Clinical evaluation of central auditory processing functions in the elderly

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Background

Central auditory processing dysfunction is a general term that is applied to individuals whose hearing in quiet settings is normal or almost normal, and yet who have substantial hearing difficulty in the presence of auditory stressors such as competing noise and other difficult hearing situations. It is noticed that the prevalence of central auditory processing dysfunction increases with age.

Objectives

Evaluation of the effects of aging on central auditory processing in elderly individuals who report good hearing sensitivity.

Methodology

Thirty elderly individuals ranging in age from 60 to 75 years, right-handed, and who reported good hearing sensitivity participated in this study. The results of the synthetic sentence identification with an ipsilateral competitive message (SSI–ICM) and staggered spondee words (SSW) tests were compared with those of 15 young adults ranging in age from 20 to 40 years with normal hearing sensitivity as a control group.

Results

The findings of the study showed a statistically significant difference between the control group and the elderly group in terms of SSI, with a lower percentage in the elderly group. The results of the SSW test showed that there was a significant difference in scoring between competing and noncompeting conditions, with more affection in the competing condition in both the control and the elderly groups. When we compared the control group and the elderly group in terms of the SSW error score in the competing condition in both ears, it was found that there was a statistically significant difference between the two groups, with more error scores in the elderly group.

Conclusion

Central auditory processing is affected by aging as shown by the lower percentage of results of the SSI–ICM test and more errors in the SSW test mainly in the competing conditions relative to the control group.

Keywords:

central auditory processing, staggered spondaic words, synthetic sentence identification

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Introduction and rationale

Central auditory processing dysfunction (CAPD) is a general term that is applied to individuals whose hearing in quiet settings is normal or almost normal, and yet who have substantial hearing difficulty in the presence of auditory stressors such as competing noise and other difficult hearing situations. It is noticed that the prevalence of CAPD increases with age [1,2].

It is known that CAPD may affect up to 75% of the elderly population and may compromise success with hearing aids, particularly binaural hearing aids [3], Bellis (2006).

The purposes of central auditory testing are two-fold: first, to identify the presence of abnormalities or dysfunction of the central auditory nervous system (CANS) and to diagnose CAPD, and second, to determine the nature and extent of the disorder to develop management and intervention programs for affected individuals [4]. Auditory processing assessment information is important to identify functional deficits that could be associated with difficulties in speech understanding, in audiological rehabilitation/training [5], and to determine the results of treatment interventions [6]. Central auditory dysfunction can occur without a concomitant decline in peripheral hearing sensitivity, cognitive function, or linguistic competence (Gary *et al.*, 1990).

Behavioral (psychophysical) tests of central auditory function may be categorized as speech or nonspeech (i.e. verbal or nonverbal); speech tasks remain an important component of the CAPD test battery, as CANS deficits are often apparent for speech (vs. nonspeech) signals in children and adults on both psychophysical and electrophysiological measures. It is likely that speech signals provide access to different processing mechanisms in the CANS than do nonspeech signals and that the processing of speech signals may be more vulnerable to disruption by CANS dysfunction, resulting in atypical neurophysiologic responses and/or hemispheric asymmetries in CANS function that are apparent for speech signals, but not for nonspeech signals [7–12].

CAPD may be suspected by below-normal responses on a more heterogeneous group of auditory tests that stress the auditory system in several ways such as synthetic sentence identification with an ipsilateral competitive message (SSI–ICM) in a monauarl task; it reduces the speech redundancy signal by means of speech competition, identifying brain stem involvement [13].

The alternate dissyllable test by means of dichotic tasks as staggered spondee words (SSW) is another test that is based on the simultaneous presentation of different words to the right ear and the left ear; it identifies affection of the brain stem, right hemisphere, left hemisphere, and interhemisphere connections [14–17].

The SSW test was initially developed to evaluate the integrity of the central auditory pathway [16] and has been adopted to identify central auditory dysfunction [18]. This test has three modes of scoring: the original analysis, the traditional analysis, and number of error (NOE) analysis. The original analysis is used for site-of-lesion testing; the traditional and NOE analyses are used for auditory processing evaluations. Currently, the NOE analysis is the accepted auditory processing method [16,19].

Additional evidence of age-related changes in central auditory processing comes from dichotic listening (DL) studies. When linguistic materials such as syllables or words are used, a majority of individuals tend to report more accurately the information presented to their right ear as compared with their left ear (i.e. a right-ear advantage). Conversely, when nonlinguistic materials are used, such as environmental noises or complex tone bursts differing in their fundamental frequencies, information presented to the left ear is more accurately reported than that presented to the right ear (i.e. a left-ear advantage). Asymmetry in behavioral performance is believed to reflect underlying hemispheric biases in processing different aspects of auditory information [20].

In this research, the effect of aging on the central auditory processing functions in elderly individuals with good hearing sensitivity was evaluated. The results were compared with those of young adults and this will help in the development of rehabilitative programs for elderly populations.

Participants and methods

Participants

The participants were divided into two groups: group 1 was the control group, which included 15 young adults ranging in age from 20 to 40 years with normal hearing sensitivity, and group 2 was the study group, which included 30 elderly individuals ranging in age from 60 to 75 years, right-handed, and who reported good hearing sensitivity. Individuals with neurological diseases and chronic medical diseases that may affect the hearing were excluded. The effects of any degree of hearing loss will be compensated by presenting the stimulus at 50 dB SL. The results of the SSI–ICM and SSW tests were compared between the two groups.

A written consent was obtained from all the individuals who participated in the study and they were informed about all the steps that would be carried out and any possible side effects that may occur. The research was approved by the ethical committee of the general organization of teaching hospitals and institutes.

Equipment

Clinical audiometer Interacoustics model AC40 (Assens, Denmark), Immittance meter Interacoustics model AZ 26 (Assens, Denmark), and compact discs were used for central auditory processing assessment.

Procedure

After obtaining written consent, all the participants in this research were subjected to a full assessment of medical history, otologic examination, and a basic audiological evaluation (pure-tone audiometry, speech audiometry, and immittancemetry). Central auditory processing assessment included SSI/ICM and SSW.

For central auditory processing assessment, two tests were used:

SSI–ICM: The SSI–ICM requires the listener to repeat 10 nonsense sentences that are presented with a competing message of continuous discourse presented to the same ear. A practice presentation of one to three lists was completed at 50 dB above the pure-tone average with a +10 dB signal-to-noise ratio. Only one list of 10 sentences was presented for participants scoring 90% or better in speech discrimination, and two lists if the score was 80% or better. As raw SSI–ICM scores decrease with age and hearing level affection (peripheral presbycusis), we used a presentation level 50 dB above the pure-tone average [21]. To obtain optimal performance from the participants, pauses between presentations were taken as required for slow responders (George *et al.*, 2008).

SSW test: In this test, stimuli were arranged in a manner such that spondaic words were presented in four conditions: right noncompeting (RNC), right competing (RC), left competing (LC), and left noncompeting (LNC). These four conditions were presented in alternation between two ears; the listener was required simply to report the words heard. The words were presented at 50 dB above threshold (SL) and we used the NOE analysis for scoring.

Statistical analysis of the results was carried out using the SPSS system (Statistical package for social sciences, version16; IBM Corporation, USA) SSI percentage and the SSW errors score in both the control and the study groups. A paired-sample *t*-test and an independent-sample test were used.

Results

In this research, the central auditory functions in elderly individuals with no hearing complaint were evaluated using two central auditory tests (SSI–ICM and SSW) and the results were compared with those of young adults. For SSI–ICM, the correct identification of 80% or more of 10–30 sentence presentations is considered a normal performance. Table 1 and Fig. 1 show the mean and SD of SSI in the right and left ears in both the control group (group 1) and the study group (group 2). It was found that the mean and SD were higher in the left ear in both groups. The paired-sample *t*-test showed that there was no significant difference in SSI–ICM between the right and the left ear in both groups. Table 1 also shows that there is a statistically significant difference between group 1 and group 2 in SSI in RT and LT ears, respectively, using an independent-sample test.

The mean and SD of RNC, RC, LC, and LNC error scores in the SSW test in group 1 and group 2 are shown in Table 2, Fig. 2, and Fig. 3, respectively.

Using the paired-sample *t*-test in the SSW test, we found that there was a significant difference in scoring in group 1 between competing and noncompeting conditions in SSW, with more affection in the competing condition. Also, there was a significant difference between competing and noncompeting conditions in group 2, with more affection in the competing condition, which is similar to group 1 Table 3.

The comparison between first and second spondee errors in the SSW test showed that there was no significant difference between the first and the second spondee with RT ear and LT ear tested first in both groups Table 4.

Our results showed that two individuals of group 1 showed reversal responses, whereas 12 individuals of group 2 showed reversal responses. Comparison of the RC and LC conditions in group 1 and group 2 using the paired-sample *t*-test showed a nonsignificant difference between RC and LC conditions in both the groups Table 5. Comparison of group 1 and group 2 in the SSW error score in the noncompeting condition in both ears using the independent-sample test showed a statistically nonsignificant difference between two groups in RT and LT ears. Comparison of group 1 and group 2 in the competing condition in both ears showed that there was a statistically significant difference between group 1 and group 2 in RT and LT ears, with a higher error score in group 2 Table 6.

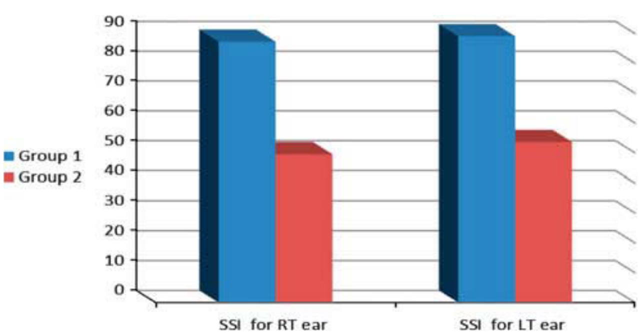
Discussion

In this research, the central auditory functions in elderly individuals with no hearing complaints were evaluated using two central auditory tests (SSI–ICM and SSW) and the results were compared with those of young adults.

For SSI–ICM, correct identification of 80% or more of 10–30 sentence presentations is considered a normal performance. The SSI tests are sensitive to cognitive decline and Alzheimer's disease (George *et al*., 2008). In this research, we found that there was no significant difference in (SSI–ICM) between the right and the left ear in both the groups. It was also found that the average correct answers percentage in group 2 was below the average results for group 1. Maura *et al*. [22] suggested that the highest NOEs in the elderly could be an indication of alterations in the central auditory pathway. This is in agreement with our results that showed a statistically significant difference between group 1 and group 2 in SSI in RT and LT ears, with a lower score in group 2. However, Clarke *et al.* (2008) studied SSI–ICM in elderly individuals; they found that no significant difference was present because of aging.

SSW results show many error patterns that can be identified in determining specific auditory deficits and associated communicative problems. Deficits in lexical decoding can be established by one of a number of significant findings on the SSW test including significant RC or LNC condition, Order low/high effect (significantly more errors on the second spondee), and ear high/low effect (significantly more errors when the test items begins with the RT ear) [16,23].

Figure 1



Mean of SSI scores in RT and LT ears in group 1 and group 2. SSI, synthetic sentence identification.

Table 1 Mean and standard deviation of SSI scores in RT ear and LT ear in group 1 and group 2 and comparison of SSI scores in the right and left ears in both groups

Groups	RT ear	LT ear	RT and LT ears	*P*
Group 1	87.272 ± 16.787	89.090 ± 15.782	− 1.818 ± 7.507	0.441
Group 2	49.545 ± 20.348	53.636 ± 19.159	− 4.090 ± 12.96	0.154
Groups 1 and 2 mean difference	37.727	35.454	−	<0.05*

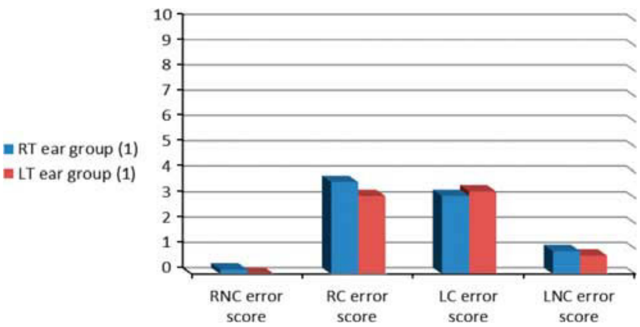
The paired-sample *t*-test showed a nonsignificant difference between the SSI score in the right and the left ears in both the groups. The independent-sample test showed a statistically significant difference between group 1 and group 2 in SSI in the right and left ears.
SSI, synthetic sentence identification.
*$P < 0.05$ significant.

Table 2 Mean and SD of RNC, RC, and LC and LNC error scores in the SSW test in group 1 and group 2

First tested ear	RNC error score	RC error score	LC error score	LNC error score
RT ear group 1	0.181 ± 0.403	3.636 ± 2.157	3.090 ± 2.879	0.909 ± 1.375
LT ear group 1	0.00 ± 0.00	3.090 ± 2.427	3.272 ± 2.258	0.727 ± 1.009
RT ear group 2	1.636 ± 3.786	8.363 ± 4.726	7.272 ± 3.466	2.272 ± 2.250
LT ear group 2	2.545 ± 1.969	7.272 ± 3.930	7.636 ± 4.259	1.454 ± 1.870

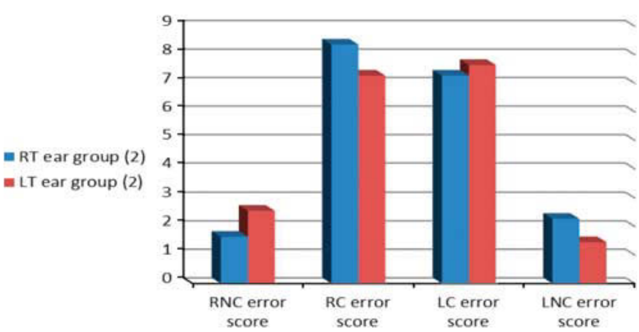
LC, left competing; LNC, left noncompeting; RC, right competing; RNC, right noncompeting; SSW, staggered spondee words.

Figure 2



Mean of RNC, RC, and LC and LNC error scores in the SSW test in group 1. LC, left competing; LNC, left noncompeting; RC, right competing; RNC, right noncompeting; SSW, staggered spondee words.

Figure 3



Mean of RNC, RC, and LC and LNC error scores in the SSW test in group 2. LC, left competing; LNC, left noncompeting; RC, right competing; RNC, right noncompeting; SSW, staggered spondee words.

Table 3 Comparison of competing and noncompeting errors in SSW in group 1 and group 2

First tested ear	Mean	SD	*P*
RT (group 1)	2.45455	2.53973	< 0.05*
LT (group 1)	2.81818	2.73664	< 0.05*
RT (group2)	5.863	3.819	< 0.05*
LT (group2)	5.454	4.212	< 0.05*

The paired-sample *t*-test showed a statistically significant difference between competing and noncompeting conditions in both the groups in conditions with RT ear and LT ear tested first.
SSW, staggered spondee words.
*$P<0.05$ significant.

There are a NOS patterns on the SSW test that indicate tolerance fading memory (which is an inability to retain/recall earlier presented information successfully), significant LC, and to a lesser extent RNC, order high/low effect (significantly more errors on the first spondee), and ear low/high effect (significantly more errors on items beginning in left ear). One must first compare the NOSs in both RC and LC conditions with the age norms. If there is no decrease in the scores between both ears, there may not be any greater inefficiency in transferring information between the hemispheres. The interpretation of the finding in this case is that of a lexical decoding deficit [24].

Table 4 Comparison between first and second spondee errors in SSW in group 1 and group 2

First tested ear	Mean	SD	*P*
RT (group 1)	−0.1818	3.400	0.863
LT (group 1)	0.7272	2.866	0.420
RT (group 2)	0.227	4.186	0.855
LT (group 2)	−0.363	3.998	0.732

The paired-sample *t*-test shows a nonsignificant difference between the first and the second spondee errors in both groups in conditions with RT ear and LT ear tested first.
SSW, staggered spondee words.

Table 5 Comparison of RC and LC conditions in group 1 and group 2

Groups	Mean	SD	*P*
Group 1	0.909	5.293	0.331
Group 2	1.090	6.038	0.406

The paired-sample *t*-test shows a nonsignificant difference between RC and LC conditions in both groups.
LC, left competing; RC, right competing.

These findings are in agreement with our results that showed that there was no significant difference between RC and LC conditions in both the groups. However, if there is a significant decrease in the scores between both ears, these findings may indicate both a lexical decoding and an integration deficit [16,23].

One of the ‘response biases’ on the SSW test is known as ‘reversal’. When the patient repeats at least three of the four words of an SSW item but does so in the wrong order, it is a reversal. In this study, two individuals in group 1 showed reversal responses, whereas 12 individuals in group 2 showed reversal responses. This was explained by Medwetsky [24], who found that a significant number of reversal (normed by age) indicates difficulty in sequencing/organization.

Our results of the SSW test showed that in both groups, there was a significant difference between competing and noncompeting conditions, with more affection in the competing condition. For spondee words, there was no significant difference between the first and the second spondee in both groups.

Table 6 Comparison of group 1 and group 2 in the SSW error scores in both noncompeting and competing conditions in both ears

	SSW RT ear		SSW LT ear	
Groups	Mean difference	*P*	Mean difference	*P*
Groups 1 and 2 in the noncompeting condition	−1.454	0.218	−1.363	0.076
Groups 1 and 2 in the competing condition	−4.727	0.004	−4.181	0.002*

The independent-sample test shows a statistically nonsignificant difference between group 1 and group 2 in SSW in the noncompeting condition in RT and LT ears.
The independent-sample test shows a statistically significant difference between group 1 and group 2 in SSW in the competing condition in RT and LT ears.
SSW, staggered spondee words.
*$P<0.05$ significant.

In this study, we found that there was no statistically significant difference between group 1 and group 2 in SSW in the noncompeting condition in RT and LT ears. This is in agreement with the results of Maura *et al.* [22], who found that in the SSW noncompetitive test, in which one hears a word alone, without any type of sound competition, the performance of the participants in the elderly group was close to that of young adults. Our study also showed that there was a statistically significant difference between group 1 and group 2 in SSW in the competing conditions in RT and LT ears, with more errors score in group 2.

Jeffrey and James (2005) found that the interaural asymmetry characterizing performance on linguistically based dichotic listening tasks increases with age. The effect is accounted for partly by a decline in cognitive abilities and partly by a decline in the efficiency of the interhemispheric transfer of information. Aging appears to affect hemispheric asymmetry in linguistic processing. Asymmetry favoring the left hemisphere leads to attenuated, or even reversed, asymmetry in elderly individuals.

The interaural differences increase with age and can be justified by the structural and cognitive models. The two models try to explain the right ear advantage and consequent left ear disadvantage in the dichotic tests. This asymmetry occurs, partially, because of a decline in cognitive skills and partially because of a decrease in the efficiency of transferring information from one brain hemisphere to the other [25].

Aging causes worsening in the performance of the elderly in the speech with noise and alternate disyllable dichotic test as in the SSW test, irrespective of a hearing complaint. The left ear has a worse performance when compared with the right one in dichotic tests, which may be associated with central auditory pathway deficit and deterioration in cognitive functions associated with aging (Alina and Maria, 2011). These findings were not in agreement with our results, which showed no significant difference between both ears.

Conclusion

(1) There was a statistically significant difference between the control group and the elderly group in SSI in RT and LT ears, with a lower score in the elderly group.
(2) There was a statistically significant difference between competing and noncompeting conditions, with more affection in the competing condition in the SSW test in both the control and the elderly groups.
(3) For spondee words, there was no significant difference between the first and the second spondee in both the groups.
(4) A statistically significant difference was found between the control group and the elderly group in SSW in competing conditions in RT and LT ears, with higher error scores in the elderly group.

Recommendations

Central auditory evaluation tests should be included in the audiological protocol for the elderly, as central auditory affection affects their quality of hearing as it affects understanding of speech.

Central auditory function tests should be carried out for assessment of the elderly as it helps in detection of impaired central auditory functions and improve the quality of therapeutic-rehabilitative interventions by selection of the suitable amplification methods needed with good rehabilitation measures.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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