Received: 9 February 2024 | Revised: 6 May 2024 | Accepted: 25 June 2024

DOI: 10.1002/dad2.12624

Alzheimer's & Dementia
Diagnosis, Assessment & Disease Monitoring

RESEARCH ARTICLE

Subjective hearing and memory problems are associated with dementia and cognition in later life

Joshua Stevenson-Hoare[1] | Hannah Stocker[2] | Kira Trares[1] | Bernd Holleczek[3] | Hermann Brenner[1,2]

[1]Division of Clinical Epidemiology and Aging Research, German Cancer Research Center, Heidelberg, Germany

[2]Network Aging Research, Heidelberg University, Heidelberg, Germany

[3]Saarland Cancer Registry, Saarbrücken, Germany

Correspondence
Joshua Stevenson-Hoare, Division of Clinical Epidemiology and Aging Research, German Cancer Research Center, Heidelberg, Baden-Württemberg, Germany.
Email: joshua.stevenson-hoare@dkfz-heidelberg.de

Abstract

INTRODUCTION: Subjective hearing and memory problems are detectable earlier than objective measures of sensory loss and cognitive decline, which are known to be related to an increased risk of dementia in later life.

METHODS: Using a population-representative cohort of 6006 individuals (aged 50–75) we examined whether participants who self-reported hearing and short-term memory issues showed greater rates of dementia within 17 years of follow-up. A sub-cohort was tested for audiometric threshold and cognition after 14 years.

RESULTS: Hearing and memory problems were associated with a greater risk of dementia (hazard ratios [HRs] = 1.42 [95% confidence interval: 1.11–1.81], 1.57 [1.30–1.90]), and poorer cognition 14 years later. The risk was greatest in those reporting both problems (HR = 1.99 [1.42–2.80]). At follow-up, the level of hearing loss was associated with lower cognitive scores.

DISCUSSION: Self-reports of hearing and short-term memory problems are associated with poorer cognitive performance and a greater risk of dementia. Subjective assessments may have predictive power over more than a decade.

Highlights:

- In a sample of older adults subjective hearing and memory problems were associated with dementia risk.
- Cross-sectionally, the audiometric screening threshold was associated with cognitive test scores.
- Subjective sensory and memory loss questions are easy to implement and show good predictive power.

KEYWORDS
cognitive decline, cohort study, dementia, hearing, memory

1 | BACKGROUND

Age-related hearing loss (ARHL), or presbycusis, is one of the most common health conditions in older populations,[1] affecting between one third and one half of all adults over age 70 in Europe. Hearing impairment (HI), including ARHL, has been associated with increased rates of mild cognitive impairment (MCI)[2] and progression from MCI to dementia.[3] Moreover, many studies have shown higher rates of dementia in individuals with HI, including both objective measures of hearing loss and self-reported hearing difficulties.[4–6]

The exact mechanisms by which HI and dementia are linked are not yet clear; however, one hypothesis is that individuals with hearing difficulties have an increased cognitive burden due to difficulties with interpreting speech and detecting sources of sound.[7] This hypothesis is linked to the cognitive reserve theory,[8] whereby individuals with a "buffer" of cognitive ability from, for example, education, physical activity, or number of regular interpersonal interactions, have delayed or reduced chance of onset of dementia.[9] Individuals with untreated hearing difficulties may require greater cognitive effort than normal hearing individuals in daily life, such as through speech comprehension and production, and auditory spatial awareness (e.g., navigating traffic).

Support for the cognitive reserve theory also comes from the finding that HI individuals who use hearing aids do not differ in their risk of dementia from non-HI controls[6] and individuals with hearing aids do not show poorer cognition than individuals who do not report hearing difficulties.[10] This may be because the amount of cognitive effort required for hearing aid users to achieve comprehension is similar to that of individuals without hearing loss.[11] In longitudinal studies, individuals with hearing difficulties who used hearing aids showed a shallower slope of cognitive decline compared to those with untreated hearing difficulties.[12,13] Cross-sectionally, other studies have failed to find an effect of hearing aid use on cognition cross-sectionally.[14,15] This suggests that there may be a significant within-individual component to any potential impact of hearing aids on cognition and dementia risk.

Cognitive decline is a well-established predictor for the development of dementia.[16] Objective measures of sensory decline, such as visual acuity and auditory acuity, have been shown to be predictive of cognitive functioning cross-sectionally[17] and up to 6 years later.[18] However, evidence suggests that subjective reports of sensory and cognitive impairment begin earlier than measurable differences in objective impairment such as cognitive scoring.[19] Hearing loss has been found to be associated with increased cognitive decline in older adults even at levels lower than that typically used for classification of hearing loss.[20] The use of subjective assessments may therefore permit the identification of at-risk individuals earlier than objective tools.

Self-reported hearing difficulty has been shown to be associated with a greater incidence of self-reported cognitive decline.[21] A population cohort in the UK[22] found that poorer ratings of subjective hearing difficulties were associated with a 39% to 57% higher risk of later-life dementia diagnosis, and the authors claimed that subjective and objective measures of HI had a fair agreement. However, it has been shown previously that self-reports of hearing difficulties have only a moderate correlation with objective hearing loss,[23] and self-reports may underestimate HI prevalence in younger age groups.[24] In a cross-sectional analysis of the ELSA study, it was suggested that factors associated with objective and subjective HI discordance include sex, age, and education level,[25] all of which are known to be associated with dementia risk.

Subjective memory problems have also been shown to be predictive of both cognitive impairment and cognitive decline[26] and dementia.[27,28] Therefore, the combination of assessing individuals' subjective hearing and memory problems may provide a simple but powerful estimation of their risk of cognitive impairment and dementia in later life.

Here, we use the ESTHER study, a population-representative cohort of older adults from Saarland, Germany, to investigate the relationship between hearing and short-term memory problems and dementia. Participants were assessed at baseline on an array of factors including subjective HI and memory impairment, and were followed for up to 17 years over multiple assessments. We assess the association of subjective complaints at baseline with the risk of developing dementia as well as cognitive performance within 17 years of follow-up. We also use a cross-section of this cohort at the 14-year follow-up, at which objective audiometric and cognitive testing was performed, to examine the association between hearing loss and poorer cognitive performance.

RESEARCH IN CONTEXT

1. **Systematic review**: Information on hearing loss impairment memory problems, cognitive decline, and dementia were collated, revealing the potential of self-reported assessments of sensory impairment and memory difficulties for models of dementia risk.
2. **Interpretation**: Our findings support the hypothesis that subjective assessments of hearing and memory are associated with dementia risk and that the combination of these problems is associated with a doubling of dementia risk compared to non-exposed populations. Furthermore, our findings suggest both acute and chronic factors of sensory impairment on cognitive impairment.
3. **Future directions**: Future work should consider how self-reported difficulties in these domains can be integrated into assessments of dementia risk and cognitive impairment. Necessary questions to be answered include the role of sensory aid interventions in moderating this risk, how the duration of subjective issues factors into risk, and how individuals' subjective sensory impairment and memory difficulties are related to specific cognitive domains.

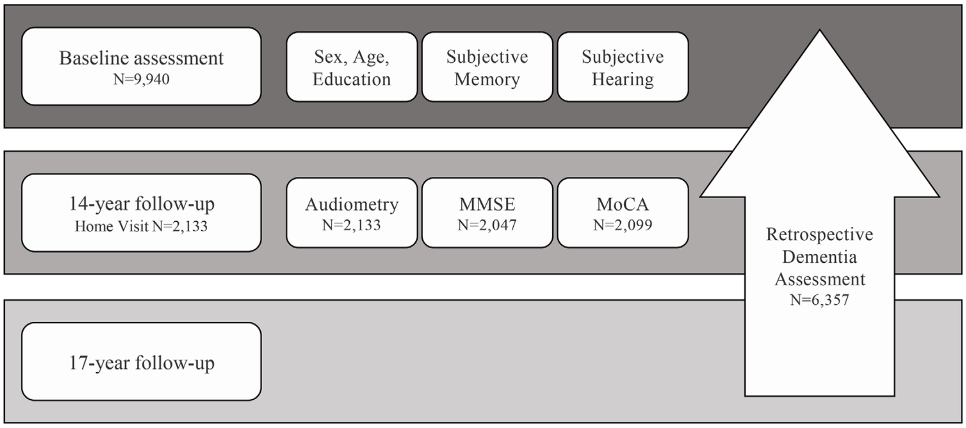

FIGURE 1 Diagram showing assessments at each follow-up for baseline, 14-year, and 17-year follow-ups. Numbers indicate number of participants with available data. MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment

2 | METHODS

2.1 | The ESTHER cohort

2.1.1 | Cohort overview

The Epidemiologische Studie zu Chancen der Verhütung, Früherkennung und optimieren Therapie chronischer Erkrankungen in der älteren Bevölkerung (ESTHER) study is a longitudinal population study of older adults from Saarland, Germany.[29] Participants were recruited between 2000 and 2002 and have been followed for 17 years at the time of this analysis. At baseline, the study contained 9940 participants aged between 50 and 75 years of age who were residents of Saarland, a federal state in southwestern Germany. Participants were recruited during a general health check-up at their general practitioner (GP). Baseline assessments included patient and GP questionnaires across a variety of fields including demographic, lifestyle, and medical factors; biometric measurements; and blood sampling. Participants were then followed up at 2-, 5-, 8-, 11-, 14-, and 17-year periods. At the 14-year follow-up, there were 4639 participants (46.7%) still within this cohort. Reasons for loss to follow-up included death and illness, choosing not to withhold further participation, or withdrawal of data. A diagram of assessment times for data used in this study, and the numbers of participants at each assessment, are shown in Figure 1.

2.1.2 | Baseline assessment

Variables of interest at baseline were the subjective reports of problems with hearing and short-term memory, level of education, and demographic questions (age, sex). For hearing problems, participants were asked in self-administered questionnaires (in German) if they had difficulties understanding someone speaking in a quiet room (Haben Sie Schwierigkeiten in einem ruhigen Raum eine Person zu hören und zu verstehen?). Participants who reported using a hearing aid were also classed as having a hearing problem. For short-term memory problems, participants were asked if they had difficulties recalling recent events that happened hours to days ago (Haben Sie Schwierigkeiten sich an kurz zurückliegende Dinge zu erinnern (Stunden bis wenige Tage)?). Years of education were categorized into none or primary ($\leq$ 9 years), secondary (10–11 years), and tertiary ($\geq$ 12 years).

2.1.3 | Cross-sectional assessment

Cross-sectional data were taken from the 14-year follow-up and consisted of audiometric testing of hearing acuity (described below), the Mini–Mental State Examination (MMSE), and the Montreal Cognitive Assessment (MoCA). All tests were performed during a home visit made to a subset of the cohort (N = 2095). Complete data for MMSE and MoCA were available for 2021 and 2073 individuals, respectively.

Participants examined cross-sectionally were younger than those lost to follow-up by an average of 2.48 years ($P < 0.01$) and were more likely to have completed tertiary education ($P < 0.001$), but were not more likely to be female ($P = 0.118$). They also reported fewer baseline hearing problems (3.95% vs. 7.56%, $P < 0.001$), but did not report more baseline memory problems ($P = 0.695$). Dementia incidence was also lower in the cross-sectional cohort (2.42%) than those lost to follow-up (8.45%) at the time of study ($P < 0.001$).

2.1.4 | Audiometric testing

Tests of auditory acuity were performed by trained assessors using an AudioScope (Welch Allyn) screening audiometer. Participants who used hearing aids were not included in these tests ($N = 431$). For these tests, the audiometer speculum was inserted into the outer ear canal and held steady. An automated series of tones was then played in a random order with each tone presented once only. These tones consisted of 500, 1000, 2000, and 4000 Hz frequencies with a total duration of 1.5 ± 0.2 s and a rise/fall time of 20–200 ms. Listeners were instructed to indicate with their hand or finger when they heard a tone. Tones were played to both ears sequentially. The initial presentation of the tones was at 25 dB HL (hearing level). If listeners failed to correctly identify all tones, the procedure was repeated with tones played at 40 dB HL, a louder level.

This test resulted in a percentage correct identification per frequency per sound level, for each listener. Listeners' screening threshold was calculated as the mean sound level (in dB HL) at which they could identify tones with ≥ 50% accuracy in the better ear. For example, a listener who identified 500 and 1000 Hz at 25 dB HL with 50% performance, and 2000 and 4000 Hz at 40 dB HL with 50% performance, would have an overall screening threshold of 32.5 dB HL. Listeners who failed to correctly identify any frequencies at 50% accuracy were used in a sensitivity analysis ($N = 318$).

2.1.5 | Dementia diagnoses

Information on dementia diagnoses was collected retrospectively from participants' primary care physicians at the 14- and 17-year follow-ups (N with assessment data $N = 6357$). Physicians were asked whether there was a recorded diagnosis of dementia for these individuals and, if so, they were asked to provide details on the date of diagnosis, dementia subtype if any, and to provide any accompanying reports from memory clinics or specialist clinicians. A full description of how dementia status was ascertained can be found in Trares et al.[30] At recruitment no participants had an existing diagnosis of dementia.

2.2 | Statistical analysis

2.2.1 | Longitudinal modeling

To analyze the risk of dementia over time, competing risk survival models were implemented in R[31] using the cmprsk package.[32] For these models, the start time was the date of baseline assessment. The end time was the date of first dementia diagnosis for participants with dementia, and either date of death or date of last follow-up for dead and alive participants without dementia, respectively. The competing risk in these models was death before dementia. All generated models were adjusted for age at baseline, sex, and years of education. Participants with missing data for age ($N = 41$) or education ($N = 119$) were excluded from the analysis. The predictors of interest were subjective hearing problems and subjective short-term memory problems. Models were calculated separately for hearing and memory problems, and an overall model was also calculated for both predictors combined.

To examine whether cognitive performance differed between participants who reported subjective problems at baseline from those who did not, analysis of covariance (ANCOVA) models were calculated. The outcome variables were total MMSE and MoCA scores, using baseline hearing and short-term memory problems as categorical variables, with covariates of age at baseline, sex, and years of education. To assess the extent of any significant differences, marginal means were compared using 95% confidence intervals (CIs).

2.2.2 | Cross-sectional modeling

To analyze the relationship between audiometric performance and cognitive scoring, two sets of models were calculated. In the first set, the auditory screening threshold values were used in a linear regression to predict the total MMSE score and MoCA score. In the second set, individuals were split into "high" and "low" auditory acuity using a median split, and a third group was generated using individuals who were not able to reach sufficient performance threshold to calculate a screening threshold (labeled "failed"). This three-group variable was then used in a linear regression as an ordinal predictor variable. Individuals with hearing aids, who were not tested for audiometric performance, were compared on cognitive scores to non–hearing aid users using an ANCOVA, both collectively and to each hearing loss group individually using estimated marginal means.

2.3 | Data approval and diversity, equity, and inclusion

All data in this study were sourced from the ESTHER study, which has been approved by the Ethics Committee of the Medical Faculty at Heidelberg University and by the Physicians' Board of Saarland. The ESTHER study is a population cohort that offered the equitable opportunity of inclusion to all eligibly aged adults within the state of Saarland during the time of recruitment. Other work has confirmed this study's representativeness of the target population.[29]

3 | RESULTS

3.1 | Subjective hearing and memory problems at baseline

In total, 6006 participants had information available on subjective hearing and short-term memory problems at baseline (median age 61.9, interquartile range [IQR] 9.85), dementia status by 17-year follow-up, and all covariates (age, sex, education). Of these, 582 reported a hearing problem at baseline, of whom 285 used hearing aids. Memory problems were reported by 1455 participants. An overview of participants at baseline assessment and by the end of follow-up (17 years) is shown in Table 1.

In the overall dataset, there were more females than males (54% vs. 46%); however, in both the hearing problem and memory problem groups males were more strongly represented (58.2% and 51.3%, both $P < 0.001$), accounting for total proportions.

3.2 | Survival models predicting dementia

Competing risk survival models were generated to predict dementia from subjective problems at baseline, adjusting for age, sex, and

TABLE 1 Overview of participants at baseline and by the end of the 17-year follow-up.

	No problems	Hearing problem	Memory problem	Hearing & memory	All participants
At baseline					
N participants (%)	4219 (70.2%)	582 (9.7%)	1455 (24.2%)	250 (4.2%)	6006
% Females/males	56.6/43.3	41.7/58.2	48.7/51.3	40.8/59.2	53.9/46.1
Median age (IQR)	61.2 (10.0)	64.8 (9.9)	63.2 (9.4)	64.4 (10.0)	61.9 (9.9)
Education (%)					
None or primary	2983 (70.7%)	479 (82.3%)	1136 (78.1%)	210 (84.0%)	4388 (73.1%)
Secondary	691 (16.4%)	41 (7.0%)	165 (11.3%)	16 (6.4%)	881 (14.7%)
Tertiary	545 (12.9%)	62 (10.7%)	154 (10.6%)	24 (9.6%)	737 (12.3%)
By the end of the follow-up					
N deceased (%)	898 (21.3%)	220 (37.8%)	416 (28.6%)	104 (41.6%)	1430 (23.8%)
Age at death (IQR)	77.3 (10.8)	79.6 (9.1)	78.5 (8.9)	79.6 (8.5)	77.9 (10.2)
N with dementia (%)	253 (6.0%)	82 (14.1%)	173 (11.9%)	41 (16.4%)	467 (7.8%)
Age at dementia (IQR)	78.4 (7.2)	78.3 (6.7)	78.1 (7.9)	79.0 (5.7)	78.1 (7.6)

Abbreviation: IQR, interquartile range.

TABLE 2 Hazard ratios from competing risk survival models for the predictor of interest, controlling for age at baseline, sex, and education, with a competing risk of death.

Predictor of interest	*N* participants with/without problem	HR	95% CI	*P* value
Individual models				
Hearing	582/5424	1.416	1.11, 1.81	0.006
Memory	1455/4551	1.571	1.30, 1.90	3.50×10^{-6}
Hearing aid use	285/5143	0.968	0.61, 1.54	0.890
Combined model				
Hearing	582/5424	1.333	1.04, 1.71	0.023
Memory	1455/4551	1.534	1.27, 1.86	1.3×10^{-5}
Both problems versus none				
Hearing and memory	250/4219	1.992	1.42, 2.80	7.50×10^{-5}

Abbreviations: CI, confidence interval; HR, hazard ratio.

years of education, with the competing risk of death before dementia. The results of these models are shown in Table 2. Using hearing problems at baseline as the predictor, there was a significantly higher risk of dementia in participants with subjective hearing problems (hazard ratio [HR] = 1.42 [95% CI 1.11, 1.81], *P* = 0.006). With subjective short-term memory problems as the predictor, there was a significantly higher risk of dementia in participants with memory problems (HR = 1.57 [95% CI: 1.30, 1.90], $P = 3.5 \times 10^{-6}$).

When combined into one model, both hearing problems (HR = 1.33 [95% CI: 1.04, 1.71], *P* = 0.023) and memory problems (HR = 1.53 [95% CI: 1.27, 1.86], $P = 1.3 \times 10^{-5}$) at baseline were significantly associated with a higher risk of developing dementia. In a separate analysis, individuals with hearing problems who used hearing aids were compared to those who did not, but there was no significant difference in the risk of dementia between these two groups (*P* = 0.89).

We further generated a model that compared participants who reported both problems (*N* = 250) to participants who reported neither problem (*N* = 4219). Participants who self-reported both hearing and short-term memory problems had approximately twice the risk of developing dementia compared to participants with neither problem (HR = 1.99 [95% CI: 1.42, 2.80], $P = 7.5 \times 10^{-5}$), shown in Table 2. Cumulative incidence curves of dementia are shown in Figure 2, split by whether participants reported both problems, memory problems only, hearing problems only, or neither problem at baseline.

3.3 | Baseline subjective problems and future cognitive performance

A subset of participants in the ESTHER study were tested for cognitive performance at the 14-year follow-up (*N* = 2047 with MMSE, *N* = 2099

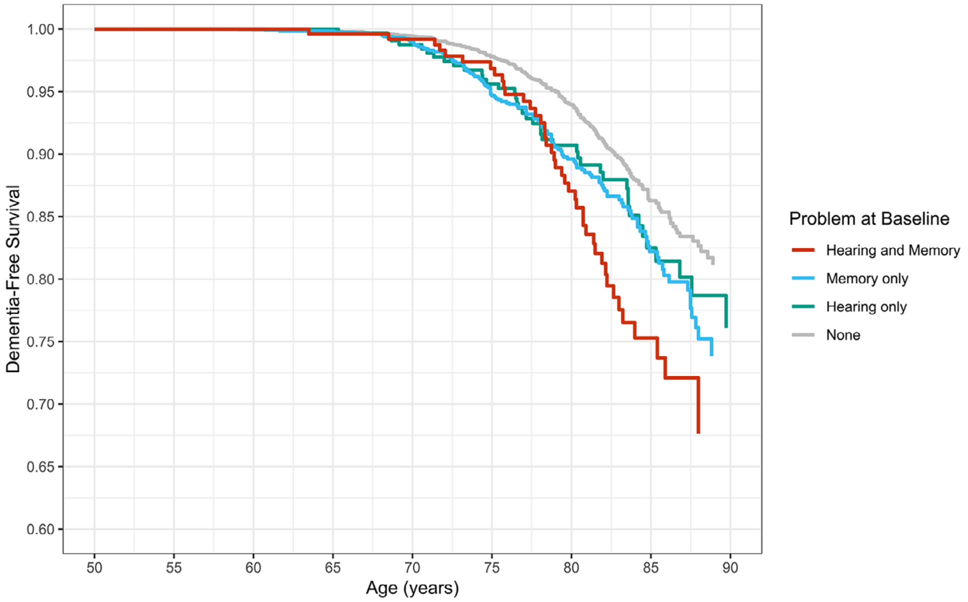

FIGURE 2 Cumulative incidence curves for dementia after accounting for the competing risk of death, split by hearing and memory problem status at baseline

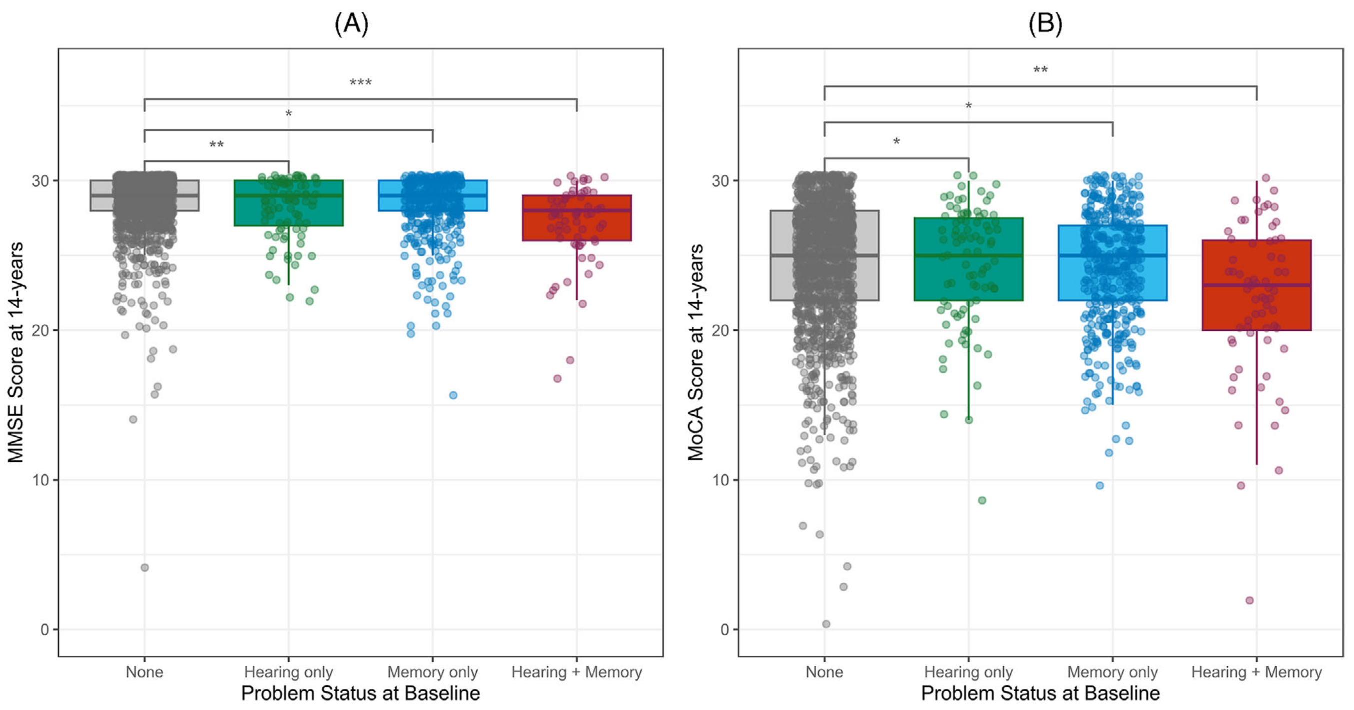

FIGURE 3 Boxplots of (A) total MMSE scores and (B) total MoCA scores at the 14-year follow-up, split by self-reports of hearing and memory problems at baseline. Individual scores are jittered to show distribution. Significance of group differences adjusted for age, sex, and education: * = $P < 0.05$, ** = $P < 10^{-3}$, *** = $P < 10^{-5}$. MMSE, Mini–Mental State Examination; MoCA, Montreal Cognitive Assessment

with MoCA). Figure 3 shows the distribution of MMSE and MoCA scores at this follow-up, split by subjective hearing and short-term memory problem status at baseline. ANCOVA models were calculated to examine whether overall MMSE and MoCA scores differed in participants who reported hearing problems or memory problems at baseline, adjusting for age, sex, and years of education.

The results showed that participants who reported hearing problems at baseline performed more poorly on overall MMSE scores than

TABLE 3 Overview of participants at 14-year follow-up, split by hearing performance.

	Low loss	High loss	Failed	Hearing aid
Demographics				
N participants (%)	636 (30.3%)	719 (34.3%)	313 (14.9%)	427 (20.4%)
% Females/males	56.8/43.2	52.4/47.6	55.6/44.4	48.5/51.5
Median age at testing (range)	72.4 (62.8, 89.1)	74.9 62.8, 88.9)	74.9 (63.1, 89.3)	77.5 (63.7, 89.2)
Cognitive tests				
MMSE score (SD)	28.7 (1.7)	28.5 (1.7)	27.8 (2.9)	28.2 (2.1)
MoCA score (SD)	24.9 (4.1)	24.8 (3.7)	23.2 (4.9)	24.0 (4.1)

Abbreviations: MMSE, Mini–Mental State Examination; MoCA, Montreal Cognitive Assessment; SD, standard deviation.

those who did not ($F[1] = 14.8$, $P = 1.25 \times 10^{-4}$), as did those who reported memory problems at baseline ($F[1] = 7.24$, $P = 0.007$). For overall MoCA scores, participants with hearing problems at baseline had poorer MoCA scores ($F[1] = 6.80$, $P = 0.009$), as did participants with memory problems ($F[1] = 4.73$, $P = 0.030$). Using estimated marginal means, we found that participants who reported both hearing and memory problems were the poorest on both tests, compared to those who reported one or neither problems at baseline (mean differences of 0.7 points for MMSE, and 0.9 points for MoCA).

3.4 | Cross-sectional audiometry and cognitive tests

Data on hearing ability, at least one cognitive test, and all covariates (age, sex, education) were available for 2095 individuals cross-sectionally at the 14-year follow-up. Of these, 1668 completed the audiometric screening. Participants' screening thresholds were split using the median value (40 dB HL) into "low loss" and "high loss" groups, as shown in Table 3. The remaining participants consisted of 427 hearing aid users, who did not participate in auditory screening.

Listeners with low loss were younger on average than high loss listeners, $P = 3.53 \times 10^{-9}$. Hearing aid users were older than non–hearing aid users, $P < 1 \times 10^{-10}$. There was also a difference in sex ratio between groups, $F(2) = 3.53$, $P = 0.030$. The hearing aid user group had more males than non-hearing aid users ($P = 0.023$).

3.5 | Association of audiometric measurements and cognitive performance

In individuals with a screening threshold, a linear regression model was generated to predict cognitive performance, adjusted for age at assessment, sex, and education. Higher thresholds were associated with lower MMSE scores ($P = 1.17 \times 10^{-5}$) and lower MoCA scores ($P = 1.50 \times 10^{-6}$). However, the size of this change was very small, with a reduction of 0.2 points per 10 dB increase for MMSE, and 0.5 points per 10 dB increase for MoCA. In a sensitivity analysis, individuals who did not reach the threshold on any frequency of the auditory screening were excluded ($N = 313$). After these individuals were removed, there was no significant association between the auditory screening threshold and either MMSE ($P = 0.254$) or MoCA ($P = 0.629$).

Using ordinal group membership (low loss, high loss, failed screening), the worse hearing was associated with significantly poorer MMSE score ($B = -0.308$, $P = 2.73 \times 10^{-6}$) and MoCA score ($B = -0.477$, $P = 3.52 \times 10^{-4}$). Total MMSE and MoCA scores split by group membership are shown in Figure 4. Post hoc tests showed that there was not a significant difference in MMSE or MoCA between low loss and high loss groups ($P = 0.292$, $P = 0.205$, respectively), but there was a significant difference between low loss and failed ($P = 1.59 \times 10^{-5}$, $P = 8.76 \times 10^{-5}$, respectively) and high loss and failed ($P = 1.78 \times 10^{5}$, $P = 2.31 \times 10^{-8}$, respectively). In both cognitive tests, "failed" score listeners performed worse than either "low" or "high" loss listeners.

In a comparison of hearing aid users to non–hearing aid users, adjusting for age and sex, hearing aid users performed significantly differently in MMSE ($F[1] = 7.25$, $P = 0.007$) and MoCA tests ($F[1] = 5.86$, $P = 0.016$). Comparing the marginal means from these models, the average MMSE was poorer for hearing aid users than "low loss" and was better than "failed" listeners. For MoCA, hearing aid users had better performance than "failed" listeners but were not significantly different from either the "low loss" or "high loss" groups.

4 | DISCUSSION

In a population-representative cohort of 6006 participants between 50 and 75 years old, subjective reports of hearing and short-term memory problems were associated with a 40% to 50% increased risk of receiving a dementia diagnosis compared to those who did not report subjective hearing and memory problems, within 17 years. Participants who self-reported both hearing and short-term memory problems had approximately twice the risk of developing dementia compared to participants with neither problem. This supports the hypothesis that subjective complaints of hearing problems and short-term memory problems have utility as early markers of individuals at higher risk for dementia. When a subsection of this cohort was assessed cross-sectionally after 14 years, poorer audiometric performance was also associated with lower overall cognitive scores. Individuals with hearing aids showed better cognitive performance than the greatest hearing loss group but were not significantly different from the high loss group.

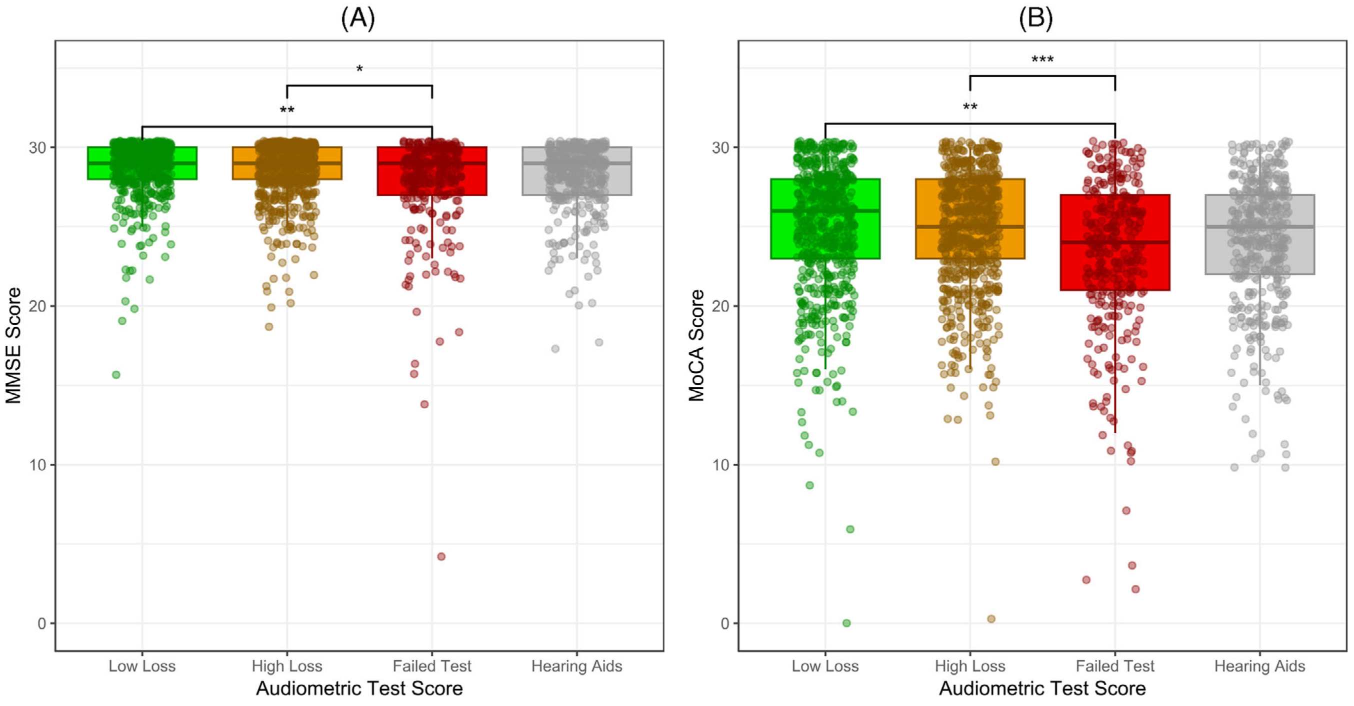

FIGURE 4 Boxplots of (A) total MMSE scores and (B) total MoCA scores split by audiometric screening outcome, plus hearing aid users. Points are jittered to show distribution. Significance of group differences adjusted for age, sex, and education: * = $P < 0.05$, ** = $P < 10^{-3}$, *** = $P < 10^{-5}$. MMSE, Mini–Mental State Examination; MoCA, Montreal Cognitive Assessment

The primary finding, that subjective self-reports of hearing and memory problems at baseline were associated with greater dementia risk, supports previous work suggesting links among hearing problems,[22] memory problems,[28] and dementia. The magnitude of the effect seen for hearing problems and dementia is similar to work using both objective hearing loss (e.g., 55% increased risk of dementia in Deal et al.[4] using pure-tone audiometry, 30% in Su et al.[5] from health insurance record of hearing loss) and subjective hearing difficulties (40%–60% increased risk of dementia in Davies et al.,[22] depending on severity). The magnitude for subjective memory problems is slightly lower than that found in other cohorts (e.g., relative risk of dementia of 1.8 in Luck et al.[27] and 2.0 in Rönnland et al.,[33] using memory complaints), although this may be because we limited our assessment to short-term subjective memory rather than all subjective memory complaints. Unlike previous work, however, our work suggests that participants who experience subjective problems across both hearing and memory domains are at the greatest risk of dementia, with approximately twice the overall risk compared to unaffected controls, accounting for age and sex. We note that there was no interaction seen between these problems, suggesting that this effect is additive.

We also found associations between subjective hearing and memory problems at baseline and cognitive performance at the 14-year follow-up, but we are more cautious in interpreting these results. The magnitude of these differences was small, with the greatest mean differences (between those who reported no problems at baseline versus those who reported both problems at baseline) being less than one point on either MMSE or MoCA. While statistically significant, this difference may not be meaningful in a clinical setting. Additionally, we do not have access to the cognitive performance of individuals in this cohort at baseline and so do not know whether, and by how much, individuals' cognitive scores have changed in the 14-year interval between baseline and assessment. For example, short-term memory is a factor that is assessed in both the MMSE and MoCA, so an association between subjective memory and cognitive performance here may represent a continuation of the same problem rather than a relationship between risk factors and outcome.

Greater levels of hearing loss assessed cross-sectionally with audiometric screening were associated with poorer cognitive performance, even in participants who did not report a hearing problem at baseline (data not reported here). These effect sizes were also small, with the greatest group differences only averaging ≈ half a point on either cognitive scale after adjustment for sex, age, and education. This suggests that there may be an acute effect of hearing problems, although we note that these participants are likely to have experienced subjective hearing problems in the interval between baseline and follow-up. Future work therefore should consider the duration of hearing problems as a contributing factor to cognitive impairment.

Other work has demonstrated a lower risk of cognitive impairment in individuals who use hearing aids[10] compared to HI individuals without the use of sensory aids. We did not find any difference in the overall risk of dementia between participants with hearing problems who did and did not use hearing aids, but this only included information on hearing aid use at baseline. In the cross-sectional sub-cohort, hearing aid users were found to have better cognitive performance than the poorest listeners (those who did not reach the threshold for any frequency on the screening test). However, hearing aid users were not significantly different from the "high loss" group in cognitive test scores. Previous work that has found links between hearing aid use and cognition has been primarily longitudinal in nature.[12,13] As we do not have information in our study on baseline cognition, and when participants started to use hearing aids, we are unable to make claims about the long-term effects of hearing aid usage on cognition or dementia risk.

Strengths of this work include the large number of participants, in particular the number with cross-sectional data available from the 14-year follow-up, ≈ 47% of the starting cohort. Additionally, as this cohort is population representative at baseline, we are able to look at the prevalence of subjective hearing and short-term memory problems in the general population in the baseline dataset (9.7% and 24.2%, respectively). These individuals were 50 to 75 years of age at inclusion, and so by the end of follow-up, all living individuals had reached the age at which late-onset dementia had begun to occur.[34] The long duration enables us to look at subjective sensory and cognitive complaints that occurred in many cases over a decade prior to the diagnosis of dementia, and several years prior to when MCI is likely to have been detectable.

A limitation of this work is that the sub-cohort used for cross-sectional data only contained individuals who lived long enough and were cognitively sound enough, to complete all tests. In the cross-sectional data, there were a small number of participants who had previously been diagnosed with dementia. However, these were low numbers (≤ 10 per group), and participants with previous or imminent dementia diagnoses also achieved moderate or good auditory screening thresholds. It was also necessary for participants to have good enough hearing to be able to process the questions being asked of them during the cognitive assessments. We do not have any information available on speech perception ability from this follow-up, so we are unable to assess its impact. Our data on objective hearing loss came from an auditory screening assessment, rather than the gold standard pure tone audiogram (PTA). As a consequence, the level of precision and total frequency coverage were lower than would be achievable with a PTA, which may contribute to the lack of group differences seen for "low loss" and "high loss" listeners.

At the 14-year follow-up, this cohort was aged 64 to 89 (median age 74.7). Although 5.2% of participants in the entire ESTHER cohort developed dementia, only 2.4% of participants who remained until the 14-year follow-up had a diagnosis of dementia by that time, compared to 8.5% in those participants without cross-sectional data from this time point. The rate of dementia in participants who remained in the study is lower than estimated dementia prevalence rates in people > age 65 in the general population, which are two to three times greater.[35,36] This sub-cohort was also more likely to have completed tertiary education, a protective factor against dementia and MCI,[8] and to have reported lower rates of baseline hearing problems, which we have shown here may be related to dementia risk. Additionally, only 4.9% of MMSE scores were < 25, a common cut-off for MCI, compared to estimates of 15% to 20%[37,38] in comparable cohorts. This means that the effects seen in participants tested cross-sectionally are likely to be underestimated, and true effects in the population may be greater.

In conclusion, subjective reports of hearing and short-term memory problems are associated with a greater risk of dementia in later life, and may also be associated with poorer cognition. As subjective complaints are detectable earlier than objective measures and can be performed simply with single questions, they have the potential for utility as tools for the earlier detection of at-risk individuals. We also show that greater levels of objective hearing loss in those > 65 years of age are associated with poorer cognitive performance, supporting the notion that uncorrected hearing loss is a contributory factor to cognitive impairment. Furthermore, individuals who self-report both hearing problems and memory problems are at the greatest risk for dementia and should be prioritized for intervention and study.

ACKNOWLEDGMENTS

The ESTHER study was supported by grants from the Baden-Württemberg Ministry of Science, Research and Arts; the German Federal Ministry of Education and Research; the German Federal Ministry of Family, Senior Citizens, Women and Youth; the Saarland Ministry of Social Affairs, Health, Women and Family; and the Network Aging Research at Heidelberg University. JS is supported by the Heidelberg-Mannheim Life Science Alliance.

CONFLICT OF INTEREST STATEMENT

The authors have no competing interests to declare. Author disclosures are available in the supporting information.

CONSENT STATEMENT

All participants in the ESTHER study provided informed consent for the collection and use of their data.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Stevenson-Hoare J, Stocker H, Trares K, Holleczek B, Brenner H. Subjective hearing and memory problems are associated with dementia and cognition in later life. *Alzheimer's Dement*. 2024;16:e12624.
https://doi.org/10.1002/dad2.12624