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# Auditory perception in the elderly with Alzheimer's disease: a systematic review

Percepção auditiva em idosos com doença de Alzheimer: uma revisão sistemática

La percepción auditiva en adultos mayores con la enfermedad de Alzheimer: una revisión sistemática

*Aline Menezes Guedes Dias de Araújo\**

*Daviany Oliveira Lima\**

*Marine Raquel Diniz da Rosa\**

*Islan Penha Nascimento\**

*Ana Karina Lima Buriti\**

## **Abstract**

**Introduction:** Population aging is a global phenomenon having dementia as one of its main consequences. The manifestations of Alzheimer's disease may cause changes in central auditory processing. **Objective:** This article aimed at assessing the scientific evidence of auditory perception and Alzheimer's disease in the elderly through fundamental aspects of a systematic review. **Methods:** The articles were researched in three databases: SciELO, LILACS, and MEDLINE. The main bibliographic search descriptors were: Alzheimer's disease, auditory perception and hearing, and their combinations. The criteria for inclusion were: full texts in Portuguese and English, with target population (elderly), diagnosis of Alzheimer's disease and published from 2005 to 2016. Repeated articles and those that did not fit the object of study were excluded. Data were analyzed quantitatively and reported in percentage. **Results:** The final sample consisted of 14 articles and 21.42% of these related hearing and Alzheimer's disease signaling to the fact that a variety of hearing behavioral assessments tests may be used in this population. **Conclusion:** Considering the low percentage of central auditory processing research in individuals with Alzheimer's, it can be suggested the need for further studies and research on this population.

**Keywords:** Alzheimer Disease; Auditory Perception; Hearing; Elderly.

\*Universidade Federal da Paraíba – UFPB – João Pessoa – PB - Brazil

**Authors' contributions:** AMGDA and MRDR study design, formal analysis, and discussion. DOL, IPN and AKLB study design, data collection, article outline, methodology.

**Correspondence address:** Aline Menezes Guedes Dias de Araújo - alinemguedes@gmail.com

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## Resumo

**Introdução:** O envelhecimento da população é um fenômeno mundial e apresenta como uma das principais consequências a demência. As manifestações da Doença de Alzheimer podem acarretar alterações no processamento auditivo central. **Objetivo:** o presente artigo teve por objetivo verificar as evidências científicas entre percepção auditiva e Doença de Alzheimer em idosos por meio de aspectos fundamentais de uma revisão sistemática. **Método:** Os artigos foram pesquisados em três bases de dados: SciELO, LILACS, e MEDLINE, sendo utilizados como principais descritores de busca bibliográfica: Doença de Alzheimer, Percepção auditiva e Audição, e suas combinações. Foram incluídos textos na íntegra, com população-alvo (idosos), sobre diagnóstico de doença de Alzheimer, nos idiomas português e inglês e publicações entre 2005 e 2016. Foram excluídos os artigos repetidos e que não condiziam com o objeto do estudo. Os dados foram analisados quantitativamente e descritos em porcentagem. **Resultados:** A amostra final se constituiu de 14 artigos. Através dos resultados deste trabalho, verificou-se que 21,42% relacionavam audição e Doença de Alzheimer, apontando para a diversidade de avaliações auditivas comportamentais que podem ser utilizadas nessa população. **Conclusão:** Considerando um percentual baixo de investigação do processamento auditivo central em indivíduos com Alzheimer, contempla-se a necessidade de novos estudos e investigação nessa população.

**Palavras-chave:** Doença de Alzheimer; Percepção Auditiva; Audição; Idoso.

## Resumen

**Introducción:** El envejecimiento poblacional es un fenómeno mundial y presenta la demencia como una de las principales consecuencias. Las manifestaciones de la enfermedad de Alzheimer pueden provocar cambios en el procesamiento auditivo central. **Objetivo:** Este artículo tiene como objetivo evaluar la evidencia científica de la percepción auditiva y la enfermedad de Alzheimer en las personas mayores a través de los aspectos fundamentales de una revisión sistemática. **Métodos:** Los artículos fueron investigados en tres bases de datos: SciELO, LILACS y MEDLINE, siendo utilizados como los principales descriptores bibliográficos: enfermedad de Alzheimer, percepción auditiva y de audición, y sus combinaciones. Fueron incluidos textos en forma íntegra, con la población objetivo (personas mayores), con diagnóstico de la enfermedad de Alzheimer, en los idiomas portugués e inglés y publicados entre 2005-2016. Se excluyeron artículos repetidos y que no se relacionaban con el objeto de estudio. Los datos fueron analizados cuantitativamente y descritos en porcentaje. **Resultados:** La muestra final consistió de 14 artículos y se encontró que en 21,42% relacionaron la audición con la enfermedad de Alzheimer y se apunta la diversidad de pruebas auditivas comportamentales que pueden ser utilizadas en esta población. **Conclusión:** Teniendo en cuenta un porcentaje bajo de la investigación del procesamiento auditivo central en personas con enfermedad de Alzheimer, incluye la necesidad de realizar más estudios e investigaciones en esta población.

**Palabras clave:** Enfermedad de Alzheimer; Percepción Auditiva; Audición; Anciano.

## Introduction

Life expectancy has increased considerably in recent decades. There is a need to better understand the elderly and their various health care priorities<sup>1</sup>.

Along with aging, several cellular, morphological and functional changes occur<sup>2</sup>. One of the most common is the reduction of auditory acuity, also known as Presbycusis. It is defined as a bilateral hearing loss for high frequency sounds arising

from degenerative and physiological changes in the auditory system<sup>3</sup>.

In addition to hearing loss, it is common to observe a decline in speech understanding in elderly. Thus, not only the peripheral auditory system, but also the central structures of the brain stem and cortex are affected by aging<sup>4</sup>. At this stage, general neuronal loss, decreased blood flow and changes in cerebral metabolism may also occur<sup>5</sup>.

Neurons store, recall and modulate memory by transmitting electrical information from the

dendrites to the end of axons<sup>6</sup>. The loss of neurons can be anticipated by degenerative diseases, such as Alzheimer's disease (AD), which may cause problems circumscribed to the areas most affected by the disease.

AD is the most common form of dementia in elderly. Neuritic plaques and neurofibrillary tangles are the characteristics most often observed. Furthermore, changes occur in the brain due to the loss of neurons and dendrites. AD presents a type of loss of neurotransmitters that may be responsible for severe cognitive impairment<sup>7</sup>.

Essential information regarding the auditory perception of the patient may be collected by the implementation of behavioral hearing tests. The evaluation of Auditory Processing (AP) complements behavioral auditory information, which conventional audiometry does not provide<sup>8</sup>.

Auditory perception refers to the processing of an audible signal, which is initiated by recipient cells sensitive to a particular stimulus<sup>6</sup>. The processing of such stimuli consists of a number of neuroanatomical connections originated in the cochlear neurons and finalized in the brain auditory cortex, i.e., it involves both the peripheral auditory nervous system (PANS) and the central auditory nervous system (CANS)<sup>9</sup>.

Auditory perception disorder in elderly has been described by some authors<sup>1,10</sup>. A study shows the relation between auditory processing and cognitive impairment in individuals with AD with mild cognitive impairment<sup>11</sup>. Another study states that elderly with cognitive impairment present poor speech recognition in auditory processing behavioral tests (dichotic hearing)<sup>12</sup>. Central auditory tests may contribute to the differential diagnosis between AD and other age-related changes<sup>13</sup>.

Alzheimer's disease is the most diagnosed dementia in later life and is characterized by a gradual loss of memory and other cognitive functions: orientation, praxis, visual perception, executive functions, attention and language<sup>14</sup>. Such characteristics may influence hearing abilities in elderly. Thus, an investigation of auditory perception is necessary since the prevalence of the change in

central auditory processing increases significantly in elderly<sup>15</sup>.

Given such relation between auditory perception and Alzheimer's disease, the aim of this study is to assess the scientific evidence for auditory perception and AD in elderly individuals analyzing key aspects in a systematic review in order to contribute to the therapeutic intervention of possible cognitive changes interfering with communication influenced by changes in auditory skills.

## Methods

This study is a systematic review of literature on the relations between auditory perception and Alzheimer's disease.

The article search was conducted in the electronic databases SciELO, LILACS and MEDLINE using the following descriptors: "auditory perception" and "Alzheimer's disease", "hearing loss" and "Alzheimer's disease", "hearing" and "Alzheimer's disease", and their combinations, during August 2016.

The articles identified by the search strategy were evaluated independently and blindly by two researchers (authors), strictly observing inclusion criteria: text in full, target population (elderly), diagnosis of Alzheimer's disease, language (Portuguese and English) and publication year (2005-2016, in order to obtain the latest information on the subject). All types of study designs and population over 60 years diagnosed with Alzheimer's disease were included. Studies that did not meet the inclusion criteria above and repeated articles that did not address the object of study were excluded.

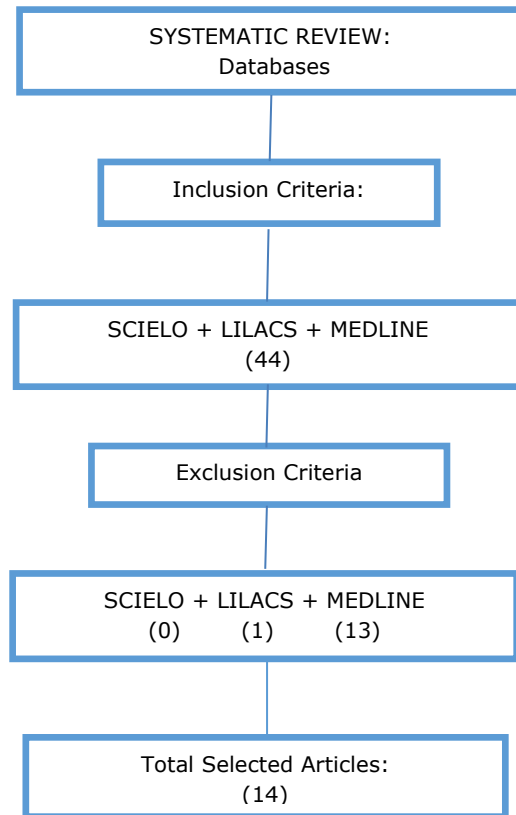
The variables analyzed were title, publication year, objectives, sample, age group, disease diagnosis time, instruments used to collect data and techniques used for evaluation/diagnosis. The data were analyzed regarding the effects of Alzheimer's disease and the characteristics of auditory perception in elderly, besides contributions to speech therapy.

The results were compiled using *Excel for Windows*, version 2007, and presented in percentage using figures and tables.

## Results

254 articles were included, of which 44 were selected. After the exclusion of repeated articles, review articles, not available articles and those with descriptors or subjects not consistent with the object of study, 14 articles were used in this study (Figure 1).

The selected studies were conducted in different countries: five in the USA<sup>16,17,18,19,14</sup>, two in the UK<sup>20,15</sup> and one study in each of the following countries: Mexico<sup>21</sup>, Sweden<sup>11</sup>, Taiwan<sup>22</sup>, England<sup>16</sup>, Japan<sup>23</sup>, Germany<sup>24</sup> and Netherlands<sup>12</sup>. Regarding publication year, articles published between 2005 and 2016 were included.



**Figure 1:** Flowchart of inclusion and exclusion criteria of the articles used in the systematic review.

By analyzing the objectives of the selected studies, the relation with the subject was observed in all (100%) articles. The following terms are highlighted: cognitive, repetition, auditory recognition, auditory naming test, auditory function, central auditory processing, processing of objects/auditory inputs.

The sample size of the selected articles ranged from thirteen<sup>18,22</sup> to forty-three<sup>11</sup> elderly with Alzheimer's disease, and only one article<sup>12</sup> did not describe the studied population.

With regard to the methods and procedures used in elderly patients with Alzheimer's disease, it was observed that the articles cited mostly audiometry<sup>11,25,20,24</sup> (35.7%), followed by logoaudiometry<sup>11</sup> and central auditory processing<sup>11,12</sup> (14.2%). Only one article (7.1%) cited imitancimetry screening and another article cited P300<sup>19</sup>. Noteworthy is language assessments such as the verbal fluency test<sup>24,17,18</sup> and the Boston naming test<sup>16,17,18</sup> (21.4%). Other procedures that analyze the presence of cognitive impairment were also cited, such as Mini-Mental State Examination<sup>20,24,16,17,18,22,26</sup> (50%), followed by CERAD Neuropsychological Battery<sup>18,20,21</sup> (21.42%), among others cited at least once in the articles evaluated, as described in Figure 3.

From the findings of this study, there is a variety of studies with elderly patients diagnosed with Alzheimer's disease. However, only three studies<sup>11,12,24</sup> (21.4%) related to auditory perception were found. They used the dichotic digits test, speech-in-noise test and cognitive P300 potential.

From the data of this study, it is evidenced that the vast majority of elderly were 56 to 87 years-old, an expected age for an Alzheimer's diagnosis associated with causes of decreased hearing acuity in elderly.

Author and publication year	Local	Descriptors	Objective	Sample (N)	Age group
Jacobson; et al,2005(26)	USA	Not informed	Investigate the sensitivity of a cognitive analysis in relation to an individual test-analysis at a pre-clinical stage during the detection of an early AD potential using tests that assess the cognition domain: attention.	25 AD 25 CG	Not informed
Olichney; et al,2010(14)	USA	Not informed	Define the neuroanatomical structures that mediate the congruent repeat effect in normal elderly and how they are affected by mild Alzheimer's disease.	15 AD 15 CG	AD -72.9 CG-68.7
Simmons-Stern; Budson; Ally,2010(18)	USA	AD, learning and memory, music, mnemonics, dementia, episodic memory.	Investigate the effects of music on the codification of subsequent recognition of associated verbal information.	13 AD 14 CG	Not informed
Brandt, Bakker, Maroof, 2010(16)	USA	Not informed	Develop a hearing naming task requiring the identification of the origin of sounds and recognition of multiple choices regarding unidentified people.	Study 1: 28 DA 74 CG Study 2: 20 AD 56 CG	Not informed
Aline; et al, 2010(21)	Mexico	MEG; Verbal Recognition; Word recognition; Normal aging; Healthy Aging; AD; MCI; Brain Mapping; Hypertension; White Matter hyperintensity	Analyze the individual variability within a group of elderly while they performed a late auditory recognition task.	30 AD	Average 74 years AD
Idrizbegovic et al, 2011(11)	Sweden	Hearing impairment related to age, PAC, dementia, hearing, subjective memory complaints, elderly	Investigate the auditory function in individuals with AD, MCI and SMC seeking dysfunction signs of central auditory processing even at early stages of cognitive impairment.	43 AD 59 MCI 34 SMC	Average 64 years
Goll et al, 2012(20)	London	AD; analysis of auditory scene; AP; voxel-based morphometry.	Perform a detailed neuropsychological and neuroanatomical characterization of the analysis of hearing scenes.	21 AD 18 CG	Average 65 years AD 65.7 CG.
Goll et al, 2011(19)	United Kingdom	Dementia, auditory perception, auditory object	Investigate different processing levels of non-verbal auditory objects and processing of impaired auditory objects.	21 AD 05 PNFA 07 LPA 01 PPA	Not informed
Cheng; et al, 2012(22)	Taiwan	M50, inhibition, AD, magnetoencefalography, negativity magnetic incompatibility	Characterize cortical deficits in the processing of auditory inputs in patients with AD	13 AD 12 CG 12 CG-Y	Average: 77.8 AD, 70.7 CG, 27.9 CG-Y.
Bouma; Gootjes, 2011(12)	Netherlands	Dichotic listening; AP; aging, AD, attention to laterality, corpus callosum MRI, MEG, Executive Function.	Use the Kimura's dichotic digits paradigm as a measurement of left hemispheric dominance for language processing stimuli.	Not informed	Not informed
Dodson et al, 2011(17)	USA	Not informed	Examine memory deficit and monitoring of patients with AD.	24 AD 24 CG	Average: AD 56-86 CG 62-90
Wu et al, 2012(23)	Japan and China.	AD; audiovisual integration; cognitive functional deficits; mild cognitive impairment; performance improvement	Test whether multisensory integration capabilities of patients with MCI and AD differed from normal-aged controls (NC).	24 NC 19 MCI 21 AD.	NC 59 and 81 years. MCI 56 and 87 years. AD 58 and 86 years.
Dhanjal et al, 2013(15)	United Kingdom	Not informed	Investigate the response of the human auditory cortex during sentence coding for episodic memory. Subsequently, this response was investigated in patients with mild cognitive impairment (MCI) and probable Alzheimer's disease (PAD).	18 MCI 18 PAD 18 CG	Not informed
Bender et al, 2014(24)	Germany	AEP, AD, working memory, source analysis, sensory gating, aging.	Investigate whether the automatic auditory post-processing is deficient in patients with Alzheimer's disease and related to sensory gating	19 AD 17 CG 17 CG-Y	Average: 75.2 AD 72.3 CG 25.9 CG-Y

**Caption:** AD: Alzheimer's disease; CG: control group; MCI: mild cognitive impairment; SMC: subjective memory complaints; CG-Y: control group - young; PAD: paired compared; AEP: Auditory evoked potential; AP(C): auditory processing (central); PNFA: progressive nonfluent aphasia; LPA: logopenic progressive aphasia; PPA: progressive aphasia

**Figure 2.** Description of the studies selected for the systematic review

Methods/Procedures	n	% <sup>(1)</sup>
<b>Hearing evaluations</b>		
Pure tone audiometry	4	28.57
Logoaudiometry	1	7.14
Central Auditory Processing	2	14.28
Tympanometry	1	7.14
P300 auditory cognitive evoked potential	1	7.14
<b>Language evaluations</b>		
Verbal Fluency Test	3	21.42
Boston Naming test	3	21.42
Classification tasks (discrimination of size and daily life) and delayed verbal recognition task.	1	7.14
Auditory and visual naming test	1	7.14
<b>Others</b>		
Mini-Mental State Examination	7	50.00
California Verbal Learning Test, WAIS-R Digit Span and WMS-R Visual, CERAD Neuropsychological Battery, Clinical Dementia Rating, etc.)	12	85.71
Base <sup>(1)</sup>	14	

**Caption:** Whereas a single article cites more than one procedure for evaluation of the elderly people surveyed, it the basis is considered for the calculation of percentages, and not the total

**Figure 3.** Methods and evaluation procedures in elderly with Alzheimer’s Disease found in the 14 selected research articles

Author and publication year	Auditory Processing Evaluation	Outcome of the procedure	Changed skill
Bouma; Gootjes, 2011(12)	Digit Dichotic Test	Difficulties in focusing attention on the left ear with an advancing age.	Not informed
Idrizbegovic et al., 2011(11)	Background Noise Test Digit Dichotic Test	Poor performance in patients with AD compared to those with subjective memory complaints both tested with two digits and three digits; the left hemisphere had the worst performance.	Not informed
Bender et al., 2013(24)	Auditory cognitive evoked potential - P300	Hearing delay in the emergence of the negative wave (400-500 ms). There were no differences between the groups (control and AD); delay was present on the previous auditory processing and the initial reaction to guide the auditory stimulation.	Encoding deficit for short-term memory.

**Figure 4.** Evaluation of the hearing/auditory perception process performed with elderly diagnosed with Alzheimer’s Disease found in the studies selected in the systematic review

**Discussion**

One of the degenerative effects of aging is the high prevalence of hearing losses because the auditory system is often affected. Such changes involve both the external, the middle and the inner ear and the central auditory nervous system (CANS)<sup>26</sup>. Thus, it is necessary to conduct studies aiming to describe methods and evaluation procedures for elderly regarding audiological aspects, language, among others.

When dealing with possible impairments of auditory perception and its diagnostic procedures, pure tone audiometry is being performed more frequently in clinical practice<sup>11,16,17,19</sup> in order to assess the effects of hearing loss on the performance of experimental and behavioral tasks performed by these individuals. The central auditory processing examination is not a test used in clinical routine. However, knowing that the hearing process is the basis for complex actions, such as understanding of the spoken language, and that its disorders nega-

tively affect the quality of life of many people, it is an important tool for monitoring degenerative diseases such as Alzheimer's disease<sup>11,12</sup>.

The lack of an auditory processing evaluation of Alzheimer's disease is probably due to the degree of the disease, since patients often come to clinics presenting more advanced stages of the disease, and this compromises the evaluation of auditory perception. Thus, patients should be early referred for Geriatrics and Neurologists. This could assist in monitoring and diagnosing.

In relation to language tests, there is a predominance of verbal fluency test and Boston naming test. These tests are important because they examine naming capacity<sup>20,27,25</sup>. A study<sup>23</sup> using the Boston naming test identified language disorders at a very early AD stage and observed statistically significant differences in auditory understanding and naming. Among the methods less used to evaluate auditory perception in these individuals, the Auditory evoked potential P300 test was the most used to investigate whether the automatic auditory post-processing was deficient in patients with Alzheimer's disease<sup>24</sup>.

Among the elderly, a difference is observed in both ears. There is asymmetry due to the progressive deterioration of the corpus callosum in function of aging, resulting in a decrease in inter-hemispheric transfer efficiency<sup>15</sup>. Thus, in elderly with Alzheimer's disease, the inter-hemispheric connectivity (calloused atrophy) and the intra-hemispheric connectivity (lesions in the subcortical white matter) are also affected. Thus, changes in the central auditory processing are very common in patients with AD, even at mild stages<sup>11</sup>, and often affect the processing of non-verbal auditory objects<sup>17</sup>.

Another study<sup>18</sup> also investigated the inappropriate inhibition of redundant hearing inputs in Alzheimer's disease through a characterization of cortical deficits in processing hearing inputs, noting that patients over 50 years may present deficits in auditory processing.

Considering the period established for this review, it was noted that the number of studies relating the investigation of auditory processing in individuals with Alzheimer's disease is still low. On the other hand, an interest in studies on the relation between aging and the central auditory processing has been growing in recent years because elderly often complain of difficulties in understanding

speech that do not match the degree of peripheral hearing loss they present.

## Conclusion

In view of the studies in this review, it is possible to conclude that there is a lack of studies that perform clinical trials relating auditory processing to AD. The percentage of studies that evaluated auditory perception in elderly with AD is considered low in relation to the diversity of studies evaluating the language of this population. Despite the importance of assessing auditory perception in elderly, studies that assess elderly patients with AD are still scarce, requiring further studies and longitudinal research on this population aiming to justify the relation of language changes with possible changes in central auditory processing.

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