EFFECTS OF AGE AND AGE RELATED HEARING LOSS ON SOME ASPECTS OF AUDITORY PROCESSING

Register No. 02SH0023

A dissertation submitted in part fulfillment for the degree of M. Sc. (Speech & Hearing), University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING

NAIMISHAM CAMPUS, MYSORE -

MAY 2004

Dedicated

To

All my Teachers

Who have influenced me in infinite ways to make me what I am today

& My Sister

For her immeasurable Love, Inspiration and Support.

CERTIFICATE

This is to certify that this dissertation entitled **"Effects of age and age related hearing loss on some aspects of auditory processing"** is a bonafide work done in part fulfillment for the degree of Master Science (Speech and Hearing) of **the student (Register No. 02SH0023)**

Prof. M. Jayaram
Director
All India Institute of
Speech and Hearing
Mysore- 6

Mysore

May 2004

CERTIFICATE

This is to certify that this dissertation entitled "Effects of age **and** age **related hearing loss on some aspects of auditory processing"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any other Diploma or Degree.

Guide

Dr. C.S. Vanaja
Lecturer,
Department of Audiology,
All India Institute of
Speech and Hearing.

Mysore

May 2004

DECLARATION

I hereby declare that this dissertation entitled **"Effects of age and age related hearing loss on some aspects of auditory processing"** is the result of my own study under **the** guidance of **Dr. C. S. Vanaja,** Lecturer, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any other Diploma or Degree.

Mysore

June 2003 **Register No. 02SH0023**

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my teacher and guide **Dr. C.S. Vanaja**, Lecturer, Department of Audiology for her valuable guidance and extreme patience throughout the work. Thank you ma'am for your concern and encouragement.

I would like to thank **Prof. M.Jayaram**, Director, All India Institute of Speech and Hearing, for permitting me to carry out the study.

I thank **Dr. Asha Yathiraj**, HOD, Department of Audiology for allowing me to use the required instruments.

I am thankful to **Mr. Sandeep** and **Mr. Ajith** for their help during the work.

I thank **Dr. Siddamallaiah**, Librarian, NIMHANS for allowing me to refer the required books and journals.

I am greatly indebted to all **my teachers** at AIISH for guiding me all these years.

I thank **Dr. Lancy D'Souza** for the help during statistical analysis.

I thank **Dr. Kelly Tremblay, Dr. Risto Naatanen, Dr. Claude Alain** and **Dr. James Jerger** for responding to my queries and sending me the required material.

I am thankful to **all my subjects**, who patiently sat through the long testing sessions and made this dissertation possible.

I thank my friends **Gopee, Shivaprakash, Vijay, BKC, JK, Raj, Sandeep, Shereen** and **Banu** for being such wonderful friends and encouraging me all the time.

Thanks are also due to **Nambi, Yatin, Sudhakar, Amit, Nitish** and **Sai Ram** for their help.

I thank **all my classmates** for their moral support.

I am thankful to **Mr. Jagdish (Graphics)** and **Mr. Shivappa**, who shaped this dissertation in black and white.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The 2001 census shows that there are about 285 million individuals in India above the age of 50. Elderly individuals constitute one of the most rapidly growing segment in the population. Aging is usually associated with global decline in all of the cognitive processes including memory, thinking and sensory abilities. Decline of auditory performance with advancing age is well known and common problem that is becoming more prevalent due to the increasing number of elderly people in our society. Hearing loss is the fourth most prevalent chronic disability among the elderly in US (National Centre for Health Statistics, 1986; cited in Gates, Cooper, Kannel & Miller, 1990).

Presbycusis refers to a variety of hearing disorders that affect the elderly It is charaterised clinically by high frequency sensorineural hearing loss. Older adults with and without normal hearing sensitivity often have difficulty in understanding speech. Gaeth (1948, cited in Jerger, Jerger, Oliver & Pirozzolo, 1989) was among the first to state that some elderly individuals show poor performance in tests of monosyllabic word intelligibility than expected on the basis of the degree and configuration of the audiometric loss. He coined the term "phonemic regression" to describe the above phenomenon. Since 1948, a number of investigators have expanded in Gaeth's findings and concluded that auditory processing disorders (APD) occur more frequently in elderly (Jerger, Jerger, Oliver & Pirozzolo, 1989; Bergman, 1971). The prevalence of auditory processing disorders increase from 20 % to 95 % as the age increases from 50 years to 80 years (Stach, Speilnjak & Jerger, 1990).

There are a number of behavioral and electrophysiological tests available for the audiologist to identify auditory processing disorders. Bellis (2003) recommended the use of some type of behavioral auditory processing test as a pait of routine hearing tests for elderly individuals. J. Jerger (personal communication, August 21, 2003) recommended the use of late cortical responses for the evaluation of APD in elderly. However, the assessment of auditory processing disorders in elderly is a difficult task for the audiologist. Tremblay, Piskosz and Souza (2003) have attributed the following reasons for it.

- Age related peripheral hearing loss contaminate the results of most of the behavioral tests used for the detection of APD.
- Electrophysiological tests like ABR are too sensitive to high frequency hearing loss and results may not be reliable.
- Aging is often associated with decline in cognition, attention etc. It is possible therefore that some of the age related differences seen dining behavioral tests of auditory perception might reflect non auditory age related factors.

However, some of the behavioral tests are relatively more resistant to hearing loss. The tests that are less affected by peripheral cochlear pathology are duration pattern test (Musiek, Baran & Pinheiro, 1990), speech perception in noise (Jokinen, 1973), dichotic digits test (Chermak, 2001) and masking level difference (Jerger, Brown & Smith, 1984).

Electrophysiological measures provide opportunity to auditory processing while minimizing age related effects such as cognition and attention. Speech evoked N1 P2 response can be used to assess neural representation of speech cues. MMN can be used to assess perceptual recognition and auditory memory. N1 P3 and MMN are not affected by peripheral hearing loss of moderate degree or lesser (Boothryod, 1984; Sivaprasad, 2000).

NEED FOR THE STUDY

Despite of the research in this field, auditory processing disorders in elderly is not well understood. It is critical that the APD be diagnosed appropriately in elderly (not just the presence of the disorder, but an analysis of the *'nature'* of the disorder). Through careful diagnosis we can appropriately address the difficulties an elderly experiences in daily life (Bellis, 2003). Only 40 to 60% of elderly hearing aid users report significant benefit from hearing aids (Humes, 2001). Because aging auditory system have more difficulty in processing temporal cues, making sounds louder through hearing aids may have less effect. The previously reported studies evaluated either behavioral or electrophysiological measures of auditory processing in elderly. None of the previously reported studies evaluated different aspects of auditory processing using both behavioral and electrophysiological methods. The effect of age related hearing loss on auditory processing is also not well understood. Hence, the present study was undertaken to evaluate the effect of aging and age related hearing loss on both behavioral and electrophysiological measures of auditory processing.

AIMS OF THE STUDY

Aims of the present study were as follows:

1) To compare the auditory processing in normal hearing adults and normal hearing elderly.
2) To find out the effect of presbycusis on auditory processing.

Both behavioral and electrophysiological tests were used for the above purpose. The electrophysiological tests used were speech evoked N1, P2, N2 and MMN. The behavioral tests included tests to check different processes involved in auditoiy processing namely binaural interaction, binaural integration, temporal sequencing and auditoiy closure/monaural separation. The tests used were masking level difference (MLD), duration pattern test (DPT), dichotic digit test (DDT) and speech perception in noise (SPIN) test.

REVIEW OF LITERATURE

Aging is characterized by global decline in all aspects of functioning. Presbycusis refers to hearing impairment related to aging. Aging results in anatomic and physiologic degeneration at all levels of the auditoiy system. The auditoiy changes associated with aging can be peripheral and/or central. Based on the location of the degenerative process, Schuknecht (1974) identified four categories of presbycusis. In sensory presbycusis, the auditoiy damage is in the form of epithelial atrophy and degeneration of the hair cells and supporting cells of cochlea. In neural presbycusis, the auditory damage is in the form of reduction in the number of functioning nerve fibers in the auditoiy system. In stria! presbycusis, the auditoiy damage is characterized by atrophy of the stria vascularis. Cochlear conductive presbycusis is caused due to degeneration of the mechanical properties of cochlear duct.

Central auditory changes with aging

The central auditoiy pathways are assumed to be subjected to alteration by the aging process. The spiral ganglion cell depletion of neural presbycusis was related to similar changes in the central nervous system by Gulya (1994). In a study encompassing subjects ranging from birth to 95 years, Nerbonne (1988) demonstrated progressive depletion in the cellular population that was not uniformly distributed throughout the cerebral cortex. Rather, of all the areas assessed, the superior temporal gyrus displayed the greatest drop in the cell number, decreasing from an average population of nearly 4000 cells in the newborn to only 1100 cells in the 70 to 95 years old bracket. Based on the review of literature, Guyla (1994) summarized the auditory nervous system changes as follows:

i. Atrophy and degeneration of ganglion cells in the ventral cochlear nucleus as , well as of the medial geniculate body with degenerative cells scattered among relatively normal cells in both the superior olivary nucleus and the inferior colliculus.

ii. Degeneration of the dorsal cochlear nucleus and accumulation of coipora amylacera in the inferior colliculus.

iii. Myelin changes through out the auditoiy system, including edema, fragmentation and degeneration.

The physiological changes in the central auditoiy nervous system lead to problem related to impaired speech perception in elderly. The problems related to impaired speech perception increases with increase in age.

Evaluation of auditory processing disorder

There are different behavioral and physiological tests available for assessing auditoiy processing. Different tests assess different auditoiy processing functions None of the tests assess the entire auditoiy processing function. Hence it is important to use more than one test to identify the nature of the disorder. Combinations of behavioral and electrophysiological tests are always better to evaluate the age effects on auditoiy processing. Behavioral tests are affected by cognitive factors such as attention, memory etc. whereas electrophysiological tests are more resistant to these factors.

Behavioral tests for the evaluation of auditory processing disorders.

Bocca (1954, cited in Silman and Silverman, 1991) was the first to give a behavioral test, to assess central auditoiy function. Over the years many were tests were proposed to assess different aspects of auditoiy processing. These tests include speech and non speech tests. The tests can be classified as monaural low redundancy tests, temporal patterning tests, binaural integration tests, binaural separation tests and binaural interaction tests. ASH A (1996) recommended that tests under each of the categories be included while evaluating auditory processing disorders.

For the assessment of the auditory processing in elderly, the tests selected should include tests which assess different functions in auditory processing. Apart from that, the tests should not be affected by the peripheral sensorineural hearing loss, because most of the elderly individuals have some amount of age related sensorineural hearing loss. The tests described in the following review seem to be less affected by the presence of any peripheral hearing loss.

Masking level difference

Binaural interaction can be assessed by measuring the release of the masking or the masking level difference (MLD) that occurs when different signals are presented to each ear. There are multiple variations among studies using MLD in terms of type of stimulus, masker, and delay used, but results for listeners with presbycusis are remarkably similar (Marshall, 1981). Persons with presbycusic hearing loss show smaller mean MLDs than do normal hearing listeners, **although** there is a considerable overlap in MLD size between the two groups. While abnormal MLDs are seen in persons with brainstem lesions, Olsen, Noffsinger and Caihart (1976) demonstrated that persons with peripheral impairments show reduced MLDs and Quranta, Cassano and Cervellera (1978) concluded that MLD (for 500Hz tones) were not useful diagnostically to detect central impairment unless peripheral healing sensitivity was normal.

Jerger, Brown and Smith (1984) evaluated the effect of symmetric and asymmetric peripheral hearing loss on MLD values at 500 Hz. They found that the MLD value in an ear with sensorineural hearing loss is not significantly different from a normal ear if the threshold at 500 Hz is within 20 dB HL. With increase in threshold the MLD value decreases and virtually becomes absent if the threshold at 500 Hz is above 40 dB HL. The investigators have given normative values to be used with individuals with peripheral hearing loss.

Strouse, Ashmed, Ohde and Grantham (1998) measured temporal processing and binaural sensitivity in 30 young and 30 elderly adults with normal hearing. Subjects were tested with gap detection test (monaural temporal processing); inter aural time difference thresholds (ITD, binaural sensitivity), speech perception in noise and masking level difference (MLD). Gap detection thresholds and ITD were obtained in three sound levels viz. 4 dB SL, 8 dB SL and 16 dB SL. Elderly listeners displayed poorer monaural temporal analysis (higher gap detection thresholds) and poorer binaural processing (higher ITD thresholds) at all sound levels. Elderly listeners also performed more poorly than younger listeners on both speech perception in noise and MLD. The findings suggest that age related factors other than peripheral hearing loss contribute to temporal processing deficits in elderly listeners.

It is evident from this review that elderly individuals perform poorly in behavioral tests such as SPIN, MLD and dichotic tests. There is no literature regarding aging and duration pattern test. All the above mentioned tests are less affected by peripheral hearing loss of moderate degree or lesser. Hence, in order to assess auditory processing in elderly hearing impaired listeners, these tests can be used.

Duration pattern test

Duration pattern test is one of the temporal ordering tests. Musiek, Baran and Pinheiro (1990) studied duration pattern test in normal subjects, subjects with cochlear hearing loss and subjects with lesions in the auditory areas of the cerebrum. Results indicated no significant difference in pattern of recognition between the normal subjects and subjects with cochlear haring loss. However, subjects with cerebral lesions performed poorly than both the groups. Hence, it can be concluded that, duration pattern test is a good test for detecting cortical lesions and it is resistant to peripheral cochlear hearing loss.

Chermak (2001) based on the review proposed that duration pattern test is the best among the temporal patterning tests in individuals with hearing loss. Other temporal patterning test like pitch pattern is affected by the threshold difference between the frequencies used for testing. If the frequencies used in the test have different thresholds, one frequency may sound louder and may contaminate the results. This disadvantage is overcome by the use of duration pattern which uses only one frequency for evaluation (1 kHz).

Dic ho tic tests

Dichotic tests assess binaural integration or separation based on the task which the subject is required to perform. Among the dichotic tests the most commonly used tests are dichotic CV, dichotic digits and dichotic sentences. Very few researchers have focused on investigating the effect of hearing loss on the dichotic tests.

Speaks, Niccum and Tascll (1985) investigated the effect of sonsormeural hearing loss on four dichotic speech tests (digits, vowel words, consonant words and

CV nonsense syllables) in 27 adults subjects with mild to moderate hearing loss. The dichotic digit test appeared to be most promising for assessing central auditory function when the patient had sensorineural hearing loss because the performance for the digits was only slightly affected by the peripheral loss .The test difficulty increased from vowel words, consonant words to CV syllables. The investigators proposed the reason for the poor performance of hearing impaired on dichotic CV as the inability of the impaired auditory system to process rapidly changing speech signal and the lack of redundant cues in dicholic CV material.

Jerger, Alford, Lew, Rivera and Chmiel (1995) studied behavioral and electro physiologic responses to dichotic listening tasks in both verbal and non verbal paradigms in young adults with normal hearing, elderly persons with normal heating and elderly persons with presbycusis. Results indicated that both elderly groups showed increasing left ear deficit on the non-verbal paradigm. It was concluded that with age there might be significant loss of efficiency of interhemispheric transfer of auditory information through the corpus callosum.

Chermak (2001) based on the review suggested the use of dichotic digits for the assessment of auditory processing disorders in individuals with peripheral hearing loss than dichotic CV. The resolution of the fast frequency and intensity transition underlies the CV recognition. This resolution is heavily dependent on cochlear processing. Hence the dichotic digits are better choice than dichotic CV in assessing auditory processing in individuals with hearing loss.

Speech perception in noise (SPIN).

Speech perception in noise is a monaural low redundancy test, which evaluates the auditory processing. The effects of aging on perception of speech in noise for listeners with relatively normal pure tone thresholds were tested using synthetic sentence identification (SSI) with a competing speech masker across a range of SNRs by Smith and Prather (1971). They studied 20 young and 20 elderly individuals in +10 dB SNR, +5 dB SNR and 0 dB SNR conditions. They found a decrement of scores in elderly listeners in comparison to young listeners for speech discrimination of CV nonsense syllable across a range of sensation levels (SLs)and signal to noise ratios (SNRs) using broadband noise. Orchik and Burgees (1977) found decrement for their older listeners in comparison to young listeners only for their more difficult SNRs (0 dB SNR and +5 dB SNR).

Other investigators also have reported that elderly listeners with hearing loss usually show decreased speech discrimination in noise as compared to young listeners with same degree and pattern of hearing loss (Jerger and Hayes, 1977; Jokinen, 1973). However, SUIT (1977) found no difference in speech identification scores in noise among 100 listeners, ranging between 30 to *90* years of age, with matched audiograms. Even though, the mean speech discrimination scores in noise of elderly listeners often are reported to be lower than those of younger listeners, Hayes and Jerger (1979) found that not all elderly listeners show problems in speech in noise task. They hypothesized that the pace of the degenerative process is different in different individuals and at later stages of life individuals with poor SPIN results increase.

Plomp and Mimpen (1979) evaluated speech recognition in noise as function of age. The results indicated a progressive decrease in performance above the age of 50 years. Dubno, Dirks and Mogan (1984) studied the effects of mild sensorineural hearing loss and listeners chronological age on speech recognition in babble in normal hearing adults (age < 55 years), hearing impaired adults, normal hearing elderly (age >55 years) and hearing impaired elderly. Differences in performance in noise as a function of age was observed for both normal hearing and hearing impaired listeners despite equivalent performance in quiet. Subjects with mild hearing loss performed significantly worse than their normal hearing counterparts. They concluded that both the age and hearing loss can affect the individual's speech identification in noise.

Divenyi and Haupt (1997) investigated SPIN in elderly individuals with mild to moderate sensorineural hearing loss and in normal hearing young adults. Genuine age related deficits were found in measures assessing measuring auditory resolution and the ability to utilize spatial temporal and/or linguistic context information to perceptually separate speech targets from surrounding speech noise.

Frisina and Frisina (1997) studied the role of peripheral and central auditory system dysfunctions in the speech recognition problems in elderly. 50 young adult and 50 elderly subjects, with normal audiometric threshold or high fiequency hearing loss were presented with three types of linguistic materials at supra threshold levels to determine speech recognition performance in noise. The results indicated that, peripheral auditory nervous system pathologies, manifested as reduced sensitivity for speech fiequency pure tones and speech materials, contribute to elevated reception threshold in quiet, and to reduce speech recognition in noise. Good cognitive ability is demonstrated in old subjects who took advantage of supportive context as well or better than young subjects, strongly indicate that the cortical portion of the speech language nervous system did not account for the speech understanding dysfunction in the old subjects. When audibility and cognitive functions were not affected, the demonstrated speech recognition in noise dysfunction remained in old subjects. This implicates auditoiy brainstem or auditory cortex temporal resolution dysfunctions in accounting for the observed differences in speech processing. Performance differences between young and elderly subjects with elevated thresholds illustrate the effects of age plus hearing loss and thereby implicate both peripheral and central dysfunctions in presbycusis.

There is agreement in the literature regarding the SPIN perfoimance of the elderly. With the advancement of age the SPIN performance is reduced. The presence of hearing loss degrades the speech perception by making sounds less audible. However, there is intersubject variability seen in scores of SPIN and not all elderly individuals perform poor in SPIN.

Electrophysiolosical evaluation

Electrophysiological tests help to evaluate auditoiy processing, while minimizing the effects of cognition and attention. Among the electrophysiological tests auditory evoked late latency responses are best suited for the evaluation of auditory processing, as it represents the processing at the higher centers of the auditory system.

Comparison of the results of the studies evaluating the late potentials in elderly *is* difficult. Different researchers considered subjects of different age groups in the elderly group. The studies also differ from each other based on the stimuli used and recording paradigms. The different stimuli used include tones and speech sounds. The deviations used to elicit MMN include frequency deviation, duration deviation, spectral deviations etc. The recording paradigms include passive and active recordings. Some studies recorded obligatory responses N1, P2 and N_2 while simultaneously collecting the discriminative responses such as MMN and P300 whereas some other studies recorded only obligatory responses.

Effect of age on late potentials of the auditory system.

The latencies of auditory evoked potential components occurring after 150 ms (P2, N2 and P3) have all been shown to increase in latency as a function of age. In contrast, components occurring before 150 ms show little or no latency change with age (Ford, Roth, Mohs, Hopkins, & Bert, 1979).

Pfefferbaum, Ford, Roth and Koppel (1980) studied auditory event related potentials in 12 elderly and 12 adult females with normal hearing. Results indicated that the early components N1 did not differ significantly between the groups. But the later components *were* affected. P3 was affected more than P2. However, Goodin, Squires, Henderson and Starr (1978) reported that increasing age results in a decrease in evoked potential amplitude and increase in latency of both N1 and P2 cortical evoked potentials. This was based on results of 20 young and 20 elderly healthy individuals with normal hearing.

Iragui, Kutas, Mitchiner and Hillyard (1993) recorded auditory event related potentials in 71 healthy individuals between 18 to 82 years of age in an odd ball task. The peak latencies of both the N1 and P2 components elicited by standard tones were slightly but significantly delayed with age. In the ERPs of target tones, the later, endogenous components (N2 and P3) showed linear increases in latency as a function of age. Later the component, more the age-related delay. In general, aging was associated with less negativity (N2) and more positivity (P3) over the anterior scalp, together with a smaller P3 and a more pronounced N2 over posterior scalp areas.

Other investigators have also shown that aging affect the potentials recorded from different locations of scalp differently. Anderer, Semi itsch and Saletu (1996) evaluated the effects of aging on event related potentials (N1, P_2, N_2 and P300) in 172 normal healthy subjects aged between 20 and 88 years in an auditoiy odd ball paradigm. With advancing age, N1 latency increased parietally (0.12 ms/year), P2 latency increased frontally (0.34 ms/ year) whereas N_2 and P300 latencies increased all over the scalp (0.37 ms/year for N_2; 0.92 ms/year for P300). With advancing age, standard tone ERP amplitudes were enhanced frontally (0.03 µV/year for N1; 0.07 µV/year for P2), N_2 amplitudes were attenuated frontally (0.11 µV/year) and P300 amplitudes were attenuated parietally (0.15 µV/year). Multichannel analysis demonstrated that ERP latencies and amplitudes are dependent on electrode location. Standard tone ERP latencies changed their topographic distribution with age, whereas taiget tone ERP latencies did not. While N1 amplitude distribution was unaffected by age, P2, N_2 and P300 topography changed significantly with age: P_2 topography to a more frontal distribution; N2 topography to a more parietal distribution; P300 topography to a more frontal and more equipotential distribution.

Amenedo and Diaz (1998a) evaluated the age dependence of the N1 P_2 complex elicited by non-target stimuli as well as N_2 and P3 elicited by target stimuli across 20 electrode sites in subjects aged between 20 to 86 years. In non-target ERPs, it was found that P2 amplitude at F_z increases linearly with advancing age and the analysis of within task change indicated that P_2 amplitude decreased during the task in young subjects at P_z, but remained unchanged in middle aged and elderly subjects. The results suggested the existence of age related inhibitory deficits that may hinder the disagreement of attentional resources from irrelevant stimuli during the task. In the target ERPs, the latencies of N_2, P3 and N_2b increased linearly at F_{za} $C_z$and P_4. The results indicate that aging related slowing begins at controlled memory comparison of non target or target stimuli.

Age related decline in coding fine temporal structure of acoustic signals using auditory evoked potentials elicited by sounds of various durations was measured by Ostroff, Mc Donald, Schneider and Alian (2003). They investigated the effect of age on N1 and P2 wave elicited by sounds of various duration was tested in 10 adults, 10 middle aged and 9 older adults. In all the three age groups, the amplitude of N1 wave increased linearly with increase in sound duration. Only young and middle aged adults showed increase in P2 amplitude with signal duration. P2 amplitude was not significantly affected by increasing signal duration in older adults. The fact that the N1 amplitude growth was comparable in all the three age groups may indicate that some preliminary encoding of sound duration is resistant to aging process, but subsequent analysis of duration as indexed by P2 wave may be impoverished in older adults. The fact that young and middle aged adults show comparable N1 and P2 growth functions suggest that age related decline in the precise encoding of sound duration takes place after the fifth decade of life.

Tremblay, Piskosz and Souza (2003) investigated the effect of aging and age related hearing loss on the perception and neural representation of a time varying speech cue. 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 tokens representing 10 ms increment along a /ba/-/pa/ VOT continuum were used to evoke responses. Each participant's ability to discriminate speech tokens was also assessed. Results indicated more difficulty in discriminating 10 ms VOT contrast for both normal hearing and hearing impaired older individuals. There were no significant age related findings for P1 latency; however N1 and P_2 latencies were prolonged for both older groups in response to stimuli with increased VOT durations. The presence of age related hearing loss resulted in significant increase in N1 amplitude in response to voiceless stimuli. The investigators concluded that aging and age related hearing loss alter temporal response properties in the central auditory system and some of the perceptual difficulties described by the older adults might be due to age related changes regulating excitatoiy and inhibitory processes.

It is evident from the above review that the late potentials are attenuated with aging. N1 is less affected compared to other potentials such as P2 or N2. This suggests that some amount of encoding is preserved in elderly. But higher levels of processing are impaired. Speech evoked N1 P_2 response reflects spatial and temporal acoustic changes contained within a speech signal (Tremblay, Piskosz & Souza, 2003). Hence the speech evoked N1 P2 can be used to assess neural representation of time varying speech cues.

Effect of age on MMN.

A sequence of discrete tones elicit a series of scalp potentials, the N1 wave being the most stable and prominent response with the latency of about 100 ms (Naatanen & Picton, 1987). When deviant tones are randomly embedded in a sequence of standard tones, a specific event related potential component called mismatch negativity (MMN) emerges. This component reflects the automatic detection of stimulus deviance in the brain (Naatanen, 2003) The peak latency of MMN is around 100- 200 ms and it partly overlaps with N1 P2 complex (Naatanen & Picton, 1987). The maximal amplitude of MMN is seen fiontally over the right hemisphere, irrespective of the ear stimulated (Naatanen, Paavilainen & Reinikainen, 1989). MMN can be elicited by changing the intensity, frequency and duration of the stimuli, changing the location of the stimuli and also by using different speech sounds (Paavilainen, Karlsson, Reinikainen, & Naatanen, 1989). MMN reflects a neural mismatch between an incoming stimulus and the transient representation of sounds in the short term memory (Naatanen, 2003).

The MMN is particularly well suited for studying age related changes in processing task irrelevant stimuli because it is elicited in paradigms in which overt attention and behavioral responses are not required (e.g. Participant reading a book or watching a movie). Because the MMN is isolated in a difference wave between the ERP to standard and deviant stimuli, it is less sensitive to peripheral factors such as heaiing sensitivity which would affect ERP's elicited by standard and deviant stimuli in a similar manner (Alain & Woods, 1999, Sivaprasad, 2000).

Compared to the amount on MMN literature in general, studies on elderly with MMN are quite few in number. Among the available studies comparison between different studies are not possible, as different researchers used different paradigms (active vs. ignored), different stimuli (frequency deviation, intensity deviation, speech stimuli etc.), different inter stimulus interval. Most predominantly the definition of aging itself is different in different studies (Pekkonen, 2000).

MMN for frequency deviance.

Verleger, Neukater, Kompf and Vieregge (1991) were the first to study MMN in aging. They measured ERPs to pitch change from 18 young and 20 elderly subjects using an active oddball paradigm at the stimulus rate of 1500 ms. In order to study MMN, they measured the early part of N2 deflection, trying to avoid the N_{zb}

overlap. The MMN (or its early part) amplitude was very similar between the groups, where as the MMN latency, like that of N2b, and P3 response was significantly delayed with aging. It was proposed that delayed processing in aging, as reflected by MMN, contributes to the delayed P_3 j.

Czigler, Csibra and Csontos (1992) recorded ERPs for frequency deviation (standard 950 Hz, deviant 1045 Hz) in 8 young and 8 elderly individuals. Inter stimulus intervals of 800, 2400 and 7200 were used. The amplitude of N1, the amplitude and latency of P_2 were increased as a function of 1SI. There was a significant age related reduction of MMN amplitude with all ISIs used. $P3_a$ component was observed in the younger group for two short ISIs. The investigators concluded that there is increased activity of the orienting system in younger subjects in compared to the older age group.

The MMN area and possible effects of aging on MMN were investigated in 27 subjects ranging in age from 18 to 85 years by Pekkonen, Jousmaki, Partanen and Kaihu (1993). Frequency deviance was employed (800 Hz standard and 552.4 Hz deviant) and the **ISI** was varied between 1 s to 3 s. MMN area remained stable regardless of age with ISI's of 1 s. Only negligible decrease of MMN area was found when **ISI** was varied from 1 s to 3 s in younger subjects (age < 60 years). MMN area was significantly attenuated in elderly (age > 60 years) when 3 s ISI was **used.** This indicates that the neuronal representations of standard stimuli in old subjects do not exist so long as in young subjects, possibly reflecting the shortening of human auditory sensory memory trace with age.

Pekkonen, Rinne, Reinikainen, Kujala, Alho and Naatanen (1996) compared MMN for frequency and duration deviance and N2b, in 13 healthy younger and

13 older subjects. IS1 was varied between 0.5 ms to 4.5 ms. Aging affected neither frequency nor duration of MMN with 0.5s ISI. This finding indicates that the automatic stimulus discrimination per se is not impaired with normal aging (frequency and duration discrimination). However with 4.5 s ISI the MMN and N_{2b}, complex attenuated significantly more in older than younger subjects. This suggests that the stimulus trace decays faster with aging.

Gunter, Jackson and Mulder (1996), performed a study with 24 young and 24 middle aged subjects using a frequency deviance and an ISI of 200 ms. Their results supported the previous findings (Verleger et al., 1991; Pekkonen et al., 1993, 1996) that the detection of the frequency change is not impaired with aging.

The N2b, component is proposed to reflect attentive change direction (Naatanen, 2003). Verleger, Neukater, Kompf and Vieregge (1991) suggested that both MMN and the subsequent N2b are delayed with aging. Their study employed an active oddball paradigm which did not optimally separate MMN and N21,. Amendo and Diaz (1998b) however used a dichotic listening task in order to study ERP response to similar stimuli under attend and ignore conditions. They obtained ERP response from 16 young, 16 middle aged and 19 elderly subjects using a frequency deviance and an ISI of 600ms. No significant age or gender related differences for the MMN amplitude or latency appeared, whereas the N2b latency significantly increased with aging. It was concluded that automatic stimulus comparison in the auditory system at short intervals is not affected by age, whereas the processing requiring attentional effort declines with age.

Gaeta, Friedman, Ritter and Cheng (1998) also reported that MMN for pitch deviations was not affected by age for stimulus presented with an ISI of 1 s. MMN for small and large pitch deviances and for novel sounds were recorded in 26 young and 20 elderly subjects in a passive condition. Although the younger group had larger and earlier MMN for all three-stimulus changes, the difference between the groups did not quite reach significance.

MMN in active and passive conditions were compared by young and elderly subjects by Kazmerski, Friedman and Ritter (1997). They recorded MMN for frequency deviation in 16 young and 16 elderly subjects with an ISI of Is. In some blocks novel stimuli consisting of environmental stimuli were intermixed with standard and deviant tones. In the passive condition, the MMN amplitude for the environmental stimuli was significantly reduced in elderly group. Their data revealed, however, that in passive condition yielding most distinct MMN responses, deviant tones differing in frequency elicited a robust MMN in both the young and elderly groups. These results clearly demonstrated that age related MMN changes might also depend on the type of deviance used. The amplitude of N21, obtained in active condition did not differ between groups.

Even though there are variations in the results of MMN for frequency deviation, most of the studies reported that detection of frequency deviation is not affected by age. MMN for frequency deviance is diminished at higher ISI because of the decline of the auditory memory with age.

*MMN **for** duration deviance in elderly*

Karayinids, Andrews, Ward and Michie (1995), observed a significantly reduced amplitude and increased latency of MMN with increased amplitude of N1 in both middle aged and elderly subjects compared with young. They studied

19 young, 12 middle aged and 15 elderly subjects in dichotic paradigm with duration deviance and ISIs of 200-500 ms.

Investigators have also probed the effect of age on scalp distribution of MMN. Woods (1992) recorded MMN for duration deviance (75 ms vs. 25 ms) in 9 elderly and 9 middle-aged subjects in a selective dichotic listening task. The 1SI varied between 200 and 400 ms. MMN amplitude was reduced in the elderly group. There was a significant change in the scalp distribution of MMN with age. The MMN was larger over the right hemisphere for middle-aged subjects but larger over the left hemisphere for the elderly subjects. Elderly subjects also had lower P3 amplitude and delayed P3 latencies.

Schroeder, Ritter and Vaughan (1995) found that the elderly subjects with normal hearing had a significantly smaller duration MMN compared with the young subjects, whereas the frequency MMN was significantly smaller in low functioning elderly and dementic group but not in the normal elderly. Further, MMN latency to novel sounds was significantly delayed in all three elderly groups compared with the young group. They recorded MMN in four different groups of subjects (14 young, 35 normal elderly, 32 low functioning elderly and 13 dementic subjects) using pitch, duration and environmental sounds as deviant tones with the ISI of 1.1 s.

Previous ERP findings (Alho, 1995; Giard, Perrin, Pemier & Bouchet, 1990) suggest that besides temporal sources frontal activity contributes to the MMN. Separation of the sources of the sources on the basis of ERP is difficult and it thus remains unsettled whether aging affects predominantly the temporal or frontal MMN. The attenuation of frontal MMN would speak for impaired involuntary attention switching with aging (Pekkonen, 2000).

Jaaskelainen, Varonen, Naatenen and Pekkonen, (1999) observed a significantly reduced magnetic mismatch response (MMNm) in the middle aged and elderly groups regardless of the ear stimulated or hemisphere measured. Further MMNm ipsilaterally, but not contralaterally to the ear stimulated was significantly delayed in the middle aged and elderly groups compared with younger groups. The gender had no significant effect on the MMN latency or amplitude and no aging on location of MMNm sources was observed. This was based on the results of healthy subjects ranging in age from 17 to 82 years for duration deviance. These findings strongly supported the view that the MMN to duration change is impaired with aging.

It is evident from this review that MMN for duration deviance is affected by the aging process. MMN for duration deviance is significantly attenuated with aging.

Speech evoked MMN in elderly

Bellis, Nicol and Kraus (2000) studied the effect of age on hemispheric asymmetry observed in the neurophysiological responses to speech stimuli in children, young adults and older adults. They used two sets of speech stimuli, the first set consisted of speech sounds which differed in two features (place and manner of articulation) and the second set consisted of stimuli which differed only in one feature. MMN and P1 N1 complex obtained over right and left temporal lobes were examined. The MMN elicited for both the stimuli *were* not significantly different in children and adults. But in elderly, MMN for the second set of stimuli had significantly lesser amplitude and MMN was absent for many elderly individuals for the second set of stimuli. Children and young adults demonstrated larger P1 N1 and

MMN responses amplitudes over the left temporal lobe than over the right, but responses from the elderly subjects were symmetrical. The study demonstrated a biological age related change in the neural representation of the basic speech sounds and suggest one possible mechanism for speech perception difficulties exhibited by aging adults.

MMN for other deviant stimuli

Bertoli, Smurzynski and Probst (2002) studied the effects of aging on temporal resolution; the electrophysiological and psychoacoustic detection thresholds for a very short silent gap within a pure tone were determined. 10 young and 10 elderly normal hearing adults served as subjects. MMN was elicited by deviant stimuli with gap duration varying from 6 to 24 ms in 3 ms steps. Behavioral gap detection thresholds were also found out. The results indicated that there was no significant difference in psychoacoustic gap detection thresholds between young and elderly subjects. In contrast, longer gaps were needed to elicit MMN in elderly subjects. They also had significantly reduced MMN peak amplitudes, increased MMN peak latencies, a significantly smaller P2 amplitude and longer P2 latency in their response to the standard stimulus, when compared to the same measures in young subjects. It was concluded that processing of basic temporal stimulus features in elderly subjects is considerably reduced at the pre attentive level (as indicated by MMN), than when attention is directed to the task (as indicated by the psychoacoustic measures).

It is clear from the above review that MMN for frequency deviance per se is not affected by aging. As auditory memory is shortened in elderly individuals MMN for longer ISI's are dampened. In contrast, the MMN for duration deviance is significantly affected by aging. This shows that elderly subjects have difficulties in discriminating and identifying duration deviance. Speech is a complex signal which requires perception of spectrotemporal changes. There are not many studies on MMN evoked by speech stimuli. Hence, the present study was undertaken to evaluate MMN for speech stimuli in elderly.

METHOD

The following method was adopted for assessing the effect of age and age related hearing loss on auditory processing.

Subjects:

Subjects of the present study were divided into 3 groups.

- Group I: Normal hearing adults.
- Group **II:** Elderly individuals with noimal hearing.
- Group III: Elderly individuals with age related hearing loss.

Subject selection criteria is depicted in Table **1**.

Table 1. Subject selection criteria.

Group I	**Group II**	**Group III**
Age range: 18-30 years	Age range: above 50 years	Age range: above 50 years
Should have hearing sensitivity within 15 dB HL (250 Hz-8kHz)	Should have hearing sensitivity within 25 dB HL (250 Hz- 8 KHz)	Should have hearing loss not exceeding 50 dB HL. The loss should be acquired.
Should have symmetrical hearing sensitivity. Difference in threshold between ears should be within 10 dB	Should have symmetrical hearing sensitivity. Difference in threshold between ears should be within 10 dB	Should have symmetrical hearing sensitivity. Difference in threshold between ears should be within 10 dB
Should have normal middle ear function as assessed by tympanometry and acoustic reflex thresholds.	Should have normal middle ear function as assessed by tympanometry and acoustic reflex thresholds.	Should have normal middle ear function as assessed by tympanometry and acoustic reflex thresholds.
Should not have any associated otological or neurological disorders.	Should not have any associated otological or neurological disorders.	Should not have any associated otological or neurological disorders.
Should be fluent Kannada speakers.	Should be fluent Kannada speakers.	Should be fluent Kannada speakers.
Should not have any difficulty in understanding speech in noisy situation.	-	-

The subjects in group 1 were aged between 18 to 25 years (Mean = 20.7 years, SD=2.07). The subjects in group 2 were aged between 52 to 76 years (Mean = **61.10** years, SD=7.67). The subjects in group 3 were aged between 55 to 86 years (Mean = 70.4, SD=10.49). The mean and SD of pure tone average (PTA) across the group is given in Table 2

Table 2. Mean and standard deviation of pure tone thresholds

		Mean	SD
Group 1	Right ear	9.83	1.99
	Left ear	9.83	1.46
Group 2	Right ear	14.01	2.63
	Left ear	14.67	2.05
Group 3	Right ear	33.49	3.96
	Left ear	35.0	4.65

Instruments:

> A calibrated clinical audiometer OB 922 (Version 2) was used to cany out the following tests.

- Pure tone audiometry.
- Assessment of speech reception threshold (SRT).
- Speech identification in quiet and noise.
- Duration pattern test (DPT).
- Dichotic digits test (DDT).
- Masking level difference (MLD).

> A Philips CD player was used for the stimulus presentation for speech identification (in quiet and noise), Duration pattern test (DPT) and dichotic digits test (DDT).

> A calibrated middle ear analyzer GSI 33 (Version 2) was used to assess middle ear function.

> MMN and N1 P2 were recorded using Intelligent Hearing System (Smart EP Version 2. lx) evoked potentials system.

Materials:

Speech identification in quiet and noise. Phonetically balanced word list in Kannada developed by Vandana (1998) was used for estimating speech identification in quiet. The word list consists of two lists, A and B each with 50 words. Material used for SPIN was developed by recording the speech identification test in Kannada developed by Vandana (1998) and the speech babble in Kannada developed by Anita (2003) in a CD at 0 dB SNR.

Duration pattern test: Duration pattern test developed by Thamne (2003) was used for the present study. The stimuli consisted of 1 kHz short (250 ms) and long (500 ms) duration tones, in six different combinations of three-tone sequence. The sequence had one of the three tones different from the other two. The tones were separated by a 250 ms gap. Thirty stimuli of the six different combinations constitute **the** test material.

Dichotic digit test: The dichotic digits test in Kannada developed by Regishia (2003) was used for the present study. The digits included were bisyllabic digits (/onṭu/, /mu:ru/, /aiḍu/, /a:ru/, /e:ḷu/, /enṭu/ and /hattu/) spoken by an adult Kannada speaker. The inter stimulus interval between the first and the second pair of digits was around 500 ms. The material consisted of a total of 30 presentations each consisting of two pairs of digits in Kannada.

N_1P_2 and MMN: The electrophysiological responses were recorded using speech stimuli (natural speech). The speech stimuli selected were /d̪a/ and /ḍa/. These stimuli were selected as they differ in place of articulation and thus in the frequency domain. Perception of fast spectrotemporal variations in the frequency regions between 1000 Hz to 2000 Hz is required for the perception of these sounds. This frequency region is important for perception of other sounds also.

The speech stimuli spoken by an adult male was recorded into a computer using a unidirectional microphone. The computerized material was scaled using AUD1OLAB software, so that both the monosyllables are of equal intensity. The wave file was then converted to a stimulus file for AEP using the software "Stimconv" provided by M/s. Intelligent Hearing Systems.

Procedure

Pure tone thresholds were obtained at octave intervals between 250 Hz to 8000 Hz for air conduction stimuli and between 250 Hz to 4000 Hz for bone conduction stimuli using modified Hughson-Westlake method (Carhart & Jerger, 1959). Speech reception thresholds (SRT) were obtained using paired words in Kannada. The minimum intensity at which 50 % scores were achieved was considered as SRT. Immitance evaluation included tympanometry and measurement of acoustic reflexes. Only those subjects who met the criteria listed earlier were selected for further testing.

Speech identification in quiet and noise: Speech identification in quiet was carried out at 40 dB SL (re: SRT). Either list A or B of the material developed by Vandana (1998) was presented to each ear separately and the subjects were asked to repeat the words. Each correct response was given a score of 2%. The total percentage of the correct responses was calculated.

SPIN was done at 40 dB SL (re: SRT). The recorded speech material (Kannada PB words and Kannada speech babble at 0 dB SNR) was presented to each ear separately. Scoring was same as that of speech identification in quiet.

Duration pattern test: Duration pattern test was done for each ear separately at 40 dB SL (re: SRT). The subjects were asked to verbally repeat the pattern. The total percentage of correct responses was found out for each ear separately.

Dichotic digit test: Dichotic digits test was done at 40 dB SL (re: SRT). The subjects were asked to repeat the digits heard in both the ears. The responses were scored in terms of single correct and double correct scores. A single correct score was given when the subject reported the syllable presented to any one ear correctly. A double correct score was given when the subjects reported the syllables presented to both ears correctly.

Masking level difference: To obtain MLD values each subject was presented binaurally with narrow band noise centered around 500 Hz at 40 dB SL. The threshold of pure tone at 500 Hz was found out in presence of noise in the following three conditions:

i. Homophasic condition (No So) - when both noise and signal are in phase at two ears.
ii. Antiphasic (NoSπ) - when phase of the signal is reversed in two ears.
iii. Antiphasic (NπSo) - when the phase of the signal is reversed in two ears

Differences between the amount of noise required for masking the signal in homophasic and antiphasic conditions gives MLD.

Electrophysiological responses: MMN was recorded from Fz.T_L, T_R and ipsilateral mastoid (A1 or A2), with forehead as ground and nose tip as reference electrode placement. TL was located halfway between T3 and T5 and T_R was located halfway between T4 and T6. The responses recorded from the ipsilateral mastoid were not considered for the analysis. Ipsilateral mastoid was selected as one criterion to identify MMN was the reversal of polarity between frontal and mastoid electrodes.

The subjects were seated in comfortable position to ensure a relaxed posture and minimum muscular artifacts. The subjects were asked to watch a silent movie, in order to assure a passive listening paradigm. The skin surface of the fore mentioned sites were cleaned and disc electrodes were placed. After ensuring permissible low impedance, the data was acquired. Electrophysiological responses were recorded by stimulating the right ear. MMN and N1 P_2 were recorded by using the protocol described in the Table 3.

To determine the latency and amplitude of MMN, the pattern of the standard, deviant and difference (deviant minus standard) waveforms were analyzed. In the difference waveform, MMN was identified using the following criteria:

> A trough in the latency range of 50 ms to 300 ms

> Should be a negative potential of amplitude more than — 0.3 μV

> Should occur either in the N1P_2 or P2 N2 complex.

> The negative peak should follow a positive peak.

From the response waveform for the frequent stimuli N1, P2 and N2 were located. P1 and P2 were the positive reflections and N1 and N2 were the negative reflections following P1 and P_2 respectively. The latency and amplitude of all the responses were found out.

Table 3: protocol used for recording electrophysiological responses.

Type of stimulus	Frequent: /d̪a/ Infrequent: /ḍa/
Intensity	50 dB SL
Stimulus duration	/d̪a/ 247 ms /ḍa/ 245 ms
No of averages for the infrequent stimuli	100
Repetition rate	1.1/s
No of channels	4
Gain	50,000
Filter settings	0.1 to 30 Hz
Recording window	0 to 400 ms
Transducer	Insert ear phones

RESULTS

The aim of the present study was to evaluate the effects of age and age related hearing loss on auditory processing. Mean and standard deviation values of the data in each group were found out. It may be recalled that group 1 included adults with normal hearing, group 2 included elderly subjects with normal hearing and group 3 included those with presbycusis. The data obtained was analyzed using the SPSS software (Version 10). The data was statistically analysed using one way ANOVA to find out the main effect of group. Whenever a main effect of group was found, Scheffe's post hoc test was performed to find out the significance of difference between the groups. Pearson's product moment correlation analysis was done to find out the correlation between age and results of different tests in elderly group. In presbycusis group Pearson's correlation analysis was carried out to check the correlation between hearing threshold and results of different tests. Tables 3 and 4 depicts the mean and SD of scores of behavioral and electrophysiological tests.

Table 4. Mean and SD of results of behavioral tests

	MLD				DPT				DDT						SPIN			
	SoNπ		NoSπ		RES		LES		RES		LES		DCS		RES		LES	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group 1	11.25	1.32	11.0	, 1.26	27.1	1.1	26.0	1.05	27.95	0.87	25.65	1.0	25.05	1.28	84.4	5.15	81.8	4.26
Group 2	10	1.67	9.5	1.05	21.3	1.34	21.0	1.83	25.65	1.29	22.95	1.93	19.05	2.38	70.0	9.29	66.4	10.53
Group 3	7.75	1.42	7.5	1.18	17.5	2.64	17.5	2.27	17.3	4.62	16.75	3.91	10.35	3.41	50.4	4.09	44.8	11.74

Table 5. Mean and SD of results of electrophysiological tests.

			F_z			T_L			T_R		
			Group 1	**Group 2**	**Group 3**	Group 1	**Group 2**	**Group 3**	**Group 1**	Group 2	**Group 3**
N,	Latency	Mean	100.26	101.81	104.79	100.03	106.12	106.71	99.5	103.3	104.7
		SD	9.89	10.01	10.36	8.05	10.04	7.33	11.26	8.90	9.87
	Amplitude	Mean	2.51	2.90	2.86	0.60	1.13	0.52	1.12	1.41	2.19
		SD	1.30	1.67	2.12	0.93	0.89	1.1	1.11	0.66	0.67
P_2	Latency	Mean	145.02	150.02	146.23	141.68	146.12	145.32	155.56	158.48	156.14
		SD	6.64	12.73	10.09	7.16	11.19	10.56	6.70	9.89	11.17
	Amplitude	Mean	4.09	4.05	2.64	2.91	2.84	1.84	2.60	2.45	1.88
		SD	1.17	1.01	1.19	0.98	0.71	0.96	0.76	0.81	0.49
N_2	Latency	Mean	178.18	188.67	195.08	187.98	200.40	204.04	199.0	203.76	211.90
		SD	4.53	13.54	13.27	8.54	11.83	9.37	9.31	8.55	12.33
	Amplitude	Mean	-0.19	1.53	1.45	-0.24	0.74	**1.2**	1.04	1.18	1.81
		SD	1.12	0.72	1.14	0.85	0.71	**1.2**	0.97	0.48	0.67
MMN	Latency	Mean	194.15	207.94	213.56	196.80	211.31	217.84	199.0	211.49	221.28
		SD	16.50	11.25	15.07	12.87	7.71	14.19	7.38	8.77	14.70
	Amplitude	Mean	-1.91	-1.19	-1.31	-1.41	-0.75	-0.62	-1.16	-0.76	-0.52
		SD	0.86	0.65	0.94	1.11	0.49	0.29	0.72	0.27	0.51

Behavioral tests

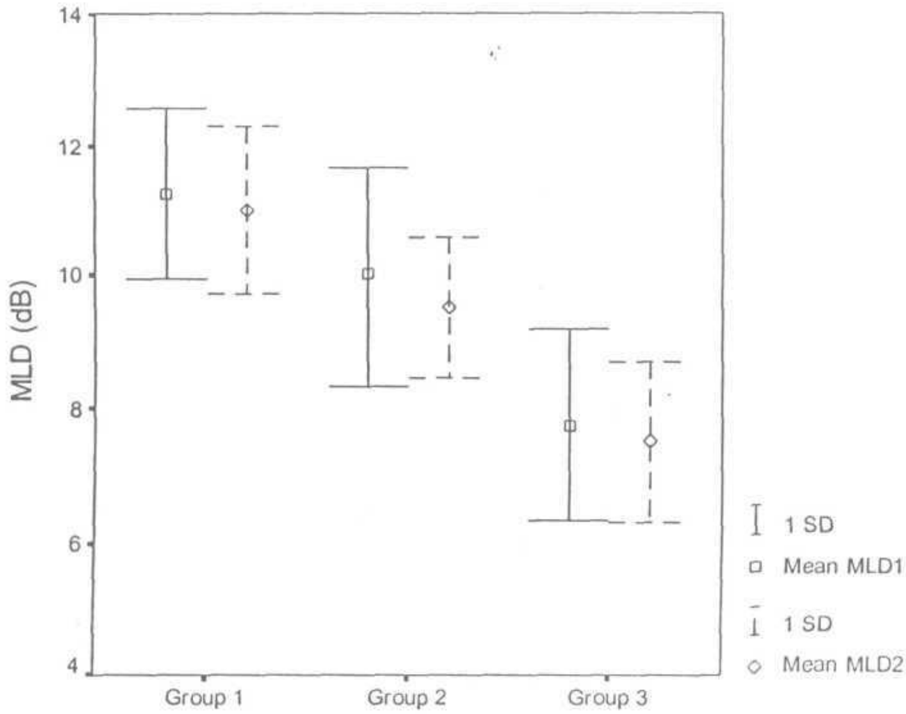
MLD

MLD values were found out in SoN_{π} and NoSπ conditions. The mean and standard deviation values of MLD in different conditions across the groups are given in the Fig. 1. It is clear from the Fig. 1 that adults had the highest MLD values in both SoNπ and NoSπ conditions. Elderly individuals and individuals with presbycusis had MLD values lesser than adults. Presbycusis population had the least MLD value.

The results of ANOVA revealed a main effect of group in SONΠ [$F (2, 27) = 14.48$, $p < 0.05$] and NoSπ [$F (2, 27) = 22.2$, $p < 0.05$] conditions. Schefte's post hoc test revealed no significant difference between adults and elderly with nonnal hearing as well as elderly with nonnal hearing and presbycusic group. However, there was significant difference between the means of adults and presbycusic group.

Pearson's product moment correlation analysis was done to find out the correlation between age and MLD values in nonnal hearing elderly and between threshold at 500 Hz and MLD values in presbycusis population. The results are shown in Table 6. The analysis showed a low negative conelation between age and MLD values and the conelation value was not significant. There was a significant moderate to high conelation between threshold at 500 Hz and MLD values, indicating a reduction in MLD with increase in age related hearing loss.

Fig 1. The mean and SD of MLD values across the groups in two conditions.



MLD 1 - MLD in SONΠ condition; MLD 2 - MLD in NoSπ condition.

Table 6. Correlation of MLD values with age and threshold.

Variables	r	Significance
Age and MLD (SONΠ)	-0.435	0.209[NS]
Age and MLD (SπNo)	- 0.406	0.245[NS]
Threshold at 500 Hz and MLD (SONΠ)	- 0.666	0.035*
Threshold at 500 Hz and MLD (SΠNO)	- 0.742	0.024*

NS not significant. * Significant at 0.05 level.

Duration pattern test

The mean and standard deviation values of the scores of the duration pattern test for each ear were found out. The results are shown in Fig. 2. Adults had the highest score in duration pattern test. Elderly individuals with normal hearing scored less compared to adulls and the presbyciisic population scored the least among the three groups.

The results of the one way ANOVA revealed a main effect of group for both right ear scores [F (2, 27) = 70.51, p < 0.05] and left ear scores [F (2, 27) = 56.97, p < 0.05]. Sheffe's post hoc test revealed significant difference among all the three groups for both right ear and left ear scores.

Pearson's product moment correlation done between age and scores of DPT in normal hearing subjects revealed a significant moderate to high negative correlation. There was also a negative correlation between hearing threshold and scores of DPT. Table 7 depicts the results of the correlation analysis.

Fig. 2. The mean **and** SD of duration pattern test scores across the groups.

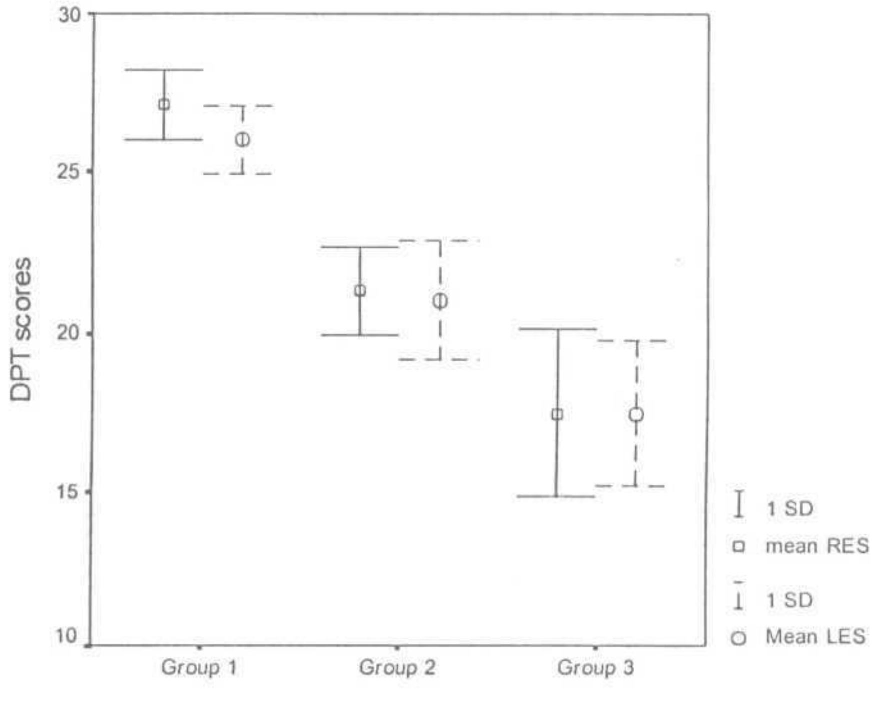


Table 7. Correlation of DPT scores with age and threshold.

Variables	r	Significance
Age and right ear scores	-0.717	0.020*
Age and left ear scores	-0.771	0.009*
Threshold at lkHz and right car scores	- 0.769	0.007*
Threshold and at 1 kHz and left car scores	-0.701	0.025*

NS- not significant; *- significant at 0.05 level.

Dichotic digits test.

Single conect and double conect scores of dichotic tests were analyzed. The mean and standard deviation of single conect and double correct scores are depicted in the Fig. 3. It can be observed from the figure that, adults had the highest score among all the three groups. Individuals with presbycusis performed poorly. The performance of elderly with normal hearing was between that of adults and individuals with presbycusis.

The results of one way ANOVA revealed a main effect of group on right ear scores [F (2, 27) = 39.65, p<0.05], left ear scores [F (2, 27) = 31.17, p<0.05] and double correct scores [F (2, 27) = 86.52, p<0.05]. Scheffe's post hoc test revealed no significant difference between adults and elderly for single conect scores. But, the single correct scores of presbycusis group were significantly poorer than the other two groups. The double correct scores of all the three groups differed significantly from each other.

Pearson's product moment correlation analysis done between age and DDT scores for normal hearing elderly as well as between threshold (PTA) and DDT scores in case of individuals with age related hearing loss revealed a moderate to high negative correlation which was statistically significant. The conelation was higher between threshold and DDT scores indicating that age related hearing loss has higher effect on DDT than aging alone. Table 8 depicts the results of the correlation analysis.

Fig. 3. : The mean and SD of DDT scores across the groups.

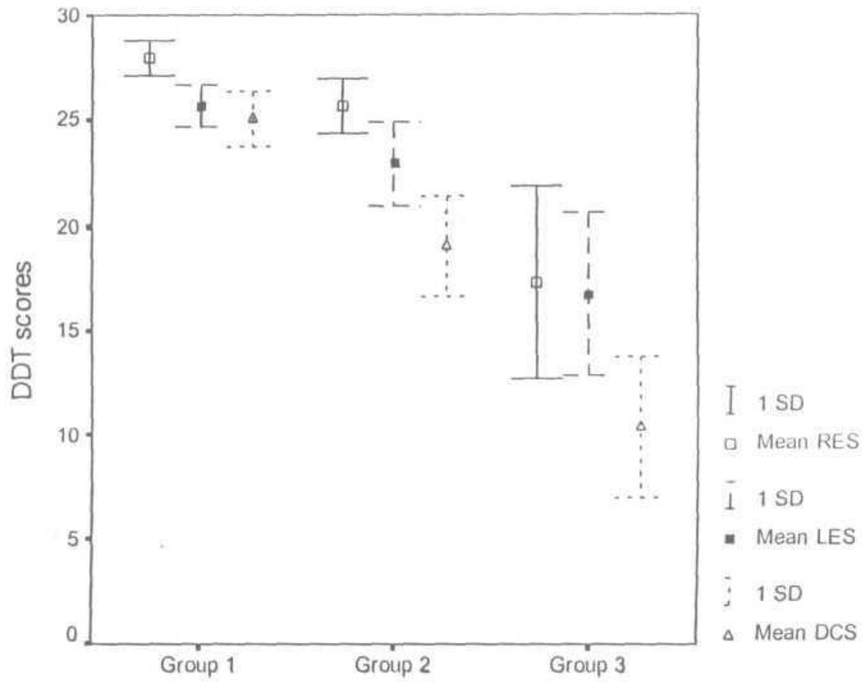


Table 8: Correlation of DDT scores with age and threshold.

Variables	r	Significance
Age and right ear scores	-0.641	0.046*
Age and left ear scores	-0.872	0.001*
Age and double correct scores	- 0.824	0.003*
Threshold (PTA) and right ear scores	-0.791	0.006*
Threshold (PTA) and left ear scores	-0.858	0.001*
Threshold (PTA) and double correct scores	-0.889	0.001*

*- significant at 0.05 level.

Speech perception in noise

SPIN scores for each ear were analysed separately. The mean and standard deviation of SPIN scores are shown in the Fig. 4. It is evident from the figure that the adults performed better than the other two groups in SPIN. Elderly individual's performance was below that of adults. Individuals with age related hearing loss performed poorly.

The results of the one way ANOVA revealed a significant main effect of group for both right ear scores [F (2, 27) - 31.14, p < 0.05] and left ear scores [F (2, 27) = 38.81, p < 0.05]. Sheffe's post hoc test revealed significant difference among all the three groups for both right ear and left ear scores.

Pearson's product moment correlation analysis done between the age **and** **SPIN** scores as well as threshold and SPIN scores showed **a** high negative correlation which was significant. The effect of hearing loss was more pronounced **than** the effect of age on the scores of SPIN (Refer Table 9).

Fig 4. The mean and SD of SPIN scores across groups.

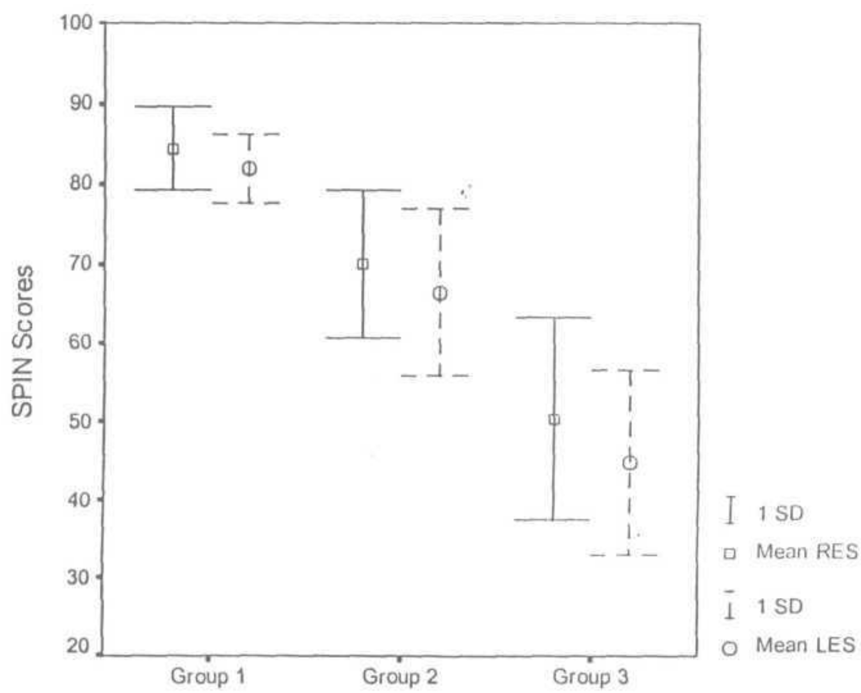


Table 9: Correlation of SPIN scores with age and threshold.

Variables	r	Significance
Age and right ear scores	-0.734	0.016'
Age and left ear scores	-0.713	0.021*
Threshold (PTA) and right ear scores	-0.859	0.001*
Threshold (PTA) and left ear scores	-0.827	0.003*

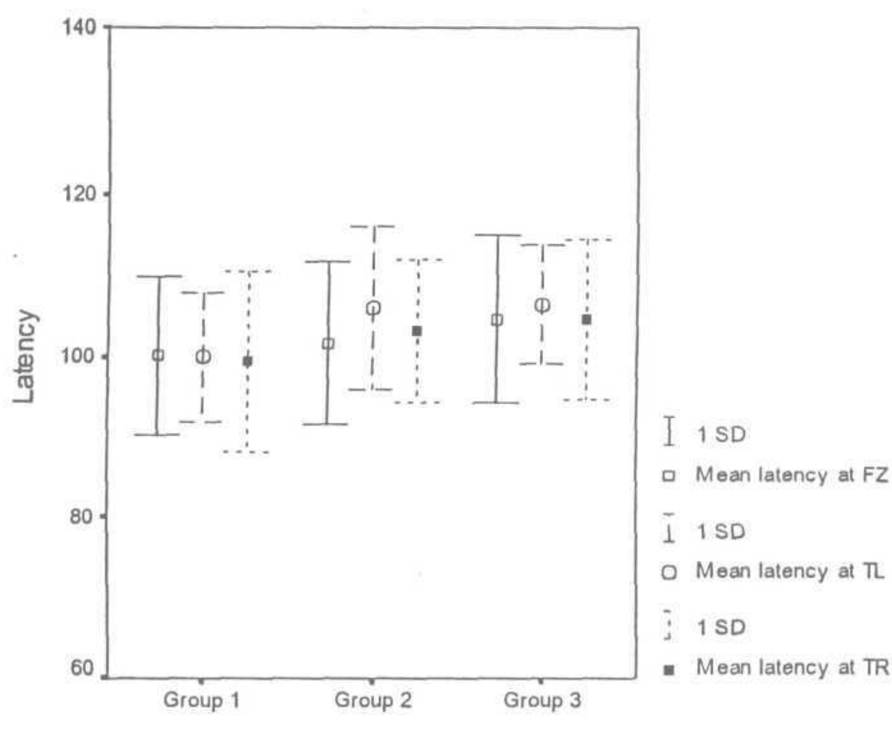
*-significant at 0.05 level

Electrophysiological tests

N *response.*

Both the latency and amplitude of the N1 response were evaluated from the three different sites viz. Fz.T_L.and TR. AS shown in the Fig. 5, the latency was shorter in normal hearing adults when compai'ed to the other two groups. Elderly with hearing loss had the maximum latency. One way ANOVA revealed no significant main effect of group at F_z [F (2, 27) = 0.520, p>0.05], T_L [F (2, 27) = 1,868, p>0.05] and T_R [F (2, 27) = 0.715, p>0 05],

Fig 5. Latency of N1 across sites for different groups.



As shown in Fig. 6, there was a slight decrement in N1 amplitude in elderly with normal hearing as well as elderly with age related hearing loss. One way ANOVA revealed no main effect of group on amplitude of N1 at Fz [F (2, 27) = 0.151, p>0.05], T_L [F (2, 27) = 1.13, p>0.05] and TR [F (2, 27) = 2.3, p>0.05].

As shown in Table 10, Pearson's product moment correlation analysis revealed latency and amplitude of N1 showed low positive correlations with both age and threshold. However, none of the correlations were significant.

Fig 6. Amplitude of N1 across sites for different groups.

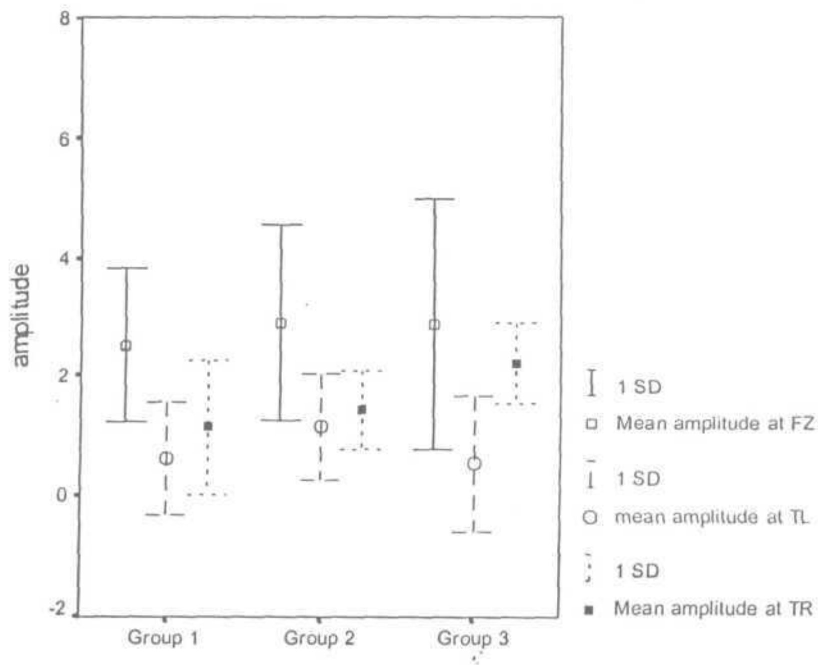


Table 10. Correlation of measures of N1 with age and threshold.

Site	**Variable**	**r**	**Significance**
Fz	Age and N1 latency	0.415	0.233 [NS]
	Age and N1 amplilude	0.375	0.285 [Ns]
	Threshold (PTA) and N1 latency	0.308	0.387 [NS]
	Threshold (PTA) and N1 amplitude	0.534'	().112[NS]
T_L	Age and N1 latency	0.459	6.182[NS]
	Age and N1 amplitude	0.629	0.052 [NS]
	Threshold (PTA) and N1 latency	0.508	0.133[NS]
	Threshold (PTA) and N1 amplitude	0.297	0.405 [NS]
TR	Age and N1 latency	0.250	0.485 [NS]
	Age and N1 amplitude	0.475	0.165 [NS]
	Threshold (PTA) and N1 latency	0.232	0.519[Ns]
	Threshold (PTA) and N1 amplitude	0.625	0.064[NiS]

NS- not significant.

P2 *response*

Both latency and amplitude of P2 recorded from Fz, TLand T_R were analyzed. The latency and amplitude of P2 response is given in the Fig. 7 and 8 respectively. It was observed that in adults with normal hearing, the latency was shorter and the amplitude was greater when compared to the other two groups. Individuals with presbycusis had longest latency and least amplitude among the three groups.

One way ANOVA revealed no main effect of group on P2 latency at Fz [F (2, 27) = 1.106, $p>0.05$], T_L [F (2, 27) = 0.583, $p>0.05$] and T_R [F (2, 27) = 0.268, $p>0.05$]. But a main effect of group was found on amplitude at Fz [F (2, 27) = 5.316, $p<0.05$],T_L[F (2, 27), $p<0.05$] and T_R [*F* (2, 27) = 3.731, $p<0.05$]. Scheffe's post hoc test revealed that the presbycusis differed significantly from the other two groups.

It can be observed from the Table 11 that Pearson's product moment correlation analysis showed a low negative correlation between P2 amplitude and age. P2 latency was significantly conelated with age. There was a moderate to high positive correlation between P_2 latency and age. Hearing threshold significantly correlated both with P_2 latency and amplitude. The direction of the relationship was reverse, i.e. increase in latency with age and decrease in amplitude with age.

Fig. 7. Latency of P_2 across sites for different groups.

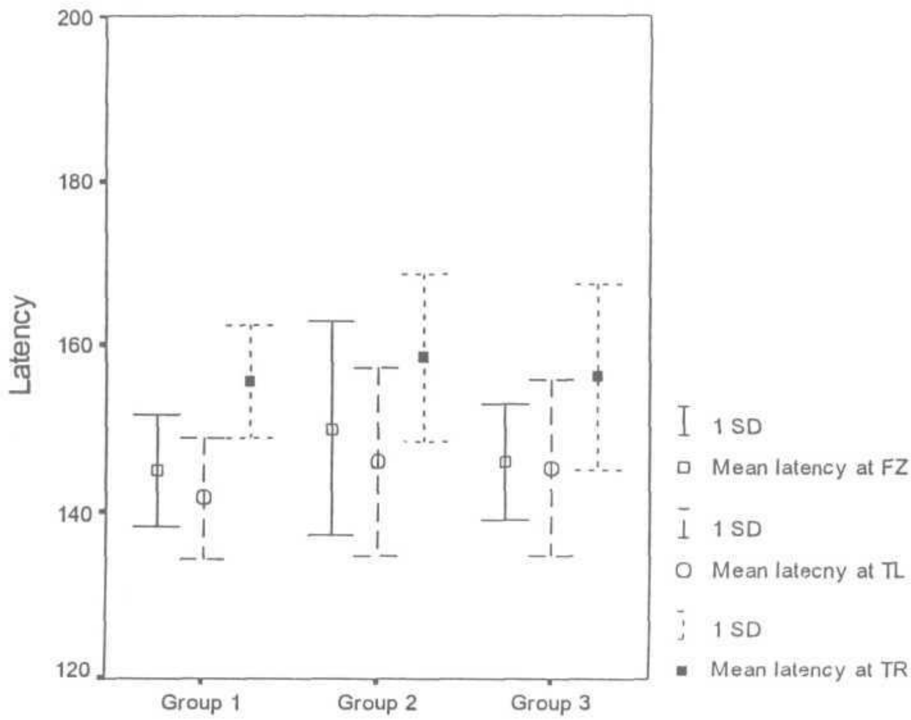


Fig. 8. Amplitude of P_2 across sites for different groups.

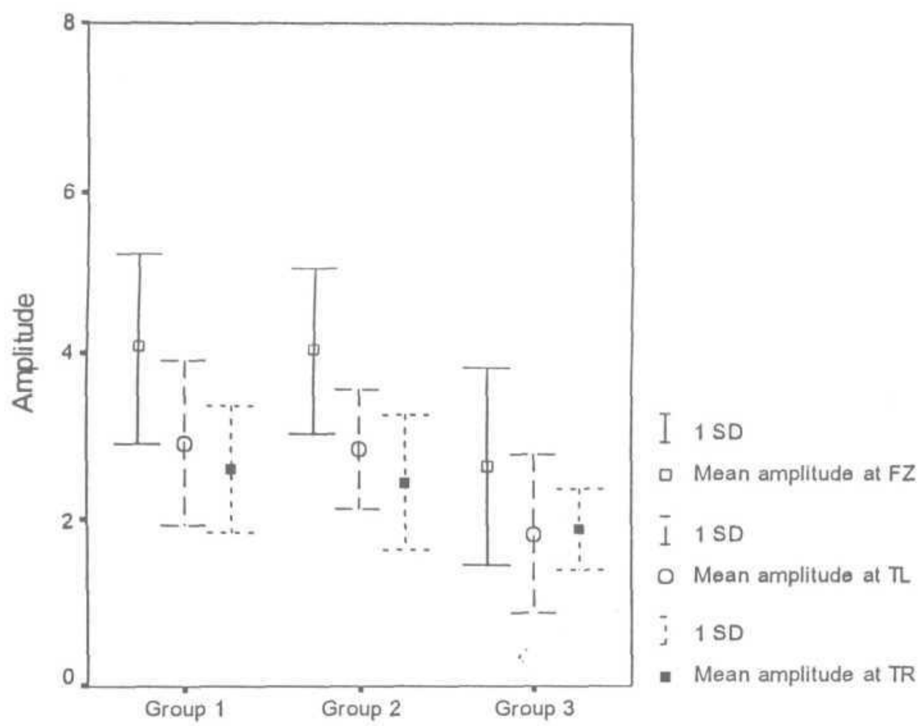


Table 11: Correlation of measures of P_2 with age and threshold.

Site	Variable	r	Significance
Fz	Age and P2 latency	0.665	0.036*
	Age and P2 amplitude	-0.399	0.254^{NS}
	Threshold (PTA) and P_2 latency	0.780	0.008*
	Threshold (PTA) and P_2 amplitude	-0.766	0.010*
T_L	Age and P2 latency	0.740	0.014*
	Age and P2 amplitude	-0.382	0.187^{NS}
	Threshold (PTA) and P_2latency	0.821	0.004'
	Threshold (PTA) and P_2 amplitude	- 0.664	0.041*
TR	Age and P2 latency	0.682	0.030*
	Age and P2 amplitude	- 0.404	0.247 ^{NS}
	Threshold (PTA) and P2 latency	0.796	0.006*
	Threshold (PTA) and P_2 amplitude	-0.671	0.044*

NS-not significant; "-significant at 0.05 level

N2 response

Both latency and amplitude of N2 recorded from Fz, T_L and T_R were analyzed. Fig. 9 and 10 represent the mean and standard deviation of N2 latency and amplitude across the groups. It can be noted from the Fig. 9 that, in adults N2 had shorter latency compared to the other (wo groups. Individuals with presbycusis had maximum latency of N2. Maximum negative amplitude of N2 was seen for adults. The amplitude of N2 reduced both with age and hearing loss (Fig. 10).

Fig 9. Latency of N_2 across sites for different groups.

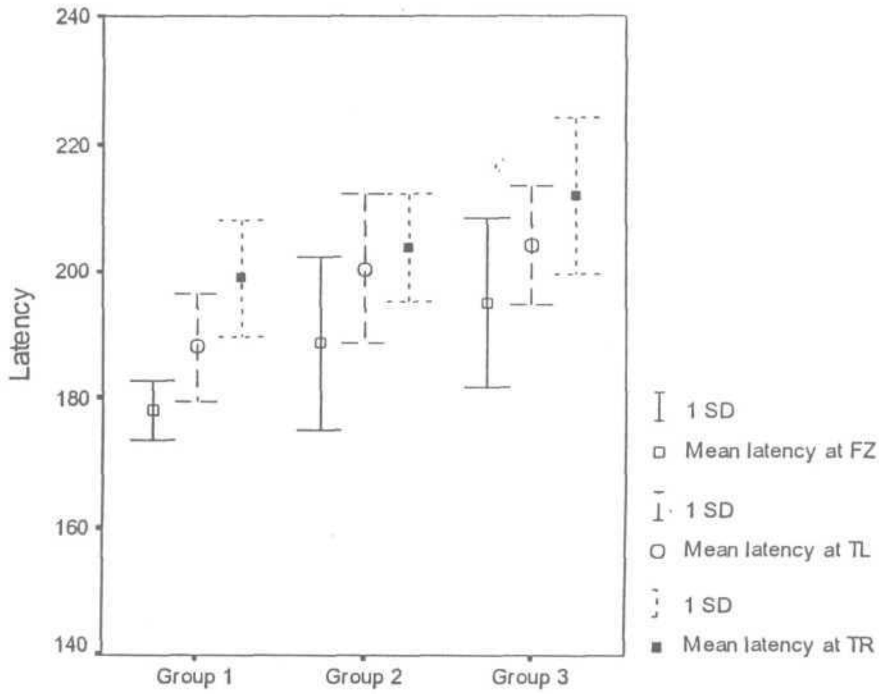
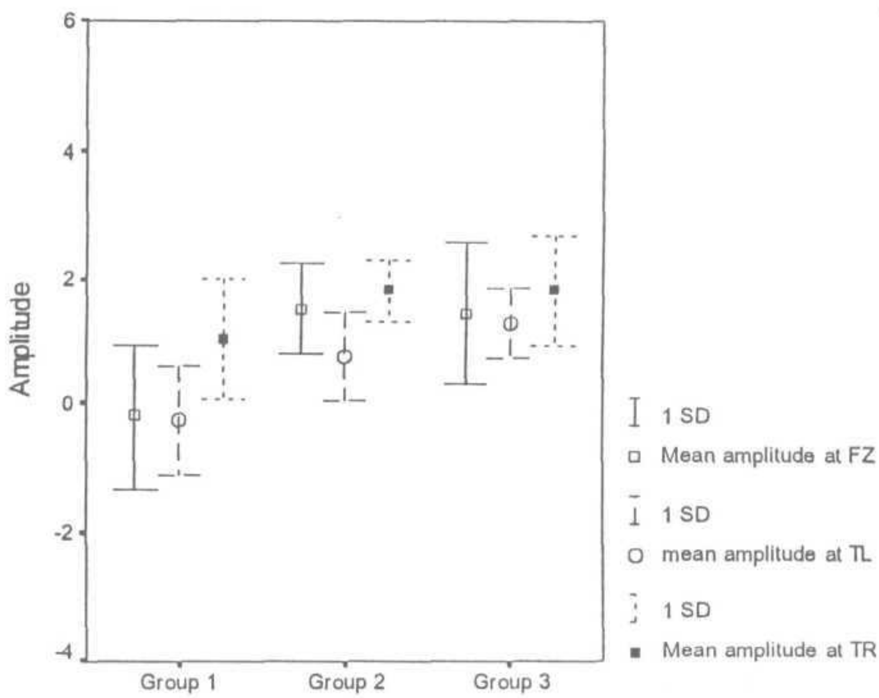


Fig 10. Amplitude of N_2across sites for different groups.



One way ANOVA for N2 latency revealed a significant main effect of group at F_z [F (2, 27) = 5.774, p < 0.05], T,.[F (2, 27) = 7.064, p < 0.05] and T_R [*F (2,* 27) = 4.096, p < 0.05]. Scheffe's post hoc test revealed a significant difference between adults and the other two groups. There was no significant difference between elderly and presbycusis groups. One way ANOVA for N2 amplitude revealed a main effect of group at F_z [F (2, 27) = 9.21, $p < 0.05$], T_L [F (2, 27) = 3.44, $p<0.05$] and TK [F (2, 27) = 3.40, $p<0.05$]. Scheffo's post hoc lest revealed a significant difference among all the groups at all the sites.

Pearson's product moment correlation showed a high positive correlation between age and N2 amplitude as well as age and N2 latency. The amplitude of N2 seemed to reduce both with age and hearing loss and there was a moderate to high correlation between them. Table 12 depicts the results of correlation analysis.

Table 12: Correlation of measures of N_2 with age **and threshold.**

Site	Variable	r	Significance
F_z	Age and N2 latency	0.763	0.010*
	Age and N2 amplitude	0.719	0.019*
	Threshold (PTA) and N2 latency	0.846	0.002*
	Threshold (PTA) and N2 amplitude	0.659	0.038*
Ti.	Age and N2 latency	0.868	0.001*
	Age and N2 amplitude	0.864	0.001*
	Threshold (PTA) and N_2 latency	0.707	0.022*
	Threshold (PTA) and N2 amplitude	0.723	0.018*
TR	Age and N2 latency	0.843	0.002*
	Age and N2 amplitude	0.681	0.047*
	Threshold (PTA) and N2 latency	0.725	0.018*
	Threshold (PTA) and N2 amplitude	0.668	0.035*

*- significant at 0.05 level

MMN

The amplitude and latency of the mismatch negativity recorded from the three scalp sites F_Z,T_L. and T_R were analyzed. All the 10 adults had MMN amplitude above -0.3 µvolts. Only 7 of the elderly and 5 of the hearing impaired had MMN amplitude above -0.3 µvolts. Only MMN with amplitude above -0.3 uvolts were considered for analysis. The Fig. 11 shows the mean and SD of MMN latency.

Adults had the minimum MMN latency among all the groups. The latencies of both elderly and presbycusis group were prolonged. One way ANOVA revealed a significant main effect of group at T_L[F (2, 19) = 8.169, $p < 0.05$] and T_R [F (2, 19) = 9.298, $p < 0.05$], but not at F_z [F (2, 19) = 2.503, $p < 0.05$]. Sheffe's post hoc test revealed a significant difference between adults and the other two groups. But there was no significant difference between elderly with or without hearing loss.

Jt is clear from the Fig. 12 that adults had higher MMN amplitude across all the groups. Elderly and presbycusis group had poorer MMN amplitude. One way ANOVA revealed a main effect of group only at T_L [F (2, 19) = 4.621, $p < 0.05$]. There was no significant main effect of group at Fz [F (2, 19) = 2.174, $p > 0.05$] and T_R[F(2, 19)= 1.175, $p> 0.05$]. Scheffe's post hoc test revealed that the normal had significantly better amplitude than the other two groups. But there was no significant difference between elderly with and without hearing loss.

Fig. 11. Latency of MMN across sites for different groups.

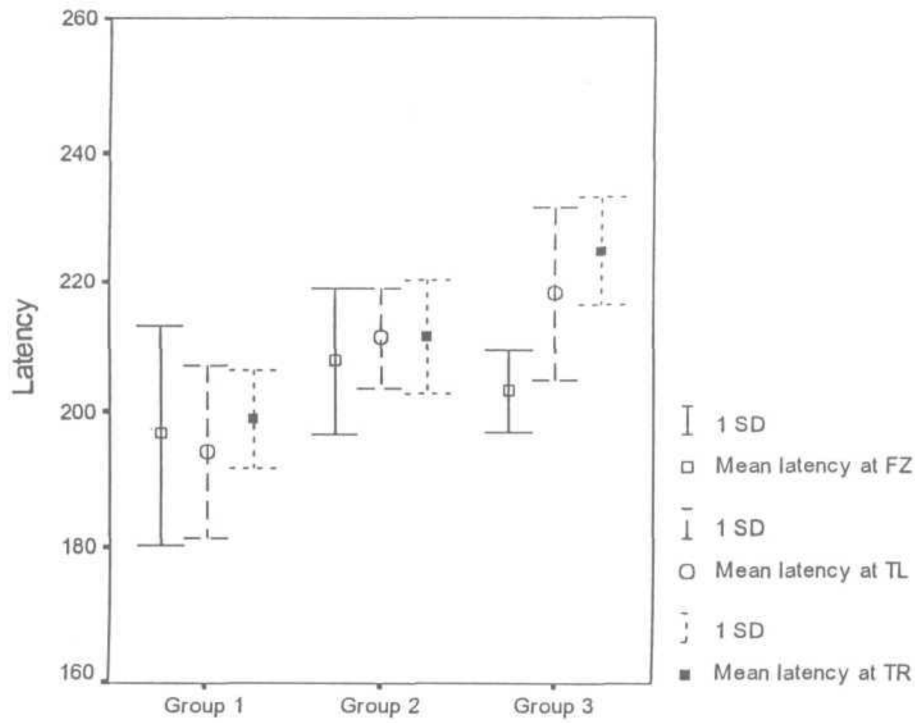
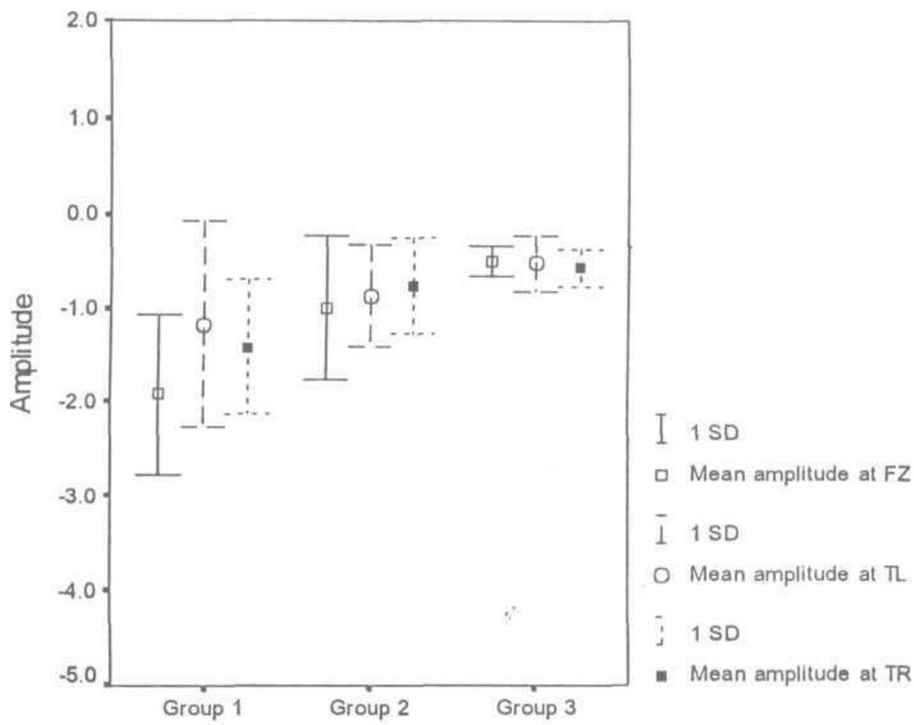


Fig. 12. Amplitude of MMN across sites for different groups.



Pearson's product moment conelation showed that latency and amplitude of MMN did not correlate significantly with age or hearing threshold. For responses recorded from T|. and TR, the latency of MMN showed a significant moderate to high correlation with both age and threshold. Amplitude of MMN also showed a significant correlation with age and threshold at T_R (Table 13).

Table 13. Correlation of measures of MMN with age **and threshold.**

Site	Variable	r	Significance
Fz	Age and MMN latency (N = 7)	0.544	0.104^{NS}
	Age and MMN amplitude (N = 7)	0.244	0.497 ^{NS}
	Threshold (PTA) and MMN latency (N = 5)	0.866	0.057 ^{NS}
	Threshold (PTA) and MMN amplitude (N = 5)	0.708	0.180^{NS}
T,	Age and MMN latency (N = 7)	0.843	0.017*
	Age and MMN amplitude (N - 7)	0.641	0.121 ^{NS}
	Threshold (PTA) and MMN latency (N = 5)	0.901	0.037*
	Threshold (PTA) and MMN amplitude (N = 5)	0.729	0.082 ^{NS}
TR	Age and MMN latency (N = 7)	0.799	0.023*
	Age and MMN amplitude (N = 7)	0.812	0.007*
	Threshold (PTA) and MMN latency (N = 5)	0.881	0.048*
	Threshold (PTA) and MMN amplitude (N = 5)	0.886	0.046*

NS- not significant; *- significant at 0.05 level.

The results of the present sltidy in context with those reported in lileraturе are discussed in the next chapter.

DISCUSSION

The results of the present study reveal that elderly individuals perform poorly in measures of auditory processing than their adult counter parts. The presence of the age related sensorineural hearing loss appears to compound the problem because older adults with hearing loss performed more poorly than older adults without hearing loss. Both behavioral and electrophysiological results show similar findings. The behavioral tests were affected more by age than the electrophysiological tests as the former require more cognitive skills.

Behavioral tests.

Behavioral tests of auditory processing assess different functions of auditory processing separately. These tests require conscious behavioral response and may be affected by many different factors such as attention, ability to perform the task, stimulus and response parameters and other factors that affect the individual's conscious perceptual abilities. Hence behavioral tests reflect not only the age related changes in auditoiy processing, but also the cognitive factors which may play an important role in speech perception performance.

Effects of age and age related hearing loss on MLD

The results of the present study revealed that the MLD values for the SoNπ and NoSπ conditions were not significantly different between adults and elderly individuals. Adults had a higher MLD value, but the difference did not reach significance. Correlation analysis between MLD values and age resulted in a low negative correlation, which shows less dependability of the MLD values on the age range selected. This finding indicates that the binaural interaction at the level of brainstem is not significantly affected by aging. Strouse, Ashmed, Ohde and

Grantham (1998) reported significantly lesser MLD values in elderly with normal hearing. The reason for the discrepancy is not clear. However, the difference can be attributed to sample size and age of the subjects considered for the study. Strouse et al., (1998) had taken 30 elderly and 30 adults, whereas in the present study 10 elderly and 10 adults were taken. The mean age in the present study was 61.1 years, whereas in Strouse et al's (1998) study the mean age was 70.2 years. Therefore it is possible that the age related changes in the MLD is occuning at a later stage in life. However this hypothesis needs to be validated.

MLD values in elderly with age related hearing loss were significantly lesser than the other two groups. However, the correlation analysis showed a significant correlation between MLD and thresholds at 500 Hz i.e. decline of the MLD values with increase in thresholds. There is a general agreement in literature regarding the effect of hearing loss on MLD. MLD reduces as the hearing loss increases and becomes diminished if the hearing threshold at 500 Hz is above 40 dB HL (Olsen, Noffsinger & Carhart, 1976; Jerger, Brown & Smith 1984). Jerger, Brown and Smith (1984) have given normative values for MLD, to be used in patients with hearing loss. According to them, MLD values of 6 to 8 dB is considered as normal if the hearing threshold at 500 Hz is between 20 dB HL to 30 dB HL. Considering this normative data, it can be concluded from the present study that aging and age related hearing loss does not affect the MLD values significantly. All these findings suggest that processing at the level of brainstem is not significantly affected by aging.

Effects of age **and** age **related** hearing loss on duration pattern test.

The present study shows a significant difference among groups in duration pattern test. The elderly performed significantly poorer than adults and the presence of age related hearing loss significantly worsens the performance. There are no previous reports studying duration pattern in elderly subjects. Musiek, Baran and Pinheiro (1990) reported no effect of peripheral sensorineural hearing loss on duration pattern test among adults. However, the conelation analysis in the present study revealed that the scores of DPT are dependent on both age and threshold of the subject.

Effects of age and age related hearing loss on dichotic digits test

In the present study, single correct scores of both ears were not significantly different between adults and elderly. There was **a** significant difference between adults and elderly in terms of double conect scores. Presbycusis population differed significantly from the other two groups in terms of right ear, left ear and double correct scores.

There is **a** general agreement in literature regarding the age related changes **in** dichotic tests. Most investigators (Jerger, Alford, Lew, River & Chmiel, 1995; Niccum 1983, cited in Speaks, Niccum & Tasell 1985) reported age related decline in dichotic CV performance. The present study also shows an age related decline in performance of dichotic digits test, in terms of the double correct scores. Both single conect and double conect scores showed a significant negative conelation with age. Hence it can be implied from the present study that the scores of the dichotic digits test shows **a** progressive decline with age. However, the present study does not support the work done by Choudhury and Yathiraj (2004), who found no age related decline in dichotic CV performance. The reason for the discrepancy is not clear.

The presence of the age related hearing loss declined the performance both in single correct and double correct scores. Studies using dichotic digits in individuals with sensorineural hearing loss of mild degree, showed it as a promising tool for assessing auditory processing in individuals with sensorineural hearing loss (Speaks, Niccum & Tasell, 1985). There was a significant negative correlation between thresholds and scores of DDT, both single correct and double correct scores Hence the poor performance in the dichotic digits test in the present study could be because of the combined effect of aging and age related hearing loss.

Effects of age and age related hearing loss on SPIN

There is a general agreement in literature regarding the effect of age and hearing loss on SPIN. Both age and hearing loss adversely affect the speech perception in noise (Smith & Prather, 1971; Jerger & Hayes, 1977) This finding was confirmed in the present study also. The performance of the elderly in SPIN was significantly poorer than that of the adults. It can be concluded therefore that aging adversely affect the perception of degraded speech (speech in presence of noise) even in the subject with normal audiogram. The poor performance of the elderly listeners in SPIN may be because of the combined effect of the impaired auditory processing mechanism due to aging and decline in the cognitive factors such as working memory capacity. The correlation between age and DDT scores was also significant.

However, the present study does not support the work done by SUIT (1977), who found no age related change in the speech perception performance in noise. He studied individuals ranging between 30 to 90 years of age using phonetically balanced words. The reason for the discrepancy is not clear.

The poor performance of sensorineural hearing impaired on SPIN is a known phenomenon (Dubno, Dirks & Mogan, 1984; Divenyi & Haupt, 1997). Individuals with age related hearing loss in the present study performed poorly than adults and elderly with normal hearing. There was a high negative correlation between thresholds and SPIN scores. The decreased audibility of the high frequency sounds caused by the high frequency hearing loss might intervene with the age related decline in the auditory processing and makes the performance worsen.

Electrophysiological responses

It is commonly accepted that the obligatory responses N1,P2 and N2 are distinct events, each reflecting several anatomic sources within the auditory cortex and serving different function with respect to auditory processing (Knight, Hillyard, Woods & Neville, 1980).

Effects of age and age related hearing loss on N1

There was no significant difference found between adults, elderly and elderly with hearing loss either in latency or amplitude of N1 in the present study. This finding is consistent with the previously reported findings in the literature. Tremblay, Piskosz and Souza (2003) reported that with increased VOT durations, Ni latencies are prolonged for elderly individuals. N1 latencies for short VOT durations (0 to 20 ms) are similar in both young adults and elderly individuals probably because the N1 is dominated by the burst of the consonant. These findings suggest that the older auditory systems are less able to time lock to the onset of voicing when there is a gap between the onset of burst and onset of voicing. Perhaps the younger systems recover more quickly than older systems resulting in earlier N1 latencies for the younger group. In the present study no significant difference in either N_1 amplitude or latency were found between the groups. There was a low correlation between age and N_1 latency as well as threshold and N_1 latency. This may be because of the difference in stimuli used. The present study used voiced stop consonant /d̪a/ and /ḍa/ which has lesser VOT durations compared to voiceless sounds. Stimuli with larger VOT durations might have evoked a prolonged N_1.

Previous studies have shown the N_1 amplitude to be larger in response to low frequency rather than high frequency signals (Picton, Woods & Proulx, 1978). It is possible that older population with high frequency sensorineural hearing loss have few units with high enough characteristic frequencies to responds to the burst spectrum (spectrum from 2500Hz to 4000 Hz), and thus most units responds to the vowel (specifically to the lower formants). Therefore high frequency hearing loss may act as a low pass filter and in turn elicit a normal or even larger N_1 response (Tremblay, Piskosz & Souza, 2003). The present study also revealed similar findings. Neither the elderly nor the presbycusis group had significantly lesser N_1 amplitude. Also there was a low correlation between age and N_1 amplitude as well as threshold and N_1 amplitude. This may be because N_1 is evoked mainly by the low frequency components of the signal and low frequencies are not affected to a large extent by aging. There are contradictory evidences in the literature regarding this explanation. Oates, Kurtzberg and Stapells (2002) found lesser amplitude of N_1 response in their younger subjects with high frequency hearing loss. Therefore this line of interpretation needs to be validated.

Effects of age and age related hearing loss on P_2

P_2 latency did not seem to be affected by either aging or age related hearing loss. P_2 amplitude was significantly reduced in presbycusis group compared to the other two groups. It is difficult to state which function of the auditory processing is revealed through P_2 because little is known about the neural mechanisms responsible for the generation of P_2. However, it is generally believed that P_2 response indicate the initial processing of the speech material.

Studies using more simple stimuli such as tones evaluating the dependency of P_2 response with age reported similar results as the present study Spink, Johannsen and Pirsing (1979) reported no age related changes either in P_2 amplitude or latency. Ostroff, McDonald, Schneider and Alain (2003) also reported reduced P_2 amplitude in elderly with N1 amplitude and latency being normal. The effect of age related hearing loss on P_2 has been studied by Tremblay, Piskosz and Souza (2003) who reported increased latency and decreased amplitude of P_2 for both voiced (lesser VOT) and voiceless (more VOT) stimuli. The present study confirmed the results, but only for the amplitude. The discrepancy in terms of variation in the latency could be because of the degree of hearing loss of the subjects in the elderly group) Tremblay et al. (2003) took subjects whose age ranged from 60 to 81 years (mean = 71.2 years) and had pure tone average of 40 dB HL, but in the present study the subjects age was ranged between 52 to 76 years (mean = 61.1 years) and the mean pure tone average of 33.5 dB HL. Therefore,/the difference in terms of latency being not significantly affected in the present study could be because of the combined effect of relatively lower age of the subjects and better thresholds of the subjects in the present study. /This hypothesis is confirmed by the conelation analysis which showed a high correlation between age and P_2 amplitude and latency as well as threshold and P_2 amplitude and latency.

Effects of age and age related hearing loss on N_2

The brain mechanism responsible for the generation of N2 is not clearly known. However, the N2 component is believed to reflect certain later aspects of stimulus evaluation in the auditory system (Coyle, Gordon, Howson & Mears, 1991). The latency of N2 was significantly different between the adults and elderly, but not between elderly and presbycusis group in the present study. The correlation between age and N2 latency as well as threshold and N2 latency were significant. This finding suggest that probably timing of neural activation for speech sound processing is affected in elderly, but the time taken for neural activation is not significantly affected by hearing loss. There were significant differences in the N2 amplitude across the groups. This indicates that probably, aging significantly reduces the number of neurons recruited for stimulus processing and the presence of age related hearing loss causes further reduction in the number of neurons recruited.)

Coyle, Gordon, Howson and Mears (1991) found an increase in the magnitude of the correlation coefficient between age and latency of later evoked potential components such as N2 and P3. The present study also revealed similar results. The correlation coefficient between age and N2 was higher than that of other potentials other potentials. The high correlation between age and N2 amplitude as well as threshold and N2 amplitude suggests that the neuronal networks associated with the generation of N2 component may be more sensitive to age related changes.

Effects of age and age related hearing loss on MMN

Jt is difficult to compare results of the present study with previous studies in the literature. Only one of the previous investigation (Bellis, Nicol & Kraus, 2000) compared MMN in elderly using speech stimuli. Bellis, Nicol and Kraus (2000) recorded MMN for two sets of stimuli, one set consisted of stimuli which differed in two features (place of articulation and manner of articulation) and the stimuli in the other set differed from each other in only one feature (place of articulation). Their results indicated that MMN amplitude and latency in elderly were not significantly different from adults when the first set of stimuli was used. When the second set was used MMN amplitude decreased and latency increased in elderly and in some cases MMN diminished. The results of the present study can be interpreted on the basis of this. In the present study the stimuli used were /da/ and /da/ which differed from each other only in one feature (place of articulation). The absence of MMN in 3 of the elderly and 5 of the presbycusis population could be because of this. As only one feature differed between the stimuli, making it difficult to discriminate between them, the elderly and presbycusis population had more difficulty in discriminating the stimuli. However, this hypothesis needs to be validated by behavioral measures of speech sound discrimination.

Previous studies investigating MMN in elderly individuals using non speech materials have shown that frequency discrimination is not affected by aging, but duration discrimination is impaired in elderly listeners (Pekkonen et al, 1993, Karayinids et al, 1995; Woods, 1992). An alternate explanation of the age related changes found in the present study can be given based on this. Speech perception requires discriminating rapid spectral and temporal changes in the signal. By having the temporal discrimination impaired, it becomes difficult to discriminate between the speech sounds, even though the frequency discrimination is intact. Hence it can be hypothesized that the elderly individuals had more problems in discriminating the temporal aspects and had poor discrimination.

The presence of age related hearing loss did not significantly worsen the amplitude or latency of MMN in elderly. The presbycusis group was not significantly different from the elderly group. This finding is supported by the previous studies by Boothroyd (1984) and Sivaprasad (2000), who found that the MMN in individuals with moderate hearing loss is not significantly different fiom **the** normal hearing individuals. It can be concluded fiom the present study that decreasing audibility produced by peripheral sensorineural hearing loss does not affect the speech sound discrimination. It is the age related changes in the auditory system, which is responsible for the poor performance. Hence MMN can be used to study auditory processing even in subjects with peripheral hearing loss.

Implications of the study

Speech perception depends on multiple spectral temporal and intensity cues which were not examined in the present study. Therefore the present study represent only a fraction of the age related changes that may be associated with impaired speech understanding in elderly. The physiological responses in the present study were elicited using a passive paradigm that did not draw memory and cognition; it can be argued that the age related differences observed in the electrophysiological responses are unrelated to the cognitive ability. When there was a greater cognitive demand, in case of the behavioral tests, the performance of the elderly was affected more.

The results of the present study indicate that binaural interaction at the level of brainstem is not affected either by aging or age related hearing loss as reflected by MLD results. Temporal sequencing as reflected by DPT seems to be affected with aging. The presence of age related hearing loss seems to compound the temporal sequencing function. 4 of the elderly and 6 of the presbycusis individuals had poorer scores in DPT. Single conect scores of dichotic digit test, which evaluate the channel capacity in binaural integration was not affected by aging. The presence of age related hearing loss significantly reduces the channel capacity. Double correct scores of dichotic digit test, which evaluate the auditory capacity in binaural integration was affected both by aging and age related hearing loss. 6 elderly (4 of them had poor DPT scores also) and 8 presbycusis individuals had poorer scores in DDT (6 of them had poor DPT scores also) Auditory closure abilities in elderly as reflected by SPIN, seems to be poor. The presence of age related hearing loss significantly worsens the performance. All the elderly subjects except one had poor SPIN scores. All the subjects in presbycusis group had poor SPIN scores. Among the electrophysiological measures, the early potentials (Ni and P?) which indicate the neural representation of stimulus onset were not affected by aging The late potential which reflects the stimulus processing at a later stage (N2) was affected by aging. The presence of age related hearing loss affects the amplitude of these responses rather than latency. This indicates that presence of age related hearing loss significantly reduces the number of neurons recruited for the processing of the signal. Perception of the stimulus deviance as reflected by MMN also seems to be affected by aging.

Together these brain and behavioral measures suggest that some of the speech understanding difficulties expressed by elderly adults may be related to impaired processing in the aging auditory system. The problem appears to be compounded by the presence of significant high frequency age related hearing loss. This might explain why older adults frequently complain that wearing hearing aid makes speech loud but does not necessarily improve their ability to understand speech. Hearing aids help to overcome audibility issues by increasing the intensity of sounds. However, a hearing aid cannot compensate for impaired auditory processing in the aging auditoiy system. Because recent experiments have shown that temporal processing can be improved through auditoiy training (Tremblay, Kraus, McGee, Ponton & Otis, 2001), older adults who wear hearing aid might improve their ability to understand speech through auditory training. It has been reported in literature that the individuals with auditoiy processing disorders benefit from benefit specific programs (Chermak, 2001; Bellis, 2003). Administration of behavioral tests in elderly will help in planning such programs.

The results of the present study suggest that even though these behavioral tests are affected by threshold, they can be used to study age related changes in the auditoiy system. These tests can also be used to record improvement with therapy. Electrophysiological tests can be used as an objective tool when it is not possible to administer behavioral tests. MMN has an additional advantage in assessing age related changes as it is resistant to peripheral hearing loss

SUMMARY AND CONCLUSIONS

Elderly individuals are one of the rapidly growing segment in the population. Elderly individuals with and without hearing loss often have difficulty in understanding speech, especially when it is degraded in presence of noise. Research findings shows that the difficulties are because of the auditory processing disorders and it occur more frequently in elderly (Jerger, Jerger, Oliver & Pirozzolo, 1989, Bergman, 1971). The presence of age related sensorineural hearing Joss also affects auditory processing. There are no studies reported in literature, evaluating auditory processing using both behavioral and eleclrophysiological measures in elderly individuals. The effect of age related hearing loss on auditory processing is also not well understood.

The present study was undertaken to investigate the effects of aging and age related hearing loss on some measures of auditory processing. Three groups of subjects were selected. The first group consisted of normal hearing adults, the second group consisted of elderly with normal hearing and the last group consisted of elderly with age related sensorineural hearing loss of degree lesser than 50 dB HL. The tests included both behavioral and electrophysiological tests. Behavioral tests were masking level difference (MLD), dichotic digits test (DDT), duration pattern test (DPT) and speech perception in noise (SPIN). The electrophysiological tests were speech evoked N1, P2, N_2 and MMN. MMN was evoked by two voiced slop consonants /da/ and/da/, which differed in place of articulation. A calibrated clinical audiometer (OB 922) along with a Philips CD player was used for DDT, DPT and SPIN. MLD was done using GSI 10 clinical audiometer. The electrophysiological responses were recorded u.sing HIS .small EP' system.

The results indicated a poor performance of elderly individuals in a majority of the tests compared to normal adults. The presence of age related hearing loss seems to affect the performance on these tests adversely. The results of the different tests were as follows:

- MLD was not different between adults and elderly. Presbycusis reduced the MLD values, but the variation was within the normative values for the degree of hearing loss.
- DPT and SPIN were significantly different among all the three groups.
- The double correct scores of DDT were significantly different between adults and elderly. In presbycusis group both single correct and double correct scores were significantly different from other two groups.
- Among the electrophysiological measures, N1 was not affected by either age or by age related hearing loss.
- The amplitude of P2 was significantly affected by age related hearing loss. The latency was unaffected.
- Both latency and amplitude N_2 seems to be significantly affected by aging and age related hearing loss.
- MMN amplitudes were smaller and latencies were longer in elderly and presbycusis group compared to normal and the difference was statistically significant.

The following inferences can be drawn based on these results:

> Binaural interaction at the level of brainstem is not affected either by aging or age related hearing loss.

> Temporal sequencing seems to be affected with aging and age related hearing and age related hearing loss.

> Binaural integration is affected by aging and age related hearing loss.

> Auditory closure abilities are poor in elderly subjects.

> The neural representation of stimulus onset was not affected by aging.

> The stimulus processing at a later stage in the auditory system is affected by aging and age related hearing loss.

> Perception of the stimulus deviance also seems to be affected by aging.

Implications

It is important that the nature of the auditory processing problems in the elderly should be evaluated in the routine audiological evaluation. The tests used should be resistant to the peripheral hearing loss also. Based on the present study, it can be concluded that late cortical potentials such as N2 and MMN can be used for evaluation among the electrophysiological tests. Among the behavioral tests, the tests which can be used are dichotic digit test, duration pattern test and speech perception in noise test. The above tests are sensitive to age related changes in auditory processing. The results of these tests can also be used to plan auditory training program for the elderly subjects with or without peripheral hearing loss and also to monitor the changes in auditory processing skills as a result of therapy.

REFERENCES

Alain, C, & Woods, D.L. (1999). Age related changes in processing auditory stimuli during visual attention: evidence for deficits in inhibitory control and sensory memory. *Psychology of Aging, 14(3),* 507-519.

Alho, K. (1995). Cerebral generators of mismatch negativity (MMN) and its magnetic counterpart (MMNra) elicited by sound changes. *Ear and Hearing, 16(1),* 38-50.

Amenedo, E., & Diaz, F. (1998a). Automatic and effortful processes in auditory memory reflected by event related potentials. Age related findings. *Electroencephalography and Clinical Neurophysiology, 108(4),* 361-369.

Amenedo, E., & Diaz, F. (1998b). Aging related changes in processing of non target and target stimuli during an auditory odd ball task. *Biological Psychology, 48(3),* 235-267.

American Speech Language and Hearing Association (1996). Central auditory processing: Current research and implications for clinical practice. *American Journal of Audiology, 5,* 41-54.

Anderer, P., Semlitsch, H.V., & Saletu, B. (1996). Multichannel auditory event-related brain potentials: effects of normal aging on the scalp distribution of Nl, P2, N2 and P300 latencies and amplitudes. *Electroencephalography and clinical neurophysiology, 99(5),* 458-472.

Anita, R. (2003). *The effect of speech babble of different languages on speech identification scores.* Unpublished Independent Project. Mysore. University of Mysore.

Bellis, T.J. (2003). Auditory processing disorders: It's not just kids who have them. *The Hearing Journal, 56{5),* 10-19.

Bellis, T.J., Nicol, T., & Kraus, N. (2000). Aging affects hemispheric asymmetry in the neural representation of speech cues. *The Journal of Neuroscience, 20(2),* 791-797.

Bergman, M. (1971). Hearing and aging. *Audiology, 10,* 164-171.

Bertoli, S., Smurzynsky, I, & Probst, R. (2002). Temporal resolution in young and elderly subjects as measured by mismatch negativity and a psychoacoustic gap detection task. *Clinical Neurophysiology,* 7/5(3), 396-406.

Boothryod, A. (1984). Auditory perception of speech contrasts by subjects with sensorineural hearing loss. *Journal of Speech Language and Hearing Research, 27,* 134-144.

Carhart, R., & Jerger, J.F. (1959). Preferred method for clinical determination of pure tone thresholds. *Journal of Speech and Hearing Disorders, 24,* 330-345.

Chermak. G.D. (2001). Auditory processing disorder: An overview for the clinician. *The Hearing Journal, 54(*7), 10-25.

Choudhury, M, & Yathiraj, A. (2004, January). *Age and gender variations in dichotic CV test.* Paper presented at the 36th Annual Conference of Indian Speech and Hearing Association, Mysore, India.

Coyle, S., Gordon, E., Howson, A., & Mears, R. (1991). The effect of age on auditory event related potentials. *Experimental Aging Research, 17(2),* 103-111.

Czigler, I., Csibra, G, & Csontos, A. (1992). Age inter-stimulus interval effects on event related potentials to frequent and infrequent auditory stimuli. *Biological Psychology, 33(2-3),* 195-206.

Divenyi, P.L., & Haupt, K.M. (1997). Audiological correlate of speech perception deficits in elderly listeners with mild to moderate hearing loss. I. Age and lateral asymmetry effects. *Ear and Hearing, 18(\),* 42-61.

Dubano, J.R., Dirks, D.D., & Morgan, D.E. (1984). Effects of age and mild hearing loss on speech recognition in noise. *Journal of the Acoustical Society of America, 76(1),* 87-96.

Ford, J.M., Roth, W.T., Mohs, R.C., Hopkins, W.F., & Bert, S. (1979). Event related potentials recorded from young and old adults during a memory retrieval task. *Electroencephalography and Clinical Neurophysiology, 47,* 450-459.

Frisina, D.R., & Frisina, R.D. (1997). Speech recognition in noise and presbycusis: relations to possible neural mechanisms. *Hearing Research, 106(1-2),* 95-104.

Gaeta, H., Friedman, D., Ritter, W., & Cheng, J. (1998). An event related potential study of age related changes in sensitivity to stimulus deviance. *Neurobiology of Aging, 19(5),* 447-459.

Gates, G.A., Cooper, J.C., Kannel, W.B., & Miller, M.A. (1990). Hearing in the elderly: The Framingahm cohort, 1983-1985.1. Basic audiometric test results. *Ear and Hearing, 11* (4), 247-256.

Giard, M.H., Perrin, R, Pernier, J., & Bouchet, P (1990). Brain generators implicated in processing of auditory stimulus deviance: A topographic event related potential study. *Psychophysiology, 27,* 627-640.

Goodin. D.S., Squires, K.C., Henderson, B.H., & Starr, A. (1978). Age related variations in evoked potentials to auditory stimulus in normal human subjects. *Electroencephalography and Clinical Neurophysiology, 44,* 447-458.

Gunter, T.C., Jackson, J.L., & Mulder, G. (1996). Focusing on aging: an electrophysiological exploration of spatial and attentional processing during aging. *Biological Psychology, 43(2),* 103-145.

Guyla, A.J. (1994). Structural and physiological changes in the auditory and vestibular mechanisms with aging. In H.F. Schuknecht (Ed.), *Geriatric communication disorders* (pp 39-54). St.Louis: Mosby.

Hayes, D., & Jerger, J. (1979). Aging and the use of hearing aids. *Scandinavian Audiology, 8,* 33-40.

Humes, L.E. (2001). Issues in evaluating effectiveness of hearing aids in elderly: what to measure and when? *Seminars in Hearing, 22,* 303-315.

Iragui, V.J., Kutas, M, Mitchiner, M.R., & Hillyard, S.A. (1993). Effects of aging on event-related brain potentials and reaction times in an auditory oddball task. *Psychophysiology, 30(1),* 10-22.

Jaaskelainen, I.P., Varonen, R., Naatanen, R., & Pekkonen, E. (1999). Decay of cortical pre attentive sound discrimination in middle age. *Neuroreport, 10(\),* 123-126.

Jerger, J., & Hayes, D. (1977). Diagnostic speech audiometry. *Archives of otolaryngology, 103*, 216-222.

Jerger, J., Alford, B., Lew, H., Rivera, V., & Chmiel, R. (1995). Dichotic listening, event related potentials and interhemispheric transfer in the elderly. *Ear and Hearing, 16(5),* 482-498.

Jerger, J., Brown, D., & Smith, S. (1984). Effect of peripheral hearing loss *on* the masking level difference. *Archeves of Oolaryngology, 100,* 290-296.

Jerger, J., Jerger, S., Oliver, T., & Pirozzolo, F. (1989). Speech understanding in elderly. *Ear and Hearing, 10(3),* 79-89.

Jokinen, K. (1973). Presbycusis. VI. Masking of speech. *Act a otolaryngologica, 76,* 426-430.

Karayanidis, R, Andrews, S., Ward, P.B., & Michel, P.T. (1995). ERP indices of auditory selective attention in aging and Parkinson's disease. *Psychophysiology, 32(4),* 335-350.

Kazmerski, V.A., Friedman, D., & Ritter, W. (1997). Mismatch negativity during attend and ignore conditions in normal and Alzheimer's disease. *Biological Psychiatry, 42,* 382-402.

Knight, R.T., Hillyard, S.A., Woods, D.L., & Neville, H.L. (1980). The effects of frontal and temporal - parietal lesions on the auditory evoked potentials in man. *Electroencephalographv and Clinical Neurophysiology, 50,* 112-124.

Marshall, L. (1981). Auditory processing in aging listeners. *Journal of Speech and Hearing Disorders, 12,* 226-240.

Musiek, F.E., Baran, J.A., & Pinheiro, M.L. (1990). Duration pattern recognition in normal subjects and subjects with cerebral and cochlear lesions. *Audiology, 29,* 304-313.

Naatanen, R. (2003). Mismatch negativity: clinical research and possible applications. *International Journal of Psychophysiology, 48,* 179-188.

Naatanen, R., & Picton, T. (1987). The N_1 wave of the human electric and magnetic response to sound: A review and an analysis of the component structure. *Psychophysiology, 24*(4), 375-425.

Naatanen, R., Paavilainen, P., & Reinikainen, K. (1989). Do event related potentials to infrequent decrements in duration of auditory stimuli demonstrate a memory trace in man. *Neuroscience Letters, 107,* 347-352.

Nerbonne, A.J. (1988). Neuronal changes with increasing age. III. A study of the human cerebral cortex. *Annals of Otology, Rhinology and Laryngology, 95,* 501-513.

Oates, P.A., Kurtzberg, D., & Stapells, D.R (2002). Effects of sensorineural hearing loss on cortical event related potentials and behavioral measures of speech sound processing, *Ear and Hearing, 23,* 399-415.

Olsen, W.O., Noffsinger, D., & Carhart, R (1976). Masking level difference encountered in clinical populations. *Audiology, 15,* 287-301.

Orchik, D.J., & Burgess, J. (1977). Synthetic sentence identification as a function of the age of the listener. *Journal of Speech and Hearing research, 20,* 322-336.

Ostroff, J.M., McDonald, K.L., Schneider, B.A., & Alain, C. (2003). Aging and the processing of sound duration in auditory cortex. *Hearing research, 181*(1-2), 1-7.

Paavilainen, P., Karlsson, M., Reinikainen, K., & Naatanen, R. (1989). Mismatch negativity to change in spatial location of an auditory stimulus. *Electroencephalography and Clinical Neurophysiology, 73*, 129-141.

Pekkonen, E. (2000). Mismatch negativity in aging and in Alzheimer's and Parkinson's disease. *Audiology and Neuro Otology, 5*(3-4), 216-224.

Pekkonen, E., Jousmaki, V., Partanen, J., & Karhu, J. (1993). Mismatch negativity area and age related auditory memory. *Electroencephalography and Clinical Neurophysiology, 87*, 321-325.

Pekkonen, E., Rinne, T., Reinikainen, K., Kujala, T., Alho, K, & Naatanen, R. (1996). Aging effects on auditory processing: an event related potential study. *Experimental Aging Research, 22*(2), 171-184.

Pfefferbaum, A., Ford, J.M., Roth, W.T., & Kopell, B.S. (1980). Age related changes in auditory event related potentials. *Electroencephalography and Clinical Neurophysiology, 49*, 266-276.

Picton, T.W., Woods, D.L., & Proulx, G.B. (1978). Human auditory sustained potentials. II stimulus relationships. *Electroencephalography and Clinical Neurophysiology, 45*, 198-210.

Plomp, R., & Mimpen, A.M. (1979). Speech reception thresholds for sentences as a function of age and noise level. *Journal of the Acoustical Society of America*, 66, 1333-1342.

Quaranta, A., Cassano, P., & Cervellera, G. (1978). Clinical value of the tonal masking level difference. *Audiology, 17,* 232-238.

Regishia, A. (2003). *Maturational effect on dichotic speech tests: A comparison between dichotic CV and dichotic digits test.* Unpublished Independent " Project. Mysore: University of Mysore.

Schuknecht, H.F. (1974). Effect of aging on the cochlea. *Acta Otolaryngologica, 78,* 78-92.

Schroeder, M.M., Ritter, W., & Vaughan, H.G. (1995). The mismatch negativity to novel stimuli reflects cognitive decline. *Annals of New York Academy of Science, 89,* 399-403. Abstract retrieved December 22, 2003, from www.ncbi.nlm.org

Silman, S., & Silverman, C.A. (1991). *Auditory diagnosis: Principles and Applications.* San Deigo: Academic Press.

Sivaprasad, R. (2000). *MMN in ears with sensorineural hearing loss.* Unpublished master's dissertation. Mysore: University of Mysore.

Smith, R.A., & Prather, W.F. (1981). Phone discrimination in older persons under varying signal to noise conditions. *Journal of Speech and Hearing Research, 24,* 630-638.

Speaks, C, Niccum, N., & Tasell, D.V. (1985). Effects of stimulus material on the dichotic listening performance of patients with sensorineural hearing loss. *Journal of Speech and Hearing Research, 28,* 16-25.

Spink, U., Johannesn, S., & Pirsing, W. (1979). Acoustically evoked potential: dependence upon age. *Scandinavian Audiology, 8,* 11-14.

Stach, B A , Spernjak, M.L., & Jerger, J. (1990). The prevalence of central presbycusis in a clinical population. *Journal of American Academy of Audiology, 1,* 109-115.

Strouse, A., Aslunead, D.I I., Ohde, R N , & Grantham, D.W. (1998). Temporal processing in the aging auditory system. *Journal of the Acoustical society of America, 104(4),* 2384-2399.

SUIT, R.K. (1977). Effect of age on clinical hearing aid evaluation results. *Journal of the American Auditor}' Society, 3,* 1-5. Abstract retrieved January 12, 2004, from www.ncbi.nlm.org.

Thamne, G. (2003). *Duration pattern test: Development of norms.* Unpublished independent project. Mysore: University of Mysore.

Tremblay, K.L., Kraus, N., McGee, T., Ponton, C, & Otis, B. (2001). Central auditory plasticity: Changes in N1-P2 complex after speech sound training. *Ear and Hearing, 22(* 1), 1-11.

Tremblay, K.L., Piskosz, M., & Souza, P. (2003). Effects of age and age related hearing loss neural representation of speech cues. *Clinical Neurophysiology, 114(7),* 1332-1343.

Vandana, S. (1998). *Speech identification test for Kannada speaking children.* Unpublished Master's Dissertation. Mysore: University of Mysore

Verleger, R , Neukater, W., Kompf, D., & Vieregge, P. (1991). On the reasons for the delay of P3 latency in healthy elderly subjects. *Electroencephalography and Clinical Neurophysiology, 79(6),* 488-502.

Woods, D.L. (1992). Auditory selective attention in middle aged and elderly subjects: an event related brain potential study. *Electroencephalography and Clinical Neurophysiology, 84(5),* 456-468.