1, 23)= 158.743, p<0.01, ŋp^2=0.873] but no main effect of groups [F(1, 23)= 0.323, p>0.05, ŋp^2=0.014]. There was a significant interaction between intensity and repetition rates[F(1, 23)= 7.883, p=0.01, ŋp^2=0.255], but no interaction of repetition rates and age group [F(1, 23)= 0.267, p>0.05, ŋp^2=0.011] and intensity and age group [F(1, 23)= 0.087, p>0.05, ŋp^2=0.004]. Also there was no interaction effect among intensity, repetition rate and age groups [F(1, 23)= 1.855, p>0.05, ŋp^2=0.075].

Because main effect of interaction between repetition rate and intensity was significant, post hoc test i.e. paired t-test was done to compare the repetition rate effects separately at 80 dB nHL and 50 dB nHL. The results revealed that repetition rate effects were significant at both intensities (80 dB nHL: t= -16.192, p<0.01; 50 dB nHL: t= -9.001, p<0.01), but greater in magnitude at 50 dB nHL (Mean difference= 0.5712) than 80 dB nHL (Mean difference= 0.3448).

Wave V:

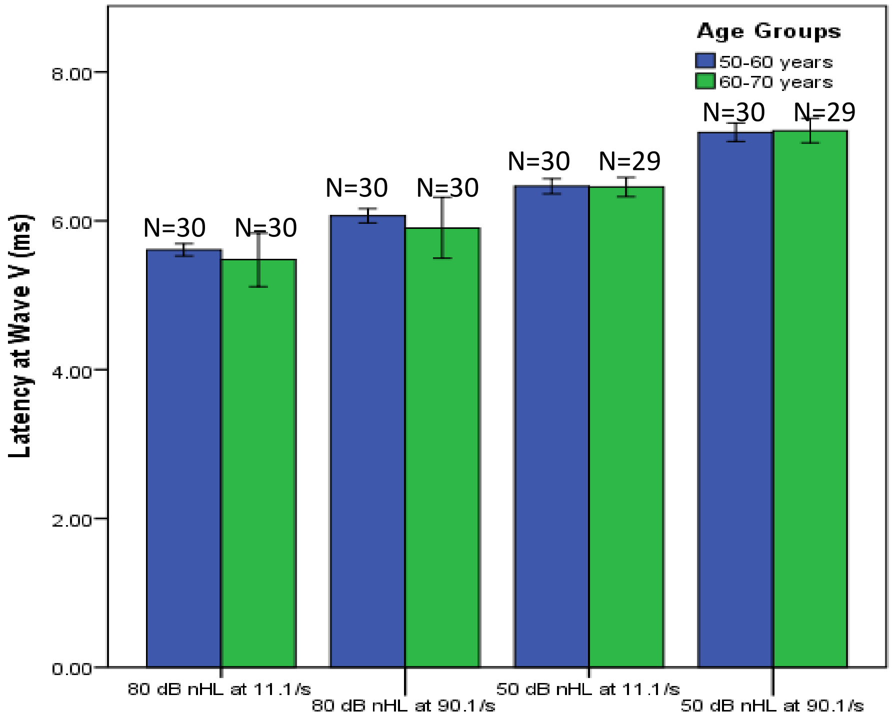

Figure 4.5. Mean latency of wave V at different intensities and repetition rates. The error bars represent two standard errors from the mean.

The figure 4.5 shows that there is an increase in the latency of wave V with the increase in repetition rate and decrease in intensity. The values are also uniform across the groups for latency of wave-V at each intensity (50dBnHL and 80dBnHL) and each repetition rate (11.1/s and 90.1/s).

Mixed ANOVA was done for intensity level and repetition rates as within subject conditions and age groups as the between subject condition. It revealed a main effect of intensity [F(1, 30)= 89.184, p<0.01, ŋp^{2}=0.935] and repetition rate [F(1, 30)= 638.393, p<0.01, ŋp^{2}=0.915], but no main effect of groups [F(1, 30)= 0.894, p>0.05, ŋp^{2}=0.002]. There was no significant interaction between intensity and repetition rates [F(1, 30)= 0.536, p>0.05, ŋp^{2}=0.443], repetition rates and age group [F(1, 30)= 0.093, p>0.05, ŋp^{2}=0.002] and intensity and age group [F(1, 30)= 0.145, p>0.05, ŋp^{2}=0.004]. Also there was no interaction effect among intensity, repetition rate and age groups [F(1, 30)= 0.459, p>0.05, ŋp^{2}=0.003].

4.2.3.2 Inter peak latencies differences

The inter-peak latency differences were calculated for waves I-III, III-V and I-V for 80 dB nHL and 50 dB nHL at 11.1/sec and 90.1/s. The mean values are shown in figure 4.6, 4.7 and 4.8, respectively.

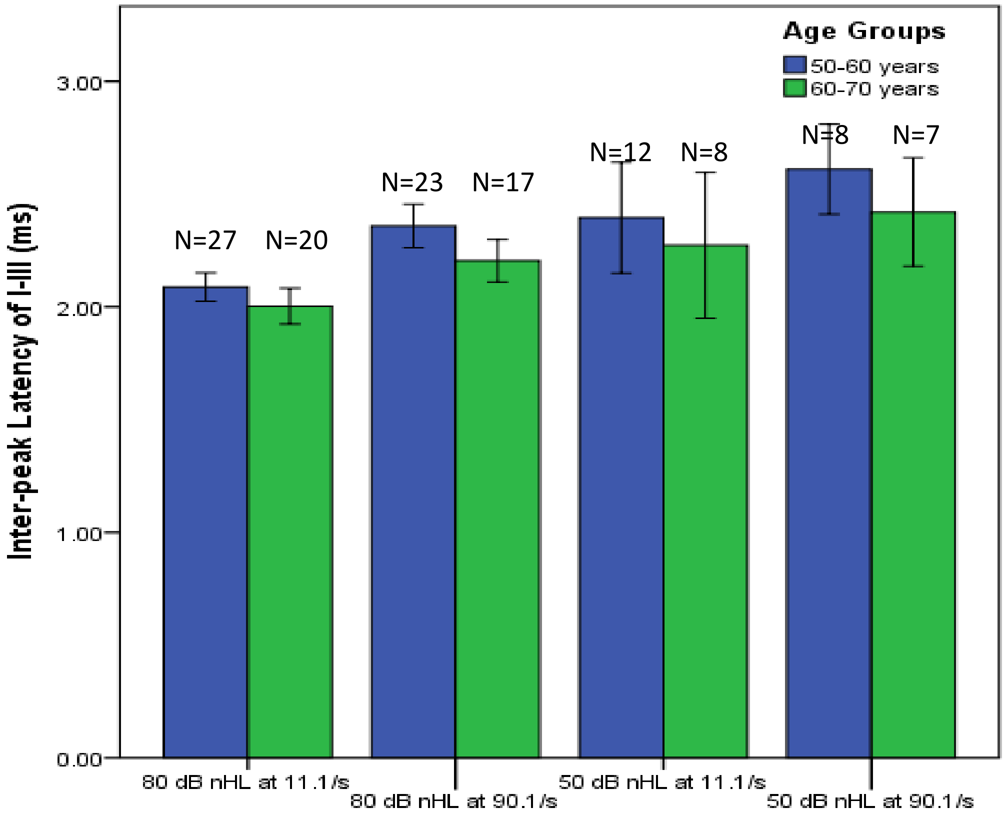

Figure 4.6. Mean inter-peak latency of wave I-III at each intensity and repetition rate. The error bars represent two standard errors from the mean.

Figure 4.6, suggests that the values for I-III IPL increases as increase in repetition rate. Also older group had larger IPLs than younger group.

Mixed ANOVA was done with repetition rates as within subject conditions and age groups as the between subject condition. Only 80 dB nHL was considered, but not 50 dB nHL since wave I and III were rarely present at 50 dB nHL. It revealed a main effect of repetition rate [F(1, 35)=78.725, p<0.01, ŋp^2=0.692] and groups [F(1, 35)= 8.483, p<0.05, ŋp^2=0.195]. This means I-III IPL increases significantly as repetition rate between the groups. There was no significant interaction between intensity and repetition rates [F(1, 35)= 0.009, p>0.05, ŋp^2=0.000].

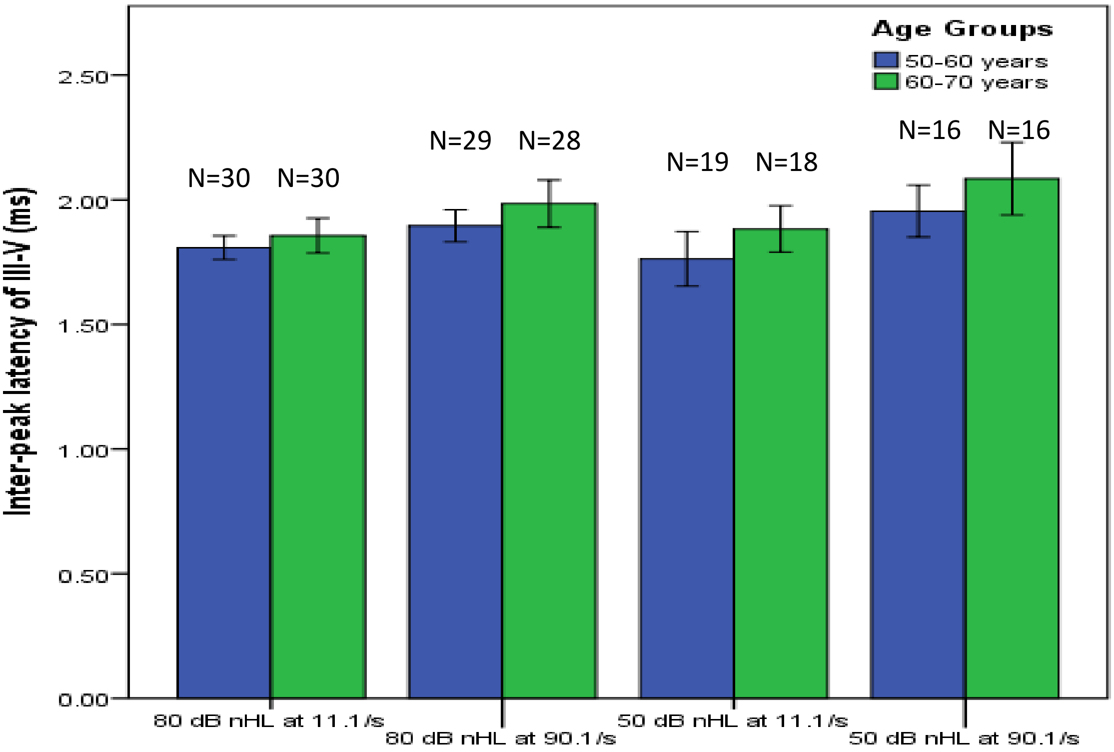

Figure 4.7. Mean inter-peak latency of wave III-V at each intensity and repetition rate. The error bars represent two standard errors from the mean.

The above figure reveals that III-V IPL values increases as repetition rate increases and intensity decreases. The IPLs were similar for both the groups at each intensity (50dBnHL and 80dBnHL) and repetition rate (11.1/s and 90.1/s).

Mixed ANOVA was done with intensity level and repetition rates as within subject conditions and age groups as the between subject condition. It revealed a main effect of repetition rate [F(1, 24)=51.370, p<0.01, ŋp^2=0.010], but no main effect of intensity [F(1, 24=0.233, p>0.05, ŋp^2=0.682] and groups [F(1, 24)=2.845, p>0.05, ŋp^2=0.106]. This means the III-V IPL increases as the repetition rate increases. There was no significant interaction between intensity and repetition rates [F(1, 24)=1.402, p>0.05, ŋp^2=0.055], repetition rates and age group [F(1, 24)= 0.315, p>0.05, 0.000] and intensity and age group [F(1, 24)=0.000, p>0.05, ŋp^2=0.013]. Also there was no interaction effect among intensity, repetition rate and age groups [F(1, 24)=0.798, p>0.05, ŋp^2=0.032].

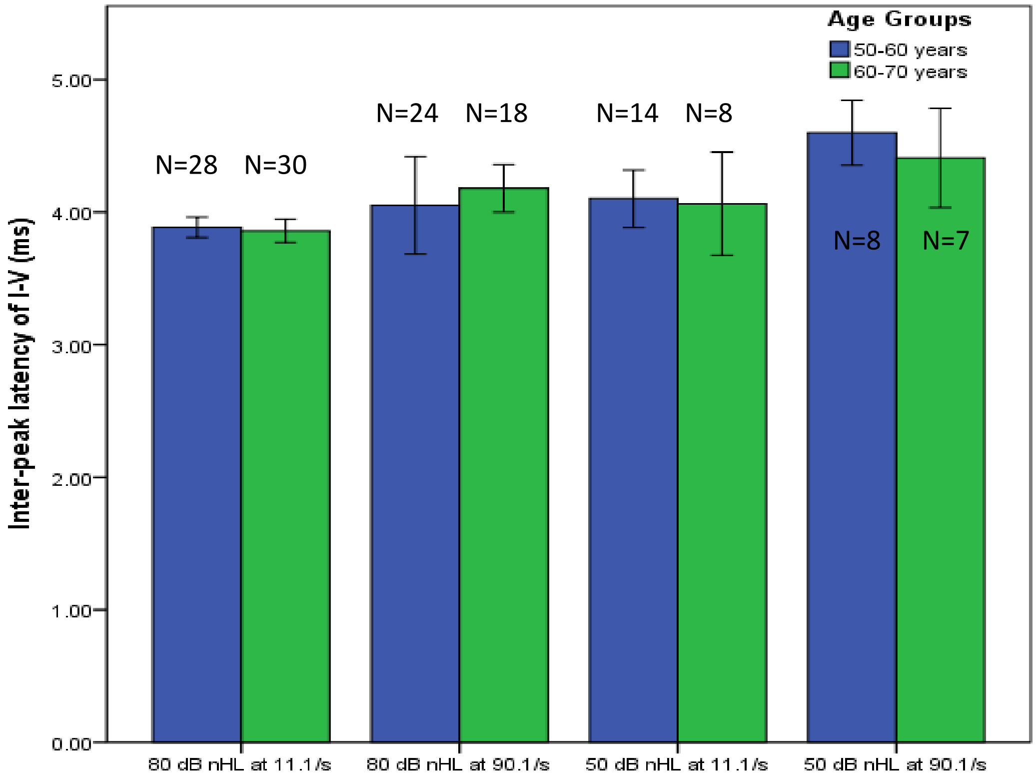

Figure 4.8. Mean inter-peak latency of wave I-V at each intensity and repetition rate. The error bars represent two standard errors from the mean.

The above figure reveals that the I-V IPL increases as the rate increases. The values were similar for both the groups for I-V IPL at each intensity (50dBnHL and 80dBnHL) and repetition rate (11.1/s and 90.1/s).

Mixed ANOVA was done with intensity level and repetition rates as within subject conditions and age groups as the between subject condition. It revealed a main effect of repetition rate [F(1, 5)=139.637, p<0.01, ŋp^2=0.965], but no main effect of intensity [F(1, 5=0.980, p>0.05, ŋp^2=0.164] and groups [F(1, 5)=0.189, p>0.05, ŋp^2=0.036]. there is significant increase in I-V IPL with increase in repetition rate. There was no significant interaction between intensity and repetition rates [F(1, 5)=0.016, p>0.05, ŋp^2=0.003], repetition rates and age group [F(1, 5)= 0.036, p>0.05, ŋp^2=0.354] and intensity and age group [F(1, 5)=0.049, p>0.05, ŋp^2=0.010]. Also there was no interaction effect among intensity, repetition rate and age groups [F(1, 5)=1.396, p>0.05, ŋp^2=0.218].

4.2.3.3 The Latency shift, with different repetition rates for waves I, III and V, at 80 dBnHL.

The latency-shift of wave I, III and V, at 80dBnHL was calculated and tabulated. Latency shift was measured by finding the difference in latency, obtained in two repetition rate i.e 11.1/s and 90.1/s at 80 dB nHL. The mean and standard deviation are shown in following Figure 4.9.

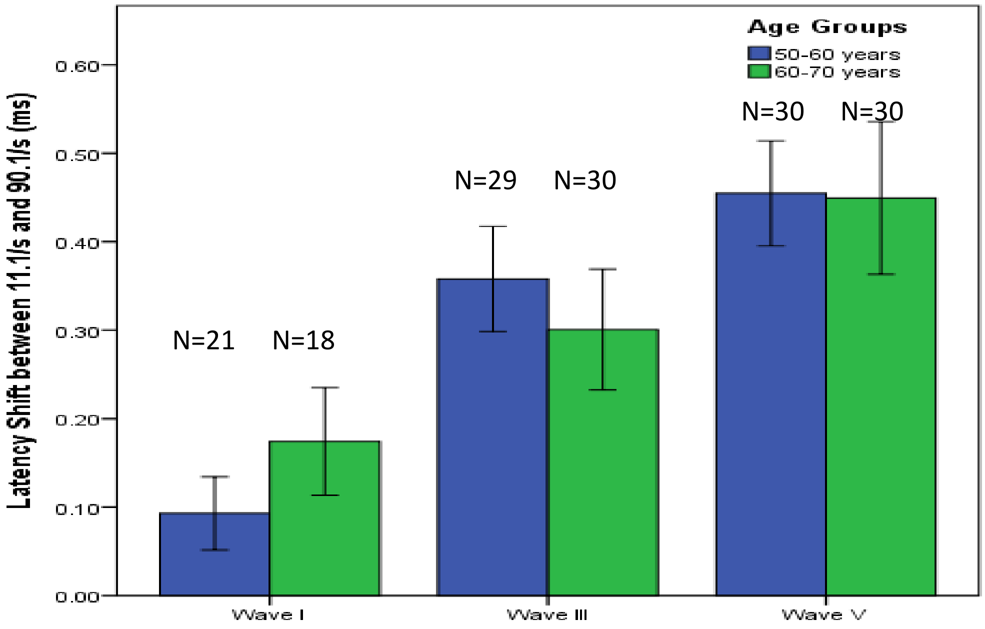

Figure 4.9. Mean latency shift (11.1/s – 90.1/s) for waves I, III and V, at 80 dB nHL. The error bars represent two standard errors from the mean.

The figure reveals that the latency shift was maximum for wave V compared to wave I and III at higher intensity in both the groups. Both the groups had similar values for latency shift (11.1/s – 90.1/s) for waves I, III and V, at 80 dB nHL.

MANOVA was performed and revealed no main effect of groups [F (1, 36) = 1.155, p<0.01] on latency shift (11.1/s and 90.1/s) at 80 dB nHL for wave I, III and V.

4.1.3.4 The Latency shift, with different intensities for waves I, III and V, at 11.1/s and 90.1/s.

The latency-shift was measured by finding the difference in latency at 80dBnHL and 50dBnHL, at both the repetition rates i.e. 11.1/s and 90.1/s. The results are given in figure 4.10.

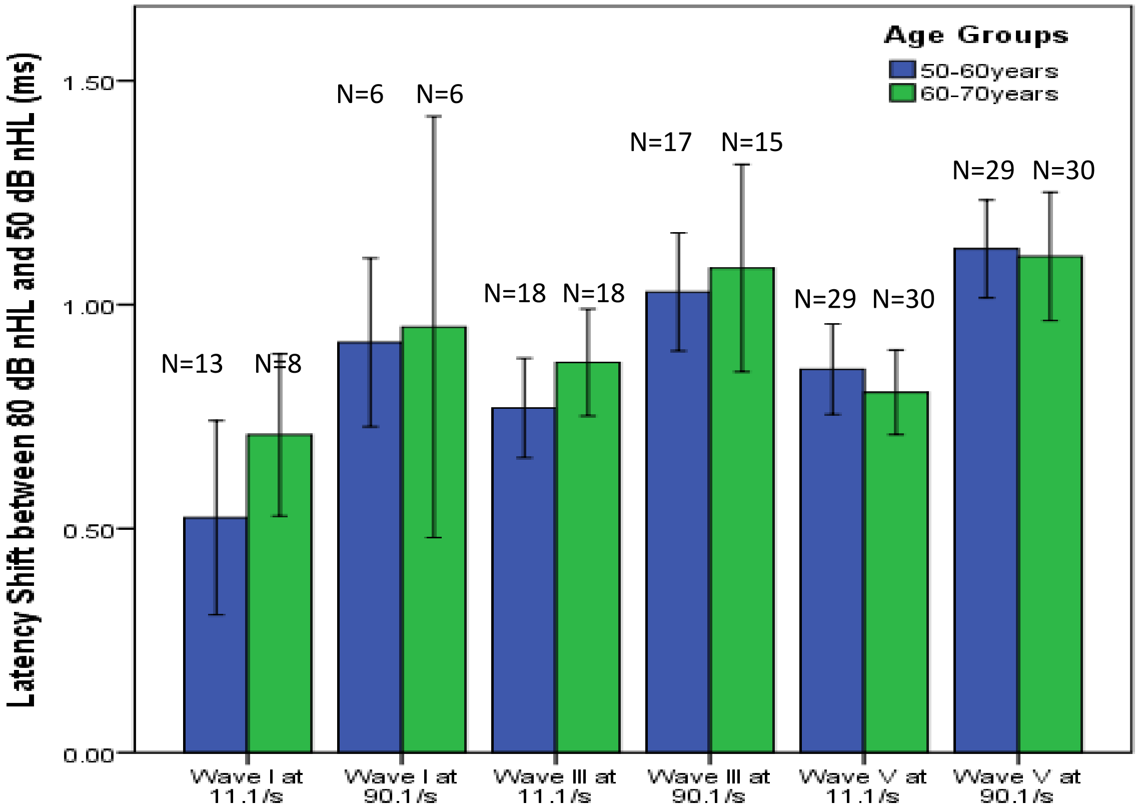

Figure 4.10. Mean latency shift (50dBnHL- 80dBnHL) for waves I, III and V, at 11.1/s and 90.1/s repetition rates. The error bars represent two standard errors from the mean.

The above figure shows that reduction in intensity and increase in repetition rate produced a greater latency shift in wave V followed by wave III and wave I. The latency shift was similar across both the age groups.

Mixed ANOVA was done for latency shift of wave III and V at 11.1/s and 90.1/s, to see the effect of repetition rate as within subject condition and age groups as the between subject condition. Latency shift of wave I was not considered for mixed ANOVA as the sample size for that parameter was very small.

For latency shift of wave III there was a main effect of repetition rate [F (1, 23) = 9.585, p=0.005, ŋp^2=0.294] but no main effect of groups [F(1, 23)= 0.647, p>0.05, ŋp^2=0.000] and no interaction effect [F (1, 23)= 0.647, p>0.05, ŋp^2=0.027].

Similarly, for latency shift of wave V, there was a main effect of repetition rate [F (1, 5)=46.171, p<0.01, ŋp^2=0.448] but no main effect of groups [F(1, 23)= 0.245, p>0.05, ŋp^2=0.017]. There was no interaction effect among the two [F(1, 23)= 0.983, p>0.05, ŋp^2=0.017].

4.2.3.4 Duration of wave V across intensities, at different repetition rates

The duration of wave V was calculated from the end of wave III to the end of wave V, as the presence of wave IV is ambiguous even in individuals with normal hearing sensitivity.

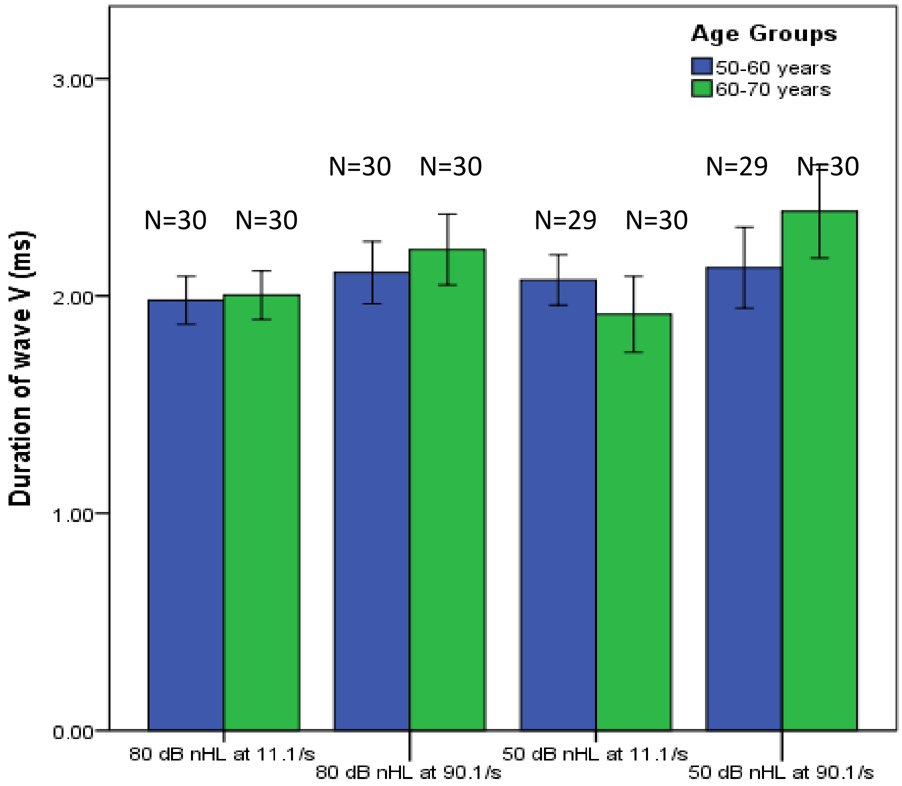

Figure 4.11. Mean duration of wave V, at each intensity and repetition rate. The error bars represent two standard errors from the mean.

The mean duration of wave V increases with increase in repetition rate and decrease with increase in intensity across the groups, as displayed in above Figure 4.11. Older group had larger duration of wave V than younger group.

Mixed ANOVA was done with intensity level and repetition rates as within subject conditions and age groups as the between subject condition. It revealed a main effect of repetition rate [F(1, 23)= 5.578, $p<0.05$, ŋp^2=0.195], intensity[F(1, 23) =5.298 , $p<0.05$, ŋp^2=0.187] and groups [F(1, 23)= 4.351, $p<0.05$, ŋp^2=0.159]. It means as there was significant increase in repetition rate and decrease in intensity there was increase in duration of wave V across the groups. There was a significant interaction between intensity and age groups [F (1, 23) =16.056, $p<0.01$, ŋp^2= 0.411], but no interaction effect of repetition rates and age group [F(1, 23)= 0.776, $p>0.05$, ŋp^2=0.033] and intensity and repetition rate [F(1, 23)= 0.884, p>0.05, ŋp^2=0.037]. Also there was no interaction effect among intensity, repetition rate and age groups [F(1, 23)=1.349, p>0.05, ŋp^2=0.055].

Because there is significant interaction between intensity and age groups, post hoc test i.e. independent t-test was done to see group differences across 50 dB nHL and 80 dB nHL. The results revealed there was statistically significant difference between the groups at 80 dB nHL(t= -2.039, p<0.05), but not at significant at 50 dB nHL (t= -0.750, p>0.05). The differences were greater in magnitude at 50 dB nHL (Mean difference= 0.1359) than 80 dB nHL (Mean difference= 0.0685).

4.1.3.4. Slope of wave V at different intensities and repetition rates

The slope of wave V was calculated by measuring the peak amplitude of the wave V and dividing it by the time taken for the wave to reach its trough from the peak.

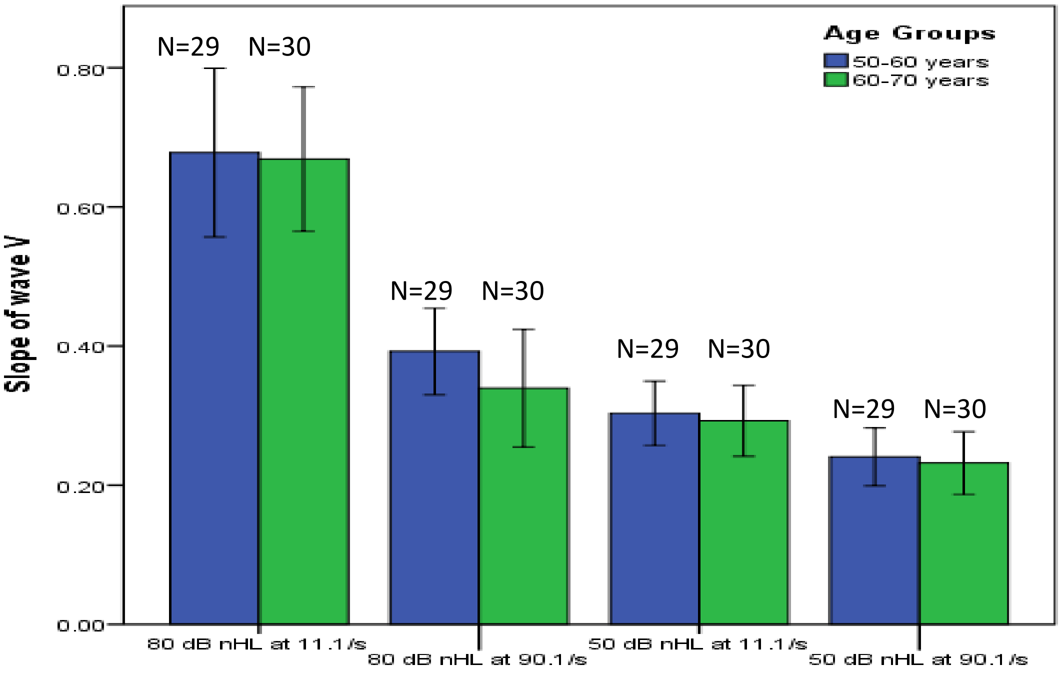

Figure 4.12. Mean slope of wave V, at different intensities and repetition rates. The error bars represent two standard errors from the mean.

The figure 4.12 revealed the mean of slope of wave V increased with increase in the intensity and decrease with repetition rate across the groups. The slope of wave V was better in younger group than older group.

Intensity level and repetition rates were taken as within subject conditions and age groups as the between subject condition for mixed ANOVA. It revealed a main effect of repetition rate [F(1, 57)= 69.309, p<0.01, ŋp^2=0.549], intensity [F(1, 57)= 122.187, p<0.01, ŋp^2=0.682] and groups [F (1, 57)= 505.755, p<0.01, ŋp^2= 0.041]. There was a significant interaction between intensity and repetition rates [F(1, 57)= 28.408, p<0.01, 0.333], but no interaction effect of repetition rates and age group [F(1, 3)= 3.831, p>0.05, 0.063] and intensity and age group [F(1, 57)= 1.332, p>0.05, ŋp^2= 0.023]. Also there was no interaction effect among intensity, repetition rate and age groups [F(1, 57)= 2.147, p>0.05, ŋp^2=0.036].

Because main effect of interaction between repetition rate and intensity was significant, post hoc test i.e. paired t-test was done to compare the repetition rate effects separately at 80 dB nHL and 50 dB nHL. The results revealed repetition rate effects were significant at both intensities (80 dB nHL: t= 10.248, p<0.01; 50 dB nHL: t= 5.021, p<0.01) but greater in magnitude at 80 dB nHL (Mean difference= 0.293) than 50 dB nHL (Mean difference= 0.0617).

4.3 Correlational Analysis

The aim of the present study was also to see the relationship between temporal processing ability as measured using AC GDT, SPIN and different parameters of ABR in elderly individuals with normal hearing sensitivity. Data from the two groups were clubbed and correlation was obtained using Pearson correlation coefficient on the following parameters:

1. SPIN scores at 0dB and -5dB and AC GDT
2. SPIN scores and the different temporal parameters of ABR

4.3.1 SPIN scores and Across Channel Gap Detection Threshold (AC GDT)

The correlation of AC GDT values and SPIN scores at different SNRs was obtained. The results revealed that there is a significant negative correlation (r_{xy}= -0.459, p<0.01) and (r_{xy}= -0.264, p<0.05) between Across Channel Gap detection threshold and SPIN scores obtained at 0dB SNR and -5 dB SNR, respectively. The same is illustrated in the scatterplot for better understanding.

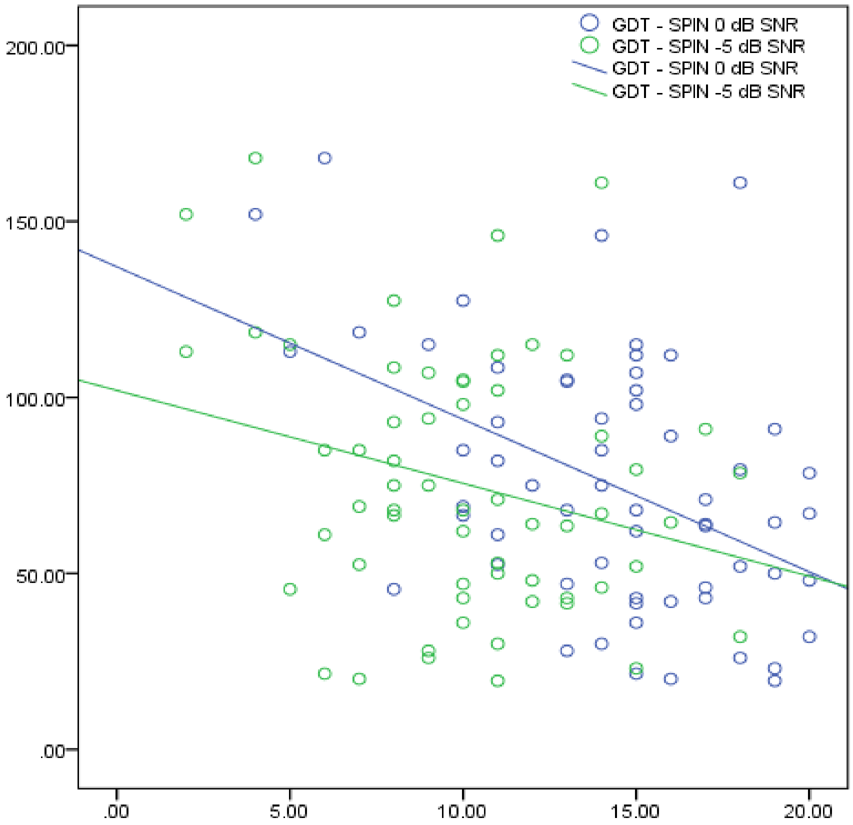

Figure 4.13. Scatterplot of AC GDT and SPIN scores at 0dB SNR and -5dB SNR.

The Figure shows that there is a significant negative correlation between the AC GDT values and SPIN scores revealing as there is decreases in the AC GDT values, the SPIN scores improves, that is, when the AC GDT values are more in individuals with normal hearing sensitivity, they are likely to have more difficulty in perception of speech in adverse listening conditions, like in noise.

4.3.2 SPIN Scores and the temporal parameters of ABR

The correlation between SPIN scores and the different parameters of ABR was established using Pearsons correlation test and the scores are given in Table 4.3.

Table 4.3.

Results of Pearsons correlation test with Test Statistic (r_{xy}) and significance values for SPIN scores at 0dB SNR and -5dB SNR and different ABR parameters.

	SPIN scores at 0dB SNR		SPIN scores at -5dB SNR	
	r_{xy} values	*p* values	r_{xy} values	*p* values
Latency of wave I at 80 dB nHL and 11.1/s	-0.198	0.128	-0.134	0.307
Latency of wave I at 80 dB nHL and 90.1/s	0.147	0.264	0.095	0.473
Latency of wave I at 50 dB nHL and 11.1/s	0.046	0.838	-0.078	0.728
Latency of wave I at 50 dB nHL and 90.1/s	0.298	0.300	-0.238	0.414
Latency of wave III at 80 dB nHL and 11.1/s	0.053	0.689	0.056	0.672
Latency of wave III at 80 dB nHL and 90.1/s	0.076	0.574	0.100	0.459
Latency of wave III at 50 dB nHL and 11.1/s	0.212	0.214	0.100	0.563
Latency of wave III at 50 dB nHL and 90.1/s	0.074	0.682	-0.212	0.236
Latency of wave V at 80 dB nHL and 11.1/s	0.154	0.239	0.164	0.210
Latency of wave V at 80 dB nHL and 90.1/s	0.157	0.232	0.170	0.193
Latency of wave V at 50 dB nHL and 11.1/s	0.056	0.673	-0.016	0.904
Latency of wave V at 50 dB nHL and 90.1/s	0.027	0.841	-0.023	0.860
Wave I-III IPL at 80dBnHL and 11.1/s	0.173	0.199	0.163	0.227

Wave III-V IPL at 80dBnHL and 11.1/s	0.143	0.277	-0.111	0.399
Wave I-V IPL at 80dBnHL and 11.1/s	0.023	0.862	0.065	0.627
Wave I-III IPL at 80dBnHL and 90.1/s	0.183	0.258	0.113	0.486
Wave III-V IPL at 80dBnHL and 90.1/s	-0.274*	0.039	-0.263*	0.048
Wave I-V IPL at 80dBnHL and 90.1/s	0.060	0.647	0.070	0.597
Wave I-III IPL at 50dBnHL and 11.1/s	0.054	0.820	0.015	0.951
Wave III-V IPL at 50dBnHL and 11.1/s	-0.222	0.187	-0.079	0.644
Wave I-V IPL at 50dBnHL and 11.1/s	-0.122	0.589	-0.190	0.396
Wave I-III IPL at 50dBnHL and 90.1/s	-0.112	0.691	0.086	0.761
Wave III-V IPL at 50dBnHL and 90.1/s	-0.187	0.305	-0.044	0.011
Wave I-V IPL at 50dBnHL and 90.1/s	-0.178	0.525	0.119	0.674
Slope of wave V at 80dBnHL and 11.1/s	0.056	0.670	0.032	0.806
Slope of wave V at 80dBnHL and 90.1/s	-0.229	0.078	-0.212	0.078
Slope of wave V at 50dBnHL and 11.1/s	-0.057	0.667	0.002	0.988
Slope of wave V at 50dBnHL and 90.1/s	-0.049	0.712	-0.162	0.221
Duration of wave V at 80dBnHL and 11.1/s	-0.159	0.224	-0.127	0.332
Duration of wave V at 80dBnHL and 90.1/s	-0.360**	0.006	-0.238	0.077
Duration of wave V at 50dBnHL and 11.1/s	-0.025	0.883	0.139	0.418
Duration of wave V at 50dBnHL and 90.1/s	0.199	0.275	0.255	0.159
Latency Shift (11.1/s-90.1/s) at 80dBnHL of wave I	0.028	0.867	0.080	0.627
Latency Shift (11.1/s-90.1/s) at 80dBnHL of wave III	-0.023	0.862	-0.005	0.971
Latency Shift (11.1/s-90.1/s) at 80dBnHL of wave V	-0.185	0.158	-0.211	0.106
Latency Shift (80dBnHL-50dBnHL) at 11.1/s of wave I	0.463*	0.034	0.401	0.072
Latency Shift (80dBnHL-50dBnHL) at 11.1/s of wave III	-0.066	0.702	-0.091	0.598
Latency Shift (80dBnHL-50dBnHL) at 11.1/s of wave V	0.038	0.775	0.028	0.835
Latency Shift (80dBnHL-50dBnHL) at 90.1/s of wave I	0.109	0.736	-0.266	0.404
Latency Shift (80dBnHL-50dBnHL) at 90.1/s of wave III	0.011	0.950	-0.201	0.270
Latency Shift (80dBnHL-50dBnHL) at 90.1/s of wave V	0.123	0.353	0.022	0.871

**Correlation is significant at the 0.01 level.* Correlation is significant at the 0.05 level.

The table reveals that only 3 parameters were significantly correlated with SPIN: Inter-peak Latency of wave III-V at 80 dB nHL and 90.1/s there was a significant negative correlation with SPIN scores at both the SNRs. The duration of wave V at 80 dB nHL and 90.1/s had a negative correlation whereas the latency shift (80dBnHL-50dBnHL) at 11.1/s of wave I had a significant positive correlation with SPIN scores only at 0dB SNR.

For better depiction data has been given in below scatterplot 4.14, 4.15 and 4.16.

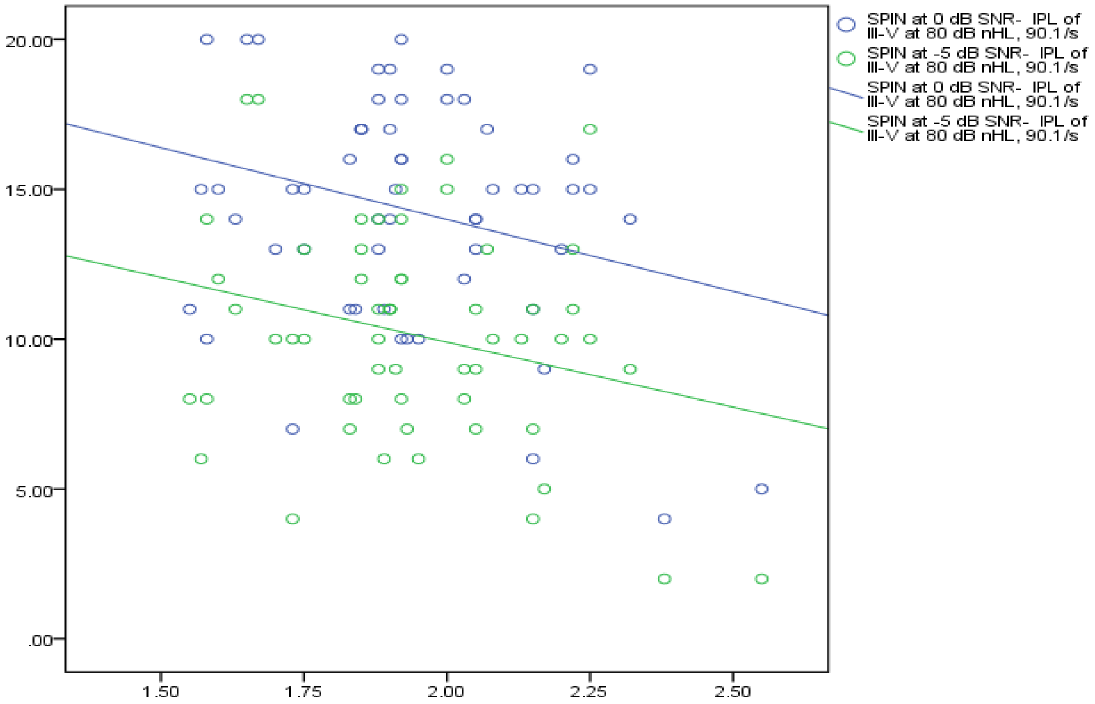

Figure 4.14. Scatterplot of SPIN scores at 0 dB SNR and -5 dB SNR with Inter-peak Latency of wave III-V at 80dBnHL and 90.1/s.

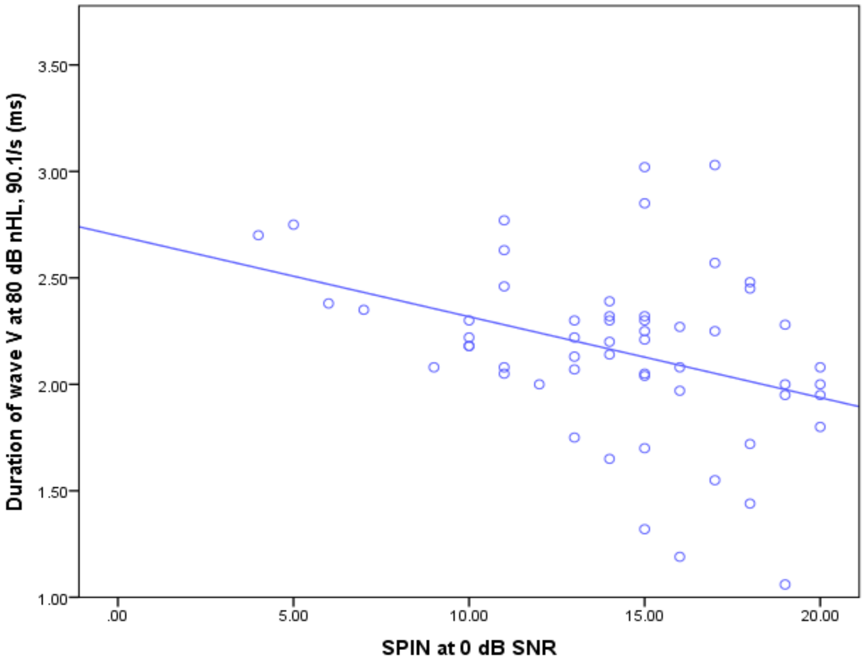

Figure 4.15. Scatterplot of SPIN scores at 0dB SNR with duration of wave V at 80dBnHL and 90.1/s.

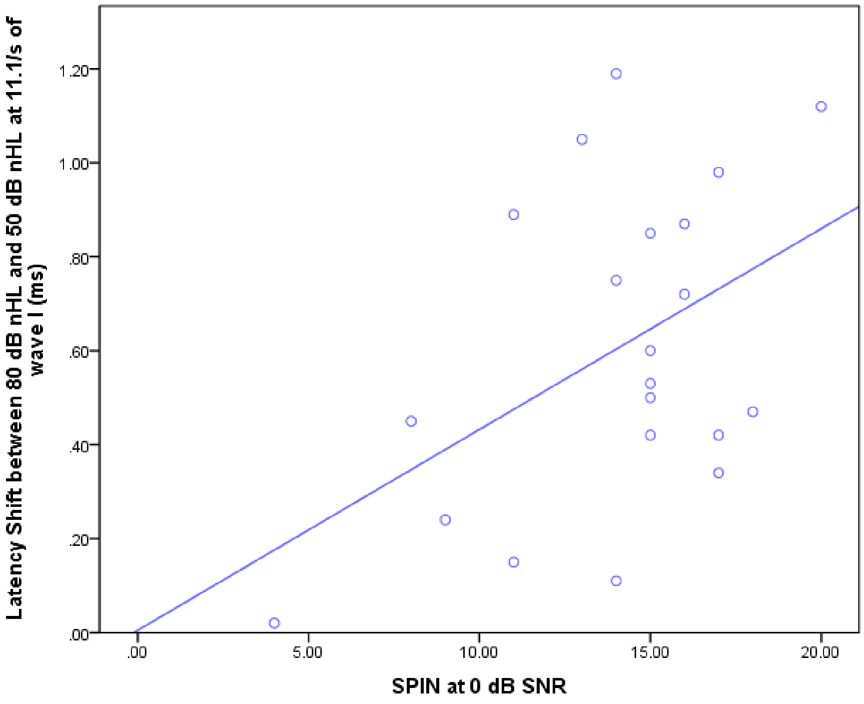

Figure 4.16. The distribution data and correlation of SPIN scores at 0dB SNR with Latency Shift (80dBnHL-50dBnHL) at 11.1/s of wave I.

Chapter V

Discussion

The aim of the study was to see the relationship between parameters of auditory brainstem responses, across channel gap detection ability and speech perception in noise performance in older adults with normal hearing. Data obtained were analysed descriptively and inferentially. The discussion on the obtained results are as follows.

Comparison of gap detection thresholds within and across the groups

Gap detection threshold was significantly different between the groups. The group I (50-60 years) performed better than group II (60-70 years). There was large variability in the thresholds of AC GDT in both the groups.

A similar result was also obtained by previous investigators (Hess et al., 2012; Phillips & Smith, 2004; Lister et al. 2002 and Grose, Hall, Buss, & Hatch, 2001). They found that GDTs are smallest and least variable for younger adults with normal hearing and the group differences were more apparent for across channel (AC GDT) than within channel (WC GDT) conditions.

The reason for such wide variability in data in both the groups could be because the task is more complex i.e., it involves identification of the time difference between the offset of the first neural channel activated to the onset of an entirely new channel (Phillips et al., 2010). This comparison across two neural channels to detect the silence requires highly precise temporal processing skills. This could be the reason for the wide range of AC GDT values obtained in the current study.

AC GDT values were significantly more for older group, revealing the older adults performed poorer than the younger adults which is in congruence with earlier findings (Lister et al., 2002 and Fitzgibbons & Gordon-Salant, 1994). This suggests that the gap detection depends on temporal mechanisms that deteriorate with age and stimulus complexity (Lister et al., 2002). The result also supports a primarily central auditory contribution to the temporal deficits, although peripheral system damage can also influence temporal resolution (Oxenham& Bacon, 2003; Moore &Oxenham, 1998; Glasberg & Moore, 1992).

Comparison of speech perception scores in noise at different SNRs within and across the groups

The SPIN scores in younger group had significantly better scores than the older group. Also, performance was significantly better at 0 dB SNR when compared to -5 dB SNR in both the age groups.

The SPIN scores became poorer in the older group. Similar results were also obtained by Gossens et al. (2016), Shojaei et al. (2016) and Wiley et al. (1998). Also, as expected the SPIN scores decreased with the decrease in the SNRs (Corbin et al., 2016, Manjula et al. (2012 and Helfer et al., 2009).

The reduced speech perception in noise could be because of auditory system dysfunction in the brainstem or auditory cortex independent of a peripheral sensitivity loss (Gordon-Salant& Fitzgibbons, 1993; Humes& Christopherson, 1991). There also could be loss of cochlear nerve fibres and low spontaneous rate fibres due to aging (Sergeyenko et al. 2013) leading to decrease in SPIN scores. It has also been reported through electrophysiological measures that due to age, there are deficits in neural coding of temporal fine structure (Clinard& Cotter, 2015; Clinard& Tremblay, 2013) and speech envelop (Gossens et al. 2016 and Tlumak et al. 2015).

The SPIN scores reduce as the SNRs become poor could be because of the decrease in the depth of temporal modulation of the envelope of speech, with the increase in noise leading to loss of information. Temporal envelope rather than spectral information is important to perceive speech in quiet (Drullman, 1995; Shannon et al. 1995). So, even when the spectral information was degraded with the temporal envelope intact, individuals could obtain good speech recognition scores in quiet. While in the presence of noise, the temporal modulations of the target speech reduce as the noise fills in the peaks and troughs of the temporal waveform of the speech signal (Drullman, 1995 and Baer & Moore, 1993). Also, maskers which have similar temporal information as target speech like speech shaped noise or speech babble degrades the speech perception by degrading the temporal envelop of the target, this results in poor speech perception in noise. With the increase in the intensity of the masker, ‘listening in dips’ becomes more difficult and SPIN scores reduce further (Cooke, 2006).

Comparison of different parameters of ABR within and across the groups

Latency of wave I, III and V at different repetition rates and intensities

There is significant main effect of intensity and repetition rate on the latency of wave I, III and V. There was an increase in latency of wave I, III and V with increase in repetition rate and decrease in the intensity in both the groups. The effect of repetition rate on latency was significantly greater at 50 dB nHL than at 80 dB nHL in older adults. Repetition rate effect was lower at higher intensity and more at lower intensity. Intensity related effects were more at higher repetition rate for all the waves, more so for wave V. There was no group effect for latency of all waves.

Absolute latencies of ABR waves tend to increase in older adults (Martini, Comacchio, &Magnavita, 1991; Ottaviani, Maurizi, D’Alatri, &Almadori, 1991; Allison, Hume, Wood, & Goff, 1984; Otto & McCandless, 1982; Allison, Wood, & Goff, 1983; Jerger& Hall, 1980; Rowe, 1978). Studies also show that with increase in the repetition rate, the latency of wave I, III and V increases (Burkard & Sims, 2001; Mitchell et al., 1989; Suzuki et al., 1985; Chiappa et al., 1979; Stockard et al., 1979; Rowe, 1978).

The effect of repetition rate on latency of waves is because as there is increase in repetition rate, the auditory neurons may undergo metabolic changes at the cellular level leading to poor synchronous firing (Don et al., 1977). Another contributing factor to the prolonged latency of wave V can be due to the increased latency of wave I, due to adaptation at the junction of inner hair cell-auditory nerve (site of generation of wave I). This can lead to prolonged conduction time of the stimulus to the generation site of wave V explaining prolongation of wave V latency with the increase in repetition rate in our study. Some authors report decrease in latency due to deficit in inhibitory neurotransmitters in older adults (Caspary et al., 1995) while some others (Beagley& Sheldrake, 1978) do not find any latency abnormalities in older adults. One observation what we made in our recordings was that wave I morphology was often better at 90.1/s than 11.1/s when presented at 50 dB nHL. This could be due to the increased loudness perceived due to temporal integration of energy at higher repetition rate (Zwislocki, 1969).

There is effect of intensity on latency of waves as maximum intensity will be responsible for maximum motion of basilar membrane and synchrony of neurons to elicit response directly that impacts the latency of ABR (Møller, 1985). So, with increase in intensity, the excitation pattern of basilar membrane becomes highly non-linear leading to response from the entire basilar membrane (Davis et al., 1985) which can give rise to earlier latencies as found in the present study also. Auditory nerve consists of low and high spontaneous rate fibres. At the higher intensities, both type of fibres will be activated (but high spontaneous rate neurons get saturated), giving rise to earlier latencies, whereas, at lower intensities (50 dB nHL), only the high spontaneous rate fibres will be firing leading to increased latency values (Winter, Robertson & Yates, 1990). The neurons start firing at a higher rate when the stimulus is presented, but as the stimulus progresses, the spike rate of the individual neurons reduces, which may increase the latency of the wave when the total neuronal activity is considered over time (Sumner & Palmer, 2012). This all reasons support the findings of present study where intensity effect on latency of the waves is present i.e. as intensity increases the latencies are early.

As age increases, there could be reduction in neural activity, due to the adaptation of neurons (Shepherd et al., 2004) which leads to prolonged latency with the increase in the repetition rate as well as with decrease in intensity as found in present study. Adaptation of neurons can affect latency of waves of ABR in two ways. One, the change in the modal frequency of the neurons shifting the peak of the wave and two, reduction in the neural activity of a dominant set of fibres at the generation site, leading to altered latencies (Don et al. (1977). There could be slower conduction of stimulus from wave I to wave V as the generators of these waves are different i.e. wave I generated by axonal potentials while wave III and V have contributions from dendritic potentials from the nuclei (Fowler &Noffsinger, 1983). Latencies for peaks III and V are increased in the older individuals, although the latency for peak I did not, which is because of increase in neural transmission time change (Backoff& Caspary, 1994; Cooper et al., 1990).

The inner hair cell-auditory nerve synapse has been recently identified as the most vulnerable part of the auditory system rather than the hair cells or the neurons themselves (Makary et al., 2011; Sergeyenko et al., 2013). Cochlear synaptopathy has also been identified as one of the primary factors involved in ageing related auditory deficits (Lin et al., 2011; Kujawa& Liberman, 2009). So, along with increased adaptation and poorer synchrony, synaptopathy could be a contributor towards less efficient encoding of stimuli at the neural level.

There was no group differences as the groups taken were very close by in ages and was mainly to see the fine age differences which weren't present for the given parameter. As reported by Martini et al., 1991 when large age differences between the groups were present, there was increase in latencies in the older group (Rowe, 1978).

Interpeak Latency differences

There is significant main effect of repetition rate on the interpeak latency of wave I-III, III-V and I-V. There was no intensity effect on III-V and I-V IPLs. There was also no group effect on the parameters. There was also reduced I-III IPL in older group.

Similar findings were obtained by Burkard and Sims (2001); Rupa and Dayal (1993); Mitchell et al. (1989); Elberling and parbo (1987). Above results could be due to reduction in neural synchrony aging (Harkins, 1981). As seen above, the absolute latencies were more prolonged for wave III and wave V compared wave I because of different generators i.e. wave I generated by axonal potentials while wave III and V have contributions from dendritic potentials from the nuclei (Fowler &Noffsinger, 1983). Thus, prolongation of I-V IPI and different inter-peak latencies also seen in our results, suggests possible increases in neural transmission time change (Backoff& Caspary, 1994; Cooper et al., 1990). A high rate of stimulation also leads to reduced neural synchrony leading to prolongation of waves (Willott et al., 2008).

As seen in Figure 4.3 and 4.4, it was observed that wave I latency increased with age but wave III latency was similar between the two groups. This could have led to the reduction in I-III IPL. Similar observations were reported by Costa et al. 1991, who also reported increased wave I latencies relative to later peaks. High frequency loss with age could lead to increased wave I latency (Otto & McCandless, 1982), which may be compensated at the level of brainstem.

Latency shift with changes in repetition rate and intensity

Reduction in intensity and increase in repetition rate produced a greater latency shift in wave V followed by wave III and wave I. Repetition rate effect was lower at higher intensity and more at lower intensity. Intensity related effects were more at higher repetition rate for all the waves, more so for wave V. there is no group effect on this parameter.

The direct implication is repetition rate could be made more sensitive by presenting lower intensity. This observation per se has not been made previously by the previous investigators (Martini et al., 1991; Beagley and Sheldrake, 1978) and represents a unique contribution to scientific literature. Similarly, intensity effects are more at higher repetition rates (Rowe, 1978).

Burkard and Sims (2001); Mitchell et al. (1989); Debruyne (1986); Picton, Stapells, and Campbell (1981) also found greater rate-related shifts for wave V peak latencies compared with wave III and I. Differential increase in wave V latency relative to earlier peaks suggest neural degeneration which is more central in its location with milder degeneration of the more peripheral structures. Also there is poor synchrony and reduced neural activity, due to the adaptation of neurons in older subjects (Shepherd et al., 2004), leading to prolonged latency with the increase in the repetition rate and decrease in intensity.

There is no much age influence on rate and intensity effect (Boettcher, 2002). Due to aging there is prolongation of waves which is more for wave III and V (Harkins, 1981) compare to wave I because of different generator sites of all waves.

Duration of wave V across intensities, at different repetition rates

There was a significant main effect of repetition rate and intensity on duration of wave V. It is slightly more for higher repetition rate. The effect of intensity across the groups was significantly greater at 50 dB nHL than at 80 dB nHL. Group differences were also present.

The literature reviewed revealed no prior studies have considered duration of wave V as a parameter to analyse with the change in intensity and repetition rate in older adults. However, this slight change could be explained due to the reduction in neural firing caused by adaptation of neurons and diminished neural synchrony with increase in repetition rate (Suzuki et al., 1985; Fowler &Noffsinger, 1983; Chiappa et al., 1979; Stockard et al., 1979; Rowe, 1978) along the auditory pathway. So, increase in the duration of wave V is indicative of reduced neural synchrony. These evidences could also explain the age-related group differences along with synaptopathy (Lin et al., 2011) due to aging.

Slope of wave V at 80 and 50 dB nHL at different repetition rates

There was statistical significant effect of repetition rate and intensity on slope of wave V i.e. it increased with increase in intensity and decreased with increase in *repetition rate. The effect of repetition rate on slope of wave V was significantly greater at 80 dB nHL than at 50 dB nHL. Also, there was group differences present.*

Slope of wave V depends on wave V amplitude (numerator) as well as on the difference in latency between the peak and trough of wave V (denominator) and is an attempt to quantify morphology of wave V. The slope of wave V decreases with increase in repetition rate, as the neural activity reduces at higher repetition rates due to adaptation and decreased neural firing (Suzuki et al., 1985Fowler &Noffsinger, 1983; Chiappa et al., 1979; Stockard et al., 1979; Rowe, 1978) leading to prolonged onset and offset of wave V.

With decrease in intensity, the number of active neurons reduces (Chiappa et al., 1979; Stockard et al., 1979 and Don et al., 1977) leading to diminished synchrony of firing which is more pronounced at lower intensities.

As we know, with better synchrony of firing, the peak of the wave is sharper with increased amplitude (Rowe, 1977). While, poor synchrony would lead to reduced amplitude of wave V and broadening of peak. Thus, reduced synchronous firing with the increase in the repetition rate and decrease in intensity, leads to decreased slope of wave V. Poor synchrony of firing would have resulted in reduced amplitude of wave V and increased broadness thereby reducing the value of slope. The morphology of wave V was better, leading to good slope in younger group compared to older group.

Sensitive ABR parameters for stimulus manipulation and age-related group differences

Based on the effect size, sensitive ABR parameters for manipulation of repetition rate and intensity as well as for age related group differences were identified. Wave III and V were the most sensitive to intensity variations. Interpeak latency of I-V was found to be the most affected by repetition rate changes. The inter peak latency of I-III had the largest differences between the younger and older age groups. These parameters were most sensitive for subtle changes in the system and can be taken into consideration for further studies.

Correlation between SPIN Scores and Across Channel Gap Detection Threshold (AC GDT)

There is a significant negative correlation between SPIN scores obtained at 0 dB SNR and -5dB SNR with Across Channel Gap detection threshold. As the AC GDT values are more in individuals with normal hearing sensitivity, they are likely to have more difficulty in perception of speech in adverse listening conditions, like in noise.

Similar correlation between temporal resolution and speech perception in noise are reported by Summers et al. (2013), Papakonstantinou et al. (2011), Hopkins and Moore (2009), Helfer and Vargo (2009) and Lorenzi et al. (2006). They used different tests to assess temporal resolution like amplitude modulation, gaps in noise, temporal masking to correlate the findings with the scores of speech perception in noise. They reported that the ability for the person to ‘listen in dips’ is highly important for speech perception in noise. They explained the poor speech performance is mainly because of aging leading to deficits in temporal processing abilities and not because of audibility.

Walker et al. (2011) found a correlation between AC GDT and reading performance. They concluded that for phonological awareness, the relative timing of two or more perceptual tasks is very important, and reflected in the reading abilities.

Elangovan and Stuart (2008) have stated that AC GDT highly correlates with voice onset time phonetic boundary. Within Channel GDT showed no correlation. VOT is the temporal cue responsible of categorical perception between voiced and unvoiced sounds. They have suggested that one of the psychophysical perceptual aspects responsible for the categorical perception of VOT could be AC GDT.

Snell and Frisina (2000) found a relationship between gap threshold and spondee-to-babble noise thresholds in older subjects. They found no correlation between spondee-in-babble thresholds and gap detection thresholds in older adults while it was present in younger adults. They stated age-related changes in temporal acuity may begin long before age-related changes in word recognition.

Strouse et al. (1998) and Stuart and Phillips (1996) correlated speech perception and temporal resolution. There was a correlation with high intensity level gap carrier and word recognition task in MLD paradigm. They suggested age-related changes in the auditory processing occur over many decades and the decline in word recognition in noise in older adults reveals changes occurring in early decades.

These all helps in explaining the role of temporal resolution in speech perception in noise, especially when the SNR is poor. Similar results have been reported by previous investigators showing temporal resolution is essential for perception in adverse listening conditions (Fitzgibbons & Wightman, 1982; Glasberg & Moore, 1989; Gordon-Salant& Fitzgibbons, 1993, Snell et al. 1994; Lorenzi at al. 2006 and Hopkins and Moore, 2009).

Correlation between SPIN scores and the different parameters of ABR

SPIN scores and inter-peak latencies

A significant negative correlation was obtained between III-V IPL for high intensity and high repetition rate and SPIN scores at both 0 dB and -5 dB SNRs.

Higher intensity stimulates the low spontaneous rate neurons (Schmiedt et al., 1996) which in turn are more susceptible to increased repetition rates (Relkin&Douced, 1991). Low spontaneous rates of firing are affected by both aging (Schmiedt et al., 1996) and noise (Liberman &Kujawa, 2017; Furman et al., 2013). It is thus possible that this combination of high intensity and high repetition rate is more sensitive to possible synaptopathic deficits which have been reported in presbycusis (Sergeyenko et al., 2013). Also, age related deterioration in the brainstem region, but not in the peripheral structures had been reported in CBA mice (Walton et al., 1995) and these results are consistent with such aging related effects.

SPIN scores and duration of wave V

A significant negative correlation was obtained between duration of wave V for high intensity (80 dB nHL) and high repetition rate (90.1/s) and SPIN scores at both 0 dB SNR.

The duration of ABR waves is mainly dependent on synchronous firing of auditory neurons (Fowler &Noffsinger, 1983; Suzuki et al., 1985; Chiappa et al., 1979; Stockard et al., 1979 and Rowe, 1978). So, increase in the duration of wave V is indicative of reduced neural synchrony. Neural synchrony is important for speech perception in noise (Anderson & Kraus, 2002) also, explaining the correlation between duration and SPIN scores.

As mentioned above the higher intensity stimulates the low spontaneous rate neurons (Schmiedt et al., 1996) which in turn are more susceptible to increased repetition rates (Relkin&Douced, 1991). It is thus possible that this combination of high intensity and high repetition rate is more sensitive to possible synaptopathic deficits which have been reported in presbycusis (Sergeyenko et al., 2013). Also, age related deterioration in the brainstem region, but not in the peripheral structures had been reported in CBA mice (Walton et al., 1995) and these results are consistent with such aging related effects. This explains the correlation of duration at higher intensity and higher repetition rate with the SPIN scores.

Cunningham, Nicol, Zecker, Bradlow and Kraus (2001) conducted behavioral speech perception measures of just noticeable difference to the /da/-/ga/ continuum in quiet and in noise, click evoked ABR, speech evoked ABR to stimulus /da/ and cortical responses in typically developing children and children with learning problems. They observed a correlation between just noticeable differences in for conversational /da/-/ga/ continuum in noise and ABR wave V latency in noise. They reasoned the importance of neural synchrony to code for the temporal cues of speech. King, Warrier, Hayes and Kraus (2002) conducted a similar study and also found a correlation between just noticeable differences for speech and FFR, but not with click evoked ABR. They have also attributed these findings to neural synchrony and its importance in perceiving speech in adverse conditions.

SPIN scores and latency shift between 80 and 50 dB nHL at 11.1/s.

A significant positive correlation was obtained between latency shift (80 dB nHL -50 dB nHL) at 11.1/s of wave I and SPIN scores at 0 dB SNR.

Those with greater shifts tended to have better SPIN scores. Changes in wave I latency with intensity is associated with shifting excitation patterns on the basilar membrane (Møller, 1985 and Davis et al., 1985). At higher intensities, there is a more basal spread of excitation leading to earlier latencies. So, the wave I latency shift from 80 to 50 dB nHL probably taps deficits at a more peripheral level (in and around cochlea) when compared to parameters discussed before. Subjects with cochlear hearing loss make little use of temporal fine structures i.e. cochlear damage leads to temporal deficits (Hopkins & Moore, 2007). This could be the reason that wave I latency shift correlates with SPIN scores. It is also possible that these results arise from sampling errors and are just random occurrences. Future studies need to focus on these particular parameters to refine the findings obtained in the study.

Though wave V parameters (latency, interpeak, duration and slope) tended to be the most sensitive to intensity and repetition rate manipulations as well as group differences, it didn’t necessarily correlate with speech in noise scores. This suggests that SPIN as well as AC GDT is affected by a host of factors- peripheral as well as central. Finally, they might also be affected by factors like working memory, attention, linguistic proficiency and motivation (Lecumberri, Cooke & Cutler, 2010; Norris & McQueen, 2006, Cooke, 2016). Larger sample sizes with greater power is required to more precisely understand the processes with small effect sizes and random errors. Also, these effects are limited to latency and related parameters and does not cover effects on amplitude.

The current study utilized clicks for ABR, however, more complex stimuli like speech could potentially be more useful. Papakonstantinou et al. (2011) had used chirp stimulus to elicit ABR, whereas Cunningham et al. (2001) and King et al. (2002) elicited ABR using click and speech stimulus, they also assessed the temporal resolution measures of just noticeable difference using speech.

Chapter VI

Summary and Conclusion

The present experiment was done to explore the variations in temporal resolution in older individuals with normal hearing sensitivity and its utilization for perception of speech in noise. In this study, temporal resolution skills were assessed using across channel gap detection test and electrophysiological measures (ABR) at the level of brainstem. The results of temporal resolution and temporal parameters of ABR were correlated to the scores of speech perception in noise obtained at 0 dB and -5 dB SNRs.

A total of 30 Kannada speaking older adults in the age range of 50-70 years were taken up and divided among two groups, group I (50-60 years) and group II (60-70 years) for the present study. Each group consisted of 30 ears from 15 participants. Through a detailed case history, it was confirmed that none of the participants were exposed to long durations of noise or music and also had no history or presence of any neurological and otological disorders. An audiological test battery consisting of pure tone audiometry, speech audiometry, immittance measurements, and transient evoked otoacoustic emissions was carried out, to rule out the presence of any peripheral auditory abnormality.

To assess the temporal resolution abilities, a behavioural measure i.e. Across Channel Gap Detection Test (AC GDT) was done, using NBN centered at 1000Hz (lead marker) and 2000Hz (lag marker) on all the participants using Psycon v2.18 experimental software. The speech perception in noise was assessed using PB words in Kannada. The noise used was speech shaped noise mixed with the PB words at 0 dB and -5 dB SNR. Electrophysiological measure of temporal processing was assessed using Auditory Brainstem Response (ABR) which was elicited using clicks at intensities of 80 and 50 dB nHL and repetition rates of 11.1/s and 90.1/sec. The parameters considered were latency of wave I, III and wave V, inter-peak latency, latency shift due to intensity and repetition rate effect, duration of wave V and slope of wave V. The findings were:

In general, the AC GDT threshold were larger and ABR morphology was poorer with high repetition rate in older individuals because of adaption of neurons, poor synchronous firing, different generators of the waves leading to slower conduction time, degeneration at more central level and cochlear synaptopathy.

The AC GDT values were different between the groups with large variability in thresholds observed in both the groups. This could be due deterioration of temporal mechanism with age and complexity of the task i.e. processing of lead and lag marker of AC GDT in two separate neural channels.

The SPIN scores in younger group were better than older group. There were decreased scores with the decrease in SNR. This is due to aging results in loss of cochlear nerve fibres and low spontaneous rate fibres and also the reduction in the modulations of the temporal waveform due to the masking by the noise leading to reduced ‘listening in dips’ leading to poorer scores at decreased SNR.

There was significant effect of repetition rate on latency of wave I, III and V, inter-peak latency of wave I-III, III-V and I-V and latency related parameters, also on the duration and slope of wave V. This could be due to poor synchronous firing and adaptation of neurons leading to poor neural activity.

The significant effect of intensity is on latency of wave III and V, duration of wave V and slope of wave V. This could be due to the participation of high and low spontaneous rate fibres at the higher intensities, and activation of only high spontaneous rate fibres at lower intensities. Asynchrony and neural adaption could also have played a part.

Age effect was seen on I-III interpeak latency which could be because of high frequency loss with age, which is compensated at brainstem level. The age effect was also seen on duration and slope of wave V.

The most sensitive parameters for subtle changes in the system were interpeak latency of I-V for repetition rate changes and wave III and V latencies to intensity variations. The inter peak latency of I-III had the largest differences between the younger and older age groups.

There was a negative correlation between SPIN scores and AC GDT. Poor SPIN performance is mainly because aging which causes deficits in temporal processing.

There was a significant negative correlation of SPIN scores with III-V IPL and duration of wave V for 80 dB nHL at 90.1/s could be because of cochlear synaptopathy due to aging. However, a positive correlation was found with wave I latency shift between intensities at 11.1/s that could be explained by shift of excitation patterns on the basilar membrane at higher intensities.

Conclusion

The results of the current study emphasize the correlation between across channel gap detection test (AC GDT) and speech perception in noise. The most sensitive parameters for subtle changes in the system due to repetition rate changes was interpeak latency of I-V while because of intensity variation were wave III and V. The I-III IPL was the most sensitive for finer age group differences. ABR obtained at higher repetition rate and higher intensity for III-V IPL, duration of wave V and also latency shift of early wave at lower repetition rate are preferable to study correlation with SPIN. This study needs to be replicated on a larger sample and should include stimuli which are closer to speech so that correlation with behavioural measures becomes more meaningful.

Implications

The outcomes of the present study imply that:

1. The most sensitive parameter for intensity and repetition rate manipulations is wave V related parameters.
2. Repetition rate effects are larger at lower intensity and intensity effects are larger at higher repetition rate. So, lower intensity with high repetition rate ABR will be sensitive.
3. AC GDT can be used as a predictor for SPIN especially in older individuals with normal hearing sensitivity.
4. ABR with specific parameters may be used to predict speech perception in noise.
5. The study gives a better understanding of the relationship between speech perception in noise, temporal processing and the neural activity at the level of brainstem.

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