EFFECT OF NOISE SPECTRUM ON CORTICAL EVOKED AUDITORY POTENTIAL IN YOUNGER AND OLDER ADULTS WITH NORMAL HEARING SENSITIVITY

Madhusagar
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Certificate

This is to certify that this dissertation entitled **“Effect of Noise Spectrum On Cortical Evoked Auditory Potential in Younger and Older Adults with Normal Hearing Sensitivity”** is a bonafide work in part fulfillment for the Degree of Master of Science (Audiology) of the student (Registration No.14AUD010). 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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Declaration

This dissertation entitled **“Effect of Noise Spectrum On Cortical Evoked Auditory Potential in Younger and Older Adults with Normal Hearing Sensitivity”** is the result of my own study under the guidance of Dr. Animesh Barman, Professor of Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier in any other University for the award of any Diploma or Degree.

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ABSTRACT

Cortical auditory evoked responses (CAEPs) can be employed to study the neural encoding of speech. This on the other hand helps us in understanding the speech processing that happens at higher level. CAEPs can be used on different populations to see how their perception is affected by noise. Older individuals often complain about trouble in understanding speech in noisy situations. These individuals with or without hearing loss usually exhibit difficulty in perception of speech compared to young listeners especially in the presence of background noise.

The present study was designed to identify the effect of different type of noise spectrums on the cortical auditory evoked potentials (CAEPs) in younger and older population and its correlation with behavioral measure (speech in noise test results). 15 younger adults and 15 older adults with normal hearing sensitivity participated in the study. Stimulus /ba/ and /da/ stop consonants in four different test environment such as in quiet, highpass noise (>4000 Hz), lowpass noise (<200 Hz) and speech noise was used in the study. Latency and amplitude of N1 and P2 were considered for the study. Significant shift in latency and reduction in amplitude was seen in N1 of the older adults. Stimulus condition quiet showed significantly better latency and amplitude compare to other three noise conditions in both the groups. Significant negative correlation was seen between SPIN scores and N1 and P2 latencies. These results indicate, age-related refractory differences in younger and older auditory systems could have reflected in CAEPs. Refractory issues might in turn affect synchronized neural activity and hence result in poorer latency and amplitude. Different noise spectrum affects CAEPs differentially and N1 is most affected by lowpass noise and P2 is most affected by highpass noise. The data indicates that use

of CAEPs in measuring effect of noise at cortical level and its correlation with speech perception has excellent potential for future research among older adults.

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Chapter 1

INTRODUCTION

Auditory system employs series of events to understand speech. The acoustic signals entering the ear is converted into mechanical signals and then to electrical signals. These electrical signals then give rise to nerve impulses and information are then sent to the brain where they are interpreted and perceived as meaningful sound. Different sounds with different frequency composition stimulate different parts of the inner ear (cochlea) and sent to the auditory cortex via different neurons thus helping the brain to distinguish among various sounds.

One way to evaluate what happens in the cortex as it does cognitive acts (coding and differentiating of sounds) is to record the electrical field generated by the cortex. Cortical auditory evoked potentials (CAEPs) evoked by speech sounds have been investigated to determine the effect of phonologic and acoustic features on the cortical waveform and to recognize the cortical areas activated by these features (Crottaz, Herbette & Ragot, 2000). Auditory Late latency responses (ALLR) are believed to index the sound arrival to the cortex and initiation of cortical sound processing. Hence, by assessing ALLR complex one can comment on the signal detection and processing the at cortex.

Auditory Late Latency Response (ALLR) components are seen between 50 and 300 ms with four important peaks i.e. P1 (P60), N1 (N100), P2 (P160), and N2 (N200). Amongst the components P2 is believed to be more prominent and N2 is least prominent. These ALLR peaks are clustered together and name it as P1- N1- P2 complex or N1- P2 complex or P2- N2 complex (Allison, McCarthy, Wood, Williamson & Spencer, 1989).

Like any other evoked potentials ALLR is also affected by many factors, one of such factor is noise. Martin and Stapells (2005) observed that as the cutoff frequency of lowpass noise is raised, ERP latencies increased and amplitudes decreased. N1 latencies shows significant changes when lowpass masker was raised to 1000 Hz whereas no changes were seen in N2 and P3 until lowpass masker was raised to 2000 Hz. They concluded stating that, “reduced audibility from masking affects N1 in differential manner compared to N2 and P3”. And also N1 indicates the presence of audible stimulus energy, as N1 was present when the signal was heard but the N2 and P3 peaks were present only when the signals were discriminable, hence indexes discrimination of speech sounds.

Decreased audibility of the speech sounds produced by high-pass noise-masking was also studied by Martin and stapells (1997,1999). Increase in latency and decrease in amplitudes of the ERP peaks was observed by them in the presence of high pass noise. The masking noise had a differential effect on the N1, N2, and P3 waves as well. The later the wave, the greater the effect of high-pass masking noise. Polich, Howard and Starr (1985) have also odserved that presence of white noise increased P3 latencies by approximately 10 ms. Whiting, Martin and Stapells (1998) concluded that “decreased audibility as a result of masking, affects the various ERP peaks in a differential manner and the latency are more sensitive indicators of these masking effects than are amplitudes”.

Age is another factor which also affects ALLR and speech perception. Older adults often have difficulties in understanding speech (Jerger, Jerger, Oliver & Pirozzolo, 1989 1990). Older adults frequently complain stating that “I can hear you, but I can’t understand you”. Because speech is a complex signal, composed of various time-varying acoustic cues, numerous investigators have hypothesized that aging negatively affects the ability to process temporal cues. More specifically, it is speculated that impaired temporal processing results from age-related factors affecting neural synchrony (Frisina & Frisina, 1997). Older individuals with normal pure tone thresholds also exhibit difficulties in perceiving speech in noise same as that is observed in hearing impaired individuals. This suggests, some functional deficits central to the cochlea may be the reason in poor speech perception in noise (Humes, 1996). Affected neural synchrony caused by age related changes in older persons could be another reason for poor speech perception in noise. (Frisina & Frisina, 1997; Schneider & Pichora-Fuller, 2001).

The ability to understand speech and temporal processing gets affected in older adults (Yilmaz, Sennaroglu, Sennaroglu & Kose, 2007). As the age increases from 50 years to 89 years the prevalence of auditory processing disorders increases from 20% to 95% (Stach, Spetnjak & Jerger, 1990). Among individuals aged 55 years or older the prevalence of auditory processing disorder found to be 76.4%. This happens due to consequence of structural changes that happens in the auditory system (Golding, Carter, Mitchell & Hood, 2004). Helfer and Vargo 2009 reported that temporal processing may be an underlying cause for difficulty in understanding speech in competing speech in older adults.

In an attempt to see the effect of aging on ALLR, Tremblay, Billings and Rohila (2004) recorded ALLR in different age group and found that N1 and P2 latencies were prolonged for older listeners in response to the speech stimulus but not the tonal stimulus. While age-related delays were observed for both stimuli at the faster rate, these age effects are not seen when presented at slower stimulus presentation rates. Goodin, Squires, Henderson and Starr (1978) observed that P3 component latency increased at a rate of 1.64 ms/year. Some of the other components

(N1, P2 and N2) increased in latency with age, but the magnitude of these latency increases was not more than half of the magnitude of the P3 latency. And also aging affects the scalp distribution of the stimulus evoked components differently than the event related components. Thus suggesting that the aging process is reflected in the auditory evoked potential which is not the simple inverse of maturational processes.

The Pl-N1-P2 complex is generated in the thalamo-cortical pathways of the central auditory system, and is sensitive to the acoustics of the evoking stimuli (Vaughan & Ritter, 1970; Wolpaw & Penry, 1975; Hyde, 1997). The P1- N1-P2 is particularly useful in assessing speech-in-noise processing. It can be evoked using a variety of speech stimuli (Martin & Stapells, 2005). Their AEP components can be evoked in the presence of variety of background noises (Billings, Papesh, Penman, Baltzell & Gallun, 2012) and these potentials closely track the effect of background noise (Phillips & Hall, 1986). Furthermore, abnormal PI-NI-P2 responses have been associated with individuals who experience perception difficulties, such as older group, children with central auditory processing disorders (CAPD), children with learning disability and those with hearing impairment (Kraus et al., 2000; Oates, Kurtzberg & Stapells, 2002; Tremblay, Billings & Rohila, 2004).

Using an Acoustic Change Complex (ACC) paradigm, Harris, Mills and Dubno, 2007 reported “decreased sensitivity to intensity changes and significantly delayed response latencies in older subjects as compared to younger subjects, with greater differences at lower than higher frequencies”. These changes in response to latency have been associated with a general slowing of neuronal processing, as well as reduced neuronal synchrony or temporal jitter within the central auditory nervous system. Therefore, in addition to decreased sensitivity to changes in frequency, older subjects were found to exhibit changes in brain activity, including delayed latencies.

Need for study

Research findings and also clinical experience suggests that older adults need a diagnostic and management protocol distinctive to their needs. American Academy of Audiology Guideline for the Audiological Management of Adult Hearing Impairment (2005) proposed a protocol which stress on gaining an objective measure for hearing status and speech understanding under a multiple conditions including differing Signal to Noise Ratios (SNRs). It also insists to design objective tests to find out the listening difficulties and to determine listening strategies used in degraded/noisy listening conditions. This gives rise to the need for an objective test which measures the effect of noise on speech stimulation to compare with the behavioral measures. One approach to study speech in presence of noise encoded in the human central auditory system is to use cortical auditory evoked potentials (CAEPs). This can offer valuable information about the temporal encoding of large populations of cortical neurons recorded at the scalp (Billings, Bennett, Molis & Leek, 2011). Hence in the current study ALLR has been considered to objectively assess speech perception abilities.

Martin et al., (1997 & 2005) showed the differential effect of various type of noise on ALLR and how each noise differentially affects various peaks of ALLR. Although studies showed effect of age on cortical potentials, some studies (Maria, Pedro, Fleming, Rafaele & Elenara, 2010) have shown no effect. Maria José et al., (2010) stated that “latencies of auditory potentials N1 and P2 did not present any alterations on elderly patients who complained of speech understanding difficulty and who presented normal puretone audiometry on frequencies lower than 4000 Hz”, which suggested that the latency of such potentials is not affected by age of the individuals. The fact that these individuals (complaining of speech understanding) did not show alterations on latency of such potentials. This suggests that the hearing disorder might not have been present in the sites which were assessed in this study (cortical region).

Tremblay, Piskosz and Souza, (2003) found that speech sounds (/ba/-/pa/) used during perceptual testing, evoked abnormally prolonged N1 and P2 latencies in older adults. The authors have attributed different components of ALLR to different aspects of speech perception in normal individuals and have tried to correlate the parameters of ALLR and speech perception. However, the literature is scarce on the differential effects of different spectrum of noise on different peaks of ALLR. This is important since spectrum of noise differently affects spectrum of speech. This design will be helpful in older adult population since speech in noise performance is poor in the older adults (Moore, 2003). Further by correlating the outcome of electrophysiological test with a behavioral test will assist in relating the neural encoding to the activities of the individual in terms of speech identification difficulties. This in turn would help in shaping the selection of appropriate management option and counseling.

Aim of the study

The aim of the study was to find the effect of different types of noise spectrum on various peaks of ALLR in younger and older adults with normal hearing sensitivity and to investigate which component of ALLR best correlates with the speech perception ability.

Objectives of the study:

The objectives of the study were as mentioned below:

1. To see the effect of different test environment (quiet, low pass filter, high pass filter and speech noise) on different components of ALLR in younger adults with normal hearing sensitivity.
2. To see the effect of different test environment (quiet, low pass filter, high pass filter and speech noise) on different components of ALLR in older adults with normal hearing sensitivity.
3. To compare the effect of different spectrum of noise on different components of ALLR between the two groups.
4. To find out the correlation between different components of ALLR and SPIN scores.

Chapter 2

REVIEW OF LITERATURE

Human being has the unique ability to exchange thoughts through speech. In day to day life speech perception plays a very important role to every individual to achieve the successful communication. There are some instances where people find it challenging to understand speech, such as listening in background noise, understanding faster speech and so on. These difficulties are not only faced by person with hearing impairment but also by individuals with normal peripheral hearing sensitivity, older individuals with normal hearing abilities, children with learning disabilities and person with central auditory processing disorder.

One must understand how the auditory system works and encodes speech signals. How acoustic energy is converted to mechanical energy and into electric energy and coded at cortex. What are the factors which will hinder the auditory system to do so. In this review we will understand how different type of noises affect ALLR differently, effects of biological aging on cortical potentials, behavioral and electrophysiological studies revealing these effects in difficult listening conditions.

2.1: Role of ALLR in assessing cortex

Auditory late latency responses elicited by speech sounds have recently been used to determine the effect of phonologic and acoustic features on the cortical waveform (Crottaz-Herbette & Ragot, 2000) and to recognize the cortical areas which gets activated by these features (Mäkelä, Alku & Tiitinen, 2003). This objective measure provides us with a tool to examine the neurophysiological processes that cause our ability to perceive speech (Purdy, Katsch, Dillon, Storey, Sharma & Agung, 2004; Tremblay, Piskosz & Souza, 2003) and eventually may permit us to comprehend the neural encoding of speech in persons with impaired auditory pathways (Eggermont & Ponton, 2003).

Numerous studies have demonstrated that variety of speech sounds can reliably elicit CAEPs (Obleser et al, 2003; Sharma, Kraus, McGee & Nicol, 2002; Tremblay, Billings & Rohila, 2004) Other studies have shown that with the changes in spectral characteristics such as periodicity and amplitude of the stimulus cortical morphology also changes (Martin & Boothroyd, 1999,2000).

Additional significant finding is that the presence of CAEPs appears to correlate well with speech recognition ability in children with auditory neuropathy/dys-synchrony. In these children, pure-tone thresholds alone provide a poor indication of the ability to develop speech and language (Starr, Picton, Sininger, Hood & Berlin, 1996). Rance, Wesson, Wunderlich and Dowell (2002) observed normal latency, amplitude, and morphology of CAEPs in children with auditory neuropathy who had "reasonably good speech perception performance". Whereas the children with poor speech recognition scores showed absent CAEPs. For these reasons, CAEPs are thought to reflect the functional integrity of the auditory pathways involved in processing of complex speech stimuli (Novak, Kurtzberg, Kreuzer & Vaughan, 1989; Ostroff, Martin & Boothroyd, 1998; Tremblay et al, 2003).

2.2: Effect of noise on ALLR

Sharma, Pudy, Munro, Sawaya and Peter (2014) evaluated Effects of broadband noise on CAEPs at different loudness levels. They considered Young adults with no history of hearing concerns. Speech syllable /da/ was presented in the presence and absence of noise at three distinct loudness levels i.e. soft, comfortable, and loud, at a static signal-to-noise ratio i.e. +3 dB. They found at soft and loud levels P1 latency increased. Whereas N1 and P2 latency increased at all three levels of noise when compared with the quiet condition. In amplitude, at the loudest level P1 was significantly larger in quiet than in other noise conditions. For the softer level N1 amplitude was larger in quiet than in noise. P2 amplitude was reduced in the presence of noise to a similar degree at all loudness levels. They found that the differential effects of noise on P1, N1, and P2 suggest differences in auditory processes underlying these peaks. The combination of level and signal-to-noise ratio should be considered when using cortical auditory evoked potentials as an electrophysiological indicator of degraded speech processing.

Martin and Stapells (2005) used low pass masker on cortical ERP’s to investigate the effects of reduced audibility in low frequency spectral regions. Where the lowpass cutoff being 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, and speech stimulus used were /ba/ and /da/. And they found that as the cutoff frequency of lowpass noise was raised, ERP’s latencies increased and amplitudes decreased. N1 latencies showed significant changes when lowpass masker was raised to 1000 Hz where as N2 and P3 did not change until lowpass masker was raised to 2000 Hz. They concluded that, reduced audibility from masking affects N1 in differential manner compared to N2 and P3 and also N1 indicates the presence of audible stimulus energy, where N1 was present when the signal was heard but the peaks N2 and P3 were present only when the signals were discriminable, hence indexes behavioral discrimination of speech sounds.

Martin, Kurtzberg and Stapells (1997, 1999) also investigated the effect of highpass masking noise on ALLR. They presented speech sounds /ba/ and /da/ at 65 and 80 dB SPL Where the highpass cutoff being 4000, 2000, 1000, 500, and 250 Hz. They found that as the cutoff frequency of highpass masker was reduced, latencies increased and amplitude decreased. Gradual changes were seen in latency and amplitude of N1 as the masker cutoff frequency was lowered. N2 and P3 showed marked changes below a masker cutoff of 2000 Hz. This is the frequency region where the primary acoustic cues differentiating /da/ from /ba/ occur. As lower frequency regions were masked, ERP amplitudes decreased and latencies increased even further. Thus masking produced differential effects for different components in LLR.

Whiting, Martin and Stapells (1998) assessed The Effects of broadband noise on CAEPs. They considered ten normal-hearing adult listeners who were asked to actively discriminate (button-press response) the speech sounds /ba/ and /da/ presented in quiet (no masking) or with broadband masking noise (BBN). The BBN was presented at 50, 60, and 70 dB SPL when speech sounds were presented at 65 dB SPL and at 60, 70 and, 80 dB SPL when speech sounds were presented at 80 dB SPL. They observed that an average, the 50, 60, 70, and 80 dB SPL BBN maskers produced behavioral threshold elevations of 18, 25, 35, and 48 dB (average for 250 to 4000 Hz) respectively. The BBN maskers produced significant decreases (relative to quiet condition) in ERP amplitudes and behavioral discriminability. These decreases did not arise until the noise masker intensity (in dB SPL) was greater than or equal to the speech stimulus intensity, that is, until speech to noise ratios (SNRs) were ≥0 dB. N1 was identified even after N2, P3, and behavioral discriminability were absent. Whereas, ERPs and behavioral latencies showed significant decreases at higher (better) SNRs. Significant latency increased when the noise maskers were within 10 to 20 dB of the stimuli (i.e., SNR ≤ 20 dB). Masking noise affected N1 latency the most followed by N2 latency. P3 latency or behavioral reaction time was least affected. Results indicate that “decreased audibility as a result of masking affects the various ERP peaks in a differential manner and that latencies are more sensitive indicators of these masking effects than are amplitudes”.

2.3: Age related changes in auditory system

Aging can lead to a structural or functional deficit at various levels of the auditory system. These changes may occur in outer ear, middle ear, inner ear, auditory nerve and central auditory nervous system. The changes which associated with aging occur in outer ear are; excessive production of cerumen (Miyamoto & Miyamoto, 1995), growth of hair around the ear canal (Maurer & Rupp, 1979), ear canal collapse (Ballachanda, 1995), changes in physical property of the skin including loss of elasticity, atrophy and dehydration which leads to trauma and breakdown (Ballachanda, 1995) and enlargement of pinna (Tsai et al. 1958). It has been reasonably documented that surface ridges of pinna alter frequency response of incoming complex signals. These surface ridges provide acoustic gain at higher frequency components which are responsible for speech intelligibility. Pinna plays a major role in localization and elevation of sound. It’s the angular shape enables a comparison between reflected and incidental sound waves, thus providing a peripheral model for sound localization (Brttau, 1968; Gatehouse & Oesterrech, 1972). This structural capability, when enhanced by head movement and by additional information received by the other ear, supports ability to hear meaningful signals in adverse listening conditions. Hence changes in pinna with aging may contributes for hearing loss at higher frequency region, reduced speech discrimination and difficulty in listening in noisy environment. These functional changes in pinna may alter some extent of frequency response of auditory system.

The changes which occur primarily in middle ear associated with aging are; thinning, stiffening and loss of vascularity of tympanic membrane (Covell, 1952; Rosenwasser, 1964), atrophy and degeneration of the fibers of middle ear muscles and the ossicular ligaments (Covell, 1952), ossification of the ossicles (Covell, 1952), calcification of cartilaginous support of the Eustachian tube and muscle function that opens the tube (Belal, 1975). Covell (1952) and Rosenwasser (1964) stated that the deterioration of function of two middle ear muscles may lessen the amount of protection provided by these muscles in the presence of intense sound. Rosenwasser (1964) reported that degenerative changes in middle ear muscles and ligaments results in inefficient operation of middle ear ossicles, thus causing minor decreasing in hearing acuity and producing some degree of disorientation within conductive mechanism.

The organ of corti in inner ear is most susceptible to age related changes (Schuknect, 1993). It is reported that there is decrease in outer hair cells and inner hair cells number in individuals after 45 years of age (Engstrom, Hillerdal, Aurell & Bagger, 1987). In individuals more than 60 years of age the degeneration was wide spread along the turns of cochlea (Scholtz et al. 2001). The number of spiral ganglion cells reduces with increasing age with loss of 2000 neurons per decade (Otte, Schuknect & Kerr, 1978). It is reported that the atrophy of spiral ganglion cells in individuals above 50 years of age (Suzuki et al.2006). Individuals above 50 years of age auditory nerve appeared to be normal. However, there might be some myelin abnormalities in neurons (Xing et al.2012). Schuknect, (1964) reported structural atrophy of stria vascularis resulting in substantial interruption of transduser action activity within cochlea. The degeneration of stria vascularis is major factor in explaining the depression in hearing acuity observed in presbycusis.

Brain stem also undergoes major structural changes in older individuals (Kirake, Sato & Shitara, 1964). The fibers of lateral lamnisci also reduces with aging (Willott, 1991). It is reported that poor response to auditory stimuli in inferior colliculus with advancing age (Palombi & Caspary, 1996). Hansen and Reskenelson (1965) found severe degeneration in glial part of acoustic nerve as well as in white matter of brainstem. They reported that alterations were more pronounced in white matter of the hemispheres, next in the brainstem and finally in nuclei and the cochlea. Amplitude of Fo and F1reduced significantly above 55 years of age and noise further reduce the amplitude. Thus, it explains why elderly probably have problem in perceiving speech especially in noise (Kumar & Barman 2014).

2.4: Effect of age on speech perception

It is well documented that older individuals have difficulty in understanding speech. The most common problem that they report is inability to comprehend speech in the presence of a background noise irrespective of their hearing threshold.

Yilmaz, Sennaroglu, Sennaroglu and Kose (2007) assessed the speech recognition in noise at +10 dB SNR. They considered 53 women and 48 men having normal hearing sensitivity in six different age, ranging from 10 to 69 years with 10 years' interval between the groups. They noticed reduction in speech recognition scores after 50 years and significant reduction occurs after 60 years of age. The authors concluded that with advancing age the ability to identify speech in the presence of background noise decreases. The occurs due to the aging affects temporal processing which in turn affects speech perception.

Many researches demonstrated that the speech understanding ability and temporal processing gets affected in older adults. Helfer and Vargo (2009) obtained speech understanding in the presence of steady state noise and competing speech. Gap in Noise test was administered to assess temporal resolution. Results indicated that, performance of subjects with the age range of 45 to 54 years was significantly poorer than that of young adult group in the presence of competing noise. Although performance in this listening condition was unrelated to pure tone threshold, it was strongly correlated with scores obtained on Gap In Noise test. So the authors concluded that the temporal processing may be an underlying cause for difficulty in understanding speech in competing speech.

Wiley, Chappel, Carmichael, Nondahl and Cruickshanks (2008) investigated age related changes across different age groups of 48 to 59 years, 60 to 69 years, 70 to 79 years and 80 to 92 years using word recognition in quiet and in the presence single talker competing message. They found that older individuals performed poorer than younger groups in both condition. It also showed that males perform poorer than females. Detailed analysis revealed that degree of hearing loss accounted for largest portion of variance in speech identification in quiet and in the presence of single talker babble.

Calais, Russo and Borges (2008) assessed the hearing abilities of older individuals using monoaural speech perception test in quiet and in the presence of background noise. Fifty-five subjects in the age range of 60 years and above having normal hearing sensitivity were considered for the study. There was no gender effect noticed. All the participants had significantly lesser speech perception scores in the presence of noise. Thus they concluded that the results per se is not an indication of speech perception problem in noisy condition.

The above mentioned studies suggest that speech perception in quiet and noise is poorer in older adults. This may coexist with or without hearing loss. Hence, there is a need to adopt some strategy to improve speech perception in this population as a part of rehabilitation.

2.5: Effect of age on ALLR

Tremblay et al., (2003) evaluated the effects of age and age-related hearing loss on the neural representation of speech cues. In this study P1, N1 and P2 cortical responses were recorded from younger and older normal-hearing adults, as well as older adults with age-related hearing loss. Synthetic speech tokens representing 10 ms increments along a /ba/-/pa/ voice-onset-time (VOT) continuum were used to evoke the responses. They found that older adults with and without hearing loss had more difficulty discriminating 10 ms VOT contrasts. In addition, both older groups elicited abnormal neural response patterns. There were no significant age-related findings for P1 latency; however, N1 latencies were prolonged for both older groups in response to stimuli with increased VOT durations. Also, P2 latencies were delayed for both older groups. Researchers concluded that “some of the perceptual difficulties described by older adults might be due to age-related changes regulating excitatory and inhibitory processes”.

Tremblay, Billings and Rohila (2004) considered ten younger and ten older normal-hearing adults to see the effects of stimulus complexity and stimulus presentation rate across the age. A 1000 Hz tone burst as well as a speech syllable /pa/ were used to elicit the N1-P2 complex. Three different interstimulus intervals (ISI) were used (510, 910, and 1510 msec). they observed that, N1 and P2 latencies were prolonged for medium presentation rate (910 msec ISI) in older listeners in response to the speech stimulus but not for tone stimulus. Authors didn't find any age effect at a slower rate (1510 msec ISI). They concluded that "refractory issues might in turn affect synchronized neural activity underlying the perception of critical time-varying speech cues and may partially explain some of the difficulties older people experience understanding speech".

Billings, Penman, McMillan and Ellis (2015) studied the effects of hearing impairment and age on CAEPs and speech perception and how well CAEPs correlate with and predict speech perception in noise. Two groups of older participants (15 older normal hearing individuals (ONH) and 15 older hearing impaired individuals (OHI)) were tested using speech-in-noise stimuli to measure CAEPs and sentence-level perception of speech. The syllable /ba/ used to evoke CAEPs, and sentences were presented in speech-spectrum background noise at four signal levels (50, 60, 70, and 80 dB SPL) and up to seven SNRs (-10, -5, 0, 5, 15, 25, and 35 dB). These data were compared between groups to reveal the hearing impairment effect and then combined with previously published data for 15 young normal-hearing individuals to determine the aging effect. Results showed that Significant effects of age were seen for both CAEPs and perception, while hearing impairment effects were only found with perception measures. CAEPs correlate well with perception and can predict SNR50 to within 2 dB for ONH. However, prediction error is much larger for OHI and varies widely (from 6 to 12 dB). Authors concluded that "When background noise is present, SNR dominates both perception-in-noise testing and cortical electrophysiological testing, with smaller and sometimes significant contributions from signal level. It is interesting that the hearing impairment effect size was more than five times larger than the aging effect size for CAEPs and perception. Sentence-level perception can be predicted well in normal-hearing individuals; however, additional research is needed to explore improved prediction methods for older individuals with hearing impairment.

Based on the above review it can be concluded that since there are no studies which has explored the effect of different noise spectrum on cortical evoked auditory potentials in younger and older adults, the current study used /ba/ and /da/ as stimulus in four different test conditions (quiet, highpass noise, lowpass noise, speech noise). And also to correlate between components of ALLR and speech in noise test. It also helped in determining the effect of age in processing of these speech signals. CAEPs are thought to reflect the functional integrity of the auditory pathways involved in processing of complex speech stimuli (Novak et al., 1989; Ostroff, Martin & Boothroyd, 1998; Tremblay et al, 2003). Thus the need of the study is justified.

Chapter 3

METHOD

The objective of this study was to compare the effect of different types of noise spectrum on different components of cortical potentials in different age groups. Two groups of participants were considered in order to study these objectives. Following procedure was administered for the same.

3.1: Participants:

Two groups of normal hearing individuals were taken for the study.

Group I: Consisted of fifteen participants having Normal hearing, young healthy adults aged from 15 to 40 years.

Group II: Consisted of fifteen participants having normal hearing, older healthy adults aged from 50 to 70 years.

Participant selection criteria for both the groups:

As both the groups consisted of individual with normal hearing sensitivity, same selection criteria were adopted except for the age of the participants. The criteria were as follows:

- All the participants were native speakers of Kannada.
- Pure tone air and bone conduction thresholds of all the participants were within 25 dB HL (Goodman 1965) at octave frequencies from 250 Hz to 8000 Hz and from 250 Hz to 4000 Hz respectively
- Participant’s speech recognition thresholds were within ± 12 dB of PTA and speech identification scores were above 90% in both the ears in quiet condition.

- All participant’s had normal middle ear functioning with 'A' type tympanograms and acoustic reflexes present at least at 500 Hz and 1000 Hz in both the ears.
- All of them had normal auditory brainstem responses at 80 dBnHL with a repetition rate of 11.1/s.
- Transient-evoked otoacoustic emissions in both ears were present in all participants.
- None of them had any history of middle ear infections, speech and language disorder, neurologic disorder or any cognitive listening deficits.
- All participants showed normal tympanic membrane and earcanal in otoscopy examination.
- They did not have any complaint of illness at the time of testing.

For participants in group II (older adults), Screening Checklist for Auditory Processing in Adult (Vaidyanath & Yathiraj 2014) was administered to rule out Auditory processing disorders. Those who had cleared the test scoring less than 6 points were considered for the study.

3.2: Instrumentation:

- A calibrated two channel diagnostic audiometer, GSI-61 (Grason-Stadler Incorporation, USA) with Telephonics TDH 50 supra aural headphones and Radio ear B-71 bone vibrator calibrated as per ANSI (2004) was used for threshold estimation and speech audiometry.
- A calibrated GSI-tympstar (Grason-Stadler Incorporation, USA) clinical immittance meter, calibrated as per ANSI (1987) was used for tympanometry and reflexometry.

- ILO 292 DPEcho port system (Otodynamics Inc., UK) was used to measure transient evoked otoacoustic emissions.
- Intelligent Hearing Systems (IHS smart EP windows USB version 3.91) with AgCl electrodes and ER-3A insert earphones was used to record auditory brainstem and cortical responses.
- A personal computer with windows 8 operating system (32 bits) with Adobe Audition version 3.0 and Aux viewer version 1.37 software installed in it was used to record and mix different types of noise with speech syllables /ba/ and /da/.

3.3: Stimulus preparation:

1. Two naturally recorded speech syllables /da/ and /ba / were used for the study. These syllables were recorded using an adult native male speaker. A high quality Omni directional microphone was used to record. The microphone was kept approximately 6 inches away from the speaker’s mouth. This was recorded on to a PC at 32 bits and 44100/sec sampling frequency using Adobe Audition 3.0 software.

   Wilson et al., (1990) in their study observed that even though the female and male voice were recorded at ‘0’ vu, the intensity of the female voice had to be raised by 10-13 dB in quiet and 12-16 dB in noise to produce performance function similar to male voice. Hence, adult male was selected for recording the stimulus.
2. Speech syllables /ba/ and /da/ were recorded five times by a male native kannada speaker. Initial and last stimulus were deleted and center three stimuli were selected. Goodness test was carried out by giving recorded stimulus to 5

audiologists. Best rated stimuli /ba/ and /da/ were selected to mix with different types of noise.

The Speech stimuli /ba/ and /da/ were chosen since they vary in place of articulation and thus in the frequency domain (Martin et al., 1997). These speech syllables differ largely in the second and third formant onset transition frequencies. The overall frequency range of /da/ is broader than /ba/ with higher frequencies in the second and third formants. /ba/ has spectral energy more at low frequency as compared to other sounds which are of high frequency (Vesco, Bon, Ryan & Polich 1993). Also Martin and Stapells (1995,97) investigated the effect of high pass masking noise on ALLR using /ba/ and /da/ syllables. Hence finding obtained in the current study can be discussed with reference to their findings.

3. Three types of noise were considered, Low pass noise (<200Hz), High pass noise (>4000Hz) and Speech noise. Total duration of the stimulus was 500 ms. In which speech stimulus /ba/ and /da/ of 100 ms were embedded from 300 ms to 400 ms. Last 100ms of the stimulus was consisted of only noise. The initial and final 10 ms of all stimuli were ramped with a cosine window to ensure smooth onset and offset. All the above was carried out with Aux viewer version 1.37.

   Initial 300 ms noise was kept before stop consonants /ba/ and /da/ is for a reason that cortical potentials elicited by the onset of the noise will get over before 300 ms. Hence, the ALLR recorded after 300 ms will be the response of the stop consonant used. And later 100 ms of noise was used to avoid contamination of offset response due to offset of the stimulus and noise.

Each stimulus was consisted of 500 ms of noise onto which, a 100 ms stop consonant was mixed at 300 ms as shown in the figure below

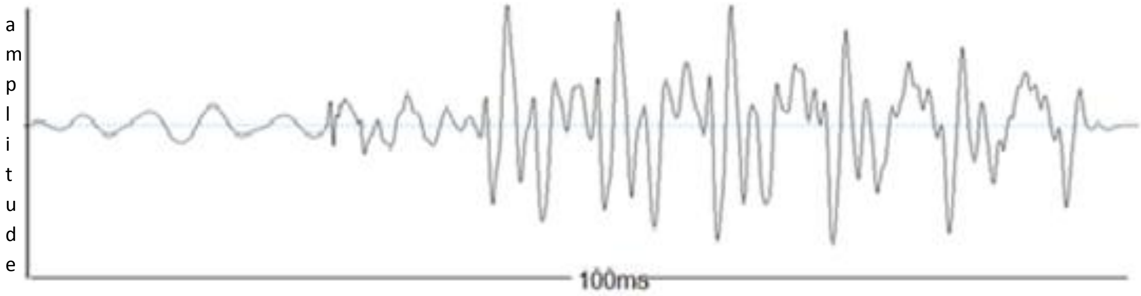

Figure 3.1: Syllable /ba/ of 100 ms.

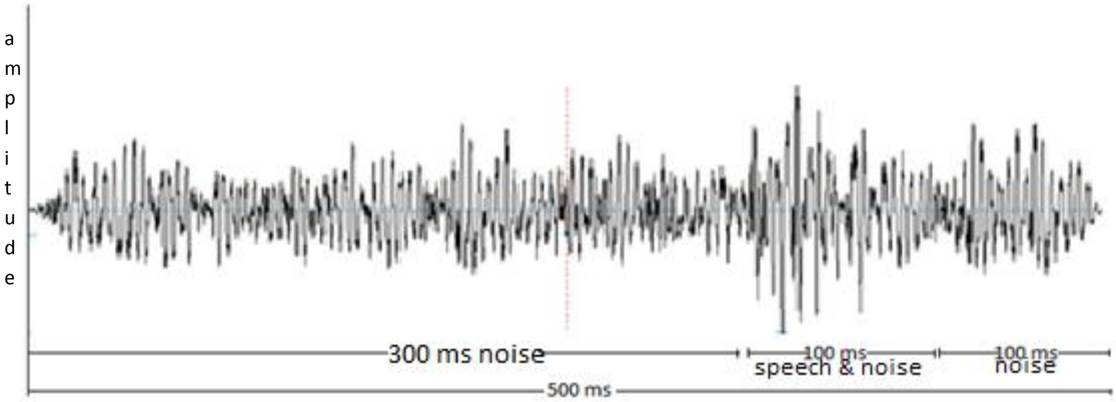

Figure 3.2: Stimulus of 500ms duration having initial 300ms and last 100ms speech noise and 100ms speech syllable /ba/ along with the speech noise at 300ms.

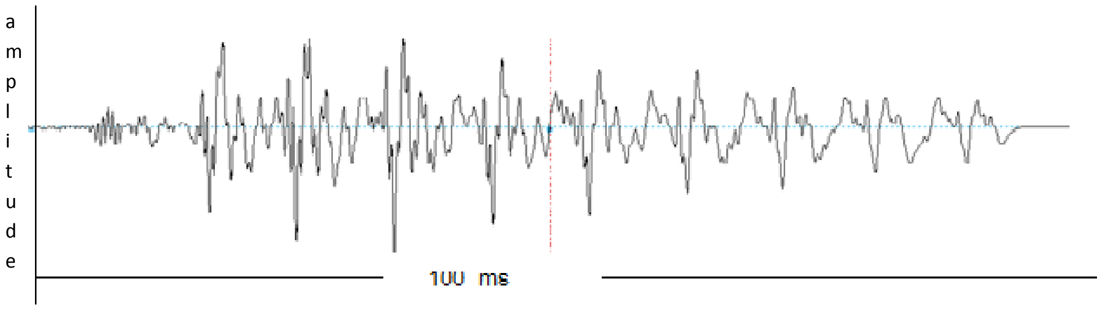

Figure 3.3: Syllable /da/ of 100 ms

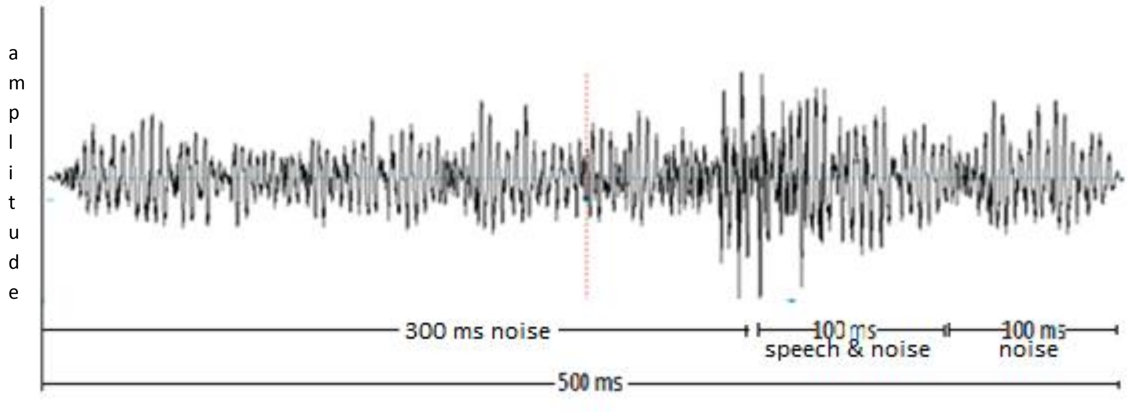

Figure 3.4: Stimulus of 500ms duration having initial 300ms and last 100ms speech noise and 100ms speech syllable /da/ along with the speech noise at 300ms.

A total of 8 stimuli were generated i.e.

i. /ba/ in quiet having 100 ms duration.
ii. /ba/ in high pass noise(>4000Hz) having 500 ms duration.
iii. /ba/ in low pass noise (<200Hz) having 500 ms duration.
iv. /ba/ in speech noise having 500 ms duration.
v. /da/ in quiet having 100 ms duration.
vi. /da/ in high pass noise(>4000Hz) having 500 ms duration.
vii. /da/ in low pass noise (<200Hz) having 500 ms duration.
viii. /da/ in speech noise having 500 ms duration.

Noise was generated using software Aux viewer (version 1.37). Root mean square (RMS) value of speech syllable /ba/ and /da/ for 100 ms was found out then it was equated with the RMS value of the noise of 500 ms duration to get 0dB SNR. Where the stimulus consisted of 300 ms noise before the speech syllable and 100 ms noise after speech syllable. After mixing of noise with the recorded speech syllable /ba and /da/ all the stimuli were converted to wave files and then loaded to Intelligent Hearing Systems (version 3.91) and calibrated to dBnHL.

3.4: Test environment:

Testing was carried out in an air conditioned sound treated room. Ambient noise level was within the permissible limits [ANSI S3.14991(R-2003)].

3.5: Procedure:

- ***Otoscopy:*** As an initial procedure, otoscopic examination was carried out to rule out external ear and tympanic membrane pathologies.
- ***A detailed case history*** *was taken before the commencement of routine Audiological assessment.*
- ***Pure-tone thresholds*** were obtained using modified version of Hughson and Westlake procedure (Carhart & Jerger, 1959) at octave frequencies between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction.
- ***Speech audiometry*** SIS scores were obtained using phonemically balanced words in kannada developed by Yathiraj and Vijayalakshmi (2005). The stimulus was presented at 40 dB SL (with reference to PTA i.e. average thresholds obtained at 500 Hz, 1000 Hz & 2000 Hz) in quiet.
- ***Immittance audiometry*** was carried out with a probe tone frequency of 226 Hz. Ipsilateral and contralateral acoustic reflex thresholds were measured for

500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. A minimum change in admittance of 0.03ml was considered as presence of acoustic reflexes.

- ***Transient-evoked Otoacoustic emissions*** were obtained for 260 nonlinear click stimuli. SNR of more than 6 dB in at least 3 consecutive octave frequencies in both ears, with reproducibility greater than 75% were considered as presence of OAEs (Jessica, Sinnet & Douglas 2013).
- ***Auditory Brainstem Responses*** were recorded using standard ABR protocol with 11.1/ sec repetition rate in all the participants.

Fifteen subjects from each group who passed all the criteria mentioned were selected for the study. All subjects were informed about purpose of the study and their consent for the participation in the study was taken.

3.6: Testing phase:

The testing phase was carried out similarly in both the groups. Testing involved 2 phases.

Phase I (behavioral): In this phase Speech in noise (SPIN) scores were obtained at 0 dB SNR. SPIN was administered through audiometer. It consisted of recorded stimulus of phonemically balanced Kannada word list (Yathiraj & Vijayalakhshmi, 2005) presented at 40dB SL through Telephonics TDH 50 headphones. Participants were instructed to repeat the words as they heard. Total of 25 words were presented, each word weighted 4%, maximum score could be obtained was 100%. Correctly repeated words were marked and scored.

Phase II (electrophysiological): Recording and Analysis of cortical evoked potentials.

3.7: Electrode placement:

Initially the electrode sites were cleaned using skin preparation paste (Nuprep). The silver chloride disc type of electrodes was placed on the scalp at electrode placement site with adequate amount of conduction paste. The non-inverting electrode was positioned on the vertex (Cz) and inverting electrode was positioned on the mastoid of the test ear (channel A). Ocular channel was added to eliminate ocular artifacts (channel B), non-inverting electrode was placed on superior rectus muscle and inverting electrode was place on inferior rectus muscle. Ground electrode was placed on Nasion. These electrodes were taped to prevent any dislocation of electrodes by means of surgical tape. Stimulus was presented through ER-3A insert ear phones from the IHS AEP instrument. The stimulus and acquisition parameters used to record cortical potentials are given below.

Table 3.1: *Stimulus and Acquisition parameters used for recording ALLR*

Stimulus parameter		**Acquisition parameters**	
Speech stimulus	/da / ;/ba/	Analysis Time	-50ms to 1024ms
Duration of stimulus	1) /ba/ and /da/ in quiet 100ms 2) In noise 500ms (300ms noise+100ms noise and speech+100ms post stimulus noise)	Band pass filter	1Hz-30Hz
Noise	Low pass noise (<200Hz), High pass noise (>4000Hz) and Speech noise.	Number of channels used	2 channels: Channel A: cortical potentials Channel B: ocular potentials
Stimulus level	70db nHL	Sweeps	120
Polarity	Alternating	Electrode Impedance	≤5 kΩ
Transducer	Insert earphones ER-3A	Inter Electrode Impedance	≤2kΩ
Repetition rate	0.9/sec	Number of trials	2 for replicability
Mode of presentation	Ipsilateral presentation of speech stimulus in quiet and in the presence of noise monaurally.	Notch filter	Off
		Artifact rejection	±100 micro Volt
		Gain	Channel A: 50000 (cortical potentials) Channel B: 5000 (ocular potentials)

ALLRs were obtained for all the 8 stimuli mentioned above. Blocks of 30 sweeps for each stimulus were recorded (randomly), blocks with less noise and better morphology were considered for averaging. Averaged waveforms obtained from same stimulus blocks were used to check for replication between waveforms and to aid in peak marking. The obtained peaks (P1, N1, P2 and N2) were marked by three experienced Audiologists. /ba/ and /da/ in quiet condition were considered as a baseline. ALLR parameters obtained in other three conditions were compared with these to see the effect of different noise spectrum.

Latencies and amplitudes of ALLR components were noted (N1 & P2). For quiet condition 1st ALLR was noted for both /ba/ and /da/, whereas for other 3 noise conditions 2nd ALLR starting after 300ms were considered, as the 1st ALLR was elicited from the onset of the noise. Latencies of all peaks were measured, baseline to peak amplitude (absolute) was measured for all components, i.e. N1 and P2. All values were tabulated and nonparametric statistics was done as there was a lot of variability in the data except for latency for speech syllable /da/ in younger adults. As the data was normally distributed.

Chapter 4

RESULTS

The present study was aimed to identify the effect of different type of noise spectrums on the cortical auditory evoked potentials in younger and older population. And to see the correlation between behavioral (speech in noise test results) and electrophysiological (ALLR) results in the above mentioned populations. This was performed by obtaining ALLR for stop consonants /ba/ and /da/ in four different test environment such as in quiet, highpass noise, lowpass noise and speech noise. 15 subjects were considered in both the groups (younger adults and older adults), for each subject ALLR and SPIN scores were obtained. Latency and amplitude of N1 and P2 were considered for the study. As P1 and N2 were absent in many subjects were not considered for further analysis. This is the reason why most of the studies (Tremblay, Piskosz & Souza, 2003) involving adults not involving attention did not consider P1 and N2. Amongst the components P2 is believed to be more prominent and N2 is least prominent (Allison, McCarthy, Wood, Williamson & Spencer, 1989). Obtained data were tabulated and analyzed using Statistical Package for Social Sciences (SPSS, version 20).

The data obtained were initially checked for normal distribution by administering Shapiro-Wilk’s test in SPSS (v 20). Most of the data did not follow the normal distribution, so, non-parametric tests were administered for the data except for the latency of N1 and P2 obtained using /da/ stimulus in younger adult’s group which followed normal distributions. The following is a summary of the statistical analysis that was performed to investigate the objectives of the present study.

- Descriptive analysis was done to obtain mean, median and standard deviation of N1 and P2 latencies and amplitude for both the groups across different test conditions.

- Mann-Whitney U test was done to compare the data between the groups at each test condition.

- As most of the data in the current study are not normally distributed Friedmann test was done to see the significant effect of different types of noise on ALLR within the group.

- If Friedmann test showed any significant effect, then Wilcoxen signed rank test for pairwise comparison was done to see between which two noise spectrum there exists a significant difference.

- Only for latency N1 and P2 of ALLR in younger adult group for speech stimulus /da/ parametric test was done, as the data was normally distributed. In this, repeated measures ANOVA was used to see the significant main effect of different types of noise.

- If repeated measures ANOVA showed significant main effect, Bonferroni test for pairwise comparison was done to see between which two noise spectrum there exists a significant difference.

- Correlation was done for N1 and P2 latency and amplitude of ALLR and SPIN scores using Pearson correlation for normally distributed data and Spearman correlation for the data which is not normally distributed.

For better understanding, the results of these tests are discussed under the following subheadings:

1. Descriptive statistics across groups and conditions for different ALLR parameters.
2. Comparison of effect of noise on ALLR components (N1 and P2) across group (younger vs older adults).
3. Comparison of effect of noise on ALLR parameter within the group.
4. Correlation of ALLR parameters with speech in noise test results.

4.1: Latency

4.1.1: Descriptive statistics across groups and conditions:

Descriptive statistics were carried out to obtain the mean, median and standard deviation for the latencies of N1 and P2 in different test conditions in both the groups for /ba/ and /da/ stimulus. The mean, median and standard deviations for N1 and P2 obtained at different test conditions by both the stimulus /ba/ and /da/in both the groups are tabulated and shown in the Table 4.1 and 4.2.

Table 4.1: *Mean, median and standard deviation (SD) of latency of N1 elicited by speech syllable /ba/ and /da/ in different test conditions for younger and older adults*

Stimulus	**Younger adults**			**Older adults**		
	Mean (ms)	**Median (ms)**	**SD**	**Mean (ms)**	**Median (ms)**	**SD**
/ba/ in quiet	114.86	110	20.38	110.33	108	22.41
/ba/ in highpass noise	122.26	122	25.25	110.86	104	14.37
/ba/ in lowpass noise	129.73	136	33.15	117.20	120	19.58
/ba/ in speech noise	126.70	125	20.86	104.26	100	28.30
/da/ in quiet	98.80	100	7.24	102.20	102	9.57
/da/ in highpass noise	113.46	112	12.29	110.86	110	7.18
/da/ in lowpass noise	101.33	110	23.09	114.20	116	5.85
/da/ in speech noise	104.73	102	23.61	116.66	118	14.81

The above table shows that, latencies of N1 elicited by speech stimulus /ba/ in younger adults are longer than older adults in all stimulus conditions. Also latency of N1 obtained in quiet condition is shorter than other conditions except in the presence of speech noise in older adult group. In younger adults N1 latencies are longer for noise condition than quiet. Latencies of N1 elicited by speech syllable /da/ in younger adults are earlier than older adults in all stimulus conditions except for highpass noise condition. And it can be observed that N1 latency in quiet condition are earlier than other three conditions in both groups.

Table 4.2: *Mean, median and standard deviation (SD) of P2 latency elicited by speech syllable /ba/ and /da/ in different test conditions for younger and older adults*

Stimulus	**Younger adults**			**Older adults**		
	Mean (ms)	**Median (ms)**	**Median**	**Mean (ms)**	**Median (ms)**	**SD**
/ba/ in quiet	173.33	170	22.24	196.33	182	40.48
/ba/ in highpass noise	202.66	218	39.85	209.66	234	50.20
/ba/ in lowpass noise	191.40	198	40.97	194.06	174	42.60
/ba/ in speech noise	178.06	165	46.64	176.60	199	41.45
/da/ in quiet	162.00	154	13.24	165.86	160	17.07
/da/ in highpass noise	187.06	190	22.19	188.93	180	34.06
/da/ in lowpass noise	172.00	174	18.09	182.80	178	17.05
/da/ in speech noise	186.60	187	43.59	199.86	186	20.44

The above table shows that for speech stimulus /ba/, latencies of P2 in younger adults are earlier than older adults except in the presence of speech noise. And also latency of P2 in quiet condition is earlier than other three conditions for younger adults. Whereas in older adults it can be observed that P2 latency is least for /ba/ in the presence of speech noise followed by /ba/ in the presence of lowpass, quiet condition and in the presence of highpass noise.

P2 latencies elicited by speech syllable /da/ in younger adults are earlier than older adults in all three conditions. And it can also be observed that for speech syllable /da/ in quiet condition P2 latency is earlier than other three stimulus conditions in both the groups.

4.1.2: Comparison of effect of noise on N1 and P2 latency across group (younger vs older adults) and conditions for /ba/ and /da/ stimulus.

Descriptive statistics showed there are variations in latencies of N1 and P2 elicited by /ba/ stimulus across conditions and groups. To see whether the group has any effect on N1 and P2 latencies in different stimulus condition Mann-Whitney U test was administered. The results of Mann-Whitney U test are given in the Table 4.3 for all test conditions.

Table 4.3: |Z| *-values along with significance level obtained for N1 and P2 latencies between the older adults and younger adults at all test conditions for /ba/ and /da/ stimulus*

Stimulus condition	**N1**		**P2**	
	Z-value	**Significant level**	**Z-value**	**Significant level**
/ba/ in quiet	0.81	0.41	1.45	0.14
/ba/ in highpass noise	1.43	0.15	0.70	0.48
/ba/ in lowpass noise	2.18	0.02*	0.31	0.75
/ba/ in speech noise	1.10	0.26	0.43	0.66
/da/ in quiet	1.25	0.20	0.716	0.474
/da/ in highpass noise	1.08	0.27	0.249	0.803
/da/ in lowpass noise	2.27	0.02*	1.00	0.317
/da/ in speech noise	1.62	0.10	0.85	0.393

*Note: * $p<0.05$*

Mann Whitney U test result showed a significant difference for N1 latency between the groups in two conditions i.e. /ba/ in lowpass noise and /da/ in lowpass noise. This suggest that lowpass noise has significant effect on N1 latency. No significant difference was seen for other conditions between younger and older adults. None of the test conditions showed significant difference for P2 latency. Indicating age related factors didn’t affect cortical potentials to a greater extent.

4.1.3: Within group comparison of effect of different type of noise on N1 and P2 latency elicited by speech syllable /ba/

To see the effect of noise on latencies of ALLR components (N1 and P2), Friedman’s test was administered. This was done separately for each group. The results of the effect of noise on latencies of N1 and P2 elicited by speech syllable /ba/ is given in the Table 4.4.

Table 4.4: *Chi-Square value along with degrees of freedom and significant level obtained for N1 and P2 latencies for /ba/ stimulus in younger and older adults*

	Younger adults		**Older adults**	
	N1	**P2**	**N1**	**P2**
Chi-Square	5.8	3.76	4.20	3.60
df	3	3	3	3
Significance level	0.13	0.28	0.24	0.30

*Note: * p<0.05*

It can be observed that none of the conditions exhibited significance difference for speech syllable /ba/ in all four conditions. Hence, Wilcoxon's signed rank test was not conducted to see pairwise comparision for different test conditions in.

4.1.4: Within group comparison of effect of different type of noise on N1 and P2 latency obtained by speech syllable /da/ in younger adults

To see the effect of noise on latencies of ALLR components (N1 and P2) repeated measure ANOVA was used as it was normally distributed data. If there was any significant difference Bonferroni test was employed to see the differences between different noise condition within the group. The results of the effect of noise on latencies of N1 and P2 elicited by speech syllable /da/ are given in the Table 4.5.

Table 4.5: *F-value along with degrees of freedom and significance level obtained for N1 and P2 latencies for /da/ stimulus in younger adults*

		df	**F**	**Sig.**
N1	**Sphericity Assumed**	3	2.11	0.11
Error	**Sphericity Assumed**	42	--	--
P2	**Sphericity Assumed**	3	3.46	0.00*
Error	**Sphericity Assumed**	42	--	--

*Note: * $p<0.05$*

It can be observed that P2 latency showed significant effect of noise for younger adults. Hence, pairwise comparison was carried out by using Bonferroni test only for P2 latency in younger adult group. The results are represented in the Table 4.6.

Table 4.6: *Bonferroni pairwise comparison of latencies of P2 for speech stimulus /da/ in younger adults*

P2 latency condition pair	**Mean Difference**	**Standard deviation**	**Significance level**
/da/ Quiet – /da/ Highpass noise	25.06	4.76	0.00*
/da/ Quiet – /da/ Lowpass noise	10.00	5.12	0.429
/da/ Quiet – /da/ Speech noise	24.60	12.11	0.370
/da/ Highpass noise- /da/ Lowpass noise	15.06	6.68	0.244
/da/ Highpass noise - /da/ Speech noise	0.46	10.78	1.00
/da/ Lowpass noise – /da/ Speech noise	14.60	12.44	1.00

*Note: * p<0.05(significant difference)*

It can be seen that, there was a significant diference in P2 latency obtained in the quiet condition and in highpass noise for speech stimulus /da/. This significant difference was seen only for P2 latency in younger adults. The results showed that the highpass noise had more effect on cortical potentials than other noises used in the study.

4.1.5: Within group comparison of effect of different type of noise on N1 and P2 latency obtained by speech syllable /da/ in older adult group

To see the effect of noise on latency of ALLR components (N1 and P2), Friedman’s test was administered. This was done separately for each group. The results of the effect of noise on latency of N1 and P2 elicited by speech syllable /da/ is given in the Table 4.7.

Table 4.7: *Chi-Square value along with degrees of freedom and significance level obtained for N1 and P2 latencies for /da/ in older adults*

	N1	**P2**
Chi-Square	14.59	22.71
df	3	3
Significant level	0.002*	0.000*

*Note: * p<0.05*

It can be observed that both N1 and P2 latencies elicited by speech syllable /da/ for older adults showed significance main effect within group across test conditions. Hence, pairwise comparison was carried out by using Wilcoxon's signed rank test or both N1 and P2 latency in older adult group. The results are represented in the following Table 4.8.

Table 4.8: *Wilcoxon's signed rank pairwise comparison of N1 and P2 latency for speech stimulus /da/ in older adults*

Stimulus	**N1**		**P2**	
	Z	**Significant level**	**Z**	**Significant level**
/da/ high pass - /da/ quiet	2.89	0.004*	2.75	0.006*
/da/ low pass - /da/ quiet	3.41	0.001*	3.01	0.003*
/da/ speech - /da/ quiet	2.67	0.008*	3.42	0.001*
/da/ low - /da/ high pass	1.59	0.111	0.94	0.346
/da/ speech - /da/ high pass	1.19	0.232	1.45	0.147
/da/ speech - /da/ low pass	0.56	0.571	3.05	0.002*

*Note: * $p<0.05$*

It was observed that there was significant difference in N1 and P2 latency obtained in quiet condition from rest of the stimulus condition (highpass noise, lowpass noise, speech noise). This significant difference was seen for both N1 and P2 latencies in older adults. The result showed that all type of noise had some effect on the N1 and P2 latencies.

4.2: Amplitude

4.2.1: Descriptive statistics across groups and conditions

Descriptive statistics were carried out to obtain the mean, median and standard deviation for the amplitudes of N1 and P2 in different test conditions in both the groups for /ba/ and /da/ stimulus. The mean, median and standard deviations for N1 and P2 obtained by different test conditions in both the groups are tabulated in the Table 4.9 and 4.10.

Table 4.9: *Mean, median and standard deviation (SD) of amplitudes of N1 elicited by speech syllable /ba/ and /da/ in different test conditions for younger and older adults*

Stimulus	**Younger adults**			**Older adults**		
	Mean (μv)	**Median (μv)**	**SD**	**Mean (μv)**	**Median (μv)**	**SD**
/ba/ in quiet	-3.39	-3.29	1.36	-3.08	-3.29	1.01
/ba/ in highpass noise	-1.93	-1.79	1.40	-1.52	-1.63	1.91
/ba/ in lowpass noise	-2.23	-1.81	1.37	-2.02	-1.48	2.02
/ba/ in speech noise	-0.38	-.23	1.29	-0.89	-.34	1.44
/da/ in quiet	-3.94	-3.90	1.49	-3.50	-3.19	1.49
/da/ in highpass noise	-2.87	1.97	1.68	-2.59	-2.68	0.99
/da/ in lowpass noise	-2.74	-2.17	1.47	-2.33	-2.11	1.32
/da/ in speech noise	-0.31	0.02	1.08	-2.05	2.63	1.46

The above table shows that, amplitude of N1 elicited by speech stimulus /ba/ in younger adults are greater than older adults except in the presence of speech noise. Also N1 amplitude obtained in quiet condition is greater than other three test conditions (lowpass noise, highpass noise, speech noise) in both the groups. Amplitude of N1 elicited by speech stimulus /da/ in younger adults are greater than older adults except in the presence of speech noise. Also N1 amplitude obtained in quiet condition is greater than other three test conditions (lowpass noise, highpass noise, speech noise) in both the groups.

Table 4.10: *Mean, median and standard deviation (SD) of P2 amplitude elicited by speech syllable /ba/ and /da/ in different test conditions for younger and older adults*

Stimulus	**Younger adults**			**Older adults**		
	Mean (µv)	**Median (µv)**	**SD**	**Mean (µv)**	**Median (µv)**	**SD**
/ba/ in quiet	4.39	4.54	2.24	2.33	2.49	2.43
/ba/ in highpass noise	3.27	3.34	1.85	1.94	1.70	1.89
/ba/ in lowpass noise	3.01	3.28	2.30	2.58	1.95	2.29
/ba/ in speech noise	2.57	1.73	1.37	1.77	1.10	1.26
/da/ in quiet	4.05	3.88	1.97	3.64	3.33	1.45
/da/ in highpass noise	3.85	3.41	1.65	3.29	2.72	2.45
/da/ in lowpass noise	3.65	3.59	1.68	3.10	2.96	1.81
/da/ in speech noise	2.63	2.92	1.23	3.15	3.51	1.66

The above table shows that for speech syllable /ba/, P2 amplitude in younger adults are greater than older adults in all four conditions. In younger adults, quiet condition has greater amplitude than other three conditions. In older adults, /ba/ in lowpass noise had greater amplitude than other three conditions.

For speech syllable /da/, P2 amplitude elicited in younger adults had greater amplitude than that of older adults except in speech noise condition. P2 amplitudes were greater for quiet condition than other three conditions for both the groups.

4.2.2: Comparison of effect of noise on N1 and P2 amplitude across group (younger vs older adults) and conditions for /ba/ stimulus

Descriptive statistics showed there are variations in amplitudes of N1 and P2 elicited by /ba/ and /da/ stimulus across conditions and groups. To see whether the group has any significant effect on N1 and P2 amplitudes in different stimulus condition Mann-Whitney U test was administered. The results of Mann-Whitney U test is given in the Table 4.11 for all test conditions.

Table 4.11: ǀZǀ *-values along with significance level obtained for N1 and P2 amplitudes between the older adults and younger adults at all test conditions for /ba/ and /da/ stimulus*

conditions	**N1**		**P2**	
	Z-value	**Significance level**	**Z-value**	**Significance level**
/ba/ in quiet	0.12	0.901	1.59	0.110
/ba/ in highpass noise	0.91	0.361	1.18	0.236
/ba/ in lowpass noise	1.05	0.290	0.95	0.340
/ba/ in speech noise	0.97	0.329	1.16	0.245
/da/ in quiet	0.85	0.394	1.41	0.158
/da/ in highpass noise	0.83	0.406	1.16	0.244
/da/ in lowpass noise	2.03	0.042*	0.70	0.480
/da/ in speech noise	3.15	0.002*	0.56	0.575

*Note: * p<0.05*

Mann Whitney test showed a significant difference in N1 amplitude between two groups i.e. /da/ in lowpass noise and /da/ in speech noise). No significant difference was seen for other conditions between younger and older adults. None of the test conditions showed significant difference in P2 amplitude between the groups.

4.2.3: Within group comparison of effect of different types of noise on N1 and P2 amplitude elicited by speech syllable /ba/

To see the effect of noise on amplitudes of ALLR components (N1 and P2), Friedman’s test was administered. This was done separately for each group. The results of the effect of noise on amplitude of N1 and P2 elicited by speech syllable /ba/ is given in the Table 4.12.

Table 4.12: *Chi-Square value along with degrees of freedom and significance level obtained for N1 and P2 amplitudes for /ba/ stimulus in younger and older adults*

	Younger adults		**Older adults**	
	N1	**P2**	**N1**	**P2**
Chi-Square	21.32	16.49	17.40	10.77
df	3	3	3	3
Significant level	0.000*	0.001*	0.001*	0.013*

*Note: * $p<0.05$*

It can be observed that conditions have significant effect on N1 and P2 amplitude for both younger and older adults. Hence, pairwise comparison was carried out by using Wilcoxon’s signed rank test for N1 and P1 in younger adults. The results are represented in the following Table 4.13 and Table 4.14.

Table 4.13: *Wilcoxon’s signed rank pairwise comparison of N1 amplitude elicited for speech stimulus /ba/ in younger adults*

Conditions (Amplitude)	**N1**		**P2**	
	Z	**Significance level**	**Z**	**Significance level**
/ba/ highpass - /ba/ quiet	3.12	0.002*	3.35	0.001*
/ba/ lowpass - /ba/ quiet	2.89	0.004*	2.44	0.014*
/ba/ speech - /ba/ quiet	3.35	0.001*	2.27	0.023*
/ba/ lowpass - /ba/ highpass	0.88	0.378	1.59	0.112
/ba/ speech - /ba/ highpass	1.25	0.211	1.98	0.047
/ba/ speech - /ba/ lowpass	1.30	0.191	0.05	0.955

*Note: *P<0.05*

It can be observed that for speech syllable /ba/ there is a significant difference in N1 and P1 amplitudes between quiet condition and other three conditions. However, there is no significant difference between any two noise conditions.

Similarly, pairwise comparison was carried out by using Wilcoxon’s signed rank test for amplitudes of N1 and P1 in older adults. The results are represented in the following Table 4.14.

Table 4.14: *Wilcoxon's signed rank pairwise comparison of N1 amplitudes elicited for speech stimulus /ba/ in older adults*

Conditions (Amplitude)	**N1**		**P2**	
	Z	**Significant level**	**Z**	**Significant level**
/ba/ highpass - /ba/ quiet	3.06	0.002*	0.71	0.478
/ba/ lowpass - /ba/ quiet	2.38	0.017*	0.79	0.427
/ba/ speech - /ba/ quiet	3.40	0.001*	2.10	0.036*
/ba/ lowpass - /ba/ highpass	1.36	0.173	2.85	0.004*
/ba/ speech - /ba/ highpass	1.25	0.211	2.32	0.020*
/ba/ speech - /ba/ lowpass	1.19	0.233	0.65	0.513

*Note: * P<0.05*

It can be observed that, for speech syllable /ba/ there is a significant difference in N1 amplitudes obtained between quiet and other three noise conditions. Whereas for P2 amplitude significant differences were seen between speech noise and quiet, lowpass noise and highpass noise, and speech noise and highpass noise.

4.2.4: Within group comparison of effect of different types of noise on N1 and P2 amplitude elicited by speech syllable /da/

To see the effect of noise on amplitudes of ALLR components (N1 and P2), Friedman's test was administered. This was done separately for each group. The results of the effect of noise on amplitudes of N1 and P2 elicited by speech syllable /da/ is given in the Table 4.15.

Table 4.15: *Chi-Square value along with degrees of freedom and significant level obtained for N1 and P2 amplitudes for /da/ stimulus in younger and older adults*

	Younger adults		**Older adults**	
	N1	**P2**	**N1**	**P2**
Chi-Square	22.05	5.25	11.61	6.74
df	3	3	3	3
Significant level	0.000*	0.154	0.009*	0.080

*Note: * p<0.05*

In this table we can see that there in a significant effect of noise on N1 amplitude for both younger and older adults. However, there was no significant effect of noise on P2 amplitude. Hence, pairwise comparison was carried out by using Wilcoxon's signed rank test was used for N1 amplitude in younger and older adult group. The results are represented in the Table 4.16.

Table 4.16: *Wilcoxon's signed rank pairwise comparison of N1 amplitudes elicited for speech stimulus /da/ in younger and older adults*

Condition pair	**Younger**		**Older**	
	Z-value	**Significant level**	**Z-value**	**Significant level**
/ba/ highpass - /ba/ quiet	2.35	0.019*	3.23	0.001*
/ba/ lowpass - /ba/ quiet	3.12	0.002*	2.38	0.017*
/ba/ speech - /ba/ quiet	3.35	0.001*	3.07	0.002*
/ba/ lowpass - /ba/ highpass	1.64	0.099	0.56	0.570
/ba/ speech - /ba/ highpass	2.89	0.004*	1.47	0.140
/ba/ speech - /ba/ lowpass	2.22	0.026*	0.47	0.638

*Note: * $p<0.05$*

From the table we can see that, in younger adults there is a significant difference in N1 amplitude between quiet and other three conditions and between speech noise and highpass noise and also between speech noise and lowpass noise condition. Whereas in older adults, significant difference is seen between quiet and other three conditions and no significant difference was observed between any two noise conditions.

4.3: Correlation between components of ALLR with SPIN test scores

One of the objective was to find the correlation between N1 and P2 latency of ALLR and SPIN for speech syllables /ba/ and /da/. To do so Pearson correlation was used for normally distributed data (N1, P2 latencies for /da/ in younger adults) and

Spearman correlation was used for the data which was not normally distributed (N1 and P2 latencies for /ba/ in both groups and for /da/ in older adults).

The correlation factors and significant level for N1 and P2 latencies elicited by /ba/ and /da/ stimulus are given in the Table 4.17.

Table 4.17: *r-value and significance level for SPIN scores and N1 and P2 latencies of ALLR components in younger and older adults across different stimulus condition*

ALLR components (latency)	**Younger adults (SPIN scores)**				**Older adults (SPIN scores)**			
	Speech syllable /ba/		**Speech syllable /da/**		**Speech syllable /ba/**		**Speech syllable /da/**	
	r-value	**Sig. level**	**r-value**	**Sig. level**	**r-value**	**Sig. level**	**r-value**	**Sig. level**
N1 in quiet	0.07	0.786	0.65*	0.009	-0.70**	0.003	-0.36	0.187
N1 in lowpass noise	0.32	0.233	0.15	0.591	0.41	0.120	0.34	0.203
N1 in highpass noise	0.23	0.398	0.09	0.742	-0.02	0.925	-0.34	0.204
N1 in speech noise	0.02	0.941	-0.07	0.805	0.22	0.425	-0.13	0.642
P2 in quiet	-0.40	0.132	0.41	0.129	0.43	0.104	-0.01	0.957
P2 in lowpass noise	-0.69*	0.009	0.01	0.964	0.22	0.420	-0.25	0.357
P2 in highpass noise	0.06	0.068	0.17	0.536	0.21	0.442	-0.03	0.914
P2 in speech noise	0.21	0.219	-0.00	0.991	0.03	0.914	-0.20	0.475

*Note: * $p<0.05$*

From the above table we can observe that there is strong negative significant correlation between SPIN scores and N1 latency of speech syllable /ba/ in quiet condition. Moderate negative significant correlation between SPIN scores and P2 latency for speech syllable /ba/ in the presence of lowpass noise in younger adults. Moderate significant correlation between SPIN scores and N1 latency for speech syllable /da/ in quiet condition for older adults. No other N1 and P2 latency obtained at other stimulus condition showed significant correlation with SPIN scores for younger and older adults.

Similarly, correlation between N1 and P2 amplitude of ALLR and SPIN was done for speech syllables /ba/ and /da/. Spearman correlation was used as the data was not normally distributed. The correlation factors and significant level for N1 and P2 amplitudes are given in the Table 4.18.

Table 4.18: *r-value and significant level for SPIN scores and N1 and P2 amplitude of ALLR components in younger and older adults across different stimulus condition*

ALLR components (Amplitude)	**Younger adults (SPIN scores)**				**Older adults (SPIN scores)**			
	Speech syllable /ba/		**Speech syllable /da/**		**Speech syllable /ba/**		**Speech syllable /da/**	
	r-value	**Sig. level**	**r-value**	**Sig. level**	**r-value**	**Sig. level**	**r-value**	**Sig. level**
N1 in quiet	-0.01	0.946	-0.12	0.666	0.16	0.549	-0.22	0.423
N1 in lowpass noise	0.03	0.898	-0.65**	0.008	-0.35	0.199	0.03	0.903
N1 in highpass noise	-0.15	0.579	-0.25	0.353	-0.11	0.685	0.30	0.276
N1 in speech noise	0.34	0.207	-0.15	0.584	-0.02	0.941	0.18	0.521
P2 in quiet	-0.32	0.235	-0.29	0.284	0.13	0.643	-0.35	0.200
P2 in lowpass noise	0.17	0.533	0.08	0.767	0.03	0.917	0.41	0.120
P2 in highpass noise	-0.3	0.163	-0.46	0.079	0.12	0.666	0.16	0.565
P2 in speech noise	0.05	0.851	-0.12	0.655	0.04	0.885	-0.29	0.287

*Note: * $p<0.05$*

From the above table we can observe there is moderate negative correlation between SPIN scores and N1 amplitude elicited by speech syllable /ba/ in the presence of lowpass noise observed in younger adults. None of the other N1 and P2 amplitude obtained at different stimulus condition showed significant correlation with SPIN scores in younger and older adults.

Chapter 5

Discussion

The aim of the study was to know the effect of different noise spectrum on the components of ALLR in different age group i.e. younger and older adults. And how well speech in noise test correlates with ALLR components in younger and older adults having normal hearing sensitivity. Cortical potentials were obtained for 8 stimulus conditions and SPIN test was done for all participants. Obtained data were tabulated and analyzed using Statistical Package for Social Sciences (version 20.0). Results obtained from both the groups are discussed below.

5.1: Latency:

5.1.1: Effect of spectrum of masker on latency in younger and older adults.

In the present study significance latency shift was seen for N1 in older adults only in lowpass noise suggesting lowpass noise affected older adults more than younger adults. This agrees with the previous investigators, Kim et al., (2012) found that N1 latencies to tones in quiet for older adults were delayed than younger adults when stimulus was presented at 60 dB SPL.

*Older adults had prolonged N1 latency in the presence of lowpass noise for speech stimulus /da/ and /ba/. However this significance was not observed in highpass noise and lowpass noise. This suggests that lowpass noise has significant effect on N1 latency***.** The result of the present study agrees with the previous investigators (Martin, Krutzburg & Staples 1999). They concluded that as the lowpass cutoff frequency increases N1 showed a smaller increase in latency and a smaller decrease in amplitude.

In contrast to above mentioned results, Martin and Stapells (2005) found that N1 latencies did not show latency shift until lowpass noise cutoff was raised to 1000 Hz. Significant delay was present only when low-pass noise masker was raised above 1000 Hz.

Speech sounds usually have more energy at low frequencies. Thus probably masking effect is observed more for lowpass noise. This could be the possible reason for prolonged latencies in N1.

5.1.2: Effect of spectrum of masker on ALLR latency.

For speech stimulus /ba/, there was no significant effect of different types of noise on N1 and P2 latencies in both groups.

This result is in consensus with the results obtained by Martin and Stapells (2005). They found that N1 amplitudes showed significant changes when the low-pass noise masker cutoff was raised to 1000 Hz. Also Martin, Sigal, Kurtzberg and Stapells (1997) found that significant latency shifts was seen in N1 latency when highpass cutoff of reduced to 1000 Hz. In the present study we have used lowpass cutoff as 200 Hz and highpass cutoff as 4000 Hz. This may be the reason for not getting significant difference.

In younger adults:

For speech stimulus /da/, it was found that P2 latency was significantly prolonged for highpass noise condition in younger adults. Latency prolongation was also present in other noise conditions, but did not reach statistical significance.

We can see similar results in other studies, Martin et al., (1997) found that presence of highpass noise decreases the audibility of the stimulus which may affect the latency of the response. Effect of highpass noise on /da/ is more pronounced may be because both /da/ and highpass nose has similar frequency range so highpass noise could have probably affected perception of /da/ which lead to prolonged P2 latency. Also since P2 comes at relatively longer latency it is possible that increased P2 latency suggests a distortion in central auditory processing.

In this study we have found significant latency shift for /da/ but not for /ba/. One reason for latency delay in /da/ but not in /ba/ may be due to their differing spectra. Another reason could be due to differences in rise time. /da/ had shorter rise time (19 ms) than /ba/ (43ms) and hence must have result in a differential neural activation (Davis & Zerlin, 1966).

In older adults:

For speech stimulus /da/, prolongation of latencies was found in all noise conditions with respect to quiet condition. Prolongation of latency could be due to reduction in audibility due to noise (Martin & Stapells, 2005) as well as due to reduced speed of sensory information processing (Leppanen & Lyytinen, 1997).

Though there was a trend for increased latencies with noise, statistical significance was not found in some noise conditions due to larger variability. N1 latency had a trend to be more prolonged for /da/ in high pass noise than /da/ for low pass noise probably due to its high frequency spectral energy.

Statistically significant shifts in latency were found for N1 in highpass noise and lowpass noise conditions and for P2 in lowpass noise and speech noise condition.

These results are in consensus with the results obtained by Martin, Sigal, Kurtzberg and Stapells (1997). They found that N1 showed gradual changes as the lowpass masker cutoff frequency was lowered. N2, P3, and behavioral measures showed marked changes below a masker cutoff of 2000Hz.

In contrast to above mentioned results, Martin and Stapells (2005) found that N1 latencies showed significant delay when the low-pass noise masker was raised to 1000 Hz, whereas other latencies i.e. N2 and P3 latencies did not change significantly until the low-pass noise masker was raised to 2000 Hz. Showing lowpass maskers affects N1 in a differential manner compared with N2 and P3. N1 indexes the presence of audible stimulus energy, being present when speech sounds are audible, whether or not they are discriminable.

5.2: Amplitude:

5.2.1: Effect of spectrum of masker on amplitude in younger and older adults.

There was a trend towards reduction in amplitude in the older group compared to the younger group for both N1 and P2 amplitudes. Statistical significance however was achieved only for /da/ in low pass noise condition.

This agrees with the previous investigators, Tremblay, Billings and Rohila (2004) found that N1 amplitude reduced for older adults. These age effects were absent when stimuli were presented at a slower rate (1510 msec Inter stimulus interval). Tremblay, Piskosz and Souz (2003) also found that N1 amplitude was reduced for older group. Dum, (1983) studied cortical potentials in guinea pigs and found that threshold was 44 dB higher in the cortical potentials in old animals than young animals.

One potential explanation for this age effect might be the age-related refractory differences in younger and older auditory systems. Refractory issues might in turn affect synchronized neural activity and hence result in reduced amplitudes. (Tremblay, Billings and Rohila (2004).

It was also observed that N1 amplitude in the older group was significantly more than that of the younger group for /da/ in speech noise. This Increase in amplitude in older adults may be due decrease in inhibition at the cortical level (Bromfield, Cavazos & Sirven, 2006). Similar results have been reported in those with learning disability (Anderson, Chandrashekar, Yi & Kraus, 2010) and hearing loss (Oats, Kurtzberg & Staplles, 2002).

5.2.2: Effect of spectrum of masker on amplitude in different conditions.

In younger adults:

There was a trend towards reduction in amplitudes of both N1 and P2 in all noise conditions when compared to quiet condition. Significant differences were found between quiet and all noise conditions for both N1 and P2 amplitudes in /ba/ and only for N1 amplitude in /da/. This was true for both younger and older adults. Speech noise caused a greater reduction in amplitude than low and high pass noise conditions for /da/ in both the groups, but was significant only in the younger adults.

These results are in consensus with the results obtained by Martin and Staplles (2005). They found that N1 amplitude significantly reduced in the presence of different spectral noises. Martin et al., 1995 found that N1 amplitude decreased by 0.63 mV when the highpass cutoff was increased to 2000 Hz.

Decreased audibility results in decreased ERP amplitudes (Martin & Stapells, 2005). The lowpass noise and speech noise probably affects the audibility, hence affected N1 amplitude. Whereas high frequency noise and speech noise probably has masked perception of /ba/, which leads to decreased P2 amplitude.

5.3: Correlation between ALLR and Speech in noise test results

In latencies, Strong negative significant correlation was found between SPIN scores and N1 latency of /ba/ in quiet condition in older adults. Moderate negative significant correlation was found in P2 latency of /ba/ in lowpass noise in younger adults.

Negative correlation seen between SPIN scores and N1 and P2 latencies hints us about the relation between behavioral and electrophysiological aspects of speech perception. This negative correlation indicates that as the SPIN scores increased N1 and P2 latencies decreased. Suggesting latencies were better for individuals who had better SPIN scores. This agrees with the previous investigators, Narne and Vanaja (2005) found that there were better latencies and amplitudes for higher SPIN score group in individuals with auditory neuropathy.

It was also observed that there was moderate significant negative correlation between SPIN and N1 amplitude for /ba/ in lowpass noise. These correlations in this study are contradictory. Possible potential reason for this contraindication may be the inhibition at the cortical level (Bromfield, Cavazos & Sirven, 2006). Oats, Kurtzberg and Stapells (2002) found better latencies and amplitudes in individuals with hearing loss who had poor speech scores than that of normal hearing individuals. Anderson et al., (2010) also found similar results in learning disability children.

Chapter 6

Summary and conclusion

Cortical auditory evoked potentials (CAEPs) is one of the approach to study speech in the presence of noise encoded in the human central auditory system. This can offer valuable information about the temporal encoding of large populations of cortical neurons recorded at the scalp. Older adults with aging experiences global decline in almost all aspects of body structure including auditory system. It is known that older adults with normal hearing sensitivity often have difficulty in perceiving speech in the presence of noise. So, these individuals need a diagnostic and management protocol distinctive to their needs. Thus, this study was taken with the purpose

a) To determine how younger adults and older adults differ in their performance for different components of ALLR across different spectrums of noise.

b) To know the effect of different spectrum of noise on different components of ALLR within the groups.

c) To find out the correlation between different components of ALLR and SPIN scores.

To achieve the above, 15 younger adults with normal hearing sensitivity with the age range of 15 to 40 years and 15 older adults with normal hearing sensitivity with the age range of 50 to 70 years were taken. Two naturally recorded speech syllables /da/ and /ba / in four different test environments (quiet condition, Low pass noise (<200Hz), High pass noise (>4000Hz) and Speech noise) were used for the study. The collected data was statistically analysed and the correlation between SPIN and ALLR was checked.

Analysis of the data revealed the following results.

Effect of groups on latencies and amplitudes:

- *For latency, it was found that older adults had longer N1 latency in the presence of lowpass noise for both speech stimulus /da/ and /ba/.*
- *For amplitude, there was a trend towards reduction in amplitude in the older group compared to the younger group for both N1 and P2 amplitudes. Statistical significance however was achieved only for /da/ stimulus in low pass noise condition.*

These differences might be the outcome of the related refractory differences in younger and older auditory systems. Refractory issues might in turn affect synchronized neural activity and hence result in reduced amplitudes and prolonged latencies.

Effect of conditions on latencies and amplitudes:

- *For latencies , it was found that P2 latency was significantly prolonged for highpass noise condition in younger adults for speech stimulus /da/. In older adults latency shift was found in N1 in highpass noise and lowpass noise conditions and for P2 in lowpass noise and speech noise condition.*
- *For amplitudes, there was a trend towards reduction in amplitudes of both N1 and P2 in all noise conditions when compared to quiet condition. Significant*

differences were found between quiet and all noise conditions for both N1 and P2 amplitudes in /ba/ and only for N1 amplitude in /da/ in both populations.

The decreased audibility probably resulted in decreased ERP amplitudes (Martin & Stapells, 2005). The lowpass noise and speech noise probably affects the audibility, hence affected N1 amplitude. Whereas high frequency noise and speech noise probably has masked perception of /ba/ and /da/, which leads to decreased P2 amplitude.

Correlation between speech in noise scores and ALLR parameters:

In the study a strong negative significant correlation was found between SPIN scores and N1 latency of /ba/ in quiet condition in older adults. Moderate negative significant correlation was found within P2 latency of /ba/ in lowpass noise in younger adults.

Negative correlation here indicates higher the SPIN scores better the latencies. With the above correlations we can conclude that cortical potentials can be used to comment on speech perception in younger and older adults.

Conclusion:

From the above results it can be concluded that Cortical electrophysiological measures are sensitive to subtle changes in the auditory processing which takes place in the older individuals. So assessing cortical potentials in noise one can partly understand the effects of noise on audibility and perception of sounds. In this study we found that, Low pass noise and speech noise are better maskers and more deleterious to efficient auditory processing. Amplitudes of later peaks are reduced in the older individuals possibly indicating the beginning of possible perceptual deficits. In the study we found significant correlation between N1, P2 latencies and SPIN scores, suggesting cortical potentials can be used to partly study the speech perception abilities of an individual.

Implications of the study:

- It is hoped that the study will lead to an increased understanding of the components in LLR that could be differential for different noises in older adult population.

- By comparing the same with the ALLRs of normal individuals in noise, it can be possible to note which component of ALLR is vastly deviant in the presence of noise.

- It can also be test to correlate behavioral speech in noise deficits to electrophysiological deviations in noise.

- This study would give us whether elderly adult perceive differently from young adults.

- Added information to the literature.

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