Relationship between Auditory Processing Disorder and Hearing Aid Benefit in Elderly Subjects

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Abstract

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. Subjects consisted of fifteen elderly individuals (aged >55years) with hearing loss not exceeding 55dBHL. Gap detection test, temporal modulation transfer function test, and dichotic digit test were administered to check for temporal resolution and binaural integration. For hearing aid benefit assessment aided audiogram, aided speech identification in quiet as well as scores on a self-assessment scale with and without hearing aid condition was investigated. Results revealed a deficit in temporal resolution and binaural integration in majority of the individuals. However the results of auditory processing tests showed insignificant correlation with all the three hearing aid outcome measures.

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. 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) observed 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

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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 Hescot, Lorenzi, Debraille and 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 listeners 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 the presence of peripheral hearing loss (Musiek, 1983). Martin, Dougals, Cocanford and Jerry (1991) administered dichotic digit test and found that older subjects performed poorer than younger subjects

Reduced auditory processing abilities in the elderly may hamper 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 that 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".

Despite of research in the field the lack of benefit derived from hearing aids for the elderly individuals is 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. So, 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.

Method

Participants

Participants of the present study consisted of fifteen elderly individuals (aged > 55 years) with bilaterally symmetrical hearing loss not exceeding 55 dBHL. The mean pure tone averages for the right ear was 50.6 dB with a standard deviation of 4.5 and mean for the left ear was 51.4 dB with a standard deviation of 4.1. Participants had normal middle ear functioning as assessed by tympanometry and acoustic reflex thresholds and had no history of neurological disorder. All the participants had used hearing aids for more than one year and less than three years.

Instruments

A calibrated clinical audiometer OB 922 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) and Temporal modulation transfer function (TMTF) test and 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 was used to assess the aided outcome measures.

Materials

Paired words in Kannada developed in the department of audiology were used for determining the speech reception thresholds. Phonetically balanced word lists in Kannada developed by Vandana (1998) were used for estimating speech identification scores. The CD version of Dichotic digit test in Kannada developed by Regishia (2003) was used for assessing binaural integrity. It consisted of a total of 30 presentations and each presentation consisting of two pairs of digits with inter-stimulus interval of 500 ms between the first and second pair of digits. The CD version of Gap detection test developed by Shivaprakash (2003) which consists of 56 stimuli including 6 catch trials and four practice items (at the beginning of the test) was used. Each stimulus set consists of 3 noise bursts of 300 ms duration separated by a silence of 750 ms. One of the three stimuli had a gap. The size of the gap varied from a maximum of 20 msec to a minimum of 1 msec. 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 500 ms and a ramp of 2.5 ms. Modulation depth varied between 0 to 30 dB for each stimulus (0 dB is equal to 1005 modulation depth). Stimulation consisted of modulation at 4 Hz, 16 Hz, 32 Hz, 50 Hz & 100 Hz. 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 have to be answered using a 3 point rating scale.

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 were obtained at 20 dBSL individually for each ear for all the subjects using paired words in Kannada. Live voice was used to present the words and the VU meter deflection was monitored at 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 was carried out under earphones at 40 dBSL (re: SRT). 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 was carried out at 40 dBSL (re: SRT). 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 repeated the syllables presented to both ears correctly.

Gap detection test was carried out at 40 dBSL (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.

TMTF test was done at 40 dBSL (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 100 Hz, 16 Hz, 50 Hz, 32 Hz and 4 Hz.

For Hearing aid benefit assessment aided measures were carried out with subjects own hearing aid at recommended settings. Aided audiogram was obtained using frequency modulated tones with carrier frequency 250 Hz, 500 Hz, 1000 Hz, 2000 Hz & 4000 Hz. Stimuli was presented through loudspeakers positioned at 45^0 azimuth and at a distance of one meter to the subject with hearing aid. Aided speech identification was carried out first at 40 dBSL with list of words which were routed from audiometer to the loudspeaker. The loudspeaker was positioned at a distance of one meter from the subject at an azimuth of 45^0 in a calibrated sound field. Subjects were asked to repeat the words. Correct responses were scored in terms of percentages and a score of 2% was given for each correct score.

For self assessment of hearing handicap an interview was conducted in Kannada, the language of the subjects and the subjects had to rate the questions according to their problem as > 75% of the time as 'most of the time'; 25-50% 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

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 20 msec in noise burst. Results on temporal modulation transfer function test showed a deviation of thresholds obtained for different modulation frequencies from normative mean and standard deviation. For 16 Hz and 4 Hz modulation frequency normal thresholds were obtained bilaterally in three individuals. Bilateral normal thresholds on TMTF test were also obtained for 50 Hz modulation frequency for only one subject. Normal thresholds were obtained unilaterally for 100 Hz in three subjects, for 16 Hz MF in four subjects, for 4 Hz in three subjects and 50 Hz MF 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 subject and in left ear for two subjects) whereas 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 TMTF thresholds obtained for 16 Hz modulation frequency (-.64), 4 Hz modulation frequency (-.67) and 32 Hz modulation frequency (-.57) in the left ear. Low negative correlations were observed between other TMTF tests thresholds (obtained with 32 Hz and 50 Hz 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 score with hearing aid condition and 100 Hz 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.

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

	APD tests	Right ear	Left ear
	GDT	-.12	.14
	DDT	-.42	.38
TMTF	100 Hz MF	.70	.20
	16 Hz MF	-.14	-.64
	32 Hz MF	-.14	-.57
	4 Hz MF	-.29	-.67
	50 Hz MF	-.09	-.38

Table 2: Correlation between APD tests and self-assessment scale without hearing aid

	APD tests	Right ear	Left ear
	GDT	.36	. 33
	DDT	-.36	-.04
TMTF	100 Hz MF	.15	.01
	16 Hz MF	.57	.23
	32 Hz MF	.71	.35
	4 Hz MF	.42	.22
	50 Hz MF	.07	.15

However the correlation between the auditory processing tests and the perceived benefit was not statistically significant. It can be observed from Table 2 that statistically insignificant correlations were also obtained between the self-perceived handicap scores with out a hearing aid and results of auditory processing disorder.

Table 3: Correlation for the APD test scores and the scores of aided speech identification

	APD tests	Right ear	Left ear
	GDT	-.09	-.39
	DDT	-.01	.27
TMTF	100 Hz MF	-.19	-.05
	16 Hz MF	-.48	.06
	32 Hz MF	-.25	.07
	4 Hz MF	-.33	-.07
	50 Hz MF	.29	.27

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

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

APD Tests		Aided thresholds									
		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		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
T	100 Hz	-.09	-.29	-.10	-.15	-.10	.04	.19	.40	.10	.10
M	16 Hz	.59	.11	.31	-.21	.04	-.30	-.27	-.42	-.11	-.43
T	32 Hz	.47	.18	.03	-.18	-.05	-.18	-.44	-.41	-.31	-.61
F	4 Hz	.32	.20	.06	-.06	.10	-.04	-.12	-.26	-.40	-.53
	50 Hz	-.19	-.04	-.43	-.36	-.34	-.30	-.13	-.16	-.34	-.30

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

Discussion

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 and 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 reveals that scores on dichotic digit test to be poorer for older subjects 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 deficits in all aspects assessed 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 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 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 and Jerger (1979) evaluated aided performance for elderly individuals 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 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, they concluded that benefit derived from hearing aids in 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 if 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.

Conclusion

The results of the present study indicate that a majority of the elderly subjects have deficit in auditory processing disorder. However the auditory processing disorder did not explain the variability in the benefit obtained from a hearing aid in these individuals.

References

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

Chmeil, R. & Jerger, J. (1996). Hearing aid use, central auditory disorder and hearing handicap in elderly persons. *Journal of American Academy of Audiology*, 7(3), 190-202.

Dubno, J., Hortiwtz, A. & Ahlstrom, J. (2003). Recovery from prior stimulation: Masking of speech by interrupted noise for younger and older adults with normal hearing. *The Journal of the Acoustical Society of America,* 113, 2083-2094.

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.

Gates, G.A., Cooper, J.C., Kannel, W.B. & Miller, N.J. (1990). Hearing in the elderly: The Framingham cohort, 1983-1985. *Ear and Hearing,* 11, 247-256.

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

Hayes, D., Jerger, J., Taff, J. & Barber, B. (1983). Relation between aided synthetic sentence identification scores and hearing aid user satisfaction. *Ear and Hearing*, 4, 158-161.

Helfer, K.S. (1992). Aging and the binaural advantage in reverberation and noise. *Journal of Speech and Hearing Research*, 35, 1394-1401.

Hescot F., Lorenzi, C., Debraille, X. & Camus, J.F. (2000). Measurement of the temporal modulation transfer function for a single listener with cochlear hearing loss and left hemisphere damage. *British Journal of Audiology*, 34, 341-351.

Humes, L.E. & Christopherson, L. (1991). Speech identification difficulties of hearing impaired: The contributions of auditory processing deficits. *Journal of Speech and Hearing Research,* 34, 686-693.

Jerger, J. & Hayes, D. (1976). Hearing aid evaluation: Clinical experience with a new philosophy. *Archives of Otolaryngology,* 102, 214-225.

Jerger, J., Oliver, T. & Pirozzolo, F., (1990). Impact of central auditory processing disorder and cognitive deficit on the self-assessment of hearing handicap in the elderly. *Journal of the American Academy of Audilogy,* 1, 75-80.

Martin D.R., Dougals, R., Cocanford. & Jerry, L. (1991). Age-related changes in binaural processing: II. Behavioral findings. *American Journal of Otology*, 12(5), 365-369.

Maurer, J.F., & Rupp, R.R. (1979). Aging and the outer and middle ear. In Williot, J.F. (Ed.), Aging *of the auditory system* (pp- 8-17), San Diego, Singular publishing group.

Moore, B.C.J., Peters, R.W. & Glasberg, B.R. (1993). *The Journal of the Acoustical Society of America,* Detection of temporal gaps in sinusoids: effects of frequency and level. *The Journal of the Acoustical Society of America,* 93, 1563-1570.

Moore, B.C.J., Shailer, M.J. & Schooneveldt, G.P. (1992). Temporal modulation transfer functions for band-limited noise in subjects with cochlear hearing loss, *British Journal of Audiology,* 26, 229-237.

Musiek, F.E. (1983). Results of three dichotic speech tests on subjects with intracranial lesions. *Ear and Hearing*, 4(6), 318-323.

Nabelek, A. & Robinson, P. (1982). Monaural and binaural speech perception in reverberation for listeners of various ages. *Journal of the Acoust. Society of America*, 71, 1242-1248.

Oxemham, A. & Bacon, S. (2003). Cochlear compression: Perceptual measures and implications for normal and impaired hearing. *Ear and Hearing,* 24, 356-366.

Speaks, C., Niccum, N. & Van Tasell, D. (1985). Effects of stimulus material on the dichotic listening performance of patients with sensorineural hearing loss. *Journal of speech and Hearing Research,* 28 (1), 16-25.

Stach, B., Loiselle, L.H. & Jerger, J.F. (1991). Special hearing aid consideration in elderly patients with auditory processing disorders. *Ear and Hearing,* (suppl), 131S-138S.

Vanaja (2000). Self Assessment of Hearing Handicap: A few audiological correlates. An Unpublished doctoral thesis, Submitted to University of Mysore, Mysore.