Chapter-1

Introduction

INTRODUCTION

With age as an important factor associated with acquired hearing loss in the adult population, difficulty in speech discrimination is reported under various conditions such as in noisy or in quiet conditions *(Fitzgibbons & Gordon-Salant,2010).*The aspect primarily contributing to this difficulty is reduction in temporal processing speed *(Fitzgibbons & Gordon-Salant,1996; Lister & Richard ,2005;Smurzynski& Probst,1999; Wingfield, Sandra ,Peelle & Cox 2006).*As the age advances, the reduction in the processing of frequently changing acoustic cues such as formant transitions, which consists of rapidly changing frequency and amplitude could be seen as the predominant reason for the reduction of speech discrimination *(Mendelson & Lui, 2004).* It has been proven by various researchers that speech discrimination errors commonly occur in the absence of evident age-related peripheral changes, therefore advocating that these changes could be at the central nervous system level.

As the society matures, there is an increase in the number of individuals in their 50s to 80s and longer, as a consequence of factors such as advanced health care and the related treatment outcome. Within the elderly section of our society, hearing loss is reported to be the second debilitating condition after arthritis *(Bielefeld, Tanaka, Chen & Henderson, 2010).* The causes of senile deafness or presbycusis are not well understood. Functional deterioration of the nervous system is considered as the fundamental attribute of aging. This functional decline in the central nervous system may be the result of reduction in neuronal connections rather than lack of neurons in the aging individuals. Presbycusis is one of the most prevalent ailment of the geriatric population which is affecting over fifty percent of the individuals beyond 75 years of age *(Bao & Ohlemiller,2010).*Thereby, with the steady rise of the elderly

population round the globe, there is a dire need to comprehend how these changes are affecting the aged individuals' hearing abilities, speech processing and their overall quality of life.

Speech sounds consists of very highly time varying acoustic cues. The capability to accurately encode such complex temporal aspects of speech signal is an integral component in speech perception. This capability mandates high resolution temporal processing in milliseconds. Age-related changes in the complex neuroanatomical and neurophysiological system can cause altered neural timing that may subsequently lead to issues with speech recognition, as evident in geriatric listeners (*Pichora-Fuller & Pamela, 2003).*The most predominant effect often reported by individuals is at the central level for the acoustic processing in difficult situations. The clinicians have therefore inferred the existence of an aging component centrally and have conducted studies on its effects on hearing. However, most of the studies have been done either psychoacousitcally or partly electrophysiologically that could only give naive superficial information about the complex auditory processing abilities in older population *(Pichora-Fuller & Pamela, 2003,Bao & Ohlemiller, 2010).*

Majority of the aging individuals have reported difficulty in speech perception particularly with background noise *(Dubno, Lee, & Matthews, 1997.; Pichora, Schneider, & Daneman, 1995).*The geriatric population most often complain that ''I can hear your speech but I cannot comprehend your speech'' .The reason being the speech signal consists of very complex multiple time-varying acoustic cues, which makes it more difficult for the older adults to understand the speech. Aging has negative effect on the capability to process temporal cues; this could be one of the possible reasons for the impaired speech perception in

the elderly *(Frisina & Frisina, 1997).* Recent literature on "how the human auditory system responds to speech in older adults" has revealed that not only peripheral hearing loss relates to abnormal speech perception but also there is a strong evidence of central nervous systems contributions in impaired perception *(Wong, Ettlinger, Sheppard, Gunasekera, & Dhar, 2010).*

Several perceptual studies have been done using gap-detection thresholds *(Schneider & Hamstra, 1999),* Voice Onset Time (VOT) discrimination *(Tremblay, Piskosz, & Souza. 2003),* Temporal Modulation Transfer Functions (TMTFs) *(Ning, Mills, Ahlstrom &Dubno, 2008)* and masking level differences *(Strouse, Ashmead, & Ohde, 1998)* on humans to reveal the age associated changes in temporal resolution. Age associated alterations in temporal resolution have also been reported in human physiological studies using silent gaps in noise *(Clinard ,Tremblay, & Krishnan, 2010),* VOT *(Tremblay, Piskoz & Souza., 2002,Tremblay et al 2003),* sound duration *(Ostroff, Martin, & Boothroyd, 1998),* Amplitude- Modulated (AM) tones *(Leigh & Fowler, 2006),* and interaural timing cues *(Rossa, Tremblay & Picton, 2007).*

Auditory evoked potentials (AEPs) represent the electrical events generated within the auditory system in response to a repeated, controlled auditory stimulus. The continuous *Electroencephalogram (EEG)* can be recorded by placing electrodes on the surface of the scalp. The auditory systems response can be subsequently attained and can be computed with computer averaging methods. AEPs facilitate the objective examination of neural encoding and depiction of vital speech signals at the subcortical and cortical levels of the aging central auditory system. Several studies have reported using AEPs to understand the neural processing of many spectral and temporal aspects of speech at the cortical region

*(Kaukoranta, Hari, & Lounasmaa, 1987;Ostroff et al 1998; Martin & Boothroyd 1999, 2000,Tremblay, et al, 2002;Tremblay et al 2003;Tremblay, Billings & Rohila 2004).*Individuals with altered speech perception such as Auditory Neuropathy Spectrum Disorders (ANSD) and children with learning problems have reported aberrant speech-evoked cortical auditory potentials *(Cunningham, Nicol, Zecker, Bradlow & Kraus. 2000;Kraus, et al. 2000.;King, Warrier Hayes & Kraus, 2002, Purdy, Kelly, &Davies, 2002.;Rance, Wesson, Wunderlich, & Dowell, 2002).* Numerous studies have thus reported abnormal neural encoding of time dependent acoustic signals at the cortical region in elderly individuals as against the younger group *(Tremblay et al. 2002, 2003, 2004; Harkrider ,Plyle&Hedrick, 2005).*

The effect of aging on the neural ability to process speech signals at the subcortical region is still unclear. Several studies done to explore the influence of aging on the Auditory Brainstem Response (ABR) in response to click stimuli continue to be debatable. Many researchers have reported delayed click-evoked ABR (C-ABR) peak latencies in aging population in contrast to the younger individuals *(Rosenhamer, Lindstrom, & Lundborg, 1980.; Allison, Hume, Wood, & Goff, 1984.; Boston & Moller,1985; Rosenhall, Bjorkman, Pedersen, & Kall, 1985; Debruyne 1986; Rosenhall, Pedersen, & Dovetall, 1986.;Batra, Kuwada & Maher,1986;Trune, Mitchell, & Phillips, 1988; Oku & Hasegewa 1997).* There is also a section of researchers that have reported nil or minimal influence of aging on C-ABR latencies *(Otto & McCandless, 1982; Jerger & Johnson 1988; Anias, Lima,& Kos, 2004).* Further, the C-ABR latency differences between the older and younger groups have been attributed to the differences among the groups in audiometric threshold rather than the reduced neural encoding at the central auditory system *(Harkins, 1981; Otto & McCandless,*

1982; Martini, Comacchio, & Magnavita, 1991; Ottaviani, Maurizi, Alatri,&Almadori. 1991).

It is believed that a complex stimulus such as speech would be an efficient stimulus as compared to the simple click stimulus to study the effect of aging on the neural encoding of rapidly changing acoustic cues at the subcortical level. Musical sounds, non- speech vocalizations, speech sounds such as vowels, syllables, words and phrases were the complex speech sounds used to elicit ABRs as reviewed by *Skoe and Kraus (2010).*Majority of the research studies predominantly used the synthesized consonant– vowel (CV) syllable /da/ as complex stimuli to record the auditory brain stem responses *(Cunningham, Nicol, Zecker, Bradlow & Kraus,2001; King et al. 2002; Russo, Nicol, Musacchia & Kraus, 2004; Wible, Nicol & Kraus.2004, Wible, Nicol & Kraus, 2005; Kraus & Nicol 2005; Russo, Nicol, Zecker, Hayes & Kraus, 2005; Johnson, Nicol, Zecker, Bradlow, & Kraus, 2008; Banai, Hornickel ,Skoe. Nicol, Zecker & Kraus, 2009; Hornickel, Skoe & Kraus,2009).* An exclusive peek into the understanding of how the human brain stem processes integral features of speech signals are facilitated through the scalp-recorded brainstem responses *(Krishnan, 2002).* The brainstem responses to these speech stimuli have two important constituents, the *onset* and *sustained responses - frequency-following response*. These components represent the chief acoustical aspects such as the origin and filter attributes of the specific speech cues *(Chandrasekaran & Kraus, 2010; King et al, 2002).*Therefore*, Speech-evoked ABR (SEABR)*is defined as the neural responses to the various synthesized and natural speech stimuli.

The SEABR describes the precise neural representation of the time dependent sequences in response to a CV stimulus *(Johnson, Nicol & Kraus.2005; Akhoun, Gallego,*

*Moulin, Menard, Veuillet & Vachon, 2008a;Chandrashekaran& Kraus 2010).*Encoding of syllable onset and offset constitute the transient portion of the SEABR, while the frequency following response (FFR) to the fundamental frequency and vowel formants constitute the sustained component of the response. Diverse mechanisms of temporal processing at the brain stem regions are considered to be responsible for the transient and sustained components *(Johnson et al. 2005; Akhoun, et al. 2008b).* However, it is premature to generalize these findings. Deficits in neural encoding at the auditory brainstem level could possibly be the origin for impaired speech perception, which generally co exists in children with reduced temporal resolution. SEABR is thus considered as a biological indicator for auditory temporal processing capability *(Johnson et al ,2008*: *Krizman, Skoe, &Kraus 2010).*

Children with various language based disabilities have shown aberrant neural encoding of speech sounds at the brain stem level when elicited with the CV /da/ stimulus *(Cunningham, et al. 2001; King et al. 2002; Hayes, Warrier, Nicol, Zecker, & Kraus, 2003;Wible et al. 2004, 2005; Banai, Nicol & Zecker.2005; Russo et al. 2005; Song ,Banai, Russo & Kraus, 2006).* Numerous studies reported in children with poor auditory processing abilities have shown abnormal SEABRs, but normal C-ABRs.*(Kraus et al. 2000; Cunningham et al. 2001,; King et al. 2002;Wible et al. 2004, 2005; Banai et al. 2005; Johnson et al. 2005; Song et al. 2006; Johnson, Nicol, Zecker & Kraus, 2007).*

Limited studies are reported in the literature on how the aging brainstem encodes the speech sounds. These few reported studies have taken only a limited number of participants into account *(Vander Werff& Burns, 2011).*However, these results should be interpreted with caution, specifically the effect of age and hearing impairment on the SEABR, as the sample

studied was not considerably large. Therefore, studies analyzing speech perception and temporal processing capabilities in aging individuals at the brainstem level by using SEABR could be a better way of exploring the possible clinical relevance of speech processing at the brainstem level in younger and older adults. Further, it would delineate the clinical requirement for the hearing aid selection as well.

1.1 Need for the study

It has been observed that older listeners express difficulty in hearing tasks that involve multiple features of the auditory temporal processing. Majority of the tasks utilized comparatively simple stimuli. The listeners were subsequently asked to identify short temporal gaps between two consecutive sounds. Profound effect of aging was indicated when the testing was performed with short duration stimuli or with stimuli events with rapid presentation rates. The particular origin of age related hearing issues with rapid changes in speech is still not clear and seems to be diverse and complex. It is believed that this issue could be partly linked to the acoustic diverse complexity of the speech cue in itself. However, the acoustic characteristics of rapid speech could be described as auditory events with decreased periods of concurrent sound segments and silence gaps, along with the subsequent shifts in sequence timing features. The processing difficulties in aging listeners could thus be attributed to any deficiency of sensitivity to these varied temporal aspects of speech sequences. Nonetheless, the studies on older listeners using stimulus sequences comprising of speech sounds is limited. Thus, minimal information is available regarding the particular temporal processing deficiencies in this section of the population.

While several studies focus on the influence of aging on the auditory system, relatively very few studies have analyzed if aging has an effect on the neural temporal processing and its ability to process rapidly varying acoustic signals like speech cues. The auditory brainstem response to speech resembles the spectro-temporal aspects of the stimulus and phase locked to speech formant structure below 1000 Hz. The upper limit of brainstem phase-locking can also be observed in both the spectral and temporal domains. Thus, the SEABR may be used as an indicator of precise neural encoding of vital time – varying speech sounds at the sub-cortical level in the elderly listeners. The ability to process time varying speech signal is an area of interest for many researchers. Lacks of strong methodological bases and limited subject participation have been a concern regarding the efficacy of the studies that have questioned its reliability. Much of the earlier studies using SEABR are concentrated mainly on children using single syllable/da/. This could be attributed to its remarkable fidelity and the ability to represent the phase locked responses from the brainstem.

Till date, to our knowledge, there is a dearth of concrete studies on how speech consonants are processed and especially, the ability to encode consonants at the brainstem level in young, middle aged and older adults. Thus, the present study is an attempt to examine the SEABR in three sections of adult populationie; young, middle and older adults with normal hearing to identify if the latency, amplitude, and timing characteristics of the SEABR vary in older adults when compared to young and middle aged adults. The hypothesis is that elderly listeners would demonstrate impairment in the neural encoding at brain stem region that would be evident from ABR (i.e., the SEABR) responses elicited using the CV syllables of voiced stop consonants / da/ .

Stop consonants are generated by a temporary hindrance of airflow along the vocal tract and occur in three stages: firstly closure of the oral cavity, followed by the subsequent mounting of pressure within the closed cavity and lastly the opening of the cavity permitting the airflow to reassume along the cavity. A stop consonant is diverse in acoustic cues that are specific to the place of articulation and voicing like formant transitions, existence of post release aspiration, spectrum of the stop release burst and timing of vowel syllable voicing onset cues. Stop consonant will also pose greater challenge in speech processing compared to other consonants and are prone to clinical misperception especially in hearing impaired and in people with auditory processing disorders.*(Wible et al, 2004,Song et al, 2006 &Johnson et al, 2008).*Thus, in the current study, voiced stop consonant is used to enrich the knowledge on the temporal processing of speech sounds. It is reported that frequency content of the constituent formants is detrimental in the encoding of the stop consonants at the cortical level. Thus, it is believed that the principal analytic methods for obtaining timing and formant information from filter cues are response latency measures and spectral coding. The ''pitch'' quality could be inferred from signal periodicity and this source cue is thought to be extracted by the analytic mode of neural phase-locking.

The process involved in the encoding of acoustic signals in speech stimuli /da/ by the auditory brain stem is an increasingly interesting subject of research. Acoustically, the trajectory of the second and the third formant frequencies (F2 and F3) seen during the formant transition period, in natural speech, is the prime variance among these syllables. However, F2 and F3 are beyond the phase locking limit of the rostral brainstem and phase-locking to these frequencies is not evident in the response. Response timing is perceived to be dependent on the tonotopicity of brain stem nuclei, could probably be used to differentiate the spectral cues.

Thus, by using the voiced consonant stimuli, it would be possible to comment on how the complex speech sounds are processed in the healthy and aging auditory system, which will give an insight into the complex neural processing in the young, middle aged and older adults.

Successful speech recognition requires multiple spectral and temporal cues and achieving these features through hearing aids is considered as the ultimate aim in aural rehabilitation. It is understood that hearing impairment will scroll down the spectral and temporal properties of the acoustic signal. Hearing aids are designed to amplify the acoustic signal and avail the maximum cues from it. Therefore, optimization of hearing aid fitting warrants more objectivity by assessing how the hearing impaired individuals processes the acoustic time varying signals while using the hearing aid. This, in turn could ensure appropriate selection of the hearing aid as well as its benefit to the end user.

By focusing on improving the quality of life of these individuals who are in the edge of psychological distress due to hearing loss, these objective methods will reflect on how the impaired auditory system processes speech sounds when aided with amplification. Thus, by corroborating the knowledge obtained from the normal hearing individuals' study, it is presumed that it would be possible to understand how the impaired neural system processes such a complex, time varying acoustic cues in hearing impaired individuals. Thus, the current study also attempts at studying how the hearing impaired adults' process the speech stimuli at the brainstem level with the amplification system in use. It is further felt that the knowledge on the break down in the neural processing in aged adults would enable the rehabilitation professionals to have a better understanding of the impaired mechanism and facilitate appropriate hearing aid selection with its benefits to the recipient.

1.2. Aim of the study:

To explore the neural encoding of speech sounds in young, middle aged and older adults using Speech Evoked Auditory Brainstem Response (SEABR)

1.3. Objectives:

1.3.a) Primary objectives

1. To examine the SEABR in younger adults using voiced stop consonant /da/

2. To examine the SEABR in middle aged adults using voiced stop consonant /da/

3. To examine the SEABR in older adults using voiced stop consonant /da/

4. To compare the SEABR in younger, middle and older adults using voiced stop consonant /da/

1.3.b) Secondary objectives

1) To examine the SEABR in first time hearing aid users using voiced stop consonants/da/