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Cognitive Aspects of Adults and Older Adults with Hearing Loss, Users or not of Hearing Aids: A Meta-Analysis

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Research Strategies: A systematic search across seven databases and gray literature until May 10, 2022, sought studies of individuals aged >18 with hearing loss.

Selection Criteria: Both interventional and observational analytical studies were included, without language or publication date restrictions.

Data Analysis: Seven articles were included, revealing a correlation between cognitive aspects, hearing loss, and hearing aid use in adults and older adults. Comparisons were made between hearing aid users and non-users using validated cognitive questionnaires. Risk of bias assessment was assessed using the Joanna Briggs Institute Critical Assessment Checklist, followed by random effects meta-analysis. The GRADE tool determined certainty of evidence.

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Results: Hearing aid users exhibited improved Mini Mental State Examination (MMSE) performance (MD = -1.47; CI95% = -2.53 - -0.40; I2 = 7.21%), albeit with low certainty.

Conclusion: While MMSE results indicated possible cognitive benefits for adults and older adults using hearing aids, the evidence remains uncertain. Developing a comprehensive psychological assessment tool encompassing language, memory, attention, executive functions, and socialization is recommended to ensure accurate evaluations of this population's health.

Keywords: adults, older adults, hearing loss, hearing aids, cognition, cognitive decline.

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I. Introduction

As individuals age, their body undergoes several physical and biological changes that can impact their quality of life. Among these changes, hearing loss and cognitive decline are common. Regarding hearing, it should be noted that hearing impairment is the third most prevalent chronic condition in individuals aged 65 years or older, affecting approximately one-third of this demographic[1].

Sensorineural hearing loss can give rise to emotional, social, and auditory consequences, as well as impact cognitive domains, including as memory and executive functions. Some authors suggest that the decline in temporal lobe structures, which play a vital role in auditory processing, may be associated with these changes[1].

One way to mitigate these declines is through the effective use of hearing aids (HAs), which can enhance sound reception and, consequently, improve language comprehension[2]. Additionally, the use of

hearing aids can stimulate the reactivation of neurons, revitalizing or strengthening neural networks that might otherwise be compromised due to age-related declines [3; 4]. Moreover, the use of hearing aids can contribute to an overall improvement in quality of life[5;6].

When considering the cognitive aspects in patients with hearing loss who use cochlear implants, a comprehensive meta-analysis noted that the cognitive improvements after cochlear implantation depend on time and the cognitive task assessed [7].Regarding the cognitive functions of hearing aid users, there is a scarcity of systematic reviews addressing this topic. Therefore, this systematic review aims to evaluate the cognitive aspects of adults and older adults with hearing loss who are hearing aid users, in comparison to individuals with hearing loss who do not use hearing aids.

II. Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Checklist[8].

- Eligibility Criteria

The acronym PICOS was utilized to determine the eligibility of studies included and excluded in this review, based on the following criteria.

- Population (P)

Studies were included if the sample comprised patients aged 18 years or older (adults and older adults) with hearing loss. Studies that exclusively focused on individuals without hearing loss or populations not composed of adults (>18 years) were excluded. Studies in which hearing loss was associated with mental disorders or conditions such as Alzheimer's disease or dementia were also excluded. There were no exclusions based on the gender or ethnicity of the population.

- Intervention (I)

Studies were included if the intervention of interest was the use of hearing aids. Studies involving users who underwent cochlear implant procedures were excluded.

- Comparison (C)

Controlled studies that compared hearing aid users and non-users or pre- and post-use of hearing aids were included. Non-controlled studies or studies that evaluated the outcome of interest in only one of the groups were excluded.

- Outcomes (O)

Studies that assessed cognitive aspects using validated questionnaires were included. Studies that did not assess the desired outcome or used non-validated assessment tools were excluded.

- Study Design (S)

Randomized, pseudo-randomized, non-randomized clinical trials, cohorts, case-control, and cross-sectional studies were considered eligible for inclusion. Descriptive studies, reviews, case studies, letters to the editor, case series, expert opinions, and guidelines were excluded. There were no exclusions based on language or date of publication.

- Information Sources and Search Strategy

Appropriate truncations and combinations of words (descriptors and free terms) were performed and adapted to the following electronic databases: EMBASE, Latin American and Caribbean Health Sciences Literature (LILACS), LIVIVO, PubMed/Medline, PsycInfo, Scopus and Web of Science (Appendix 1). The search in the gray literature was also used as a source of information, being carried out in Google Scholar, ProQuest Dissertation & Theses and Open Grey. The searches were carried out on August 10, 2021, and updated on May 26, 2022. The references found were managed using EndNote® X7 software (Thomson Reuters, Philadelphia, PA), and duplicate references were excluded.

Further, a manual search of the references of the included articles, and consultation with a researcher with expertise on the subject, was carried out to check for any relevant articles not retrieved by the search strategy.

- Selection Process

The article selection process was conducted in two phases, with each phase performed independently by a pair of reviewers.

Prior to starting the study selection, a reviewer calibration was conducted to ensure consistency in article selection. For this, the Kappa Coefficient of Concordance was calculated based on a preliminary literature search for this purpose. The selection of studies started only after achieving a coefficient value of > 0.7, indicating satisfactory agreement. During the first phase, the titles and abstracts retrieved were independently reviewed by the reviewers. Articles that did not meet the eligibility criteria were excluded at this stage. In the subsequent second phase, the selected studies were read in their entirety, again independently. In cases where discrepancies arose between the two reviewers and were not resolved through discussion, a third reviewer was consulted for a final decision.

To ensure transparency, independence, and confidentiality throughout all stages, the Rayyan website (http://rayyan.qcri.org) was used to manage the article readings. A team member, who was not involved in the selection process, acted as a moderator, overseeing the reviewers' activities at each phase.

- Data Collection Process

The same reviewers independently collected all the information from the articles and, when necessary, discussed it with two other team members. The collection process consisted of analyzing the research structure of the studies, as well as their characteristics

(authors, country, and epidemiological design of the study), aspects of exposure or intervention related to hearing loss or hearing aids, results achieved, and main conclusions related to the outcome of interest.

- Data Items

The mean score, along with the respective standard deviation and sample size for each group, was extracted from the included articles for each validated questionnaire used.

- Study Risk of Bias Assessment

The methodological quality of the included observational studies was assessed using the Joanna Briggs Institute Critical Assessment Checklist [9]. This stage involved three reviewers who independently evaluated the articles. Each evaluation domain was categorized as "yes" or "no" based on the appropriate checklist for the specific study design. Studies were classified as having a "high" risk of bias if the percentage of "yes" obtained was between 0 - 50%, a "moderate" risk of bias if between 51 - 69%, and a "low" risk of bias if above 70%. Discrepancies, if any, were resolved through discussions involving a fourth reviewer. For randomized interventional studies, the Cochrane Collaboration's tool for assessing risk of bias in randomized trials (ROB) was used. This tool encompasses seven domains: randomized sequence generation; allocation concealment; participant and professional blinding; outcome assessor blinding; incomplete outcome data; selective reporting; and other outcomes. Data for this analysis were categorized based on information provided in the study. In cases where details where insufficient to make an accurate judgement, the domain was marked as "uncertain."

- Effect Measures

For group comparisons, the calculation of the difference between means (DM) was used, comparing the mean scores of the hearing aids user and non-user group.

- Synthesis Methods

A random effects meta-analysis, weighted by the inverse variance method, was conducted using the DerSimonian and Laird estimator for the calculation of variance (Tau^2). The Higgins inconsistency index (I^2) was used to quantify the heterogeneity in the analysis. The significance level adopted was 5% and corresponding 95% confidence intervals (95%CI) were computed. The analyses and the forest plot were performed using Stata version 16.0 software (Stata Corp LLC, College Station, USA).

- Reporting Bias Assessment

Due to the inability to assess reporting bias through funnel plot analysis ($n < 10$), a comprehensive search strategy was employed, including the inclusion of a non-English language database (LILACS), to mitigate the potential for this bias.

A subgroup analysis was also conducted to ascertain the effect size for each epidemiological design of the studies included with the meta-analysis.

- Certainty Assessment

The certainty of evidence was assessed using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) tool [10]. This tool assesses the certainty of the evidence generated at four different levels: very low, low, moderate, and high, considering five domains for assessing certainty: risk of bias, inconsistency of results, indirectness of evidence, imprecision, and publication bias.

III. Results

a) Study Selection

From the search strategy, 7187 articles were retrieved from the seven electronic databases after removing duplicate articles. In the first phase, involving the review of titles and abstracts, 37 articles were selected for full reading. Of this total, 30 were excluded (Appendix 2), leaving seven for analysis and qualitative synthesis (Figure 1).

No additional articles were included from the manual search or review of the gray literature.

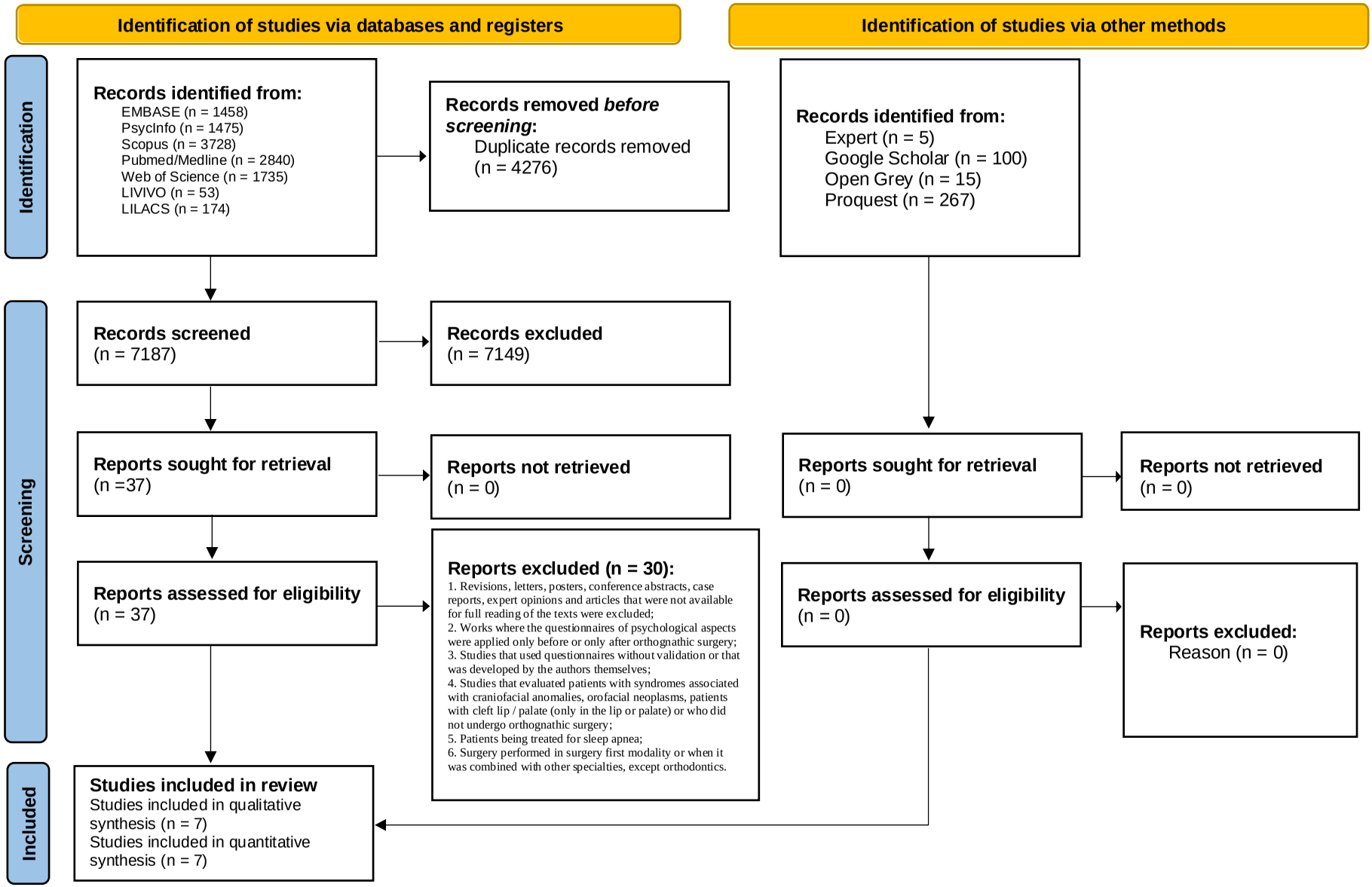

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Figure 1: PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources

b) Study Characteristics

Of the 7 articles included in the systematic review (Table1), all were published between 2011 and 2020. The selected studies encompassed various study designs, including cross-sectional observational, cohort and case-control design. One study was classified as a randomized interventional study.

The focus of these studies was on cognitive aspects and their association with hearing loss in adults and older adults. Table 1 provided a description of the study details, including authorship, publication year and country, study design, sample size, and mean age of participants, questionnaires used, results and conclusions. All the information presented was extracted from the included articles.

In the selected studies, the following psychological instruments were used for cognitive assessment of adults and older adults with hearing loss, users and non-users of hearing aids: Montreal Assessment Cognitive (MoCA) [4]; Mini Mental State Examination (MMSE) [11]; Wechsler Adult Intelligence Scale (WAIS) [12]; Visual Verbal Test; International Outcome Inventory for Hearing Aids (IOI-HA); Neupsilin [13]; The computerized Korean visual verbal learning test (VVLT) and Words-In-Noise (WIN) [3].

Table 1: Analysis and Qualitative Synthesis of the Articles

Author, Year, Country	Study design	Sample/Range or Mean Age	Questionnaire	Outcomes	Conclusion
Ávila VD, et al. 2011 (Brazil)	Cross-sectional	The sample consisted of 15 participants while 7 were male gender and 8 were female gender (MA = 73,3 ± 5,89)	IOIHA and MMSE	Regarding two groups: status normal Mini Mental (MMSE) and altered it was observed that most of the hearing aid user for a long time belongs to the group without cognitive impairment.	It was observed a trend of improved performance with hearing aids in participants without cognitive impairment
Choi AY, et al. 2011 (Korea)	Cohort	The study group comprised 18 participants (MA = 69.5 ±8.3 years) with sensorineural hearing loss who were fitted with HA and the control group comprised 11 participants (MA = 63.1±11.8 years) who were not fitted with HA	VVLT and WIN	There was no difference in mean age between the study group and control group. In the study group, total VVLT score (reflecting short-term memory) was significantly improved from before hearing aid use to 6 months after hearing aid use (P<0.05), and VVLT recognition score (reflecting learning ability) was also significantly improved from before hearing aid use to 6 months after hearing aid use (P<0.05), but there was no change in the control group. For VVLT latency score (reflecting efficiency of memory) and speech discrimination score in the WIN test, no statistically significant difference was found between the initial and 6-month assessments in the study group or in the control group (P>0.05)	The speech-related cognitive function of individuals with hearing impairment improved after using hearing aids. This finding indicates that hearing aids may induce acclimatization of the central auditory system.
Fell AC, Teixeira, AR. 2015 (Brazil)	Cohort	Thirteen participants were assessed before and three months after the fitting through the Mini-Mental State Examination (MA = 77 ± 9,02 years).	MMSE	It was found that there was a positive and significant correlation between scores in pre- and post-fitting,	The use of hearing aids improve performance in cognitive screening test (MMSE).

Fernandes DE, et al. 2021 (Brazil)	Randomized controlled trials	Three groups according to hearing aids technology: (A) premium; (B) basic; and (C) no amplification hearing devices.	NEUPSILIN	After the intervention, was observed differences in attention and memory scores ($p < 0.05$). Only reverse counting (A vs C) and recognition (B vs C) were observed in pairwise comparisons.	The level of technology of the devices had no impact on the overall satisfaction of new hearing aid users and suggest no effect on memory or attention after 12 weeks of use of hearing aids.
Gaeta L, et al. 2019 (EUA)	Case-control	Thirty older adults (60-80 years old) with mild to moderately severe hearing loss (cases) and 30 young adults (18-35 years old) with normal hearing (controls) participated in this study.	MMSE	Analyses between groups revealed no significant difference in MMSE scores. However, within-group analyses showed that education was a significant effect modifier for case participants.	The results suggest that the observed reductions in the MMSE score were mainly due to the loss of audibility of the test item. The negative effects of hearing loss may be greater in individuals with lower levels of educational attainment.
Lunner T. 2003 (Sweden)	Cohort	A total of seventy-two hearing aid users and without the use of HA (MA = 72)	Working Memory test and speed of speech processing.	The results indicate that, after controlling for age and hearing loss, significant correlations exist between the measures of cognitive performance and speech recognition in noise, both with and without hearing aids.	A good cognitive function is important for good performance in demanding listening situations, both with and without hearing aids.
Wong LL, et al. 2014 (China)	Cross-sectional	A total of 34 hearing impaired older adults (MA = 69,9 years ± 5,6). The results obtained in these participants were compared to normative data obtained in a general older population with similar demographic characteristics.	MMSE	Results showed that, even with appropriately fitted hearing aids, cognitive decline was significant.	When screening cognitive function, the presence of a hearing impairment should be accounted even with appropriately fitted hearing aids

c) Risk of bias in Studies

Regarding the risk of bias, observational studies were classified as "low" risk of bias, while the randomized interventional study was considered "moderate" risk of bias [13]. The methodological flaws identified were related to the shielding of outcome assessment and incomplete outcome data.

d) Results of Individual Studies

The included studies link hearing loss to poorer cognitive performance. Conversely, the use of hearing aids was related to better cognitive performance [14; 5; 3; 15; 18; 13]. The findings obtained from various assessment instruments demonstrated a correlation between hearing loss and cognitive impairment. Patients assessed with the MoCA and Mini Mental instruments exhibited subpar cognitive performance [19]. In tests evaluating intelligence and language aspects using the WAIS and Neupsilin instruments, it was observed that adults and older adults using hearing aids tended to achieve higher scores than non-users of hearing aids, particularly in subtests involving verbalization [19]. One study showed that regardless of the initial cognitive performance, hearing aids usage provided social and personal benefits for all evaluated older adults [5]. The data found on intelligence tests provides an understanding of intellectual aspects focused on verbal ability (vocabulary and comparative concepts or similarities) and execution (visuomotor ability and non-verbal intelligence). Another study revealed an enhancement in short-term memory and learning ability following hearing aid usage, an effect no observed among older adults who did not use hearing aids [3]. The Visual Verbal Test [5] and the Neupsilin[13] was applied to analyze and assess memory, attention and language skills. The results indicated that hearing aid users performed better on tasks requiring verbalization and short-term memory, suggesting that the use of hearing aids can help mitigate the effects of hearing loss on these cognitive functions. The International Outcome Inventory for Hearing Aids (IOI-HA) [5] was used to assess the satisfaction and benefits perceived by hearing aid users. This instrument, usually applied after the cognitive assessment, showed that the use of hearing aids provided social and personal benefits, regardless of the initial cognitive performance of the individuals. The computerized Korean visual verbal learning test (VVLT) and Words-In-Noise (WIN) [3]. were used to assess learning ability and word discrimination in noisy environments. The results showed that, even

with the use of hearing aids, individuals showed a decline in cognitive function compared to an older general population without hearing loss, suggesting that hearing deprivation is not completely compensated for using hearing aids.

In general, the data obtained from these tests indicate that hearing loss is associated with cognitive impairment, but that the use of hearing aids can mitigate some of these effects, especially in areas related to language and verbal memory. However, even with proper fitting of the devices, cognitive decline can persist, highlighting the need to consider mild or moderate hearing loss when screening cognitive function, even among hearing aid users. The authors cited in the data analysis state that this is because auditory deprivation is not being completely compensated for using ISADs, making it necessary to consider mild or moderate hearing loss, even in ISAD users when screening cognitive function [16].

e) Results of Syntheses

Three studies were eligible for inclusion in the meta-analysis, and only the MMSE cognitive assessment instrument could be assessed. When comparing the hearing aid user and non-user groups, a statistically significant difference was observed for the ISAD user group, indicating improved performance (MD = -1.47; CI95% = -2.53 - -0.40; I2 = 7.21%), albeit with a small effect size.

f) Reporting Biases and Certainty of Evidence

Among the three studies included in the quantitative synthesis, only one featured a longitudinal evaluation. Consequently, the studies were divided into subgroups based on the control group characteristic assessed, thereby reducing analysis heterogeneity (I2 = 0%; Tau2 = 0.00).

The majority of studied encompassed in the meta-analysis were cross-sectional observational studies. While the analysis revealed no inconsistency (Tau2 = 0.10; I2 = 7.21%) or imprecision (as indicated by a narrow confidence interval), the only study that showed statistical significance held the weight in the analysis due to its larger sample size and lower variance. Consequently, the certainty of evidence was classified as very low.

IV. Discussion

The primary objective of this systematic review was to investigate and analyze - from national and international literature - cognitive aspects in adults and older adults with hearing loss who are users of hearing aids as compared to those who do not use hearing aids. Generally, the results from the 7 eligible articles for review presented partial and inconclusive insights concerning the association between hearing loss and cognition, indicating limited or negligible effects of hearing aid use on the cognitive processes of adults and older adults.

One crucial variable to consider is the cognitive aspects of adults and older adults with hearing loss and the appropriate instruments are used for this population. In the selected studies, 8 instruments were identified: Montreal Assessment Cognitive (MoCA) [4]; Mini Mental State Examination (MMSE) [11]; Wechsler Adult Intelligence Scale (WAIS) [12]; Visual Verbal Test; International Outcome Inventory for Hearing Aids (IOI-HA); Neupsilin[13]; The computerized Korean visual verbal learning test (VVLT) and Words-In-Noise (WIN) [3]. However, none of these instruments were specifically tailored for individuals with hearing loss. While the objective of the instrument is to assess psychological aspects, with emphasis on cognition, it is crucial to consider the patient's sensory state when evaluating cognitive performance [5;15; 1; 13].

Several studies strive to understand the correlation between hearing loss, cognition, and hearing aid use, employing the instruments. One study found that individuals with hearing loss typically have low scores in cognitive assessment tests, noting that evaluations often neglect the individual's hearing capacity and focus solely on cognitive impairment [19]. This thus underscores the need for adapting cognitive assessment for this population. Based on this premise, studies suggest that the identification of hearing loss is related to cognitive function. Moreover, the best instrument for this population is the MoCA as it assesses mild cognitive impairment, even though it is not specifically designed for individuals with hearing loss [20; 21].

A previous sample study by used verbal-level cognitive tests [22]. This research identified a connection between auditory sensory issues associated with cognitive impairment, suggesting that older adults without hearing loss exhibited higher cognitive test scores than those with hearing loss. Notably, later research [4; 1] observed that cognitive impairment in older adults does not manifest solely within one intellectual domain, such as memory or attention, but rather across multiple domains. Additionally, these authors emphasized the need of considering acoustic competitiveness (noise, casual conversations in the same environment) while evaluating task-solving abilities, as environmental noise can influence an individual's processing speed and task completion during assessments.

Several studies within the sample [14; 3; 15] conducted comparisons between users and non-users of ISAD, revealing statistically significant differences in cognitive screening test scores between the two groups. The findings indicated that adult and older adult users of ISAD tend to have better scores in these tests, so the authors consider the importance of the proper hearing

aid user in contributing to sensory and cognitive improvement.

Additional studies [3; 16; 23] emphasize the importance of assessing the cognitive capacity of older adults, relating it to other variables, such as the degree of hearing loss, the use of hearing aids and how this use is managed. In a preliminary study, researchers found that indications of cognitive decline are linked to various factors, such as hearing deprivation, inadequate hearing aid adjustments, and challenges in fitting the device [16]. Furthermore, other studies explain that factors, such as language gaps, memory and attention deficits, limited education, and daily noise can imped the cognitive process, even with technology intended to enhance hearing. Therefore, it is important to investigate the real circumstances of patients in relation to their cognitive traits and auditory sensory loss for better monitoring of their development [17; 18].

Despite the thorough search for available literature concerning the cognitive aspects of adults and older adults with hearing loss. It is recommended that new studies be conducted to facilitate further investigations. The quantitative analysis conducted in this study through meta-analysis reveals a limitation in terms of research involving cognitive test scores among older adults with hearing loss - both users and non-users of hearing aids. For instance, among the five cognitive tests covered in this study, meta-analytical investigation was only feasible for the MMSE. The other tests did not present possibilities for meta-analysis. Another significant point pertains to the production of studies aimed at exploring multiple domains involving cognitive abilities such as memory, attention, temporal and spatial orientation, processing speed and language.

Conversely, the data derived from this systematic review has contributed to the identification of the performance of adults and older adults with hearing loss who use hearing aids, particularly in terms of overall cognitive characteristics, including memory, attention, and language. Additionally, the data suggests that, in the future, it is necessary to map and build assessment instruments and/or batteries that enable a more comprehensive perspective of the patient with hearing loss, encompassing involves a range of variables to be measured.

V. Conclusion

Older adults with hearing loss, who use appropriately adapted hearing aids, might experience a lesser impact on cognitive functions.

Social aspects and biological factors associated with aging could potentially influence the cognitive decline, even among those individuals who use hearing aids. However, the evidence for this outcome remains uncertain, and further studies are required to ensure greater robustness of the generated estimates. Furthermore, it is important to be careful about the comprehensive assessment of adults and older adults. Despite variations in results, a more comprehensive examination of the individual trajectories of these individuals is necessary. The parameterization of multidomain psychological assessment instruments, with a particular focus on older adults and adults with mild, moderate, and severe hearing impairment, is also recommended.

Data Availability Statement

This systematic review obtained its registration through the PROSPERO (International prospective register of systematic review - Centre for Reviews and Dissemination - University of York) protocol - CRD420 21261320.

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Appendix 1: Search Strategy for Each Electronic Database

Electronic Database	Keyword Search
EMBASE	('hearing aids':ti,ab,kw OR 'hearing aid':ti,ab,kw OR 'ear molds':ti,ab,kw OR 'ear mold':ti,ab,kw OR 'hearing loss':ti,ab,kw OR 'hypoacusis':ti,ab,kw OR 'hearing impairment':ti,ab,kw OR 'persons with hearing impairments':ti,ab,kw OR 'hearing impaired persons':ti,ab,kw OR 'hearing impaired person':ti,ab,kw OR 'hearing disorders':ti,ab,kw OR 'hearing disorder':ti,ab,kw OR 'dysacusis':ti,ab,kw OR 'presbycusis':ti,ab,kw OR 'age related hearing impairment':ti,ab,kw OR 'hearing difficulties':ti,ab,kw OR 'sensorineural hearing loss':ti,ab,kw) AND ('neuropsychological tests':ti,ab,kw OR 'neuropsychological testing':ti,ab,kw OR 'neuropsychologic tests':ti,ab,kw OR 'neuropsychologic test':ti,ab,kw OR 'neuropsychological test':ti,ab,kw OR 'cognitive function':ti,ab,kw OR 'cognitive test':ti,ab,kw OR 'cognitive tests':ti,ab,kw OR 'cognitive testing':ti,ab,kw OR 'cognitive':ti,ab,kw OR 'cognitive aging':ti,ab,kw OR 'mental status and dementia tests':ti,ab,kw OR 'mental status and dementia test':ti,ab,kw OR 'general practitioner assessment of cognition':ti,ab,kw OR 'gpcog':ti,ab,kw OR 'montreal cognitive assessment':ti,ab,kw OR 'mental status tests':ti,ab,kw OR 'mental status':ti,ab,kw OR 'mental status test':ti,ab,kw OR 'neurocognitive tests':ti,ab,kw OR 'neurocognitive test':ti,ab,kw OR 'neurocognitive':ti,ab,kw OR 'neurobehavioral cognitive status examination':ti,ab,kw OR 'cognistat':ti,ab,kw OR 'mini mental state examination':ti,ab,kw OR 'mini mental status examination':ti,ab,kw OR 'mini-cog':ti,ab,kw OR 'clinical dementia rating':ti,ab,kw OR 'clinical dementia rating scale':ti,ab,kw OR 'dementia rating scale':ti,ab,kw) AND ('aging':ti,ab,kw OR 'senescence':ti,ab,kw OR 'old people':ti,ab,kw OR 'older adults':ti,ab,kw OR 'old age':ti,ab,kw OR 'elderly people':ti,ab,kw OR 'biological aging':ti,ab,kw OR 'aged':ti,ab,kw OR 'elderly':ti,ab,kw OR 'adult':ti,ab,kw OR 'adults':ti,ab,kw)
LILACS	("Hearing Aids" OR "Hearing Aid" OR "Ear Molds" OR "Ear Mold" OR "Hearing Loss" OR "Hypoacusis" OR "Hearing impairment" OR "Persons with hearing impairments" OR "Hearing impaired persons" OR "Hearing impaired person" OR "Hearing disorders" OR "Hearing disorder" OR "Dysacusis" OR "Presbycusis" OR "Age related hearing impairment" OR "Hearing difficulties" OR "Sensorineural hearing loss" OR "Aparelhosauditivos" OR "Aparelhoauditivo" OR "Moldesauditivos" OR "Molde auricular" OR "Perdaauditiva" OR "Hipoacusia" OR "Deficiênciaauditiva" OR "Pessoas com deficiênciaauditiva" OR "Problemas de audição" OR "Disacusia" OR "Presbiacusia" OR "Deficiênciaauditivarelacionada à idade" OR "Dificuldades de audição" OR "Perdaauditivaneurossensorial" OR "Audífonos" OR "Audífono" OR "Moldes para losoídos" OR "Molde para losoídos" OR "Pérdida de audición" OR "Hipoacusia" OR "Deficienciaauditiva" OR "Personas con deficienciasauditivas" OR "Personas con discapacidadauditiva" OR "Trastornosauditivos" OR "Trastornoauditivo" OR "Deficienciaauditivarelacionada con la edad" OR "Dificultadesauditivas" OR "Pérdidaauditiva neurosensorial") AND ("Neuropsychological Tests" OR "Neuropsychological Testing" OR "Neuropsychologic Tests" OR "Neuropsychologic Test" OR "Neuropsychological Test" OR "Cognitive Function" OR "Cognitive Test" OR "Cognitive Tests" OR "Cognitive Testing" OR "cognitive" OR "Cognitive Aging" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Test" OR "General Practitioner Assessment of Cognition" OR "GPCOG" OR "Montreal Cognitive Assessment" OR "Mental Status Tests" OR "mental status" OR "Mental Status Test" OR "Neurocognitive Tests" OR "Neurocognitive Test" OR "neurocognitive" OR "Neurobehavioral Cognitive Status Examination" OR "COGNISTAT" OR "Mini Mental State Examination" OR "Mini Mental Status Examination" OR "Mini-Cog" OR "Clinical Dementia Rating" OR "Clinical Dementia Rating Scale" OR "Dementia Rating Scale" OR "Testes neuropsicológicos" OR "Teste neuropsicológico" OR "Funçãocognitiva" OR "Teste cognitivo" OR "Testes cognitivos" OR "cognitivo" OR "Envelhecimentocognitivo" OR "Testes de estado mental e demência" OR "Teste de estado mental e demência" OR "Avaliaçãocognitiva do clínicogeral" OR "Avaliaçãocognitiva de Montreal" OR "estado mental" OR "Teste do estado mental" OR "Testes neurocognitivos" OR "Teste neurocognitivo" OR "neurocognitivo" OR "Exame do estadocognitivoneurocomportamental" OR "Mini exame do estado mental" OR "Avaliaçãoclínica de demência" OR "Escala de avaliaçãoclínica de demência" OR

	"Escala de avaliação de demência" OR "Pruebasneuropsicológicas" OR "Pruebaneuropsicológica" OR "Funcióncognitiva" OR "Pruebacognitiva" OR "Pruebascognitivas" OR "cognitivas" OR "Envejecimientocognitivo" OR "Pruebas de estado mental y demencia" OR "Prueba de estado mental y demencia" OR "Evaluacióncognitiva del médico general" OR "Evaluacióncognitiva de Montreal" OR "estado mental" OR "Prueba de estado mental" OR "Pruebasneurocognitivas" OR "Pruebaneurocognitiva" OR "neurocognitiva" OR "Examen del estadocognitivoneuroconductual" OR "Mini examen del estado mental" OR "Mini estado mental" OR "Calificación de la demenciaclínica" OR "Escala de calificación de la demenciaclínica" OR "Escala de calificación de la demencia") AND ("aging" OR "Senescence" OR "old people" OR "Older adults" OR "Old age" OR "elderly people" OR "Biological Aging" OR "aged" OR "elderly" OR "adult" OR "adults" OR "envelhecimento" OR "Senescência" OR "idosos" OR "Adultosmaisvelhos" OR "Velhice" OR "idosos" OR "Envelhecimentobiológico" OR "envelhecido" OR "idoso" OR "adulto" OR "adultos" OR "envejecimiento" OR "Senescencia" OR "personas mayores" OR "Adultosmayores" OR "Vejez" OR "Envejecimientobiológico" OR "anciano" OR "ancianos" OR "adultos" OR "adultos")
PubMed/Medline	("Hearing Aids"[MeSH Terms] OR "Hearing Aids"[All Fields] OR "Hearing Aid"[All Fields] OR "Ear Molds"[All Fields] OR "Ear Mold"[All Fields] OR "Hearing Loss"[MeSH Terms] OR "Hearing Loss"[All Fields] OR "Hypoacusis"[All Fields] OR "Hearing impairment"[All Fields] OR "Persons with hearing impairments"[MeSH Terms] OR "Persons with hearing impairments"[All Fields] OR "Hearing impaired persons"[All Fields] OR "Hearing impaired person"[All Fields] OR "Hearing disorders"[MeSH Terms] OR "Hearing disorders"[All Fields] OR "Hearing disorder"[All Fields] OR "Dysacusis"[All Fields] OR "Presbycusis"[MeSH Terms] OR "Presbycusis"[All Fields] OR "Age related hearing impairment"[All Fields] OR "Hearing difficulties"[All Fields] OR "Sensorineural hearing loss"[All Fields]) ("Neuropsychological Tests"[MeSH Terms] OR "Neuropsychological Tests"[All Fields] OR "Neuropsychological Testing"[All Fields] OR "Neuropsychologic Tests"[All Fields] OR "Neuropsychologic Test"[All Fields] OR "Neuropsychological Test"[All Fields] OR "Cognitive Function"[All Fields] OR "Cognitive Test"[All Fields] OR "Cognitive Tests"[All Fields] OR "Cognitive Testing"[All Fields] OR "cognitive"[All Fields] OR "Cognitive Aging"[MeSH Terms] OR "Cognitive Aging"[All Fields] OR "Mental Status and Dementia Tests"[MeSH Terms] OR "Mental Status and Dementia Tests"[All Fields] OR "Mental Status and Dementia Test"[All Fields] OR "General Practitioner Assessment of Cognition"[All Fields] OR "GPCOG"[All Fields] OR "Montreal Cognitive Assessment"[All Fields] OR "Mental Status Tests"[All Fields] OR "mental status"[All Fields] OR "Mental Status Test"[All Fields] OR "Neurocognitive Tests"[All Fields] OR "Neurocognitive Test"[All Fields] OR "neurocognitive"[All Fields] OR "Neurobehavioral Cognitive Status Examination"[All Fields] OR "COGNISTAT"[All Fields] OR "Mini Mental State Examination"[All Fields] OR "Mini Mental Status Examination"[All Fields] OR "Mini-Cog"[All Fields] OR "Clinical Dementia Rating"[All Fields] OR "Clinical Dementia Rating Scale"[All Fields] OR "Dementia Rating Scale"[All Fields]) ("aging"[MeSH Terms] OR "aging"[All Fields] OR "Senescence"[All Fields] OR "old people"[All Fields] OR "Older adults"[All Fields] OR "Old age"[All Fields] OR "elderly people"[All Fields] OR "Biological Aging"[All Fields] OR "aged"[MeSH Terms] OR "aged"[All Fields] OR "elderly"[All Fields] OR "adult"[MeSH Terms] OR "adult"[All Fields] OR "adults"[All Fields]) #1 AND #2 AND #3
Web of Science	1.TS=("Hearing Aids" OR "Hearing Aid" OR "Ear Molds" OR "Ear Mold" OR "Hearing Loss" OR "Hypoacusis" OR "Hearing impairment" OR "Persons with hearing impairments" OR "Hearing impaired persons" OR "Hearing impaired person" OR "Hearing disorders" OR "Hearing disorder" OR "Dysacusis" OR "Presbycusis" OR "Age related hearing impairment" OR "Hearing difficulties" OR "Sensorineural hearing loss") 2.TS=("Neuropsychological Tests" OR "Neuropsychological Testing" OR "Neuropsychologic Tests" OR "Neuropsychologic Test" OR "Neuropsychological Test" OR "Cognitive Function" OR "Cognitive Test" OR "Cognitive Tests" OR "Cognitive Testing" OR "cognitive" OR "Cognitive Aging" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Test" OR "General Practitioner Assessment of Cognition" OR "GPCOG"

	OR "Montreal Cognitive Assessment" OR "Mental Status Tests" OR "mental status" OR "Mental Status Test" OR "Neurocognitive Tests" OR "Neurocognitive Test" OR "neurocognitive" OR "Neurobehavioral Cognitive Status Examination" OR "COGNISTAT" OR "Mini Mental State Examination" OR "Mini Mental Status Examination" OR "Mini-Cog" OR "Clinical Dementia Rating" OR "Clinical Dementia Rating Scale" OR "Dementia Rating Scale") 3.TS=("aging" OR "Senescence" OR "old people" OR "Older adults" OR "Old age" OR "elderly people" OR "Biological Aging" OR "aged" OR "elderly" OR "adult" OR "adults") 4.#1 AND #2 AND #3
Livivo	TI=("Hearing Aids" OR "Hearing Aid" OR "Ear Molds" OR "Ear Mold" OR "Hearing Loss" OR "Hypoacusis" OR "Hearing impairment" OR "Persons with hearing impairments" OR "Hearing impaired persons" OR "Hearing impaired person" OR "Hearing disorders" OR "Hearing disorder" OR "Dysacusis" OR "Presbycusis" OR "Age related hearing impairment" OR "Hearing difficulties" OR "Sensorineural hearing loss") AND TI=("Neuropsychological Tests" OR "Neuropsychological Testing" OR "Neuropsychologic Tests" OR "Neuropsychologic Test" OR "Neuropsychological Test" OR "Cognitive Function" OR "Cognitive Test" OR "Cognitive Tests" OR "Cognitive Testing" OR "cognitive" OR "Cognitive Aging" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Test" OR "General Practitioner Assessment of Cognition" OR "GPCOG" OR "Montreal Cognitive Assessment" OR "Mental Status Tests" OR "mental status" OR "Mental Status Test" OR "Neurocognitive Tests" OR "Neurocognitive Test" OR "neurocognitive" OR "Neurobehavioral Cognitive Status Examination" OR "COGNISTAT" OR "Mini Mental State Examination" OR "Mini Mental Status Examination" OR "Mini-Cog" OR "Clinical Dementia Rating" OR "Clinical Dementia Rating Scale" OR "Dementia Rating Scale") AND TI=("aging" OR "Senescence" OR "old people" OR "Older adults" OR "Old age" OR "elderly people" OR "Biological Aging" OR "aged" OR "elderly" OR "adult" OR "adults")
Scopus	TITLE-ABS ("Hearing Aids" OR "Hearing Aid" OR "Ear Molds" OR "Ear Mold" OR "Hearing Loss" OR "Hypoacusis" OR "Hearing impairment" OR "Persons with hearing impairments" OR "Hearing impaired persons" OR "Hearing impaired person" OR "Hearing disorders" OR "Hearing disorder" OR "Dysacusis" OR "Presbycusis" OR "Age related hearing impairment" OR "Hearing difficulties" OR "Sensorineural hearing loss") AND TITLE-ABS ("Neuropsychological Tests" OR "Neuropsychological Testing" OR "Neuropsychologic Tests" OR "Neuro-psychologic Test" OR "Neuropsychological Test" OR "Cognitive Function" OR "Cognitive Test" OR "Cognitive Tests" OR "Cognitive Testing" OR "cognitive" OR "Cognitive Aging" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Test" OR "General Practitioner Assessment of Cognition" OR "GPCOG" OR "Montreal Cognitive Assessment" OR "Mental Status Tests" OR "mental status" OR "Mental Status Test" OR "Neurocognitive Tests" OR "Neurocognitive Test" OR "neurocognitive" OR "Neurobehavioral Cognitive Status Examination" OR "COGNISTAT" OR "Mini Mental State Examination" OR "Mini Mental Status Examination" OR "Mini-Cog" OR "Clinical Dementia Rating" OR "Clinical Dementia Rating Scale" OR "Dementia Rating Scale") AND TITLE-ABS ("aging" OR "Senescence" OR "old people" OR "Older adults" OR "Old age" OR "elderly people" OR "Biological Aging" OR "aged" OR "elderly" OR "adult" OR "adults")
PsycINFO	("Hearing Aids" OR "Hearing Aid" OR "Ear Molds" OR "Ear Mold" OR "Hearing Loss" OR "Hypoacusis" OR "Hearing impairment" OR "Persons with hearing impairments" OR "Hearing impaired persons" OR "Hearing impaired person" OR "Hearing disorders" OR "Hearing disorder" OR "Dysacusis" OR "Presbycusis" OR "Age related hearing impairment" OR "Hearing difficulties" OR "Sensorineural hearing loss") AND ("Neuropsychological Tests" OR "Neuropsychological Testing" OR "Neuropsychologic Tests" OR "Neuropsychologic Test" OR "Neuropsychological Test" OR "Cognitive Function" OR "Cognitive Test" OR "Cognitive Tests" OR "Cognitive Testing" OR "cognitive" OR "Cognitive Aging" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Test" OR "General Practitioner Assessment of Cognition" OR "GPCOG" OR "Montreal Cognitive Assessment" OR "Mental Status Tests" OR "mental status" OR "Mental Status Test" OR "Neurocognitive Tests" OR "Neurocognitive Test" OR

	"neurocognitive" OR "Neurobehavioral Cognitive Status Examination" OR "COGNISTAT" OR "Mini Mental State Examination" OR "Mini Mental Status Examination" OR "Mini-Cog" OR "Clinical Dementia Rating" OR "Clinical Dementia Rating Scale" OR "Dementia Rating Scale") AND ("aging" OR "Senescence" OR "old people" OR "Older adults" OR "Old age" OR "elderly people" OR "Biological Aging" OR "aged" OR "elderly" OR "adult" OR "adults")
PROQUEST	noft(("Hearing Aids" OR "Hearing Aid" OR "Ear Molds" OR "Ear Mold" OR "Hearing Loss" OR "Hypoacusis" OR "Hearing impairment" OR "Persons with hearing impairments" OR "Hearing impaired persons" OR "Hearing impaired person" OR "Hearing disorders" OR "Hearing disorder" OR "Dysacusis" OR "Presbycusis" OR "Age related hearing impairment" OR "Hearing difficulties" OR "Sensorineural hearing loss")) AND noft(("Neuropsychological Tests" OR "Neuropsychological Testing" OR "Neuropsychologic Tests" OR "Neuropsychologic Test" OR "Neuropsychological Test" OR "Cognitive Function" OR "Cognitive Test" OR "Cognitive Tests" OR "Cognitive Testing" OR "cognitive" OR "Cognitive Aging" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Tests" OR "Mental Status and Dementia Test" OR "General Practitioner Assessment of Cognition" OR "GPCOG" OR "Montreal Cognitive Assessment" OR "Mental Status Tests" OR "mental status" OR "Mental Status Test" OR "Neurocognitive Tests" OR "Neurocognitive Test" OR "neurocognitive" OR "Neurobehavioral Cognitive Status Examination" OR "COGNISTAT" OR "Mini Mental State Examination" OR "Mini Mental Status Examination" OR "Mini-Cog" OR "Clinical Dementia Rating" OR "Clinical Dementia Rating Scale" OR "Dementia Rating Scale")) AND noft(("aging" OR "Senescence" OR "old people" OR "Older adults" OR "Old age" OR "elderly people" OR "Biological Aging" OR "aged" OR "elderly" OR "adult" OR "adults"))
Google Scholar	(("Hearing Aids" OR "Hearing Loss" OR "Persons with hearing impairments" OR "Hearing disorders") AND ("Neuropsychological Tests" OR "Cognitive Aging") AND ("aging" OR "adult"))
Open Grey	(("Hearing Aids" OR "Hearing Loss" OR "Persons with hearing impairments" OR "Hearing disorders") AND ("Neuropsychological Tests" OR "Cognitive Aging") AND ("aging" OR "adult"))

Appendix 2: Excluded Articles and Reasons for Exclusion (n=31)

Author, Year	Reason for Exclusion
Al-Yawer F, et al., 2019	2
Ambert-Dahan E, et al., 2017	1
Bruckmann M, Pinheiro MM, 2016	2
Claes AJ, et al., 2018	2
Dong Y, et al., 2018	2
Edwards JD, et al., 2017	2
Ellis RJ, Munro KJ, 2013	2
Gorecka MM, et al., 2018	2
Granick S, et al., 1976	2
Humes LE, 2020	2
Lim, MYL, Loo JHY, 2018	1
Lima IM, Miranda-Gonsalez EC, 2016	2
Lin FR, 2011	2
Lin VY, et al., 2017	3
MacDonald AA, et al., 2012	2
Martin HJ, et al., 2008	2
Meyer TS, Figueiredo VLM, 2017	2
Neher T, et al., 2014	1

Ng EHN, et al., 2013	1
Paige-Deming H, 2015	4
Parada JC, et al., 2020	2
Purdy SC, et al., 2017	2
Saunders GH, et al., 2018	2
Shen J, et al., 2020	2
Stewart R, Wingfield A, 2009	2
Van Boxtel MP, et al, 2000	2
Van Rooij JC, Plomp R. 1991	2
Wingfield A, et al., 2005	2
Yumba WK, 2019	2
Yusof Y, et al., 2019	2
	2

Subtitle

1) Studies in which the population consisted only of people without hearing loss, or studies in which the study population was not adults (> 18 years), or when hearing loss was associated with mental disorders or disorders, Alzheimer's Disease, or dementia; 2) Studies in which none of the groups were composed of hearing aid users, or studies where the sample was composed of cochlear implant users; 3) Uncontrolled studies, or where the assessment of interest was performed only in one of the groups; 4) Studies that did not assess the outcome of interest or where it was assessed by non-validated tools.