RELATIONSHIP BETWEEN AUDITORY PROCESSING DISORDER AND HEARING AID BENEFIT IN ELDERLY SUBJECTS

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A Dissertation submitted in part fulfillment for the degree of

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Mysore.

ALL INDIA INSTITITE OF SPEECH AND HEARING

Manasagangothri, Mysore, 570006

April, 2006.

DEDICATION

Submitting this piece of work of mine

To my

GRANDFATHER,

Late Dr. Khagesh Chandra Nandy.

CERTIFICATE

This is to certify that this Master's dissertation entitled **"RELATIONSHIP BETWEEN AUDITORY PROCESSING DISORDER AND HEARING AID BENEFIT IN ELDERLY SUBJECTS"** is the bonafide work done in fulfillment of the degree of Master's of Science (Audiology) of the student with register number **A0490008.** This has been carried out under the guidance of a faculty of this institute and has not submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This dissertation entitled **"RELATIONSHIP BETWEEN AUDITORY PROCESSING DISORDER AND HEARING AID BENEFIT IN ELDERLY SUBJECTS"** is the result of my own study and has not been submitted earlier to any other university for that award of any diploma or degree.

Place : Mysore

April, 2006

Registration No. A0490008

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INTRODUCTION

Many older people have difficulty hearing sounds. Sounds go undetected, words must be repeated, and problems arise in dealing with the acoustic world. These problems of audition frequently are equated with the process of growing older. Ageing leads to degeneration of peripheral or central or both the systems. The middle ear changes seem to have minimal effects on hearing (Maurer & Rupp, 1979). The most obvious deficit in many elderly people is the presence of a bilateral high frequency hearing loss of the cochlear origin (Gates, Cooper, Kannel & Miller, 1990) and poor speech identification scores (Nabelek & Robinson, 1982; Helfer, 1992). The poor speech identification ability in elderly individuals is poorly understood. So several studies have been carried out to investigate the possible factors responsible for these speech identification deficits.

Humes and Christopherson (1991) reported that the threshold elevation accompanying sensori-neural hearing loss was the primary factor affecting the speech identification performance of the elderly subjects with hearing impairment. Others report that degeneration of the central auditory system lead to poor speech identification in the elderly subjects (Frisina & Frisina, 1997). Jerger, Oliver and Pirozzolo, (1990) reported that elderly subjects with central processing disorders rated themselves as significantly more handicapped than those without such disorders.

Bergman (1971) reported that for individuals of middle and later age, there is a marked deterioration in the understanding of speech under conditions of distortion, time alteration and competing signals, even when the audiometric hearing is relatively normal. It is also suggested that the major changes are somehow linked to a gradual decrease in the time-related processing deficits.

An auditory system with limited temporal resolution abilities cannot follow temporal changes, if the changes occur too rapidly. The temporal modulation transfer function (TMTF) test provides important information about the processing of temporal envelopes and hence authors (Hescot, Lorenzi, Debraille & Camus, 2000) have suggested the TMTF to be useful in distinguishing peripheral and central hearing loss. It has been observed that modulation detection was much poorer in elderly listener with left hemisphere damage compared to normal hearing adults and elderly listeners with cochlear hearing loss.

Even other temporal resolution tasks such as resolving brief dips in the intensity are affected in elderly subjects, which can be studied by means of gap detection paradigm. Moore, Peters and Glassberg (1993) compared gap detection thresholds in young and elderly subjects with normal hearing and found that gap detection thresholds were higher in the elderly group.

Along with these temporal resolution tasks, the binaural performance may also be affected in the elderly individuals. This has been studied using dichotic listening tasks. Among dichotic listening tests dichotic digit test is reported to be more sensitive in identifying auditory processing deficits in presence of peripheral hearing loss (Musiek, 1983). Martin, Dougals, Cocanford and Jerry (1991) administered DDT and found older subjects performed poorer than younger subjects

Reduced auditory processing abilities in the elderly, hampers the benefit derived from audiological rehabilitation. Stach, Loiselle and Jerger (1991) reported that deficits in speech understanding in elderly individuals lead to poorer performance with hearing aids. Sandra and Gordon-Salant (2005) reported elderly individuals do not use hearing aids consistently since hearing aids do not alleviate the communication difficulties in degraded listening situations. Even Jerger and Hayes (1976) investigated hearing aid benefit and found that elderly individuals, who rated hearing aid as unsatisfactory, performed poorly with hearing aid, in varying “message-to-competition ratio”.

NEED FOR THE STUDY

Despite of research in the field, the lack of benefit derived from hearing aids for the elderly individuals was not well understood. A majority of studies have correlated speech identification in noise or competing message test with the benefit the elderly individuals derive from hearing aid. But speech in noise test is not a specific test for auditory processing disorder and it is affected by many other factors including peripheral hearing loss. Also an individual with auditory processing disorder may have problem in any of the processes such as temporal resolution and binaural performance. A few studies have been carried out to correlate dichotic listening capability with benefit derived from hearing aid. However there is dearth for studies correlating temporal processing abilities with the hearing aid benefit.

AIM OF THE STUDY

This study was designed to investigate the effect of deficit in temporal resolution and binaural integration on benefit derived from hearing aid in elderly subjects with hearing loss.

REVIEW OF LITERATURE

Elderly individuals often have more deficits in speech understanding than younger individuals with the same degree of hearing loss. These changes or deficits occur through out the central auditory nervous system (Stach, Loiselle & Jerger, 1991). Bellis (2004) has reported that about 75% of the elderly listeners may exhibit auditory processing disorder. A brief review of studies that have investigated auditory processing in elderly is presented here.

Many studies suggest that, older listeners with normal hearing sensitivity and impaired hearing sensitivity often demonstrate poorer than normal performance on tasks of speech understanding in noise. (Smith & Prathers, 1971; Town-send & Bess, 1980; Findlay & Denenberg, 1977; Peter, 2004). Deficits in temporal resolution, binaural integration or seperation have been reported in elderly subjects.

Temporal resolution in elderly listeners:

Temporal resolution is important for resolving brief dips in intensity of the interfering noise & therefore is crucial for understanding speech in these situations (Dubno, Horwitz & Ahlstrom, 2003; Oxenhan & Bacon, 2003; Peters, Moore and Baer, 1998). Temporal resolution is often studied by means of a gap detection paradigm.

Investigations on age related changes in temporal resolution have revealed that there were mean differences between the young & elderly groups reflecting shifts in the distributions of gap thresholds of the older subjects towards poorer temporal resolution (Snell, 1997). Lister, Besing and Koehnke (2002) measured temporal discrimination using a gap discrimination paradigm, for three groups of normal hearing listeners aged 18-30, 40-52 and 62-74 years. Gap duration discrimination was significantly poorer for older listeners than for young and middle aged listeners and the performance of the young and middle –aged listeners did not differ significantly. Strouse, Ashmead, Ohde & Grantham, (1998) used gap detection test to measure monoaural temporal processing for 12 young and 12 elderly adults with clinically normal hearing. Elderly listeners displayed poorer monoaural temporal analysis (higher gap detection thresholds) suggesting that age related factors other than peripheral hearing loss contribute to temporal processing-deficits of elderly listeners.

Previous investigations of temporal resolution in the auditory system indicate that hearing-impaired listeners often perform more poorly on temporal resolution tasks than do normal hearing listeners when the stimulus has a broad frequency range (Boothroyd, 1973; Irwin, Hinchcliff & Kemp, 1982; Tyler, Summerfield, Wood & Fernandes 1982; Fitzgibbons & Gordon-Salant, 1987). Several studies have attempted to control for the effect of age-related hearing loss on gap-detection thresholds (Moore, Peter & Glasberg 1992; Schneider, Pichora-Fuller, Kowalchuk & Lamb 1994; Snell, 1997). Moore et al (1992) measured thresholds for the detection of temporal gaps in sinusoidal signals as a function of subjects with “near normal” hearing. Results were compared to data collected from young normal hearing subjects, revealing that elderly subjects with near normal hearing had higher gap detection thresholds than young subjects. Nevertheless, when they compared gap detection thresholds in elderly subjects with near normal hearing to those with hearing impairment, they found no difference between the two groups.

However, some studies have shown temporal resolution in the young hearing impaired subjects (aged 20-40 years) was significantly poor than young normal subjects (aged 20-34 years) regardless of whether the comparisons were made at equal sound pressure level or at equal sensation level (Fitzgibbons & Wightman; 1982).

Florentine and Buus (1984) assessed the effect of the configuration of a hearing loss on gap detection to determine if the hearing impairment affects temporal resolution in six listeners with normal hearing, seven with hearing impairment of primarily cochlear origin and eight with impairment simulated by masking. The impaired listeners' minimum detectable gap duration (MDG) at 80 and 90 dBHL varied from about 3.5ms (equal to normal MDG) to about 8ms and it showed little correlation with their average hearing loss. At lower levels, the MDG was more for all the impaired listeners owing to decreased sensation level of noise. However, at higher levels some impaired listeners performed worse than their simulated loss counterparts, indicating that temporal resolution may be reduced in some, but not in all the impaired listeners.

Another test to assess temporal resolution is to measure the threshold for detecting changes in the amplitude of a sound as a function of the rate of changes. The function, which relates threshold to modulation rate, is called temporal modulation transfer function (TMTF) (Viemeister, 1979). The TMTF provide important information about the processing of temporal envelopes. Since the modulation of a sound modifies its spectrum, wide-band noise is often used as a carrier signal in order to prevent subjects' from using changes in the over all spectrum as a detection cue, modulation of white noise does not change its long term spectrum Burns & Viemester, (1981). In normal subjects sensitivity for detecting sinusoidal amplitude modulation of a broadband noise carrier is high for low modulation rates and decreases at high modulation rates.

Bacon and Viemester (1985) obtained modulation thresholds for sinusoidally amplitude modulated broadband noise from normal hearing and sensorineural hearing impaired as a function of modulation frequency. The resulting temporal modulation transfer functions (TMTFs) indicated that the impaired listeners were generally less sensitive than the normal to amplitude modulation. TMTFs were also obtained with band limited noise from the normal hearing listeners; the noise was low pass filtered at 1.6Khz after modulation and was generally presented with a 1.6KHz high pass marker. The TMTFs in the low pass condition were similar to the TMTFs obtained with broadband noise from impaired listeners, suggesting that the impaired temporal processing in the hearing impaired listeners is a result of a narrower effective, 'internal' bandwidth.

Takahashi and Bacon (1992) examined temporal processing of suprathreshold sounds in three groups (54.2, 64.8, 72.2 mean age) of older subjects with normal hearing or mild sensorineural hearing loss. In the first experiment (modulation detection), subjects were asked to detect sinusoidal amplitude modulation (SAM) of a broadband noise, for modulation frequencies ranging from 2 to 1024Hz. In the second experiment (modulation masking), the task was to detect a SAM signal (modulation of 8Hz) in the presence of a 100% modulated SAM masker. Masker modulation frequency ranged from 2 to 64Hz. In the final experiment, speech understanding was measured as a function of signal-to-noise ratio in both modulated and unmodulated background noise and in a SAM background noise that had a modulation frequency of 8Hz and a modulation depth of 100%. Except for a very modest correlation between age and modulation detection sensitivity at low modulation frequencies, there were no significant effects of age once the effect of hearing loss was taken into account. These results of the experiment suggest, however, that subjects with even a mild sensorineural hearing loss may have difficulty with a modulation masking task, and may not understand speech as well as normal hearing subjects do in a modulated noise background.

Contrary to these findings Moore, Shailer & Schooneveldt (1992) report that Temporal modulation transfer function is not affected by hearing loss. They measured the modulation depth required for the detection of sinusoidal amplitude modulation as a function of modulation rate. The carrier was a one-octave wide noise centered at 2 kHz, and it was presented in an unmodulated background noise low pass filtered at 5 kHz. Three subjects with unilateral cochlear hearing loss were tested. For each subject, the normal ear was tested both at the same sound pressure level (SPL) and at the same sensation level (SL) as the impaired ear. The TMTFs were similar for the normal and the impaired ears at both levels. The better ears of three subjects with bilateral cochlear losses were also tested. Again TMTFs were similar as obtained for normal ears. These results suggest that temporal resolution is not necessarily adversely affected by cochlear hearing loss, at least as measured by this task.

Investigations by Hescot, Lorenzi, Debraille & Camus, (2000) support these findings. They measured TMTF in five adult listeners with normal hearing (mean age 52 years), five elderly listeners with moderate cochlear hearing loss (mean age 66 year) and a single elderly listener (aged 73 years) with moderate cochlear hearing loss and left hemisphere damage were tested in the right ear at 50 dBSL. The five elderly listeners were matched in audiogram with the brain-damaged listener. Modulation detection was systematically poorer than normal in the five elderly listeners with cochlear hearing loss. Modulation detection was much poorer in the elderly listener with cochlear hearing loss and left hemisphere damage compared to the five normal hearing adults and five elderly listeners with cochlear hearing loss. Moreover modulation detection was poorer at 4, 64 and 128Hz than at 8, 16 and 32 Hz in the brain damaged listener, giving his TMTF a band pass appearance. These results are in agreement with the hypothesis that the main factors limiting the ability to detect changes in the temporal envelope of sounds are located at a central (retro cochlear) level of the auditory system rather than a peripheral (cochlear level). They also suggested that the TMTF approach might prove useful in distinguishing peripheral and central hearing losses.

Dichotic listening in elderly subjects:

Dichotic tests are useful in evaluating binaural integrity of central auditory nervous system. Effect of age on dichotic listening was determined in an experiment by Martin, Dougals, Cocanford and Jerry (1991) where subjects were evaluated for channel capacity measure (repetition of all the digits heard in both ears) and selective attention measure (reporting of all the digits in one ear while ignoring the digits in the opposite ear). Older subjects performed poorer than younger subjects on both the tasks.

Speaks, Niccum and Van Tasell (1985) obtained dichotic listening scores were obtained from 27 subjects with sensorineural hearing loss in response to four dichotic speech tests: digits, vowel words, consonant words, and CV nonsense syllables. The digit test appeared to be most promising for assessing central auditory function when the patient had a sensorineural hearing loss because performance for the digits was only slightly affected by the peripheral loss.

Strouse, Wilson & Brush (2000) evaluated dichotic listening in pre-cued and post-cued response conditions using a hierarchical set of one, two and three pair dichotic digit materials in thirty young adults (mean age 29.1 years) with normal hearing, and thirty older adults (mean age 68.7 years) with mild to moderate sensorineural hearing loss. In the pre-cued condition, recognition performance decreased as a function of age and left ear scores decreased faster than right ear scores resulting in a larger right ear advantage in the older adults. As, the complexity of listening task increased from easy (one pair) to difficult (three pairs), there was a corresponding decrease in recognition performance for both age groups. The increase in difference in performance on easy and difficult tasks became larger as a function of age.

Interaction of age, ear and stimulus complexity on dichotic digit recognition was studied by Wilson and Jaffe (1996) using a hierarchy of one pair, two pair, three pair and four pair dichotic digits. Two group of right handed adults (<30 years of age) and elderly (60-75 years) were taken, where adults had normal hearing and elderly listeners had mild to moderate hearing loss. As the complexity of the listening task increased from one pair to four pairs, recognition performance decreased systematically and significantly, and the difference was larger for the left ear than the right ear. Also the difference was larger for the 60-75 year old subjects than the younger group.

Peter (2004) studied the effect of age and age related hearing loss on dichotic digit test scores and found that 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 correct scores. Presbycusis population differed significantly from the other two groups in terms of right ear, left ear and double correct scores.

Thus it can be concluded from the above studies that temporal resolution and dichotic listening is affected in older individuals. Though there are contradictory reports on effects of hearing loss on these tests, it can be concluded that age has greater effect on the tests than peripheral hearing loss.

Hearing aid benefit in elderly listeners:

Jerger, Oliver and Pirozzolo (1990) studied 122 elderly subjects to check the central auditory dysfunction and self perceived handicap. Speech identification for PB words, speech identification for SSI list, speech perception-in-noise test and dichotic sentence identification test were used for assessing central auditory dysfunction and Hearing Handicap Inventory for the Elderly was administered for determining self perceived handicap. It is observed that elderly individuals with symptoms of central auditory dysfunction rated themselves as having more handicap than did the subjects with out central auditory processing disorder.

Generally, the elderly subjects with hearing loss are recommended to use a hearing aid. However the benefit they derive from a hearing aid will depend on whether the loss is only due to peripheral or both central and peripheral degeneration. Jerger and Hayes (1976) investigated hearing aid benefit in six elderly individuals using synthetic sentences and speech competition in varying "message-to-competition ratios (MCRs)" as well as follow up survey of patient's satisfaction with recommended hearing aids. They observed that those elderly individuals, who rated hearing aid use as unsatisfactory, performed more poorly with hearing aids in difficult listening situations than those who were satisfied with hearing aid use. When an elderly subject has both peripheral and central auditory processing problem, benefit derived from hearing aid may be less.

Sorri, Loutenen and Laitakari (1984) also studied hearing aid use as a function of age. They interviewed hundred and fifty patients approximately two years after they had been fitted with hearing aids and categorized them into regular users, selective users or non-users. As age increased, the percentage of patients who were non-regular users increased systematically. For those patients over the age of 75 years, fewer than half (44%) used their hearing aids on regular basis, and 36% were categorized as non-users. However, auditory processing abilities were not investigated in these individuals.

Stach, Loiselle and Jerger (1991) reported that deficits in speech understanding in elderly individuals leads to poorer performance with hearing aids, reduced satisfaction with hearing aids. Chmiel and Jerger (1996) compared self reported handicap (Hearing Handicap inventory for the elderly, HHIE) scores before and after a 6-week period of hearing aid use in subjects drawn from the pool of 115 elderly persons with hearing impairment. Subjects were divided into two categories depending on the scores of dichotic listening test (Dichotic Sentence Identification Test, DSI). After 6 weeks of first time hearing aid use, there was a significant improvement in average HHIE scores, but only in the DSI normal category. In the subgroup with dichotic deficits, average HHIE scores didnot change significantly after hearing aid use. Results confirm that those without central auditory processing disorder benefit more from hearing aid when compared to those with central auditory processing disorder.

Studies also evaluated for the aided performance in a sound field to check for performance with hearing aids of the elderly. Hayes and Jerger (1979) evaluated aided performance in a sound field by a group of patients with a speech audiometric pattern consistent with peripheral sensitivity deficit and a group with a pattern consistent with auditory processing disorder and found subjects with auditory processing component didnot perform as well with hearing aids as those subjects without auditory processing component. It was also found that performance declined with increasing degree of auditory processing component.

Hayes, Jerger, Taff and Barber (1983) surveyed satisfaction with hearing aid use in 78 subjects who have been evaluated for hearing aid use by formal speech audiometric measures (synthetic sentence identification). At 10dB message-to-competition ratio, synthetic sentence identification performance was about 30% better in satisfied than in dissatisfied users. According to them, hearing ais users having both sensitivity loss and auditory processing disorders are generally less satisfied with hearing aids than those with only peripheral sensitivity loss.

Peter, Moore and Baer (1998) reported that linear amplification combined with appropriate frequency response shaping (NAL amplification), as would be provided by a well fitted “conventional” hearing aid, only partially compensated for deficit in speech reception thresholds in presence of 65dBSPL noise. Elderly with moderate to severe cochlear hearing loss in aided condition still required a speech-to-background ratio that was 15dB higher than for young subjects with normal hearing .

Humes, Wilson, Barlow and Garner (2002) reported the results of hearing aid benefit measures obtained from 134 elderly hearing aid wearers during the first year of hearing aid usage. Benefit measures were obtained after 1 month, 6 month and 1 year of hearing aid use by all participants. Benefit measures included several objective tests of speech recognition, as well as the subjective self report scales of the Hearing Aid Performance Inventory (HAPI) and HHIE (Hearing Handicap Inventory for the Elderly). Although group means changed only slightly over time for all of the benefit measures, significant differences were observed for some of the benefit measures, especially among the subjective self-report measures. Performances for almost all of the subjects was significantly worse (less benefit) at both the six month and one year post fit. Regarding long term changes in benefit following two years of hearing aid use, minimal changes were again observed. In all the subjects there was little evidence of acclimatization of hearing aid benefit.

Thus, a review of literature shows that elderly subjects with hearing loss benefit less from hearing aid when compared to young adults with hearing loss. One of the major factors affecting their performance with hearing aid is auditory processing ability. A majority of the studies have correlated performance on speech in noise or competing message test with hearing aid benefit. A few studies have correlated dichotic listening capability with benefit derived from hearing aid. There is a dearth for studies correlating performance on temporal processing tests with hearing aid benefit.

METHOD

Subjects: Subjects of the present study consisted of fifteen elderly individuals with hearing loss. The subject selection criteria were as follows:

- Age range should be more than 55years.
- Should have hearing loss not exceeding 55dBHL. The mean pure tone thresholds averages for the right ear was 50.6 dB with a standard deviation of 4.5 and mean was 51.4 dB with a standard deviation of 4.1.
- Loss should be symmetrical.
- Should have normal middle ear function as assessed by tympanometry and acoustic reflex thresholds.
- Should have no history of neurological disorder.
- Should be using hearing aids at least for one to three years

Instruments: The following instruments were used for the study:

- A calibrated clinical audiometer OB922 was used to carry out Pure-tone audiometry, assessment of Speech reception threshold (SRT), Speech identification scores (SIS), Dichotic digit test (DDT), Gap detection test (GDT), Temporal modulation transfer function (TMTF).
- A CD player was used for the stimulus presentation for GDT and DDT.
- A computer loaded with Audiolab software was used to present stimulus for TMTF.
- A calibrated middle ear analyzer (GSI-tympstar) was used to assess middle ear function.

- Users own hearing aid.

Materials: The following materials were used for the study

- *Speech reception threshold*: Paired words in Kannada developed in the department of audiology were used for determining the speech reception thresholds.

- *Speech identification score*: Phonetically balanced word lists in Kannada developed by Vandana (1998) were used for estimating speech identification scores. The test includes two half lists of 25 words each.

- *Dichotic digit test*: The Dichotic digit test in Kannada developed by Regishia (2003) was used for the present study. The digits included were bisyllabic words spoken by an adult Kannada speaker. The materials consisted of a total of 30 presentations each consisting of two pairs of digits in Kannada. The inter-stimulus interval between the first and second pair of digits was 500ms.

- *Gap detection test*: The Gap detection test developed by Shivaprakash (2003) was used. It consists of 56 stimuli includes 6 catch trials and four practice items (at the beginning of the test). Each stimulus set consists of 3 noise bursts of 300ms duration separated by a silence of 750ms. One of the three stimuli had a gap. Gap duration of the practice items were 20, 16, 12, 7 10 ms. The size of the gap varied from a maximum of 20msec to a minimum of 1msec.

- *Temporal modulation transfer function*: The Temporal modulation transfer function test developed by Kumar (2005) was used. It consists of un-modulated and sinusoidally amplitude modulated broadband noise generated with duration of 500ms and a ramp of 2.5ms. Changing the amplitude of the modulating sine wave varied the depth of modulation. Modulation depth varied between 0 to 30dB for each stimulus (0dB is equal to 1005 modulation depth). Stimulation consisted of modulation at 4Hz, 16Hz, 32Hz, 50Hz & 100Hz).

- *Self-assessment of hearing handicap*: Self-assessment tool in Kannada developed by Vanaja (2000) was used to identify the communication difficulties in different situations. The tool has 50 questions, which has to be answered using a 3-point rating scale.

Procedure: The following procedures were carried out while administering these tests:

- Pure-tone thresholds: Pure-tone thresholds were obtained at octave intervals between 250Hz to 8000Hz for air conduction stimuli and between 250Hz to 4000Hz for bone conduction stimuli using modified Hughson-Westlake method (Carhart and Jerger, 1959).

- Speech reception thresholds: SRTs were obtained at 20dBSL individually for each ear for all the subjects using paired words in Kannada developed in the department of audiology. Live voice was used to present the words and the VU meter deflection was monitored to zero to ensure that all the stimuli were presented at the same intensity. The minimum intensity at which 50% scores were achieved was considered as SRT.

- Speech identification scores: Speech identification was carried out under earphones at 40dBSL (re: SRT). Live voice was used to present the lists developed by Vandana (1998) to each ear separately and the VU meter deflection was monitored to ensure that the stimuli were presented at same intensity. The subjects were asked to repeat the words. Each correct response was given a score of 2%. The total percentages of the correct responses were calculated.

- Dichotic digit test: The CD version of Dichotic digit test was presented at 40dBSL (re: SRT). The signal from the CD was played through a CD player where the signal from the CD was fed to the tape input of the audiometer and the output from the audiometer was given to the earphones. The subjects were asked to repeat the digits heard in both the ears or write it down on a paper. The responses were scored in terms of single correct and double correct scores. A single correct score was given when the subjects repeated 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.

- Gap detection test: Gap detection test was carried out at 40dBSL (re: SRT) and for each ear individually. The output from the CD was fed to the tape input of the audiometer and output from the audiometer was fed to the earphones. The subjects were asked to indicate verbally which of the 3-noise burst in a set had the gap. Before the actual sets, four practice sets were presented to train the subject. And the 6 catch trials were also presented in between to rule out false positive responses. The minimum gap detected by the subject was considered as gap detection threshold for that ear.

- Temporal modulation transfer function: TMTF test was done at 40dBSL (re: SRT) for each ear individually. The test material was routed from the computer to the tape input of the audiometer and output from audiometer was then fed to the earphones. The subjects were asked to indicate if the two modulated noises delivered were different or same. The minimum modulation at which the subjects indicated a difference between the two noises was considered as the threshold. This was done for modulation frequency of 100Hz, 16Hz, 50Hz, 32Hz and 4Hz.

- Hearing aid benefit assessment: Following aided measures were carried out with subjects own hearing aid at recommended settings-:
    - Aided audiogram- Aided audiogram was obtained using frequency modulated tones with carrier frequency 250Hz, 500Hz, 1000Hz, 2000Hz & 4000Hz. Stimuli was presented through loudspeakers positioned at 45^0 azimuth and at a distance of one meter to the subject with hearing aid.

- Speech identification in quiet: Speech identification was carried out first at 40dBSL. In this list of words were routed from audiometer to the loudspeaker and presented to the subject with hearing aid. The loudspeaker was positioned at a distance of one meter from the subject at a azimuth of 45^0 in a calibrated sound field. Subjects were asked to repeat the Phonemically balanced words. Correct responses were scored in terms of percentages and a score of 2% was given for each correct score.
- Self assessment of hearing handicap: An interview in Kannada, the language of the subjects was conducted and the subjects had to rate the questions according to their problem as >75% of the time as 'most of the time'; 25%-75% of the time as 'sometimes' and <25% of the time as 'seldom'. A score of zero indicated no handicap while a score of two indicated maximum handicap. The scores obtained were then converted to percentages depending on the number of questions applicable or not applicable for individual subjects. The subjects did not rate the question when it was not applicable for the respective subject. This was done for both with and with out hearing aid conditions.

The data collected was tabulated and was subjected to statistical analysis for investigating the aim of the study

RESULTS

Three outcome measures were used to assess benefit derived from hearing aid and these are as follows:

I. Aided thresholds,

II. Aided speech identification scores, &,

III. Self perceived benefit assessed through self-assessment scale.

Benefit derived from hearing aid using these three measures were assessed in all the subjects and investigated to determine, if there is a correlation between the benefit derived and the results of auditory processing disorder tests.

Results of auditory processing disorder tests:

It was observed that the temporal resolution ability as determined through gap detection test (GDT) showed higher threshold bilaterally for all elderly individuals. Some individuals could not even detect a gap of 20msec in noise burst.

Temporal modulation transfer function (TMTF) test was used as a psycho-acoustic approach to measure the threshold for detecting changes in the amplitude of a sound as a function of rate changes. This also measures for temporal resolution ability. Results on TMTF test showed, a deviation of thresholds obtained for different modulation frequencies, from the normative mean and standard deviation. For, 16Hz modulation frequency (MF) and 4Hz modulation frequency (MF) normal thresholds were obtained bilaterally in three individuals. Bilateral normal thresholds on TMTF test were also obtained for 50Hz modulation frequency for only one subject. Normal thresholds were obtained unilaterally for 100Hz in three subjects, for 16HzMF in four subjects, for 4Hz in three subjects and 50HzMF in two subjects.

Results of the Dichotic digit test (DDT) showed abnormal scores on this test for all the subjects except for three individuals for whom single correct scores were normal (in right ear for one subjects and in the left ear for two subjects), where as, double correct scores were abnormal.

To investigate the correlation between auditory processing disorder and benefit derived from hearing aid in elderly individuals with mild to moderate peripheral impairment, Pearson's Product moment correlation was carried out between the results obtained on auditory processing tests and three outcome measures of hearing aid benefit. SPSS software (Version 10) was used for statistical analysis.

Table 1 shows the correlation values between the results of auditory processing test scores and the self-perceived handicap with a hearing aid for nine subjects. Self-assessment of hearing loss with a hearing aid could not be obtained from six subjects. Pearson's Product Moment Correlation analysis revealed high negative correlation to moderate correlation between self perceived handicap with a hearing aid and for the TMTF thresholds obtained for 16Hz modulation frequency (-.64), 4Hz modulation frequency (-.67) and 32Hz modulation frequency (-.57) in the left ear. Low negative correlations were observed between other TMTF tests thresholds (obtained with 32Hz modulation frequency and 50Hz modulation frequency) with the self-assessment scale scores derived for hearing aid condition. High positive correlation (.70) was also found in the right ear between self-perceived handicap for with hearing aid condition and 16Hz modulation frequency of the TMTF test. Correlation found for the gap detection threshold and the dichotic digit test with the self-assessment scale was very low. However the correlation between the auditory processing tests and the perceived benefit was not statistically significant.

	APD tests	Self assessment scale for with hearing aid condition	
		Right ear	Left ear
	GDT	-.12	. 14
	DDT	-.42	.38
TMTF	100HzMF	.70	.20
	16HzMF	-.14	-.64
	32HzMF	-.14	-.57
	4HzMF	-.29	-.67
	50HzMF	-.09	-.38

Table 1: Correlation values for the APD test scores and self-assessment scale scores for hearing aid condition.

Similar statistically insignificant correlations were also obtained between the self-perceived handicap with out a hearing aid and results of auditory processing disorder.

	APD tests	Self assessment scale in unaided hearing condition	
		Right ear	Left ear
	GDT	.36	. 33
	DDT	-.36	-.04
TMTF	100HzMF	.15	.01
	16HzMF	.57	.23
	32HzMF	.71	.35
	4HzMF	.42	.22
	50HzMF	.07	.15

Table 2: Correlation between different APD test results and the scores on self-assessment scale for without hearing aid condition.

Table 3 depicts statistically insignificant correlation obtained between the auditory processing test scores and the aided scores obtained for speech identification in quiet. Pearson's Product Moment Correlation reveals a low negative (-.48) to low positive correlation (.29) between results of TMTF test for 16Hz modulation frequency and aided speech identification in quiet. Results of the remaining test also showed a very low correlation with aided speech identification scores.

	APD tests	Aided speech identification in quiet	
		Right ear	Left ear
	GDT	-.09	-.39
	DDT	-.01	.27
TMTF	100HzMF	-.19	-.05
	16HzMF	-.48	.06
	32HzMF	-.25	.07
	4HzMF	-.33	-.07
	50HzMF	.29	.27

Table 3: Degree of correlation for the APD test scores and the scores of aided speech identification.

Table 4 shows the correlation values for APD test results and the aided thresholds for 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz which were statistically insignificant. For, 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz. Results of the auditory processing disorder tests showed a low correlation with aided thresholds. Only TMTF at 4Hz modulation frequency showed moderate correlation and at 32Hz modulation frequency showed a high correlation with the aided threshold at 4000Hz.

	APD Tests	Aided thresholds									
		250Hz		500Hz		1000Hz		2000Hz		4000Hz	
		R.E.	L.E.	R.E.	L.E.	R.E.	L.E.	R.E.	L.E.	R.E.	L.E.
	GDT	.19	-.12	.15	.35	.12	-.01	-.01	-.03	-.24	-.43
	DDT	.24	-.18	.21	-.01	.06	.12	-.32	.48	-.08	.42
TMTF	100Hz	-.09	-.29	-.10	-.15	-.10	.04	.19	.40	.10	.10
	16Hz	.59	.11	.31	-.21	.04	-.30	-.27	-.42	-.11	-.43
	32Hz	.47	.18	.03	-.18	-.05	-.18	-.44	-.41	-.31	-.61
	4Hz	.32	.20	.06	-.06	.10	-.04	-.12	-.26	-.40	-.53
	50Hz	-.19	-.04	-.43	-.36	-.34	-.30	-.13	-.16	-.34	-.30

Table 4: Correlation values between APD test results and the aided thresholds.

Note: R.E. - Right ear; L.E. - Left ear.

DISCUSSIONS

The results of gap detection test showed a higher threshold for resolving the gaps in noise bursts indicating that these elderly individuals with mild to moderate degree of sensori-neural hearing impairment do have deficits in auditory processing ability, i.e., the “temporal resolution”. Temporal resolution is important for resolving or segregating acoustic events with in a minimum time interval and hence this is critical for understanding speech in adverse listening situations (Dubno, Horwitz & Ahlstrom, 2003; Oxenhan & Bacon, 2003). So, deficits in temporal resolution lead to impaired perception of speech in adverse listening situations and therefore the benefits derived through hearing aids can also be affected.

The results of temporal modulation transfer function also indicated temporal resolution deficits either bilaterally or unilaterally in these elderly subjects. A deficit in this aspect would not allow the subjects to follow the changes in amplitude of a sound properly with respect to rate changes suggesting that auditory system is sluggish to follow temporal envelop fluctuations, which can affect the perception of faster rate of speech. Moore, Shailer & Schooneveldt (1992) have also suggested that results of temporal resolution are not necessarily affected by cochlear hearing loss. So, confounding effects of hearing loss can be ruled out while analyzing these results, suggesting temporal resolution deficit responsible for elevated thresholds that may not be compensated by amplification device.

The results of abnormal single correct and double correct scores on dichotic digit test suggest a deficit in dichotic listening, that may be resulting from functional hemispheric disparities or impairment of the function of the corpus callosum or both. Literature also revealed that scores on dichotic digit test to be poorer for older subjects as compared to younger subjects (Martin Dougals, Cocanford & Jerry, 1991) and is only slightly affected by peripheral hearing loss (Speaks, Niccum & Van Tasell, 1985). This suggests that the scores on dichotic digit test obtained would be due to deficits in binaural performance.

It has been observed from the results that all the individuals had processing deficit in all the aspects assesses through gap detection test, dichotic digit test and temporal modulation transfer function test. But the degree of processing deficit varied from individual to individual as depicted by the thresholds and scores on these tests.

It has been reported in literature that, when individuals with processing deficit are fitted with hearing aid, the benefit they derive is less when compared to that of individuals without auditory processing deficits (Hayes & Jerger, 1979; Hayes, Jerger, Taff & Barber, 1983). This is because hearing aids do not compensate for lack of auditory processing abilities but only amplify for the required intensity levels according to the peripheral sensitivity loss. In the present study all the subjects showed central auditory processing deficit. Hence an attempt was made to check the correlation between the degree of auditory processing disorder and benefit derived from hearing aid using Pearson's Product Moment Correlation.

Insignificant correlation observed between the results of auditory processing disorder tests and hearing aid outcome measures suggested that auditory processing deficit present in these subjects did not explain the variability in speech identification scores in quiet. Insignificant correlation with self perceived handicap revealed that the poor temporal resolution and binaural integration abilities does not account for the variability in communication abilities in everyday listening situation. The aided identification scores ranged from 70% to 100% whereas the self perceived handicap ranged from 41% to 74%. These results suggest that factors other than temporal resolution and binaural integration affected communication abilities of hearing aid users.

Earlier investigations done by Hayes & Jerger (1979) evaluated aided performance for elderly individuals in subjects with auditory processing disorders. They reported that those with auditory processing disorders did not perform as well with hearing aids as those without auditory processing disorders and the performance declined with increasing degree of auditory processing component. Hayes, Jerger, Taff and Barber (1983) have also reported the similar results after a survey of hearing aid use in 78 subjects where sentence identification performance was on an average 30% better in satisfied than in dissatisfied users. The results also suggested that hearing aid users having both auditory processing disorders and peripheral loss are generally less satisfied with hearing aids than those with only peripheral loss. So, benefit derived from hearing aids by the elderly individuals depends on the processing ability of each individual.

Chmiel and Jerger (1996) reported that in a subgroup of subjects with dichotic deficits there was no change in self-perceived handicap with and without a hearing aid. However, the results of the present study does not support these findings as some of the subjects with binaural integration deficit showed a difference in the self perceived handicap with and without hearing aid whereas others did not show any difference. The difference in results of the two studies may be because of the test used for assessing binaural integration. Chmiel and Jerger used dichotic sentence test whereas the present used dichotic digit test. Dichotic digit test is easier than dichotic sentence test. So probably dichotic sentence test is more sensitive in identifying auditory processing deficit than dichotic digit test.

There is dearth for studies evaluating hearing aid benefit in subjects with temporal resolution deficits. The poor correlation observed in the present study is probably due to outcome measures used to study the benefit derived from hearing aid. None of the outcome measures used in the present study required good temporal resolution. Probably better correlation would have been observed of the hearing aid benefit in adverse listening situation was tested. Though some of the questions used in the hearing handicap scale checked for communication abilities in adverse listening situations, only total scores were considered for analysis. Analysis with scores for only those questions, which checked the communication abilities in adverse listening situation, should be carried out in further investigations.

SUMMARY AND CONCLUSIONS

Changes in the structure and function occur through out peripheral and central auditory nervous systems as a result of the ageing. Peripheral sensitivity loss results in the attenuation and distortion of the auditory signal. By selectively amplifying sound, the problem can be, to a large degree overcome. Conversely, the most important consequences of an auditory processing disorder, is the inability to extract speech from background of noise, inability to follow the changes in the amplitude of a sound as a function of rate changes as well as problem in dichotic listening; to which the application of conventional hearing aid amplification may be a failure.

Despite of research in the field, the lack of benefit derived from hearing aids for the elderly individuals was not well understood. A majority of studies have correlated speech identification in noise or competing message test with the benefit the elderly individuals derive from hearing aid. But speech in noise test is not a specific test for auditory processing disorder and it is affected by many other factors including peripheral hearing loss. Also an individual with auditory processing disorder may have problem in any of the processes such as temporal resolution and binaural performance. Few studies have been carried out to correlate dichotic listening capability with benefit derived from hearing aid. There is a need to correlate temporal processing abilities with the hearing aid benefit. So, the present study was designed to investigate the effect of deficit in temporal resolution and binaural integration on benefit derived from hearing aid in elderly subjects with hearing loss.

Fifteen elderly subjects with bilateral mild to moderate (<55dBHL) symmetrical sensori-neural hearing loss were included in the study. The subjects were using hearing aid for a period of one to three years. To check for auditory processing deficit Dichotic Digit test (DDT), Gap Detection Test (GDT) and Temporal Modulation Transfer Function (TMTF) tests were administered. These auditory processing tests were carried out at 40dBSL. Stimuli from the CD versions were routed from the CD player to the earphones through the audiometer and responses were obtained. For hearing aid benefit assessment, aided thresholds, aided speech identification scores in quiet as well as scores on a self-assessment scale with and without hearing aid condition was investigated. For determining aided thresholds, subjects with hearing aid were positioned from the loudspeaker at a distance of one meter at an azimuth of 45^0 in a calibrated sound field and stimuli were routed from audiometer to the loudspeaker. For the determining self perceived handicap an interview in Kannada was conducted with the self-assessment scale and the subjects had to rate the questions according to their problem for unaided conditions as well as with hearing aid conditions. The subjects used the prescribed hearing aids with recommended settings.

The analysis of the results revealed the following findings:

a) All the elderly individuals revealed a higher gap detection threshold bilaterally,

b) Unilateral or bilateral deviation of thresholds from the normative values were observed on Temporal Modulation Transfer Function test for all the modulation frequencies tested in these elderly individuals,

c) Dichotic Digit Test also revealed abnormal scores except for three individuals where single correct scores were normal.
d) The results of auditory processing tests showed insignificant correlation with all the three outcome measures.

Insignificant correlation observed between the results of auditory processing disorder tests and hearing aid outcome measures suggested that auditory processing deficit present in these subjects did not explain the variability in speech identification scores in quiet. Insignificant correlation with self perceived handicap revealed that the poor temporal resolution and binaural integration abilities does not account for the variability in communication abilities in everyday listening situation.

Implications and future directions:

a) Correlation between different auditory processing deficits and hearing aid benefit derived for adverse listening situations can be carried out.
b) Comparison of the hearing aid benefit in elderly subjects with and without auditory processing disorders can be carried out.
c) Studies need to be carried out on a larger group of subjects.

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