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The influence of cognition on the auditory skills of the elderly: pre- and post-hearing aid fittings

Influência da cognição em habilidades auditivas de idosos pré e pós-adaptação de próteses auditivas

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ABSTRACT

Purpose: To determine if auditory skills test results correlated with cognitive performance and evaluate their influence on hearing aid fittings in the elderly population. **Methods:** This study was carried out with 12 hearing-impaired individuals over 60 years of age. They were cognitively assessed with the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) battery assessment. The instruments used to evaluate resolution and temporal ordering, as well as separation and binaural integration, were the Random Gap Detection Test, Duration Pattern Sequence and Pitch Pattern Sequence, and Dichotic Digits Tests. Their auditory abilities were evaluated before and three months after the hearing aid fittings. The data were statistically correlated to the data obtained from the cognitive assessments. **Results:** Ordering and temporal resolution were related to some cognitive assessments. The difference in some auditory abilities performance of temporal ordering and temporal resolution after the acclimatization period was inversely related to some cognitive assessments. **Conclusion:** In the elderly the better the performance on the auditory temporal skills, the better the cognitive test results. However, when analyzing the difference in performance between the auditory abilities before and after the hearing aid fittings, the patients with the worst cognitive performance showed the most improvement. This demonstrates that there is a possibility of neural plasticity stimulation, even in those with cognitive impairment.

Keywords: Hearing aids; Cognition; Aged; Presbycusis; Auditory perceptual disorders

RESUMO

Objetivo: Verificar a relação dos resultados de testes que avaliam habilidades auditivas com o desempenho cognitivo, além de verificar a sua influência na adaptação de próteses auditivas em população idosa. **Métodos:** Doze idosos com perda auditiva bilateral simétrica de grau leve a moderado foram avaliados cognitivamente, por meio da bateria *Consortium to Establish a Registry for Alzheimer's Disease* (CERAD) e quanto às habilidades auditivas de resolução e ordenação temporal, além de separação e integração binaural, por meio dos testes *Random Gap Detection Test*, Testes Padrão de Duração e de Frequência e Teste Dicótico de Dígitos, antes da adaptação de próteses auditivas. Após três meses, as habilidades auditivas foram novamente avaliadas e então relacionou-se estes desempenhos àqueles obtidos nas avaliações cognitivas. **Resultados:** As habilidades auditivas de ordenação e resolução temporal tiveram relação com algumas avaliações cognitivas. A diferença de desempenho nas habilidades auditivas de ordenação e resolução temporal, além de integração binaural, após aclimatização, teve relação inversa com algumas avaliações cognitivas. **Conclusão:** Idosos apresentaram melhor desempenho nas habilidades de ordenação e resolução temporal auditiva, quanto melhor seu desempenho em alguns testes cognitivos. Já quando analisada a diferença de desempenho nas habilidades auditivas antes e três meses depois da adaptação de próteses auditivas, aqueles com pior desempenho cognitivo foram os que evidenciaram melhora acentuada, demonstrando que, mesmo com prejuízo cognitivo, apresentam possibilidade de estimulação da plasticidade neural.

Descritores: Auxiliares de audição; Cognição; Idoso; Presbiacusia; Transtornos da percepção auditiva

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INTRODUCTION

Presbycusis is the gradual and progressive hearing loss that develops with age. It is characterized by decreased hearing sensitivity, especially at high frequencies, and a reduced capacity to understand speech in noisy environments, detect the location of sounds, and perform central processing of auditory stimuli[1]. Furthermore, presbycusis is strongly associated with cognitive decline in the elderly[2].

Sensory function and cognition have been consistently associated in the elderly. The authors state that people with sensory impairment allocate more resources related to attention towards processing sensory information and, thereby, provide less cognitive reserve for other tasks[3].

As audiologists begin to recognize that cognitive factors can play an important role in hearing performance, researchers of language comprehension are beginning to recognize that you cannot despise hearing difficulties, which are so common in aging[4].

The use of hearing aids may possibly mitigate the effects of hearing loss and improve the quality of life of older people[5]. A likely explanation for the significant associations between cognition and success of fitting in new hearing aids users, is that better cognitive skills provides an advantage towards relearning how to associate sound to meaning[6], easily involving areas of the brain to adjust to the complex process of hearing aids fitting[7]. However, some researchers state that patients with cognitive deficit and hearing loss benefit from the use of hearing aids and point out that this improvement is not related to the cognitive development of these patients, but to the improvement of auditory function[8].

Since being fitted with hearing aids allows the individual to listen to the sounds around them, it is reasonable to think that cognitive resources, which were being used to make up for the deficit in auditory input, can be reallocated towards carrying out other activities; thus, this facilitates neural plasticity by sensory input sounds.

The evaluation of the temporal function in the elderly is very important because of their characteristic sluggishness, which may result in slow processing of information. Similarly, the integration and binaural separation processes reflect the skills of older people using the information gathered through both ears or separating them into an auditory figure ground, which are the fundamental aspects of communication.

The aim of this study was to assess cognitive status and different hearing abilities of the elderly in order to verify the relationship between the results of an assess auditory skills tests with cognitive performance and to determine their influence on the performance change in hearing abilities, after the hearing aids fitting.

METHODS

Ethical aspects

This study was approved by the Ethics Committee of the *Universidade Federal de Santa Maria*, with certificate No. 05765712.3.0000.5346.

The selected individuals participated in our research after signing the Free Statement of Consent, which guaranteed the confidentiality of their identities and gave them the choice of continuing or discontinuing participation in the research without any constraints or interruption of treatment they were receiving.

Study outline and participants

This study had a quantitative, interventional, longitudinal, descriptive design.

Seniors who were being treated at a federal institution of higher education and were awaiting hearing aid fittings through a program that was a part of the National Policy of Hearing Health of the Ministry of Health of Brazil, were invited to participate.

The following selection criteria were used: 60 years of age or older (classified as elderly in developing countries); being literate; presenting with an audiological diagnosis of mild to moderate bilateral symmetrical sensorineural hearing loss[9]; presenting with, at most, a speech recognition threshold of 65 decibels in hearing level (dBHL) in the better ear; being waiting for the hearing aids fitting and having no prior experience with the use of sound amplification; participating in all stages of the research.

Seventy-four subjects were selected and 26 agreed to participate. Among these, 18 fulfilled all the criteria and were evaluated. Individuals who, for some reason, did not agree to participant in the study, did not fulfill the selection criteria, or had conditions, such as visual or motor abnormalities, that would have interfered with the evaluations were excluded from the study. However, they were oriented to the results of their initial assessment and were assisted according to their needs within the service.

Procedures

The subjects underwent an initial and final evaluation. The initial evaluation was made before the hearing aid fittings and consisted of different sessions, one week apart. The evaluations consisted of tests performed in the Hearing Aid Laboratory of Speech and Language Therapy Service of the institution.

In the first session of the initial evaluation, the participants underwent testing (Mini Mental State Examination; Clock Drawing; Verbal Fluency for animal names; Boston

Naming Test; Word List, Immediate Recall, Delayed Recall and Recognition; Constructive Ability; and Evocation of Constructive Praxis) included in the Brazilian adaptation[10] of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD)[11], a neuropsychological battery assessment. In another session, the participants underwent the Random Gap Detection Test (RGDT)[12], Dichotic Digit Test (DD)[13], Duration Pattern Sequence Test (DPS)[14], and Pitch Pattern Sequence Test (PPS)[14].

After the initial evaluation, hearing aids were chosen and fitted in the participants, who were properly instructed on the use, care, and handling. They were fitted bilaterally with hearing aids of the same technology and used them for a period of three months, which took into consideration the acclimatization period[15], until further evaluation. The daily use of hearing aids was considered effective when used for eight hours or more. This period of time was controlled by a tool called "data logging", which presents the information in the software.

Approximately 15 days after the fitting, the participants returned to the institution for an appointment when the conditions of hearing aid use were verified, doubts were clarified, and hearing aids were tuned, if necessary.

The final evaluation took place after the acclimatization period, three months after the hearing aid fittings[15]. The tests that assessed auditory skills (RGDT, DD, DPS and PPS) were administered again under the same test conditions, with the 12 patients who attended all the appointments. The main reason for discontinuing the study was either due to the patients' satisfaction with the hearing aid use, because they lived in distant cities, or they required an escort, which made it difficult to attend multiple appointments and re-evaluations.

Both in the initial and final assessments, the measurements were obtained without the use of hearing aids, in a sound treated room, using a digital two-channel audiometer (FA-12 model, Type I; Fonix®), supra-aural headphones (TDH-39 P; Telephonics®). The stimuli were played from compact discs (CDs) that were inserted into a digital CD player (4149 model; Toshiba®) coupled to the audiometer.

The evaluations are briefly described below:

Consortium to Establish a Registry for Alzheimer's Disease (CERAD)

The CERAD[10,11] neuropsychological battery assessment involves the evaluation of multiple cognitive functions and detects dementia in the elderly[16] and showed a high level of agreement among examiners[11] when evaluated. It consists of several subtests. In this study, for evaluation of cognitive functions, the following were used: Mini Mental State Examination; Clock Drawing; Verbal Fluency for animal names; Boston Naming Test; List of Words (Immediate Recall, Delayed Recall and Recognition); Constructive Ability; and Evocation of Constructive Praxis.

Random Gap Detection Test (RGDT)

The RGDT[12] is a test that evaluates the auditory ability of temporal resolution and involves the binaural presentation of a gap inserted into a pure tone at 500, 1000, 2000, and 4000 Hz. The objective of the evaluation is to determine the shortest time interval, in milliseconds (ms), that can be detected by the subject. This is accomplished through the perception of a series of pairs of stimuli. The interval between each pair of pure tones differs by 0 ms, 2 ms, 5 ms, 10 ms, 15 ms, 20 ms, 25 ms, 30 ms, and 40 ms in each frequency.

In our study, the subjects were instructed to signify if they were listening to one or two tones with gestures. The determination of the threshold was calculated as the arithmetic average of the gap detection thresholds obtained for each frequency[17]. In patients who were unable to identify the intervals, the expanded version was applied, with intervals of 50 ms, 60 ms, 70 ms, 80 ms, 90 ms, 100 ms, 150 ms, 200 ms, 250 ms, and 300 ms. The RGDT was administered via supra-aural headphones with simultaneous bilateral presentation at a 30 dB sensation level (NS) or the maximum level of comfort for the participant[18].

Dichotic Digit Test (DD)

The DD[13] consists of lists of two-syllable words (numbers "four", "five", "seven", "eight", "nine"), presented simultaneously, in a dichotic manner. In the step that evaluates binaural integration, patients pay attention to and repeat all the words they hear. In the step that evaluates binaural separation, or directed hearing, patients repeat what they hear on one side and then on the other side, while ignoring what was said to them in the contralateral ear.

This assessment was carried out with by supra-aural headphones and the stimuli were presented at 30 dB NS or at the level of maximum comfort for the participant[18]. The hits were quantified in each ear in both steps.

Duration Pattern Sequence Test (DPS)

The DPS[14] is presented in a monaural manner, with sequences of three tones of 1000 Hz, that differentiate into two lengths (500 ms = long [L] and 250 ms = Short [S]).

The DPS was presented at 30 dB NS or at a level of maximum comfort for the participant[18], via supra-aural headphones, with 15 sequences in each ear. Patients answered in nominal form (e.g. short, long, long). The sequences could vary (e.g., LLS, LSL, LSS, SSL, SLS, or SLL). This test evaluates the recognition, temporal ordering, and naming of pattern duration.

Pith Pattern Sequence Test (PPS)

The PPS[14] evaluates the recognition, temporal ordering, and naming of pitch patterns. It is presented in a monaural manner and consists of sequences of three tones of 500 ms, which differentiate into two frequencies: 1430 Hz (High [H]) and 880 Hz (Low [L]).

This was presented at 30 dB NS or at the level of maximum comfort for the participant[18] via supra-aural headphones, with 15 sequences in each ear. The patients answered in nominal form (e.g. high, low, low). The sequence could vary (e.g., LLH, LHL, LHH, HHL, HLH and HLL).

Survey and statistical analysis of the data

After the final evaluations, the data were compared and correlated statistically, using the Spearman's Correlation coefficient. An analysis was done to determine if there was an association between data from CERAD and the results of the initial assessments of auditory abilities of the subjects, as well as the difference in results between the two phases of evaluation. A level of significance of 5% ($p \leq 0.05$) was established.

RESULTS

Twelve people with an average age of 68.3 ± 6.1 years of age participated in the survey. All of them were diagnosed with symmetrical peripheral hearing loss and were being evaluated for hearing aid fitting.

The average performances of the subjects in each component of CERAD are shown in Table 1. The results from the central auditory processing tests are shown in Table 2.

The significant results from the CERAD battery assessment and the correlation with results from each hearing ability test of the group, from the initial phase of the study, are shown in Table 3.

The strong negative correlation of RGDT scores with the two other tests indicated that the lower (lower = better) the RGDT scores, the higher the test scores. The strong positive correlation with DPS and PPS, in both ears, has shown that the higher (higher = better) score on these tests, also higher (higher = better) score on the cognitive test.

Because the RGDT, DD, DPS, and PPS tests were applied before and after the fitting, their initial scores were compared with the final scores. The CERAD battery tests that had significance and correlation, precisely with this performance difference between the two evaluations of each test applied to analyze auditory skills, are presented in Table 4.

Table 1. Average scores obtained on neuropsychological evaluations in elderly with hearing loss (n=12)

Test – Neuropsychological Battery	Average performance
Mini Mental State Examination	25.6
Clock Drawing	8.7
Verbal Fluency: Animals	15.5
Boston Nomination Test	12
List of Words (Instant Recall)	14
List of Words (Delayed Recall)	4
List of Words (Recognition)	8
Constructive Ability	10
Evocation of Constructive Praxis	6

DISCUSSION

The results obtained on different tests (RGDT, DPS - right ear [RE] and left ear [LE], PPS - RE and LE) that assesses temporal aspects of auditory processing (ordering and resolution) correlated with at least one of the cognitive and memory assessments from the initial assessment. These correlations indicate that subjects with better cognition performed better on these tests than the ones with poorer cognitive performance.

Authors state that cognitive and auditory temporal processing deficits occur commonly in the elderly[19]. The correlation between the results from the auditory skills tests with cognitive assessments was highlighted by researchers who found poorer performance in tests that evaluated the auditory processing in

Table 2. Average results of auditory skills tests, obtained pre- and post-hearing aids fitting in elderly individuals with hearing loss (n=12)

Test - Auditory skills	Average performance – Pre fitting evaluation	Average performance – Post fitting evaluation
RGDT(ms)	21.3	14.5
DD – Bin. Int. RE(%)	64.2	72.7
DD – Bin. Int. LE(%)	66	76
DD – Dir. Hea. RE (%)	79	81
DD – Dir. Hea. LE (%)	88	86
DPS – RE (%)	74.5	78.3
DPS – LE (%)	75.5	76.7
PPS – RE (%)	85.5	92.8
PPS – LE (%)	90.5	92.8

Subtitle: RGDT = Random Gap Detection Test; ms = milliseconds; DD – Bin. Int. = Dichotic Digits Test - binaural integration stage; RE = Right Ear; LE = Left Ear; DD – Dir. Hea. = Dichotic Digits Test – Directed Hearing Stage; DPS = Duration Pattern Sequence Test; PPS = Pitch Pattern Sequence Test

Table 3. Values of significance and correlation between results of auditory skills tests and neuropsychological evaluations obtained in the pre-hearing aids fitting phase in elderly individuals with hearing loss (n=12)

Initial evaluation		
Test – Auditory Skill	Test - Neuropsychological Battery	Correlation
RGDT	Clock Drawing (p=0.002*) and Word Recognition (memory; p=0.025*)	Strongly negative with both (rS=-0.797 and rS=-0.641)
DD – Bin. Int. RE	No significance to any tests	-
DD – Bin. Int. LE	No significance to any tests	-
DD – Dir. Hea. RE	No significance to any tests	-
DD – Dir. Hea. LE	No significance to any tests	-
DPS – RE	Clock Drawing (p=0.012*)	Strongly positive (rS=0.697)
DPS – LE	Clock Drawing (p=0.009*)	Strongly positive (rS=0.712)
PPS – RE	Mini Mental (p=0.025*)	Strongly positive (rS=0.640)
PPS – LE	Mini Mental (p=0.018*)	Strongly positive (rS=0.665)

* Significant values (p≤0.05) – Spearman's Correlation Coefficient Test (rS)

Subtitle: RGDT = Random Gap Detection Test; DD – Bin. Int. = Dichotic Digits Test – binaural integration phase; RE = Right Ear; LE = Left Ear; DD – Dir. Hea. = Dichotic Digits Test – directed hearing phase; DPS = Duration Pattern Sequence Test; PPS = Pitch Pattern Sequence Test

Table 4. Values of significance and correlation between results of neuropsychological evaluations and the performance difference between initial and final evaluation tests that assess auditory skills in older adults with hearing loss (n=12)

Difference between Initial and final evaluation X cognition		
Test – Auditory skills	Test – Neuropsychological Battery	Correlation
RGDT	Recognition of words (memory) (p=0.042*)	Strongly positive (rS=0.593)
DD – Bin. Int. RE	Clock Drawing (p=0.021*), Recognition of words (memory) (p=0.04*) and Constructive ability (p=0.014*)	Strongly negative with the three of them (rS=0.654; rS=0.598; rS=683)
DD – Bin. Int. LE	No significance to any test	-
DD – Dir. Hea. RE	No significance to any test	-
DD – Dir. Hea. LE	No significance to any test	-
DPS – RE	No significance to any test	-
DPS – LE	No significance to any test	-
PPS – RE	Clock Drawing (p=0.013*) and Word Recognition (memory) (p=0.025*)	Strongly negative with both of them (rS=0.689; rS=0.641)
PPS – LE	Clock Drawing (p=0.017*), Delayed Recall (p=0.036*) and Word Recognition (memory) (p=0.013*)	Strongly negative with the three of them (rS=0.670; rS=0.609; rS=0.691)

* Significant values (p≤0.05) – Spearman's Correlation Coefficient Test (rS)

Subtitle: RGDT = Random Gap Detection Test; DD – Bin. Int. = Dichotic Digits Test – binaural integration phase; RE = Right Ear; LE = Left Ear; DD – Dir.Hear = Dichotic Digits Test – directed hearing phase; DPS = Duration Pattern Sequence Test; PPS = Pitch Pattern Sequence Test

individuals with cognitive deficit, when compared to subjects of the control group[20].

Another study has shown that older adults with greater cognitive impairment had a poorer performance on auditory skills tests compared to those with better cognitive reserve[21].

As for the initial results of the Dichotic Digit test, this study presented no correlation with any assessments from the CERAD battery assessments. However, another study has shown an association of the results on Dichotic Digit test with cognitive tests. They show that the better the cognitive performance, the better the results on auditory processing tests of the subjects[22].

Several studies mention the relationship between cognition and presbycusis[23,24,25], including, authors ponder that if hearing loss actually has such a remarkable influence on cognitive decline and recommend that the hearing aids for the elderly should be strongly encouraged and fitted as soon as possible[26].

The difference in performance between the initial and final assessments indicated that older people with poorer performance on cognitive and memory tests were the ones who had greater improvement in their auditory abilities with hearing aids. This is probably because those with better cognition had already shown satisfactory results in the first assessment and therefore did not have a large increase. This represents the ceiling performance effect.

In a study in which mathematical skills of elderly people were evaluated, the authors observed that community elders obtained very high hit percentage at the beginning of the test. Therefore, it was judged that it was not possible to assess major changes in performance throughout the sessions as in the institutionalized elderly. According to the authors, a ceiling effect was observed, in the case of community elders, with a stable performance trend[27].

In this study, among those who achieved maximum performance or close to the maximum, in the first evaluation, the differences that could occur in the final evaluation skills were obscured. These individuals exhibited the ceiling effect for certain tests and for this reason, it was not possible to assess changes. It is believed that the applied tests were easy for a portion of the participants who showed good cognitive outcomes, which justifies the obtained ceiling effect.

On the other hand, in those with poorer cognitive performance, the change was more evident, since they showed a great improvement in their hearing ability. This is an important finding because it demonstrates that cognitive plasticity occurs in normal elderly subjects[28] and older adults with worse cognitive status are likely to experience neuronal changes. This leads to the understanding of results from studies that state that even individuals with mild cognitive impairment still have enough neuroplasticity for neuronal changes[29,30].

The finding supports a similar conclusion punctuated by other researchers. Patients with cognitive deficit and hearing loss benefit from the use of hearing aids and the improvement is related to the increase of auditory function[8].

In the present study, the need for multiple re-evaluations and the fact that the evaluated elderly are part of a specific public health service were some of the limitations. This resulted in a reduced number of participants. Some other relationships could possibly be identified with a larger number of subjects.

It is noteworthy that the elderly evaluated in this study made use of hearing aids and were monitored by the audiologist responsible for the fitting; however, they did not undergo auditory rehabilitation therapy. It is believed that subjects who underwent auditory training programs would display more obvious benefits in the final evaluations when compared to the initial ones.

Similar studies in other elderly populations are needed to further elucidate the relation between the performance in auditory skills and cognitive aspects. In addition to the results found in this study, future research will help clinical professionals and the scientific community understand these relationships and better address these aspects with elderly patients and their families.

CONCLUSION

The elderly participants in our study, even without the use of hearing aids, performed better in temporal ordering and temporal resolution skills, the better was their performance on some cognitive tests. There was no correlation between cognitive tests and integration and binaural separation skills.

However, when analyzing the difference between performance on hearing ability tests carried out before and three months after the hearing aid fittings, the elderly with worse cognitive performance showed a greater improvement in some auditory skills with the use of hearing aids. This shows that even older adults with cognitive impairment may have stimulated neural plasticity and improve their performance in important hearing abilities.

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