ACOUSTIC CHANGE COMPLEX AS AN OBJECTIVE GAP DETECTION TEST IN ELDERLY INDIVIDUALS

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Register No.: 15AUD015

A Masters Dissertation Submitted in part fulfilment of Final Year

Master of Science (Audiology)

University of Mysore

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May, 2017

CERTIFICATE

This is to certify that this dissertation entitled **"Acoustic Change Complex as an Objective Gap Detection Test in elderly individuals"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Audiology) of the student Registration Number: 15AUD015. This has been carried out under the guidance of faculty of the 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 is to certify that this dissertation entitled **"Acoustic Change Complex as an Objective Gap Detection Test in elderly individuals"** is the result of my own study under the guidance of **Mr. Ganapathy M K,** Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DEDICATED TO MY ACHAN AND AMMA

ACKNOWLEDGEMENT

First of all, I wish to thank God Almighty for helping me to successfully complete this dissertation.

I would like to extend my sincere gratitude to the Director, ***Dr S.R Savithri*** *for permitting me to carry out this study.*

I sincerely thank my guide ***Mr. Ganapathy M.K*** *for the constant guidance and unstining support during the dissertation period. Words would fall short while I thank you sir!! You have been very patient and understanding throughout the year. I have been fortunate enough to be your student. I respect your highly effective and efficient way of implementing responsibilities. Sir, you were always been very approachable and an amazing teacher!! Thank you so much sir for guiding me through all my short commings.*

I would like to thank my dear ***Achan and Amma,*** *for being my support system, I grew up cocooned in your love and motivated by your lives and I wouldn't have it in any other way. Thanks for all your prayers that got me through!!!*

Sandeep sir*…Trust me sir you are truly an inspiring personality and an epitome of success. To have learnt from you is a privilege. Your nature and knowledge aspires us. The class interactions and concepts that you tactfully introduced are definitely going to stay in the minds of students like me*

I would like to extend my sincere thanks to ***Dr. Santhosha C.D*** *for helping me tackle my statistics.*

Jaya aunty *I know how much trouble it was for you to travel all the way from Kannur just to help me out. Trust me aunty having people like you in the family makes life so much more easy.*

A long list of friends to thank becoz u guys has kept me sane!!

*Life in AIISH wouldnt have been any better without my besties…****Sneha, Anumol,Jasi,Kitz,Meenamma,Mamishu, Rashmi paapa…****you all have been with me through my thick and thin..thank you guys for instilling confidence in me*

whenever I was down. My dearest friends, ***Veepee, Varsha, Meri , Jeena (cheenachatti)*** *thank you so much for the daily doses of madness!!Without you guys I would have been lost.*

Thanks to all the wonderful classmates I have been with, these two years!! The memories would be always cherished.

My heartfelt gratitude to ***Nike sir,Anoop sir, Shreyank sir ,Nisha di and Ishu sir*** *for all their timely support and help throughout my dissertation.*

Akhila , Bharati, Vidya, Radhika, Akshata, Swati,, Pavithra, Swati, Sheba,Jim ! *I couldn't have asked for better seniors than you guys! Thanks for helping me out whenever I had asked for!*

To our malayalees.. ***Devika, Bincy, Jesnu, Anju BT*** *, eating together from the same plate (leaf) has brought us all together in a very short span of time. Thanks to you all for your mere presence bring joy.*

Anju (akku) , Sarga and Anu*… (the corridor partners) Typing out all the help that you guys provided would take a loooong time! Thankyou for being there!!*

Shantu.. *thanks for the help provided at the 11th hour. (I was truly in need of it).*
Swathi*.. my data collection partner..we have been through the toughest times of data collection together..But looking back now..it was fun..Thankyou…*

Manisha ,Meghu, Nayana, Lavanya ,Keerthi and Sonal *thankyou for the funfilled moments in class and postings. Trust me those were actually my stress busters.*

Devamma , Shamanta and mom *! Thanks for all the help provided for the data collection.I appreciate and acknowledge the time and effort put for the same ☺*

Chandran uncle, Rajeev uncle and Ravi uncle *thankyou so much for spending your precious time for my dissertation.The amount of support you all gave have greatly helped me to complete the dissertation.*

Irfana chechi*.. our powerhouse…you're physical presence was missed throughout the process of dissertation, but still you managed to help us all out through many other ways. Thankyou chechi for proving that distance doesn't matter at all.*

Thanks to all the participants who spent their precious time for my dissertation.

Abstract

A decline in temporal resolution abilities or the ability of the auditory system to track fast changes in incoming sounds is one factor thought to contribute to speech understanding difficulties that accompanies aging process.

Objective: The present study was carried out to find out the minimum gap duration required to elicit the Acoustic Change Complex (ACC). Also the study was carried out across age groups to find out the effect of age on the behavioral gap duration and gap duration required to elicit the electrophysiological responses.

Method: ACC and behavioral Gap Detection Test were administered on sixty participants with normal peripheral hearing, divided into four groups including fifteen young adults in Group I (18-28 years) and older adults in Group II (>50-55 years), Group III (>55-60 years) and Group IV (>60-65 years).

Results: The results showed that behavioural gap detection thresholds and gap durations required to elicit ACC increased as age increases and major detrimental effects on gap detection is seen after 60 years of age and above. The results also showed that the behavioral gap detection thresholds were lower than the gaps required to elicit ACC .

Conclusion: The results of the current study shows that due to changes in the aging auditory system older adults required higher gap duration compared to young adults in eliciting the cortical responses and also behavioral responses. These results clearly indicate slow temporal processing thus possibly leading to the difficulties faced by older adults in understanding speech in difficult listening situations. The objective test could also help in testing the difficult to test older adults with associated problems.

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Chapter 1

Introduction

Structural as well as neural degeneration occurs throughout the auditory system, in the process of ageing. It is often seen that elderly individuals have difficulty in understanding speech particularly in poor listening situations although they have adequate hearing sensitivity (Lee, 2015). Seidman, Ahmad, Joshi, Thawani, & Quirk (2004)reported that due to ageing variety of biochemical and molecular changes occur. These changes in the auditory system have detrimental consequences on the hearing of the elderly individuals.

Older listeners often perform poorly on tasks of speech understanding in noisy and reverberant listening conditions. Roberts & Lister, (2004) suggested that deficits in temporal resolution may be responsible for this condition. Studies reported that age related temporal processing deficits leads to difficulty listening in noise (Robert Frisina & Frisina, 1997; Pichora-Fuller & Souza, 2003). Robert Frisina & Frisina, (1997) implicated that auditory brainstem or auditory cortex temporal resolution dysfunctions could be accounting for the reduced abilities to listen in noise in elderly individuals with adequate cognition and normal hearing sensitivity. Numerous behavioural studies(Pichora-Fuller, Schneider, Benson, Hamstra, & Storzer, 2006; Pichora-Fuller & Souza, 2003) indicated a deficit in auditory temporal processing in elderly individuals. Elderly individuals exhibited more difficulties than younger listeners in detecting short gaps within speech and non-speech stimuli. These behavioral data indicate that cortical processing of rapid changes within an ongoing stimulus could be impaired in healthy adults with normal peripheral hearing. In a magneto encephalography (MEG) by Sörös, Teismann, Manemann, & Lütkenhöner, (2009) reported difference in P1m and N1m amplitude

betweenadults and elderly individuals. However they reported of no evidence of N1m being affected by ageing and recommended further studies on cortical temporal processing in elderly individuals. Contradictorily the mismatch negativity was assessed in elderly individuals for temporal resolution (Bertoli, Smurzynski, & Probst, 2002), the results evinced deficient temporal processing.

Due to ageing other physical and physiological changes can occur in elderly individuals (Barbera, 2012). Few of the age related changes which can be seen in elderly individuals are task performance may take longer, difficulty in learning new tasks, motor reaction time decreased, confusion (associated with Alzheimer's), or may fail to recall instructions (W. Barbara, 2012). Ageing also can have psychosocial changes such as decline in intelligence (McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002), attention deficits (Pichora-Fuller et al., 2006) and memory (Hartke, 1991). These associated problems in elderly individuals warrants for an objective test to assess the temporal processing.

1.1.Need for the study:

The use of the gap in noise test for measuring behavioural gap detection threshold is based on subjective patient feedback only. The use of an alternative method that provides objective measures is desirable and greatly needed in elderly individuals due to factors like cognitive dysfunctions, linguistic limitations, behavioral problems and others. Carrying out the behavioral tests to assess perceptual deficits in elderly individuals with associated problems may be impractical. The effects of ageing on temporal resolution ability remain unclear as Musiek et al., 2005 argued that "older subjects may present with increased GDTs in comparison to younger control subjects". Cortical evoked potentials to gaps in noise can be recorded to provide an objective measure of temporal resolution (Palmer,& Musiek, 2013). Studies which has used

ABR gap threshold (Poth, Boettcher, Mills, & Dubno, 2001; Werner, Folsom, Mancl, & Syapin, 2001) report that ABR gap thresholds tended to be lower than behavioral gap detection thresholds. Hence, there is a clinical need to investigate an objective test that has potential in identifying temporal processing deficit. A gap detection study by Michalewski, Starr, Nguyen, Kong, & Zeng, (2005) on normal hearing and hearing impaired individuals reported ACC along with behavioral scores is a reliable measure. Hence, ACC may serve as a potential tool to assess GDT in elderly individuals.

Study by Gates, Mills, Nam, D'Agostino, & Rubel (2002) reported that cochlear loss due to ageing is subjective. The hair cells are prone to damage not only because of ageing but due to other factors such as noise and trauma. Further any pre-existing peripheral hearing may also lead to alterations in central auditory system. As in the present study older adult with normal hearing are included, the CAEP results may provide details of cortical changes due to ageing.

1.2.Aim

To estimate the minimum duration of gap required to elicit ACC in young adults and in older adults.

1.3.Objectives of the Study:

1. To estimate the minimum duration of gap required to elicit ACC in young adults.
2. To estimate the minimum duration of gap required to elicit ACC in older adults.
3. To compare the minimum duration of gap required to elicit ACC across age groups.
4. To compare the minimum duration of to elicit ACC with the behavioral gap detection scores across different age groups.

Chapter 2

Review of Literature

Ageing is the process during which anatomical and functional degenerative changes accumulate in an organism as a result of the passage of time. Rose (1994), defines aging as "a persistent decline in the age-specific fitness components of an organism due to internal physiological degeneration".Seidman, Ahamed, Joshi, Thawani, & Quirk, (2004) reported that a variety of biochemical and molecular changes occur due to ageing. Resultantly these changes have an adverse effect on the auditory system of aging individuals. There are several studies that have documented changes in the auditory system due to ageing.

Difficulty in understanding speech especially in adverse listening situations is one of the most common problems in older individuals although their hearing sensitivity is within normal limits. As per the report of the Committee on Hearing and Bioacoustics and Biomechanics of the National Research Council, the factors affecting speech perception in older adults include deterioration of the peripheral and central auditory system, and the cognitive system.

Studies show that age-related temporal processing deficits lead to difficulty in listening in the presence of noise (Frisina&Frisina, 1997; Pichora-Fuller & Souza, 2003). According to FrisinaandFrisina (1997) regardless the fact that older adults have adequate cognition as well as normal hearing sensitivity, their diminished abilities to listen in noisy condition could be accounted to the temporal resolution deficits in the auditory brainstem or auditory cortex.

2.1. Changes in auditory brainstem and auditory cortex

The age dependent neuronal changes are attributed to overall loss of neurons such as neuronal shrinkage, decreased size of cell body and nucleus, decreased arborization and loss of dendrites (Powers, 1994; Shankar, 2010; Willott et al., 1991). The input-output function of the compound action potential is shallow in older animals which shows evidence of loss of auditory nerve function with ageing (Gates & Mills, 2005). Gates and Mills (2005) reported that asynchronous activity in the auditory nerve with ageing may be caused due to combined factors such as; synapse between hair cells and auditory nerve, degeneration of spiral ganglion cells, and reduced endolymphatic potential. Konigsmark and Murphy(1972) showed evidence that around the beginning of 60 years of age, there is decline in the volume of neurons in ventral cochlear nucleus along with decrease in number of myelinatedfibers, reduced vessels and capillaries. According to Crace, 1970, an increase of neurons containing pigment was seen within cochlear nucleus and many neurons degenerated with age. Willott et al. (1991) reported that aging resulted in a decrease in number of nerve fibers within lateral lemniscus and inferior colliculus. Based on animal studies, Frisina and Walton(2006) evidenced that there will be primary ageing changes in dorsal cochlear nucleus that are driven by the loss of cochlear input.

Caspary, Schatteman, and Hughes (2005) have noted a decrease in GABA release due to age-related changes in the peripheral auditory system. Further study done by Raza, Milbrandy, Atneric, and Caspary (1994) revealed that, deficits in speech discrimination and speech in noise is a manifestation of neuro-chemical changes in central auditory system due to ageing. The central nervous system reduces in volume and weight due to ageing (Shankar, 2010). Shankar(2010) reported that the pre-frontal cortex is most affected and the occipital lobe is least affected by ageing. Chance, Casanova, Switala, and Crow(2006) studied the organization of neurons in primary auditory cortex and they reported that thinning was seen in auditory association cortex but not in the primary auditory cortex due to ageing. These results do not indicate a significant structural change of the

primary auditory cortex that does not explain the clinically observed auditory behaviors in older adults.

Canlon, Illing, and Walton(2010) reported age-related decrease in the GABA enzyme levels in the primary auditory cortex of rats and it is possible that a loss of normal GABA transmission contributes to loss of speech understanding with ageing humans. Further Ling, Hughes, and Caspary (2005) reported a significant decrease in GABA in primary auditory cortex in aged rats but adjacent regions of parietal cortex did not show any significant change. According to these observations the temporal coding of older adults is likely to get altered due to the loss of GABA neurotransmission in primary auditory cortex, which in turn will affect their speech understanding.

2.2Audiological findings in older adults

The audiological tests show a variety of results in older adults. The findings from numerous studies indicate variable results from pure-tone audiometry to CAEPs. A review of findings on different results due to ageing is given below. Increasing age during adulthood is often associated with elevation of pure-tone thresholds. Wiley, Chappell, Carmichael, Nondahl, and Cruickshanks (2008) studied hearing threshold changes due to ageing as well as gender difference between 48 and 92 years. The study revealed an increase in pure-tone thresholds and steeper slope in the higher frequencies, with increase in age and gender difference, with men showing poorer thresholds in comparison with age matched women. Wiley, Chappell, Carmichael, Nondahl, and Cruichskanks (2008) further observed that nearly 60% of the individuals between 80 to 92 years, 40% between 70 to 79 years, and 10% between 60 to 69 years have greater than 60 dB HL of hearing loss. Often hearing loss due to ageing is variable i.e., the threshold change is not same within age range and between gender. (Gates, Cooper, Kannel, Brant and Fozard (1990) reported that after 50 years of age there is an increasedrate of

decline in hearing thresholds; about 41% of older adults above the age of 60 years report of hearingdifficulties. Often, older adults with decreased pure-tone thresholds have the high frequencies affected, which gradually extend to lower frequencies with further increase in age (Sharashenidze, Schacht, &Kevanishvili, 2007& Miller, 1990).

The word recognition ability is seen to decline with age and a rapid reduction in scores is seen in men (Gates et al., 1990; Wiley et al., 1998). Studies performed in older adults reveal poorer performance on speech understanding tasks. These findings infer that the primary cause for speech understanding difficulties in older adults is age-related peripheral hearing loss or presbycusis (Divenyi et al., 2005; Dubno et al., 1984; Gordon-Salant, 2005). Gelfand et al., 1986; Pichora-Fuller et al., 1995 reported poorer speech understanding in older adults compared to younger individuals despite of normal hearing sensitivity. Studies reveal that most of the elderly individuals experience difficulty in understanding speech when in noise, or at a faster rate, or when the amount of information is loaded even if they do not have hearing loss (Gordon-Salant, 2005). These studies reveal inconsistent results of speech understanding older adults. Mukari, Wahat, and Mazlan (2014) studied the effect of hearing loss and ageing on speech perception in quiet and in background noise. They reported that older adults perform better in quiet environment than in noisy environment. Further, they mentioned that factors such as central auditory processing and cognitive functions might play an important role in understanding speech in difficult listening conditions.

The hearing loss leads to reduced audibility and also can affect spectral and temporal resolution (Humes, 1996). However, peripheral hearing loss does not explain the speech-understanding problem in older adults as they have poorer speech perception scores in degraded environment, even when they have normal hearing thresholds (Gelfand, Piper, &Silman, 1986;

Pichora-Fuller, Schneider, &Daneman 1995). Further, speech perception is usually poorer in elderly individuals than in the young adults with similar degree of hearing loss (Divenyi, Stark, &Haupt 2005; Gordon-Salant, 2005). In older adults it is reported that temporal resolution is affected (Gońdon-Salant& Fitzgibbons, 1993; Snell, 1997). Temporal resolution helps in identifying phonetic contrasts and also contributes in understanding speech in noise. These temporal deficits in older adults may lead to speech perception deficits. Further, older adults perform poorer than young adults when the rate of speech increases. On time compressed speech tests, older adults showed poorer scores when compared to younger counterparts (Letowski&Poch, 1995), and the scores were drastically affected when presented in background noise (Tun, 1998). These results reflect slow perceptual processing in older adults thus leading to affected speech perception, with or without hearing loss.

In elderly individuals due to cognitive functions alterations characterized by slowness suggests a deficit in temporal processing transmission. Many auditory information characteristics are in some way influenced by time." Temporal resolution may be defined as the ability to follow rapid changes in intensity and frequency over time, a skill that is thought to be important for understanding speech in noise".

Price and Simon (1984),reported that there is a detrimental effects on temporal-resolution abilities as age increases, which in turn deteriorates the perception of temporal characteristics of speech, including perception of vowels and silent durations that help distinguish between speech sounds. Due to the negative impact of temporal processing problems on speech perception, it is necessary to assess these abilities, especially in older adults, so that they can be provided further guidance in terms ofdeficit-specific rehabilitation. Due to importance of detecting temporal processing difficulties, researchers have developed several tests to assess temporal-resolution

abilities (Keith, 2002; Lister, Roberts, Shackelford, & Rogers, 2006; Musiek et al., 2005; Shivaprakash, 2003). Tests used to assess temporal resolution include the Random Gap Detection Test developed by Keith (2002), the Gap Detection Test (GDT) developed by Shivaprakash (2003), the Gaps-In-Noise test (GIN) developed by Musiek et al. (2005), and the Adaptive Test of Temporal Resolution developed by Lister et al. (2006). These tests of temporal resolution assess the ability of individuals to detect the shortest gap embedded within a sound. Study done by Schneider and Hamstra(1999) has reported that temporal processing deficits can be recorded for older adults. Although behavioral measurements of temporal resolution widely accepted, they are influenced by many factors (e.g., memory, cognition, motivation, task, response criteria), making it inconvenient to draw inferences about the underlying physiological deficit The use of an alternative method that provides objective measures is desirable and greatly needed in elderly individuals due to factors like cognitive dysfunctions, linguistic limitations, behavioral problems and others.

2.3 Auditory Brainstem Response (ABR)

The auditory brainstem response (ABR) is a widely used clinical and research tool, which has been used to study the effects of ageing extensively. In the last decade speech stimuli has been extensively researched to study the brainstem responses for speech. Anderson, Parbery-Clark, White-Schwoch, and Kraus (2012) recorded ABR for speech stimulus in older adults with normal hearing, and reported that they had delayed brainstem responses for rapid format transition and reduced phase locking. They suggested that these responses in older adults in part may lead to their speech perception deficits. However, Werff, Burns, Vander Werff,and Burns (2010) recorded speech evoked ABR for younger and older adults with normal hearing. The results showed smaller amplitude and prolonged latencies of onset and offset responses. Further,

the sustained components of the speech ABR showed no significant effect of age, suggesting intact temporal coding for the harmonics of the speech stimuli. Similar findings were reported by Neupane, Gururaj, Mehta, and Sinha (2014). They reported no change in the encoding of fundamental frequency of the speech stimulus in older adults even with change in repetition rates. Thus, suggesting speech perception deficits because of ageing may be due to more central deficits.

2.4Cortical Auditory Evoked Potentials (CAEPs)

The late auditory evoked potentials are cortical in origin that includes Late Latency Response (LLR), Mismatch Negativity (MMN), P300, and Acoustic Change Complex (ACC) etc. The LLR are obligatory responses/exogenous potentials; whereas, the latter two types of potentials are termed as endogenous potentials. It is reported that the neuro-chemical changes in the central auditory system due to ageing contributes to speech understanding deficits in older adults (RazaMilbrandy, Atneric, &Caspary, 1994). Further, the age-related changes in the brain and resulting slowing of brain function could have implications on the comprehension of speech in complex situations (Schneider, Pichora-Fuller, &Daneman, 2010). These changes in the cortex due to ageing could be due to brain atrophy, reduced number of neurons and changes in synaptic density. By reviewing the effects of ageing on these cortical potentials an insight into the physiological aspects of ageing and possible evidences for the auditory deficits in older adults can be gained. Further, it will also point out the need to explore the cortical deficits leading to speech understand problems in older adults and thus aid in their management.

2.4.1 Late Latency Response

Late Latency Response (LLR) is an obligatory cortical response, which means that LLR varies with the physical properties of the auditory stimulus. The primary components of LLR are

P1, N1 and P2, which appears as a wave for the onset of acoustic stimulus. Usually, the amplitude of P1 is relatively small, thus the main focus is on LLR morphology and N1-P2 complex. The N1-P2 complex reflects neural synchrony of thalamo-cortical segment of the human auditory cortex. TheN1 and P2 peaks of LLR are elicited approximately at around 100msand 200 ms respectively after the stimulus onset (Näätänen&Picton, 1987). The N1 reflects the sound detection and it is sensitive to onset of the sound, such as intensity and inter-stimulus interval. The P2 reflects the sound content properties such as acoustic or phonetic structures (Naatanen&Picton, 1987). These properties of the cortical auditory evoked potential (CAEP) show that, LLR is a good tool to study the changes in central auditory system (CAS), including that due to ageing.

In a study on adults having normal hearing by Goodin, Squires, Henderson, and Starr (1978), it was reported that ageing affects the N1 and P2 responses. They reported a systematic increase in latency and decrease in amplitude due to ageing. This finding is similar to that reported by Iragui, Kutas, Mitchiner, and Hillyard (1993)on tone evoked CAEP. They reported that N1 and P2 latencies were slightly but significantly delayed with age with reduced amplitude. Study by Laffont et al. (1989)reported prolonged latencies of N1 and P2 with age; however, they reported an increase in P1-N1 amplitude in older adult participants.These results were reported for CAEPs recorded for tonal stimulus. There is little ambiguity in terms of the effect of ageing on amplitude of LLR. These results in older adults are attributed to decreased neuronal transmission, decreased conduction velocity and dendritic loss in the auditory cortex (Goodin, Squires, Henderson, & Starr, 1978).

The LLR is a potentially reliable tool to understand the effects of speech in noise in older adults. It has been successfully recorded in young adults with various signal-to-noise ratio

(Billings et al., 2009). The results showed decrease in amplitude and prolongation of latency of N1 and P2 with decrease in signal-to-noise ratio (SNR). Similar results have been recorded for speech stimulus at different signal-to-noise ratio (Sharma et al., 2014). The LLR in background noise has also been reliably recorded in children (Anderson, Chandrasekaran, Yi, & Kraus, 2010). There is limited literature on effects of ageing on cortical encoding in the presence of background noise. Kim et al. (2012) recorded LLR for a tone with a continuous broadband noise at 0 dB SNR in younger and older adults having normal hearing. They reported that N1 latency was prolonged significantly in older adults and P2 latency and N1-P2 amplitude did not show any change in comparison to LLR of younger adults. These studies demonstrate that recording CAEPs in the presence of background noise is a reliable tool to assess processing of speech in noise.

2.4.2 Acoustic Change Complex

Similar to LLR, the acoustic change complex (ACC) is an obligatory response. The components of LLR are P1, N1 and P2; whereas, for ACC there are multiple P1, N1 and P2 components (Ostroff, Martin, &Boothroyd, 1998). These multiple N1-P2 response is elicited for complex stimulus with acoustic change or changes within an on-going stimulus. To elicit an ACC, the pre-transition stimulus duration of the on-going stimulus (before acoustic change) should be ≥ 80 ms. If the duration is less than 80 ms it leads to indistinguishable/fused N1-P2 response of onset and change in the stimulus (Ganapathy &Manjula, 2016).The ACC can be evoked for changes in acoustic cues such as intensity and/or frequency change (Martin &Boothroyd, 2000), periodicity change (Martin &Boothroyd, 1999), The ACC has been a potentially useful tool in the assessment of auditory perception.They concluded that ACC could be applied to study the neural processing of speech in individuals with auditory deficits. The

ACC has also been recorded and shown to be in good agreement with the behavioural tests. Martin and Boothroyd (2000) reported that ACC elicited for amplitude change and spectral change were in good agreement with the psychoacoustic limit of the auditory system. This finding supports the use of ACC as a reliable objective test for auditory discrimination capabilities.ACC can be recorded in individuals using hearing aids and can give information on neural representation of the amplification (Tremblay, Billings, Friesen,& Souza, 2006). Friesen and Tremblay (2006) reported that ACC is also recordable in cochlear implant users and thus implying that the central auditory functioning of cochlear implant users can be recorded for complex auditory stimuli.

From the literature it can be deduced that ACC is a sensitive tool to study the cortical responses for complex acoustic stimuli. As the ACC is recorded for rapid changes within the on-going stimulus, it can help in understanding of the complex neural encoding. Further, the CAEPs correlate with behavioural thresholds. The CAEPs are recorded when awake and have good test-retest reliability to assess speech perception at cortical level. These properties make ACC a reliable cortical potential to study the effects of ageing and speech understanding problems seen in older adults. The review is unequivocal of the fact that with ageing the human auditory system endures changes anatomically and physiologically. The changes in the external ear and middle ear due to Ageing do not usually lead to hearing loss. Whereas changes in cochlea, brainstem and central auditory nervous system lead to hearing loss or speech understanding problem or both. In cochlea, changes are reported in terms of loss of hair-cells, supporting cells or other histological changes. These changes in the cochlea, lead to presbycusis/age-related hearing loss in older adults. However, ageing alone does not lead to changes in cochlea; other factors such as ototoxicity and noise induced hearing loss also lead to hearing loss in older adults (Gates, Mills,

Nam, D'Agostino,&Rubel, 2002). Further, neuronal changes with age are associated with overall loss of neurons such as neuronal shrinkage, decreased size of cell body and nucleus, decreased arborization and loss of dendrites (Powers, 1994; Shankar, 2010; Willott et al., 1991). The inferior colliculus (IC) show changes in GABA neurotransmission. These changes lead to speech comprehension difficulties, especially in noise. However, studies report that these ageing changes in the brainstem are primarily due to cochlear/peripheral hearing loss (Frisina& Walton, 2006; Ling, Hughes, &Caspary, 2005). These studies point out that in normal hearing older individuals, the hearing problems due to ageing could be due to changes in the central auditory nervous system, such as decrease in GABA in primary auditory cortex (Ling, Hughes, &Caspary, 2005) and atrophy in pre-frontal cortex (Shankar, 2010), mostly in lateral prefrontal region (Kryla-Lighthall& Mather, 2009). These changes lead to speech understanding difficulties in older individuals, which are more pronounced in presence of noise. These detrimental effects are evident in the different auditory tests done in older adults with normal hearing.

Speech understanding abilities are reported to be poorer in older adults than in younger adults, even with normal hearing sensitivity (Gelfand, Piper, & Silman,1986; Pichora-Fuller et al., 1995). It is seen that older adults perform better in quiet but poorly in noise environment (Mukari et al., 2014). In general, the older adults experience difficulty in understanding speech when in noise, or at a faster rate, or when the amount of information is loaded even in the absence of hearing loss (Gordon-Salant, 2005).

The ACC is the response for the rapid change within the ongoing stimulus, and has good test re-test reliability (Ostroff, Martin, &Boothroyd, 1998; Tremblay, Friesen, Martin, & Wright, 2003). As acoustic change complex, is a physiological response that signals the neural detection of acoustic change at the level of the auditory cortex and consistent with perceptual thresholds

for the same acoustic change (Kaukoranta, Hari, &Lounasmaa, 1987; Martin &Boothroyd, 1999; Ostroff, Martin, &Boothroyd, 1998).Michalewski et al. (2005) reported that N1 and P2 responses to gaps in broadband noise were not affected by attention and correlate well with gap detection thresholds measured behaviorally for adults with normal hearing and adults with auditory neuropathy.

In the present study Acoustic Change Complex (ACC) was recorded in young adults and elderly individuals to find out the minimum duration of gap required to elicit peaks $N1^1$ and $P2^1$ within an ongoing stimuli.

Chapter 3

Method

The main aim of the study was to find out the minimum duration of gap within an ongoing noise required to elicit Acoustic Change Complex (ACC) in young adults and older adults. To study this, stimuli were synthesized with duration of gap within the ongoing noise systematically increasing. For these stimuli cortical responses were recorded and analyzed across different age groups.

3.1. Participants

The participants were divided into three groups based on age viz.

Group I: Fifteen ears of young adults in the age range of 18 to 28 years (mean age 21.8 years)

Group II: Fifteen ears of older adults in the age range of >50 to 55 years(mean age 53.9 years)

Group III: Fifteen ears of older adults in the age range of >55 to 60 years(mean age 56.2 years)

Group IV:Fifteen ears of older adults in the age range of >60 to 65 years(mean age 63.8 years)

All the participants had normal hearing in both the ears, i.e., pure tone thresholds (Air Conduction and Bone Conduction thresholds) less than 15 dB HL at octave frequencies from 250 Hz to 4000 Hz. All participants were administered speech audiometry and individuals with scores > 90% were included for the study. Normal middle ear function was ensured in each participant with A type tympanogram with a middle ear pressure between +50 to -50 daPa; middle ear compliance between +0.3 to +1.6 ml (Jerger, 1970) with a probe tone frequency of 226 Hz, and acoustic reflex being present and recorded at <100 dB HL at 1000 Hz in both the ears.A detailed case history was taken to ensure that none of the participants have had history or

complaint of any neurological and otological problems. The group II, III and IV individuals was administered Cognitive testing using Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975). Maximum score is 30 and subjects obtaining a score of <24 are interpreted as having cognitive deficits and were not included in the study. Only participants who scored >24 were included in the study.

The following tests were carried out for selection of the participants:

A structured interview was conducted to rule out otological and neurological problems. Following which pure-tone testing was carried out. Air-conduction (AC) thresholds at octaves between 250 Hz to 8000 Hz and bone-conduction (BC) thresholds for octaves between 250 Hz to 4000 Hz were established for each ear. This was done using a calibrated clinical audiometer, TDH-39 head phone encased in MX 41AR ear cushion for AC testing and Radio Ear B-71 bone vibrator for BC testing. The hearing thresholds were estimated using modified Hughson-Westlake procedure (ANSI S3.21-1978, R-1992) with a +5 dB and -10 dB step-size. It was ensured that all participants had hearing thresholds ≤ 25 dBHL.

Cognitive testing was carried out using Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975). This is a questionnaire with 30 questions used to screen for cognitive impairment that samples various functions including arithmetic, memory and orientation. It was administered on participants in Group II, to rule out cognitive deficits. The subjects were asked a total of 11 questions and each correct response was awarded appropriate points. The maximum score is 30. Participants obtaining a score of <24 are interpreted as having cognitive deficits and were not included in the study. Only those participants who scored ≥24 were included in the study.

Tympanometry was carried out, by making the participants sit comfortably on a chair and was instructed to close their eyes and not to move until the test was completed. Immittance testing was administered with a probe tone of 226 Hz. Tympanogram and acoustic reflex thresholds for 1000 Hz were estimated to ensure normal middle ear functioning in each ear.

3.2. Instrumentation

The following instruments were used for subject selection criteria and for subjective and objective threshold estimation of GDT.

a. GSI 61 a calibrated dual channel audiometer was used to assess hearing ability of the participants

b. Middle ear analyzer GSI tympstar was used to assess middle ear status

c. Evoked potential system (Bio-logic Navigator Pro-ver 7) was used to record CAEPs.

d. CD of Gap Detection Test (GDT).

e. A personal laptop connected to GSI 61 audiometer was used for presenting the stimulus of GDT.

3.3 Test Environment

A sound treated air-conditioned double room set-up was used to administer all these tests. The noise level in the testing room was maintained within the permissible limits(ANSI, 1999).

3.4Stimuli:

For recoding ACC, stimuli were generated using Adobe Audition 1.5. and for these stimuli Cortical Auditory Evoked Potential (CAEP) was recorded. In total eight stimuli were generated. White noises were generated with a total duration of 350 ms. Gaps of duration 0 ms,

3 ms, 4 ms, 5 ms, 6 ms, 7 ms, 8 ms and 10 ms were introduced within the ongoing white noise at 150 ms duration. All stimuli were presented at 70 dBSPL. All the thresholds were obtained for right ear to avoid discrepancy due to ear advantage.

To estimate the behavioral gap detection scores Gap Detection Test CD developed by Shivaprakash and Manjula (2003) was used. This test consists of 56 stimuli with 6 catch trials and 4 practice sets. Each set of stimuli consists of three noise bursts in which one of the noise burst has the silent gap, and participant has to identify in which of the noise bursts gap was present.

3.5 Procedure

The study was carried out in two phases. In phase 1 Acoustic change complex were recorded for different gap durations. In phase 2 subjective gap detection test were administered.

3.5.1 Objective measure

To record the CAEP the stimuli were presented to the participant's monaurally using ER-3A insert earphone at 70 dBSPL using Bio-logic Navigator EP system.

Participants were seated comfortably in a reclining chair. To ensure the client cooperation, the participants were made to watch a muted movie played through a battery operated laptop computer kept at a distance of 2 meters away. Silver chloride disc electrodes were used for recording the CAEP's. Electrode sites were cleaned using a skin abrasive paste and electrodes with conduction paste were placed on the sites and attached using surgical tape. Absolute electrode impedances were maintained within 5 k Ω and relative impedances within 2 k Ω throughout the testing. Sufficient breaks were provided between the testing. Details of the protocol that were used for testing is given in the Table3.1 below.

Table: 3.1

Protocol for recording ACC

Time window	**-50 to 500 ms**
Stimulus	White noise with 0, 3, 4, 5, 6, 7,8 and 10ms gap (Eight stimuli in total)
Stimulus duration	350 ms
Stimulus intensity	70 dB nHL
Repetation rate	0.9/sec
Amplification	10,000 times
Filter	0.1 to 30 Hz band pass filter
Artifact rejection	±75 μV
Electrode montage	One channel – Ipsilateral mastoid (A2) - inverting Forehead (Fpz)- Ground Cz - non-inverting
No. of sweeps	150
No. of channels	1

The peaks $N1^1$ and $P2^1$ were analyzed. The peaks $N1^1$ and $P2^1$ reflect the response to the onset of the change (encoding of gap) within the ongoing stimulus. The duration of gaps at

which N1 and P2 were elicited were analyzed and tabulated. The marking of peaks $N1^1$ and $P2^1$ were judged by experienced audiologists.

3.5.2 Behavioral Gap Detection Test

The behavioral gap detection scores Gap Detection Test CD developed by Shivaprakash and Manjula (2003) were used. This test consists of 56 stimuli with 6 catch trials and 4 practice sets. In this study minimum gap detection scores were obtained at 50 dBSL. All the thresholds were obtained for right ear to avoid discrepancy due to ear advantage. The participants were instructed to listen to the set of three noise bursts and indicate verbally which of the three noise bursts in the set had gap. The minimum gap that was detected by the subject was taken as the gap detection threshold.

3.6. Statistical analysis

The data of behavioural gap detection values and the duration of gaps at which ACC was elicited in four different age groups were tabulated. The data obtained were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) software (SPSS version 20). Descriptive statistics was applied to estimate the mean and standard deviation for each group. Normality test was carried out for the tabulated data using Shapiro-Wilk test, which revealed normal distribution of behavioral gap detection data and gap detection scores for ACC were not normally distributed. Hence, parametric statistical test ANOVA was administered to compare across age groups for behavioural GDT and a non parametric statistical test Kruskal Wallis test was administered to compare across age groups for gap detection scores of ACC. Mann Whitney U test was carried out to assess the difference between the groups for ACC

results. Further, to compare between behavioural GDT and gap detection scores obtained from ACC,Wilcoxan Signed Rank test was carried out.

Chapter 4

Results

The present study aimed to find out the minimum duration of gap within an ongoing noise required to elicit Acoustic Change Complex (ACC) in young adults and older adults.Four groups including fifteen young adults in Group I (18-28 years) and older adults in Group II (>50-55 years), Group III (>55-60 years) and Group IV (>60-65 years) participated in the study.All the subjects were assessed for both behavioral gap detection test and ACC. The results of the older adult participants were compared with that of the younger adult group. It was ensured that all the participants included in the study had normal peripheral hearing sensitivity.

4.1 Behavioural Gap detection scores between age groups

To obtain the behavioural Gap Detection threshold the minimum gap that was detected by the subject in the Gap Detection Test was considered. Descriptive statistics were carried out to obtain mean and standard deviation of behavioural gap detection scores. The mean and standard deviation of the behavioural Gap Detection thresholds in different age groups are as shown in Table 4.1.

Table 4.1.

The mean and standard deviation of the behavioural Gap Detection thresholds in different age groups

Groups	N	Mean/ Std. Deviation
I	15	2.65/0.74
II	15	4.04/0.35
III	15	4.53/0.49
IV	15	5.40/0.46

ANOVA was carried out to see for statistical significance across groups. Results revealed statistically significant difference between the GDT values across the age groups [F(3,56)=70.135,p=0.000]. This results show that the gap detection thresholds were significantly different between age groups.

To assess between age group effect, Bonferroni's adjusted multiple comparisonswas carried out.The results are as shown in table 4.2 that shows that between all the groups there significant difference except betweenGroups II and Group III.

Table 4.2

Comparison of behavioural GDT between age groups

Age Groups	Group I	Group II	Group III	Group IV
Group I	-	SD	SD	SD
Group II	SD	-	NSD	SD
Group III	SD	NSD	-	SD
Group IV	SD	SD	SD	-

Note: SD= Significant difference (p >0.05), NSD= No significant difference(p=0.000)

4.2Gap detection scores of ACC between age groups

The ACC were recorded for eight stimuli having gaps of duration, 0ms, 3ms, 4ms, 5ms, 6ms, 7ms, 8ms and 10ms for right ear to avoid discrepancy due to ear advantage.The mean and standard deviation of the durations of gaps at which $N1^1$ and $P2^1$ were elicited are shown in the table 4.3.

Table 4.3.

Mean and standard deviation of the durations of gaps at which $N1^1$ *and* $P2^1$ *were elicited.*

Groups	N	Mean/ Std. Deviation
Group I	15	4.27/0.45
Group II	15	6.07/0.45
Group III	15	6.13/0.51
Group IV	15	7.13/0.35

Kruskal-Wallis Test was carried out to study across group comparison of the durations of gaps required to elicit ACC. The results shows that there was significant difference across the age groups ($\chi^2(3)= 49.222$, $p = 0.000$).

As the Kruskal-Wallis test results showed significant difference, Mann Whitney U test was carried out to study between which groups there was statistically significant difference.The results are as shown in the Table 4.4.The results reveal that except for the groups II and III (i.e. between the age range 51-55 years and 55-56 years),all other groups indicated statistically significant difference. These results indicate that in older adults the gap required to elicit is longer.

Table 4.4.

Comparison of duration of gaps required to elicit ACC between groups.

Groups	Z value
Group I & II	-4.878*
Group I & III	-4.840*
Group I & IV	-5.010*
Group II & III	-0.393
Group II & IV	-4.581*
Group III & IV	-4.314*

* =significant difference (p=0.000)

4.3. Comparison between Electrophysiological and behavioral measures

The results of behavioral gap detection scores and gap duration for which ACC were elicited were compared. The mean scores of the responses obtained are shown in Figure 4.1.

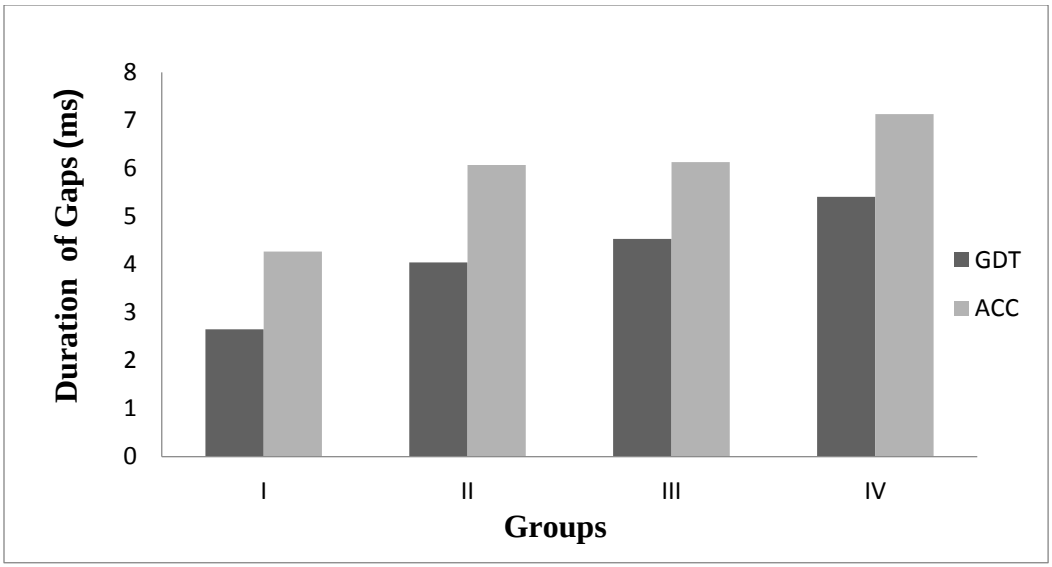

Figure 4.1. The mean scores of gap detection scores and mean gap duration required to elicit ACC across age groups. Note:GDT= Gap Detection Threshold,ACC= Acoustic Change Complex.

To compare between behavioral gap detection thresholds and gap detection required to elicited ACCWilcoxon Signed Rank test was carried out. The results are as shown in table 4.5. The results indicated statistically significant difference between values of both behavioural and objective tests. The above figure of mean scores also indicates that the behavioural gap detection scores are lesser than the gap detection scores elicited through ACC.

Table 4.5.

The Wilcoxon Signed Rank test results of comparison between GDT and ACC across the age groups

GROUPS	Z value
Group I	-3.352*
Group II	-3.416*
Group III	-3.411*
Group IV	-3.409*

* = Significant Difference (p=0.000)

Chapter 5

Discussion

The aim of the present study was to estimate the minimum duration of gap required to elicit ACC in young adults and in older adults. To study this, the following objectives were taken (1)To estimate the minimum duration of gap required to elicit ACC in young adults.(2) To estimate the minimum duration of gap required to elicit ACC in older adults.(3) To compare the minimum duration of gap required to elicit ACC across age groups.(4)To compare the minimum duration of to elicit ACC with the behavioral gap detection scores across different age groups.

5.1 Behavioural Gap detection scores between age groups

The results of the present study show that the minimum gap detection scores increases with the age. This indicates that gap detection seems to be affected by increasing age, the mean gap detection thresholds obtained in the study was smaller for the younger adults as compared to older subjects. These findings are in congruence with those reported in theprevious studies done by Snell (1997), Snell, Frisna(2000), which shows that there is significant age-related changes in auditory processing that occur throughout adulthood. Price and Simon (1984), reported that there are detrimental effects on temporal resolution abilities as age increases. Strouse, Ashmeadohde,Grantham (1998) measured gap detection scores in 12 young (mean age = 26.1 years) and 12 elderly (mean age = 70.9 years) adults with clinically normal hearing and the results revealed that elderly listeners displayed higher gap detection thresholds. Their findings suggest that age-related factors other than peripheral hearing loss contribute to temporal processing deficits of elderly listeners. Moore, Peters, Glasberg (1992) found that elderly listeners have more difficulties than younger adult listeners in detecting short gaps within noise,

reporting larger gap detection thresholds for elderly listeners than young listeners. Furthermore, they reported that age-related difference in gap detection appears to be independent of peripheral hearing loss because performance in gap detection is not correlated with pure tone hearing thresholds, this supports the present study as participants in all groups had normal hearing sensitivity yet showed greater gap detection scores.

The results also show that the age Groups II and III had reduced scores in comparison with young adults and they did not show significant difference. This indicates that ageing effects are uniform between these age groups. The results of Group IV i.e.,>60 years of age the minimum gap detection are higher, which indicates influence of age, which may be due to age related decline in physiology of auditory system.

These results show that the temporal resolution may be affected in older adults. This indicates that the ability of the aging auditory system even normal hearing sensitivity may have problems in detecting rapid and abrupt changes in the sound stimuli thus have difficulty in discriminating the shortest time interval between two acoustic cues (Zidan, Garcia, Tedesco, &Baran, 2008). This could also point out to the reduced speech understand scores in older adults even with normal hearing sensitivity (Diveny, Stark, &Haupt, 2005).

5.2 Gap detection scores of ACC between age groups

The results of the study revealed that the mean gap required to elicit ACC in young adults was 4 ms and greater. Palmer and Musiek (2013) also studied gap detection using N1-P2 complex. They report that young adults had N1-P2 complex for gaps >2ms. In older adults the gap duration required to elicit ACC was >6 ms. Older adults required wider gaps to elicit the responses. These results corroborate the study done by Harris, Wilson, Eckert and Dubno(2012).

They reported that older adults required longer duration of gaps. They found that clear N1-P2-N2 components were obtained inresponse to gaps of 6 ms or shorter in younger adults where as in older adults, N1-P2-N2 components was present in response to gaps of 9 ms,although in some subjects the ERP was not present until gap duration increased to 12 or 15ms. In the above-mentioned study the mean age of older adults was 69 years. Study byMichalewski and Pratt (2005) used N1-P2 measure to evaluate temporal processing abilities and found that older subjects require more gap duration to elicit N1-P2.

The findings of the present study indicate that the increase in gap duration indicate age related slowing in processing. These may be due to changes in auditory cortex as a result of ageing (Canlon, Illing, & Walton, 2010). FrisinaandFrisina (1997) reported that temporal resolution deficits are seen in the auditory brainstem or auditory cortex as age increases. Further, there was no significant differences seen between Group II and III suggesting that major changes in auditory systems happens after 60years of age. Konigsmark and Murphy (1972) reported that around the beginning of 60 years of age, there is decline in the volume of neurons in ventral cochlear nucleus along with decrease in number of myelinated fibers, reduced vessels and capillaries. Further Ling, Hughes, and Caspary (2005) reported in their study that there was a significant decrease in GABA in primary auditory cortex in aged rats. According to these observations they concluded that temporal coding of older adults is likely to get altered due to the loss of GABA neurotransmission in primary auditory cortex.

These results in older adults with normal hearing sensitivity the cortical auditory responses indicate possible age related deterioration of central auditory processes. Studies have reported reduced temporal resolution in hearing impaired listeners (Moore, &Glasberg, 1988;

Long, & Cullen, 1988), however the current findings point out to reduced temporal resolution due to ageing alone.

5.3 Comparison between Electrophysiological and behavioral measures

The comparison of behavioural gap detection test and ACC did not correlate. The results showed that the duration of gap required to elicit ACC was more than the behavioural gap detection scores across all age groups. Shuman, Grose, &Buchman (2012) reported that the gap detection and frequency discrimination thresholds determined by the electrophysiological measure were significantly larger than the behavioral threshold. Their thresholds for gap detection ranged from 5.0 to 8.0ms and behavioral gap detection thresholds ranged from 4.1 to 6.6 ms in older adults group. Palmer and Musiek (2013) showed that most of the young adults included in their study had responses at gaps > 2 ms, but all subjects had presentclear evoked potential responses to 20 msec.Palmer (2014) also reported that older adults demonstrated significantly larger gap detection thresholds than the younger adults. The higher gap duration required to elicit electrophysiological responses could also be due to the number of neurons responding to the gap may decrease with shorter gaps than the number of neurons responding to longer gaps (Walton, Frisina, Ison, & Neill, 1997; Palmer, Musiek, 2013).

The results of the current study show that cortical auditory evoked potentials can be recorded for gaps in young and older adults. However the older adults require higher gap durations to elicit the cortical responses. These could be due to the temporal changes in the ageing auditory system. These clearly point out the older adult problem in understand speech in difficult listening situations. Further, by establishing norms these objective tests could be used to study the temporal resolution in older adults thus helping them in the audiological rehabilitation.

The objective test could also help in testing the difficult to test older adults with associated problems.

Chapter 6

Summary and conclusion

The present study aimed to find out the minimum duration of gap within an ongoing noise required to elicit Acoustic Change Complex (ACC) in young adults and older adults. The study consisted of four groups of participants including fifteen young adults in Group I (18-28 years) and older adults in Group II (>50-55 years), Group III (>55-60 years) and Group IV (> 60-65 years). Normal peripheral hearing sensitivity was ensured for all the participants in the study through detailed audiological evaluations. The participants were assessed for both behavioural gap detection and electrophysiological using ACC.

The results of the study showed that the behavioral gap detection scores were different across age groups. The older adults require higher gap duration to detect the gaps. The behavioral data also showed that the gap duration required for Group IV was higher indicating slower temporal processing with increase in age. The results for gap detection using ACC also showed that gaps required to elicit the responses were different between age groups. The older adults required higher gap duration to elicit ACC than the younger individuals. As seen in the behavioral responses the Group IV individuals required higher gaps to elicit responses. This also indicates that the ability of the aging auditory system even normal hearing sensitivity may have problems in detecting rapid and abrupt changes in the sound stimuli thus have difficulty in discriminating the shortest time interval between two acoustic cues.

It is usually seen that older adults complaining of speech understanding problems especially in adverse listening conditions and studies have also reported it (Dubno, Lee, Matthews, & Mills, 1997; Gelfand, Piper, &Silman, 1986). The current study was carried out on

normal hearing older adults and both the behavioral and ACC data shows that with increase in age the gap required for behavioral response and cortical encoding were higher. This indicates slower temporal processing in older adults. The affected temporal processing in older adults could be a factor for speech understanding problems seen in normal hearing older adults.

Further, the comparison of behavioural gap detection test and ACC did not correlate. That is, the gap required to elicit cortical responses were higher than the gaps required to elicit behavioral responses. Even though the behavioural gap detection thresholds were significantly lower than the gap detection scores obtained for ACC but scores were still within the same range of performance in each tests carried out. Overall these results suggest that the ACC response can be used as an objective indicator of behavioral sensitivity to changes in an ongoing acoustic signal

The results of the current study shows that changes in the aging auditory system older adults required higher gap duration compared to young adults in eliciting the cortical responses and also the behavioural responses. These results clearly indicate slow temporal processing thus possibly leading to the difficulties faced by older adults in understanding speech in difficult listening situations. The objective test could also help in testing the difficult to test older adults with associated problems.

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