

Interacting Role of Social Determinants of Health and Hearing Loss on Cognitive Decline: An ACTIVE Longitudinal Study

Nathalie Gider

ngider@ucsd.edu

University of California, San Diego <https://orcid.org/0009-0001-9766-852X>

Cynthia Felix

University of Pittsburgh

Megan C. Fitzhugh

University of California, San Diego <https://orcid.org/0000-0001-5275-7361>

Caitlin A. Northcutt

University of Kentucky <https://orcid.org/0000-0003-1576-9763>

Michael

University of Alabama at Birmingham <https://orcid.org/0000-0001-7736-4441>

Karlene Ball

University of Alabama at Birmingham <https://orcid.org/0000-0003-1811-9870>

George Rebok

Johns Hopkins University <https://orcid.org/0000-0002-5371-8767>

Tyler Bell

trbell@health.ucsd.edu

University of California, San Diego <https://orcid.org/0000-0001-5702-5995>

Research Article

Keywords: sensory loss, memory, structural determinants, access to healthcare, neighborhood and built environment

Posted Date: October 20th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11406227/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: The authors declare no competing interests.

Abstract

Background

Hearing loss is a leading modifiable risk factor for dementia, yet its cognitive consequences may depend on broader social and structural conditions.

Methods

Using data from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study ($n = 2,397$; M mean age = 73.6 years; 75.9% women), we examined whether self-reported hearing loss predicted 10-year domain-specific cognitive trajectories and whether social determinants of health (SDoH) moderated these associations. Hearing status was categorized as no hearing loss, uncorrected hearing loss, and hearing loss with hearing aid use. Linear mixed-effects models adjusted for age, sex, race, education, depressive symptoms, physical morbidity, and intervention effects.

Results

Hearing loss was associated with lower memory scores and steeper memory decline. However, these associations were conditioned by SDoH. Access to healthcare significantly moderated memory trajectories among participants with uncorrected hearing loss ($\beta = .03$, $SE = .012$, $p = .029$). Individuals with uncorrected hearing loss use showed greater memory decline when healthcare access was low (-1 SD: $\beta = -.02$, $SE = .006$, $p < .001$) and average ($\beta = -.01$, $SE = .004$, $p = .010$), but not when access was high ($+1$ SD: $ps > .50$). Access to healthcare also moderated reasoning trajectories ($\beta = .06$, $SE = .017$, $p < .001$). Participants with uncorrected hearing loss declined more in reasoning at low access ($\beta = -.02$, $SE = .008$, $p = .030$), showed no difference at average access ($p = .970$), and demonstrated better reasoning trajectories at high access ($\beta = .04$, $SE = .012$, $p = .010$). Neighborhood and built environment resources similarly moderated reasoning decline ($\beta = .08$, $SE = .018$, $p < .001$), with greater decline at low resources ($\beta = -.03$, $SE = .008$, $p < .001$) and improved trajectories at high resources ($\beta = .06$, $SE = .013$, $p < .001$). No significant SDoH moderation effects were observed among participants with hearing loss using hearing aids.

Conclusion

These findings indicate that the cognitive impact of hearing loss depends on structural resources, highlighting the need to integrate sensory health and social context in dementia prevention efforts.

Introduction

Dementia continues to contribute to immense economic burden and morbidity in older age. In the United States (US), the number of new dementia cases per year is projected to increase from 514,000 (in 2020) to about one million by 2060 (Fang et al., 2025). Similarly, healthcare-related costs associated with dementia are estimated to increase from \$450 billion (in 2020) to \$3.3 trillion by 2026 (Nandi et al., 2024). Dementia is also a major cause of disability in older adults (Bowe et al., 2018). This alarming surge in both incidence and healthcare costs highlights the critical need to reduce the number of older adults with dementia. One approach for reducing dementia cases is to focus on primary prevention by targeting dementia risk factors. According to the Lancet Commission on Dementia Prevention (2024), hearing loss is the largest potentially modifiable risk factor for dementia, accounting for 7% of total risk. The risk appears to increase with the severity of hearing loss, with a dose-response relationship observed with each 10-decibel worsening in hearing associated with a 16% increase in dementia risk (Yu et al., 2024).

However, measuring hearing loss remains a methodological challenge in conducting and analyzing studies on hearing loss, particularly in large cohort studies of aging. While pure tone audiometry (PTA) is deemed the gold standard measure of hearing loss in clinical settings, its pragmatic value is limited in community-based settings due to the need for specialized equipment and trained personnel. However, PTA does not necessarily indicate the capacity of an older adult to accurately identify speech amidst noise in real-world situations, which is a challenging auditory-cognitive system task for aging adults (Anderson et al., 2013). Self-reported hearing loss may therefore be a useful pragmatic tool in cohort studies, as it reflects one's perceived hearing difficulty across situations, can be easily assessed during community surveillance, and corresponds to objective measures of hearing (Kim et al., 2022; Tsimpida et al., 2020).

Self-reported hearing loss is consistently associated with increased risk of dementia, mild cognitive impairment, and cognitive decline in older adults (Jang et al., 2025; Pabst et al., 2021; Ying et al., 2023; Yu et al., 2024; Zhao et al., 2025). Yet, dementia outcomes may overlook more subtle but clinically meaningful cognitive effects. Some studies using both audiometric and self-reported hearing measures have linked hearing loss to poorer performance across several cognitive domains, including memory, orientation, language, computation, and drawing, with some evidence of dose-response effects (Marques et al., 2026; Zhao et al., 2025). Whether hearing loss shows comparable associations with reasoning and other non-memory domains remains less studied. For effective interventions that target primary prevention of dementia, it is imperative to study early, domain-specific cognitive trajectories in dementia-free older adults with and without hearing loss.

Social and environmental factors that influence the association between hearing loss and cognitive decline are also important to investigate, as they may help identify explanatory mechanisms or modifiable pathways that could mitigate this association. Such factors can be captured by looking at social determinants of health (SDoH). SDoH describes factors leading to health disparities and include five major domains, as described by Healthy People 2030: educational access and quality, health care access and quality, neighborhood and built environment, economic stability, and social and community

context. Many of these factors have been shown to separately predict prevalence of hearing loss and access to hearing interventions (Schuh & Bush, 2022; Terhaar et al., 2024), as well as the rate of cognitive decline (Majoka & Schimming, 2021). There is also evidence suggesting that SDoH factors can moderate the association between hearing loss and cognitive decline. For example, neighborhood disadvantage and low social cohesion have been shown to relate to cognitive impairment in those with hearing loss, while higher educational attainment and economic stability are protective against both hearing impairment and cognitive impairment (Cheung & Zhang, 2024).

The purpose of the present study was to examine associations between self-reported hearing loss and cognitive performance in specific cognitive domains, and to investigate the moderating role of SDoH in these relationships. Specifically, we examined the associations of self-reported hearing loss status with memory, reasoning, and speed of processing and their change over 10 years in a community-based sample. Due to strong associations with dementia risk, we hypothesized that self-reported hearing loss would be associated with worse baseline memory and memory decline. We then explored the moderating role of SDoH, with the hypothesis that the adverse effects of hearing loss on cognition would be most pronounced among individuals experiencing socioeconomic disadvantage (e.g., more disadvantageous neighborhood and built environment, lower economic stability, health care access). Together, these aims sought to obtain a comprehensive understanding of how self-reported hearing loss contributes to cognitive aging and the contextual factors that may amplify or attenuate this risk.

Methods

Participants

The analytic sample consisted of participants from the ACTIVE study (ClinicalTrials.gov Identifier NCT00298558). The purpose of the ACTIVE study was to test the efficacy of three cognitive training programs (vs. a no-contact control) on older adults' cognition and everyday functioning. Recruitment occurred from March 1998 to October 1999 across 6 sites in the U.S.: Birmingham, Alabama; Detroit, Michigan; Indianapolis, Indiana; Baltimore, Maryland; State College, Pennsylvania; and Boston, Massachusetts.

Participants included community-dwelling adults aged 65 years and older who did not present the following exclusion criteria: (1) Mini Mental Status Examination (MMSE) < 23 or reported a diagnosis of dementia; (2) functional impairment (i.e., required extensive assistance with activities of daily living like dressing, bathing, or personal hygiene) (Morris et al., 1997); (3) self-reported diagnosis of stroke in the last 12 months; (4) self-reported diagnosis of certain cancers and/or current chemo- or radiation therapy; (5) self-reported problems in vision (e.g., difficulty reading news or visual acuity worse than 20/50), hearing or communication difficulties that would prevent full participation in the intervention or outcome assessments; (6) received cognitive training previously; or (7) had been unable to meet time requirements of the study. At the time of screening, an interviewer ensured that the participant could

hear and communicate sufficiently to complete testing, otherwise they were excluded. Additional details regarding the ACTIVE study are discussed elsewhere (Jobe et al., 2001).

The analytic sample included 2,397 participants who had complete data on cognition and hearing loss across all intervention arms in order to have maximum power for analyses. Because all participants met the MMSE ≥ 23 screening criteria at enrollment, the sample should be interpreted as a community-dwelling cohort screened for intact cognitive functioning at baseline, rather than a clinically confirmed, cognitively unimpaired group.

Procedure

All study procedures were approved by the Institutional Review Boards at participating sites. After an initial telephone screening, eligible participants provided written informed consent in person and completed baseline surveys and evaluations of daily habits, psychosocial functioning, health status, and assessments of physical and cognitive performance (see more details below). Participants were then randomized to one of three cognitive training groups or a no-contact control group. The ACTIVE intervention targeted memory, reasoning, and speed of processing - domains known to show early age-related decline and to be closely tied to daily functioning. Training was delivered in small groups over ten 60–75-minute sessions across 5–6 weeks.

Memory training emphasized verbal episodic memory through instruction and practice in mnemonic strategies; reasoning training focused on solving problems with serial patterns; and speed-of-processing training enhanced visual search and the capacity to manage increasingly complex information presented in progressively shorter time intervals. Booster training, consisting of four 75-minute sessions at 11- and 35-months post-intervention, was offered to a random subset (39%) of participants in each training group who had completed at least eight of the ten initial sessions. Follow-up assessments occurred immediately post-intervention and at 1, 2, 3, 5, and 10 years.

The present study included participants from all intervention conditions, adjusting for intervention effects in analyses to maximize sample size. Intervention effects are detailed in previous work (Ball et al., 2002; Rebok et al., 2014). All data relevant to this publication are publicly available. (<https://www.icpsr.umich.edu/web/NACDA/studies/36036>).

Measures

Hearing loss. At baseline health interviews, participants were asked “Do you feel that you have hearing loss?” with ‘yes’ or ‘no’ responses. If a participant said ‘yes,’ they were additionally asked “Do you wear a hearing aid?” with ‘yes’ or ‘no’ responses. These answers were used to create a three-level grouping variable of no hearing loss, uncorrected hearing loss, and hearing loss with hearing aid use. During assessments, participants were permitted to wear their hearing aids.

Cognitive Domains. Cognitive performance was assessed across several domains, including speed of processing, memory, and reasoning. Speed of processing was assessed using the Useful Field of View (UFOV®) test (Ball & Owsley, 1993). This was calculated as a z-score composite of UFOV® subtest 2 (UFOV2), UFOV® subtest 3 (UFOV3), and UFOV® subtest 4 (UFOV4). UFOV2 required identifying a central object and locating a peripheral object. UFOV3 involved identifying the central object and locating the peripheral object with distractor symbols included, while UFOV4 included a more complex central identification task along with the peripheral localization task and distractors. Episodic memory was evaluated using accuracy recall scores on the Hopkins Verbal Learning Test (HVLT) (Brandt, 2001), Rey-Auditory Verbal Learning Test (AVLT) (Lezak, 2004), and the Paragraph Recall subtest (PRT) of the Rivermead Behavioral Memory Test (Wilson, 1985). These tests required participants to listen to a list of words or a short story and immediately recall the information, with scores reflecting the total number of correctly recalled words. During the task, participants were permitted to use their personal hearing aids or a provided pocket talker (data on this were not publicly available). Prior to test initiation, the examiner confirmed that each participant could hear clearly. Reasoning abilities were measured based on accuracy on tasks from the Adult Development and Enrichment Project, specifically the Letter Series, Letter Sets, and Word Series tasks (Blieszner et al., 1981). These tasks involve executive function and problem-solving skills to identify patterns of letters or words (visually presented). For composites, test performance was z-scored and then used to create an average z-score for each cognitive domain. All tests and their resulting composites were z-scored in a direction such that more positive scores indicated better performance.

Social Determinants of Health (SDoH) Composites. SDoH was captured using 5 domains recognized by Healthy People 2030: economic stability, education access and quality, health care access and quality, neighborhood and built environment, and These composites were previously created by Clay et al. (2022) via factor analysis with varimax rotation to create orthogonal, uncorrelated factors. These factors included both person-level data from the ACTIVE study and neighborhood-level data sources obtained from linked 2000 U.S. Census block group level information via geocoding of participants (Clay et al., 2022; Meyer et al., 2017; Sisco & Marsiske, 2012). Other sources of information used to provide contextual information included the North American Industry Classification System (NAICS) data for a list of businesses by type in a zip code (e.g., grocery stores) and occupational information from the Dictionary of Occupational Titles to code occupational status (Clay et al., 2022; Meyer et al., 2017; Sisco & Marsiske, 2012). Economic stability was comprised of the percent of people with college degrees, the presence of sports and recreation instruction, median home value, and median rent in zip code. Education access and quality was comprised of self-reported years of education and occupation converted into ratings describing degree of involvement in data, people, and things from 1 (minimal) to 8 (a lot) from self-reported occupation. Health care access and quality was measured by the number of doctors, number of hospitals, number of pharmacies and other drug stores, number of services for older adults and persons with disabilities, and number of supermarkets and other (non-convenience) grocery stores in zip code. Neighborhood and built environment were comprised of the number of owner-

occupied homes and the number of single unit dwellings in zip code. Direction and weights of factor loading can be found in Clay et al. (2022).

Covariates. Models were adjusted for potential confounders including participant's age, sex, years of education, and race. The self-reported race options included White, Black, Asian, Native American, Pacific Islander, American Indian or Alaskan Native, Bi-racial, and Other. Due to small sample sizes, self-reported race responses were grouped in analyses as White and Black/Other. We additionally adjusted for depressive symptoms using the Center for Epidemiologic Studies Depression Scale-12 item (CESD) (Radloff, 1977). The CESD asks participants to indicate how often they experienced 12 depressive symptoms during the previous week, with response options ranging from none of the time (0) to most or all the time (3). Higher CESD scores indicate more severe depressive symptoms. Lastly, we adjusted for the intervention effect of the trial using a four-level grouping variable (1 = memory training; 2 = reasoning training; 3 = speed of processing training; 4 = no-contact control [reference level]) and an intervention group by time interaction (e.g., years since baseline_{*i*} × intervention_{*i*}).

Statistical Analysis

All analyses were conducted in R (version 4.1.0). We began by characterizing the sample through descriptive statistics and frequencies of key study variables. To address our primary research questions, we fit linear mixed-effects models using the lmer package. This approach was well suited to our data for several reasons. First, the ACTIVE design yielded repeated cognitive assessments nested within participants, and mixed-effects models appropriately account for the non-independence of these observations. Second, including a random intercept allowed us to model between-person differences in baseline cognitive performance while simultaneously estimating within-person change over time, which was essential for testing whether cognitive trajectories differed by hearing loss group. Third, linear mixed-effects models accommodate unbalanced data and participants with varying numbers of follow-up visits, preserving statistical power relative to listwise-deletion approaches.

We first estimated a series of base models, one per cognitive domain, to test whether hearing loss was associated with baseline cognition and with rate of cognitive change. Each model took the following form: Cognitive Domain_{*i*} = $\beta_0 + \beta_1(\text{years [since baseline]})_i + \beta_2(\text{hearing loss group})_i + \beta_3(\text{years}_i \times \text{hearing loss group}_i) + \beta_4(\text{sex})_i + \beta_5(\text{education})_i + \beta_6(\text{age at baseline})_i + \beta_7(\text{depressive symptoms})_i + \beta_8(\text{intervention group})_i + \beta_9(\text{years}_i \times \text{intervention group}_i) + u_{0i} + \epsilon_i$. In this specification, β_2 tested whether the cognitive domain of interest differed across hearing loss groups at baseline, and β_3 tested whether the rate of change in that domain differed across groups. The random intercept (u_{0i}) captured between-person differences in baseline performance, and ϵ_i represented the residual within-person error. Sex, education, baseline age, depressive symptoms, and intervention assignment were included as covariates; the years × intervention group term accounted for the possibility of differential change by intervention arm.

We next extended these models to examine whether SDoH moderated the relationship between hearing loss and cognition. Because our interest was in whether hearing-loss-related cognitive differences and trajectories varied by SDoH context, we specified a three-way interaction among time, hearing loss group, and each SDoH factor, along with all constituent lower-order terms. These expanded models took the following form: $\text{Cognitive Domain}_i = \beta 0_i + \beta 1(\text{years})_i + \beta 2(\text{hearing loss group})_i + \beta 3(\text{years}_i \times \text{hearing loss group}_i) + \beta 4(\text{sex})_i + \beta 5(\text{education})_i + \beta 6(\text{age at baseline})_i + \beta 7(\text{depressive symptoms})_i + \beta 8(\text{intervention group})_i + \beta 9(\text{years}_i \times \text{intervention group}_i) + \beta 10(\text{SDoH factor})_i + \beta 11(\text{years}_i \times \text{SDoH factor}_i) + \beta 12(\text{hearing loss group}_i \times \text{SDoH factor}_i) + \beta 13(\text{years}_i \times \text{hearing loss group}_i \times \text{SDoH factor}_i) + u_{0i} + \varepsilon_i$. Here, $\beta 12$ tested whether baseline differences in cognition across hearing loss groups varied by level of the SDoH factor, while $\beta 13$ (the three-way interaction) tested whether hearing-loss-related cognitive change varied by SDoH level. When interactions reached significance, we probed them using the emmeans package, estimating the association between hearing loss and cognition at low (-1 SD), average (M), and high (+ 1 SD) levels of the SDoH factor.

A priori power analyses conducted with the simr package indicated that our sample provided 91% power to detect even a small effect ($d = 0.20$) within this modeling framework. All associations are reported as approximated standardized betas (β s) to convey effect size, obtained by z-scoring continuous outcomes and continuous predictors prior to model fitting, except for time (years since baseline), which was retained in its original metric. Accordingly, β s for time and for interactions involving time represent yearly effects expressed in standard-deviation units of the outcome. To account for multiple testing across cognitive domains and SDoH factors, all p-values from models were adjusted using the Benjamini-Hochberg procedure. All code for this project is available online (https://github.com/trbellucsd/ACTIVE_Hearing_Loss).

Results

Participant Descriptives

Participants had an average age of 73.56 (SD = 5.56) years, 75.9% were female, and the mean education was 13.35 (SD = 2.67) years (see Table 1 for full participant demographics). Of the sample, 33.2% ($n = 795$) individuals had uncorrected hearing loss, and 9.2% ($n = 221$) participants had hearing loss with hearing aid use. Compared to participants without hearing loss, participants with hearing loss were generally older, more likely to be male, White, have more physical morbidities, and have worse economic stability, better educational and occupational status, and better social community contexts ($ps < .01$). Participants with hearing loss using a hearing aid were older and more likely to be male than participants with hearing loss who did not use a hearing aid ($ps < .01$).

Table 1
Descriptives of the analytical sample at baseline.

Age		Overall Sample (n = 2397)	No Hearing Loss (n = 1381)	Hearing Loss No Aid (n = 795)	Hearing Loss Using Aid (n = 221)	F/χ ²	p
	M (SD)	73.05 (5.56)	72.24 (5.19)	73.48 (5.65)	76.55 (6.00)	88.41	< .001 ^{abc}
Education (years)	M (SD)	13.35 (2.66)	13.29 (2.64)	13.36 (2.64)	13.67 (2.86)	1.72	.180
Sex	n (%)	1830 (76.3)	1129 (81.8)	575 (72.3)	126 (57.0)	78.47	< .001 ^{abc}
Female	n (%)	567 (23.7)	252 (18.2)	220 (27.7)	95 (43.0)		
Male							
Race	n (%)	1660 (69.3)	878 (63.6)	600 (75.5)	182 (82.4)	62.71	< .001 ^{ab}
White	n (%)	710 (29.6)	492 (35.6)	183 (23.0)	35 (15.8)		
Black					4 (1.8)		
Other		27 (0.01)	11 (0.8)	12 (1.5)			
Memory	M (SD)	-.09 (.91)	.14 (.84)	-.02 (.90)	-.40 (.99)	36.72	< .001 ^{abc}
Reasoning	M (SD)	-.03 (.89)	-.03 (.90)	.01 (.86)	-.06 (.91)	.74	.477
Speed of Processing	M (SD)	-.02 (.89)	.08 (.85)	-.01 (.88)	-.12 (.95)	6.16	.002 ^{ab}
Depressive Symptoms (CESD)	M (SD)	5.17 (5.14)	4.92 (4.96)	5.44 (5.32)	5.73 (5.52)	5.43	.005 ^{ab}
Physical Morbidities	M (SD)	2.52 (1.57)	2.44 (1.56)	2.64 (1.60)	2.61 (1.47)	4.93	.008 ^{ab}
SDoH Factors							
Economic Stability	M (SD)	-.04 (1.01)	-.25 (.78)	-.20 (.77)	-.07 (.85)	47.17	< .001 ^{ab}
Access to Healthcare	M (SD)	-.01 (1.00)	-.02 (.99)	-.02 (.99)	.05 (1.05)	1.02	.360

Note. ^a indicates a significant difference between no hearing loss versus hearing loss no aid, ^b indicates a significant difference between no hearing loss versus hearing loss using aid, ^c indicates a significant difference between hearing loss no aid versus hearing loss using aid.

Age		Overall Sample (n = 2397)	No Hearing Loss (n = 1381)	Hearing Loss No Aid (n = 795)	Hearing Loss Using Aid (n = 221)	F/ χ^2	p
	M (SD)	73.05 (5.56)	72.24 (5.19)	73.48 (5.65)	76.55 (6.00)	88.41	< .001 ^{abc}
Education and Occupational Status	M (SD)	.21 (.78)	.03 (1.00)	.03 (.99)	.16 (1.09)	22.94	< .001 ^b
Neighborhood and Built Environment	M (SD)	.11 (.95)	.07 (.95)	.15 (.94)	.14 (.96)	2.32	.100
Note. ^a indicates a significant difference between no hearing loss versus hearing loss no aid, ^b indicates a significant difference between no hearing loss versus hearing loss using aid, ^c indicates a significant difference between hearing loss no aid versus hearing loss using aid.							

Association of Hearing Loss Status with Baseline Cognition and Cognitive Decline

To test how cognitive domains differed at baseline and over time by hearing loss status, a linear-mixed model was conducted separately for memory, reasoning, and speed of processing. Full model results are shown in Supplemental Table 1. At baseline, people with hearing loss had worse memory than participants without hearing loss (uncorrected hearing loss: $\beta = -.09$, $SE = .037$, $p = .015$; hearing loss with hearing aid use: $\beta = -.32$, $SE = .062$, $p < .001$). Furthermore, participants with hearing loss using a hearing aid had worse memory compared to participants with hearing loss not using a hearing aid ($\beta = -.23$, $SE = .063$, $p < .001$). There were no baseline differences in reasoning or speed of processing ($ps > .05$).

Over time, participants with hearing loss had greater yearly decline in memory than participants with no hearing loss (hearing loss no aid use: $\beta = -.03$, $SE = .01$, $p = .004$; hearing loss using hearing aid: $\beta = -.06$, $SE = .02$, $p = .005$). There was no discernible difference in the rate of memory decline between participants with hearing loss using a hearing aid versus not ($p = .220$). Hearing loss status did not relate to annual changes in reasoning or speed of processing ($ps > .05$).

Moderation by Social Determinants of Health

To evaluate whether SDoH factors modified the association between hearing loss status and both baseline cognition and cognitive change, we expanded our linear mixed-effects models to include

interaction terms between hearing loss status and each SDoH factor. Full results are presented in Supplemental Table 2.

Access to healthcare significantly moderated the association between uncorrected hearing loss (vs. no hearing loss) and yearly declines in memory ($\beta = .03$, $SE = .01$, $p = .029$) (Fig. 2A). Participants with hearing loss who did not use a hearing aid showed greater decline than those without hearing loss when access to healthcare was low (-1 SD: $\beta = -.02$, $SE = .006$, $p < .001$) and when it was average ($\beta = -.01$, $SE = .004$, $p = .010$). However, when access to healthcare was high ($+1$ SD), their rate of memory decline did not differ from those without hearing loss ($ps > .50$).

Access to healthcare also significantly moderated the association between uncorrected hearing loss (vs. no hearing loss) and reasoning ($\beta = .06$, $SE = .02$, $p < .001$) (Fig. 2B). Participants with uncorrected hearing loss also declined more than those without hearing loss when access to healthcare was low (-1 SD: $\beta = -.02$, $SE = .008$, $p = .030$). At average levels of access, there was no difference between groups ($p = .970$). At high access to healthcare ($+1$ SD), participants with hearing loss and no aid use showed better reasoning over time compared to those without hearing loss ($\beta = .04$, $SE = .012$, $p = .010$).

Neighborhood and built environment factors showed a similar moderating effect on reasoning decline. Compared to participants without hearing loss, those with uncorrected hearing loss had greater reasoning decline when neighborhood/built environment resources were low (-1 SD: $\beta = -.03$, $SE = .008$, $p < .001$), no difference at average levels ($p = .930$), and better reasoning over time when resources were high ($+1$ SD: $\beta = .06$, $SE = .013$, $p < .001$). This moderation is illustrated in Fig. 3.

A notable asymmetry in these findings warrants acknowledgment: hearing loss showed no significant main effect on reasoning trajectories in the base models, yet SDoH factors moderated reasoning change specifically within the uncorrected hearing loss group. The mechanism underlying this pattern is not clear. Given the limited prior literature on hearing loss and reasoning specifically, these findings should be treated as exploratory.

Lastly, no SDoH factor moderated the association of hearing loss with annual changes in speed of processing ($ps > .05$). As well, no SDoH factor moderated the association of hearing loss with aid use and baseline cognitive functioning or annual decline compared to those who reported no hearing loss.

Discussion

Hearing loss is a major risk factor for dementia, but how hearing loss relates to early cognitive change is less clear. In this study, we found that hearing loss is related to poorer memory at baseline and accelerated memory decline over 10 years – even in a sample that was relatively healthy and cognitively unimpaired at baseline. Our main finding that hearing loss related to worse memory and greater memory decline is consistent with prior longitudinal work (Jang et al., 2025; Lin et al., 2013; Pabst et al., 2021). Whether these memory-related effects generalize across social and structural contexts – or whether

structural conditions fundamentally alter the cognitive impact of hearing loss – is the central question addressed by the SDoH analyses discussed below.

Our most important findings focused on SDoH moderators of the association of hearing loss with cognitive decline. First, we found that the cognitive consequences of hearing loss appear dependent on access to healthcare. Among people with lower access to healthcare, hearing loss was related to decline in memory and reasoning – but not so in individuals with high levels of access. No other study has directly assessed the moderating role of access to healthcare – but this is aligned with studies highlighting the importance of healthcare barriers. For example, in the US only 1 in 5 adults with hearing loss have access to hearing aids, likely due to a combination of their high cost, lack of insurance coverage, and lack of knowledge about healthcare options (Loughrey et al., 2018). Furthermore, the National Academies of Sciences, Engineering, and Medicine has called for addressing access barriers through expanded screening opportunities, delivery of hearing care services, and coverage for assistive hearing devices (Lin et al., 2016). Across quantitative and qualitative studies, older adults name inconsistent access to quality care as the top reason for lack of prompt treatment, including fewer screening opportunities and unaffordable hearing technology (Arnold et al., 2022; Barnett et al., 2017; Ingram et al., 2016). The findings in our study should be interpreted in historical context: the ACTIVE study enrolled participants between 1998 and 1999, well before the 2022 FDA rulemaking that made hearing aids available over the counter without a prescription. The structural barriers documented here may be less prohibitive under the current policy environment, though disparities in uptake and awareness persist.

Second, we found that neighborhood and built environment moderated the association of hearing loss with reasoning decline; whereby the association was in the expected direction for people residing in low neighborhood and built environments but nil and opposite at higher levels of neighborhood and built environments. This observation expands on previous work highlighting the importance of neighborhood and built environment for dementia risk. In the National Health and Aging Trends (NHATS), participants residing in neighborhoods with physical disorder, characterized as having litter, trash, graffiti, and vacant homes/businesses, were more likely to develop dementia (Cheung & Zhang, 2024).

We did not find a significant moderating role of social cohesion, which is surprising given previous studies – however, the direction of these effects is complex and inconsistent. For example, in one study, hearing loss was associated with worse cognitive function among those with low social activity and social networks (Cao et al., 2023). Whereas, in another study using NHATS data, moderate to severe hearing loss was associated with dementia in individuals who were not socially isolated, but not among socially isolated individuals (Venkatesh et al., 2026). In our study, the null result for social cohesion moderation may also reflect limitations in how this domain was operationalized. The SDoH composites rely substantially on zip code and census block-level data; the social and community context composite may not capture the individual-level social network quality or degree of social isolation that characterizes more targeted measures used in prior work. Thus, social cohesion may be too complex to examine at the population-level without more detailed measures that capture phenotyping at the individual level.

Regarding our hearing aids results, hearing aids have generally been positioned as protective against cognitive decline and dementia. Observational studies have reported that hearing aid use is associated with reduced incidence of Alzheimer's disease and related dementias (Buchholz et al., 2021; Cantuaria et al., 2024) and attenuated rates of cognitive decline (Deal et al., 2017; Lin et al., 2023; Maharani et al., 2018). Cross-sectional evidence further suggests better cognitive performance among aid users than among individuals with uncorrected hearing loss (Dawes et al., 2015). A recent large-scale clinical trial found that hearing aids slowed cognitive decline, but only among participants with additional dementia risk factors (Lin et al., 2023). Contrary to the existing literature, we found that hearing aid use, within the subset of participants self-reporting hearing loss, was associated with lower baseline memory scores compared to both individuals who reported normal hearing and individuals who reported hearing loss but did not use hearing aids. We also found that the rate of cognitive decline was the same between individuals who reported hearing loss, regardless of hearing aid use, suggesting that hearing aids did not appear to mitigate longitudinal cognitive decline in this sample.

Given that this study used self-reported impressions of hearing loss, and not objective assessments, our findings on hearing aids should be interpreted with caution. It is known that hearing aid use increases with hearing loss severity (Reed et al., 2023). It is also known that older adults with hearing loss may wait around nine years to adopt hearing aids after learning they qualify for aids (Simpson et al., 2019). The hearing aid group in this study therefore most plausibly reflects individuals with more severe and longer-standing hearing loss relative to those with uncorrected hearing loss, rather than a group receiving a standardized rehabilitation intervention. This representation of hearing loss severity — not aid use per se — likely accounts for their substantially lower baseline memory scores and limits conclusions about the incremental cognitive effect of hearing aid adoption in this sample.

The current study findings should be interpreted in the context of methodological limitations. Foremost, hearing loss was assessed via self-report rather than audiometry. Thus, the no hearing loss group may have included participants with hearing impairment. However, because ACTIVE screened out individuals with hearing difficulties that interfered with in-person testing, the no-hearing-loss group was unlikely to contain many participants with moderate-to-severe uncorrected hearing loss, which likely limited misclassification to mild cases. Another issue is that our measure of memory was auditory, and no visual memory test was available. This could mean that issues in memory are simply a lack of sensory input rather than actual issues in memory recall and learning. Two factors mitigate this confound to some degree. First, testers made sure that participants could hear and communicate normally during screening, and those who could not were excluded. Second, if our associations with memory were just due to poor hearing of words, we would expect a baseline association but not a more rapid decline in memory. A related issue is that we did not have information on the duration, frequency, fit, or perceived benefit of hearing aid use. The hearing aid group should therefore be interpreted as people with self-identified hearing loss that was severe enough to motivate device adoption, rather than a group receiving a standardized intervention. Lastly, besides White and Black individuals our sample had limited representations for other racial groups, such as Hispanic communities.

In conclusion, self-reported hearing loss was associated with lower baseline memory and accelerated memory decline over 10 years, with these associations most pronounced among older adults with limited healthcare access. These findings suggest that hearing loss is a salient risk factor for memory loss, and that obstacles to healthcare are essential to address. Expanding Medicare coverage for hearing evaluations, hearing aids, and related services could mitigate well-documented financial obstacles to treatment, while investments in community-based screening and over-the-counter hearing aid availability may improve reach among underserved populations. Coupling these strategies with broader efforts to strengthen healthcare infrastructure may provide a more equitable framework for preserving cognitive health in later life.

References

1. Anderson S, White-Schwoch T, Parbery-Clark A, Kraus N (2013) A dynamic auditory-cognitive system supports speech-in-noise perception in older adults. *Hear Res* 300:18–32
2. Arnold ML, Reyes CA, Lugo-Reyes N, Sanchez VA (2022) Hispanic/Latino perspectives on hearing loss and hearing healthcare: Focus group results. *Ear Hear* 43(6):1620–1634
3. Ball K, Berch DB, Helmers KF, Jobe JB, Leveck MD, Marsiske M, Morris JN, Rebok GW, Smith DM, Tennstedt SL, Unverzagt FW, Willis SL (2002) Effects of cognitive training interventions with older adults: a randomized controlled trial. *JAMA* 288(18):2271–2281. <https://doi.org/10.1001/jama.288.18.2271>
4. Ball K, Owsley C (1993) The useful field of view test: a new technique for evaluating age-related declines in visual function. *J Am Optom Assoc* 64(1):71–79
5. Barnett M, Hixon B, Okwiri N, Irungu C, Ayugi J, Thompson R, Shinn JB, Bush ML (2017) Factors involved in access and utilization of adult hearing healthcare: a systematic review. *Laryngoscope* 127(5):1187–1194
6. Blieszner R, Willis SL, Baltes PB (1981) Training research in aging on the fluid ability of inductive reasoning. *J Appl Dev Psychol* 2(3):247–265. [https://doi.org/10.1016/0193-3973\(81\)90005-8](https://doi.org/10.1016/0193-3973(81)90005-8)
7. Bowe B, Xie Y, Li T, Mokdad AH, Xian H, Yan Y, Maddukuri G, Al-Aly Z (2018) Changes in the US burden of chronic kidney disease from 2002 to 2016: an analysis of the global burden of disease study. *JAMA Netw Open* 1(7):e184412
8. Brandt J (2001) Hopkins Verbal Learning Test. *Clinical Neuropsychologist*
9. Bucholc M, McClean PL, Bauermeister S, Todd S, Ding X, Ye Q, Wang D, Huang W, Maguire LP (2021) Association of the use of hearing aids with the conversion from mild cognitive impairment to dementia and progression of dementia: a longitudinal retrospective study. *Alzheimer's Dementia: Translational Res Clin Interventions* 7(1):e12122
10. Cantuaria ML, Pedersen ER, Waldorff FB, Wermuth L, Pedersen KM, Poulsen AH, Raaschou-Nielsen O, Sørensen M, Schmidt JH (2024) Hearing loss, hearing aid use, and risk of dementia in older adults. *JAMA Otolaryngology–Head Neck Surg* 150(2):157–164

11. Cao X, Liu Q, Liu J, Yang B, Zhou J (2023) The impact of hearing loss on cognitive impairment: The mediating role of depressive symptoms and the moderating role of social relationships. *Front Public Health* 11:1149769. <https://doi.org/10.3389/fpubh.2023.1149769>
12. Cheung ESL, Zhang Z (2024) Moderating Role of Neighborhood Environment in the Associations Between Hearing Loss and Cognitive Challenges Among Older Adults: Evidence From US National Study. *Res Aging* 46(7–8):400–413. <https://doi.org/10.1177/01640275241234372>
13. Cheung ESL, Zhang Z (2024) Moderating role of neighborhood environment in the associations between hearing loss and cognitive challenges among older adults: evidence from US national study. *Res Aging* 46(7–8):400–413
14. Clay OJ, Ball KK, Wheeler KM, Crowe M, Marsiske M, Dean LT, Thorpe RJ, Jones R, Owens JH, Rebok GW, Willis SL (2022) Evaluating Social Determinants of Health Domains and Their Predictive Validity Within Black/African American and White Older Adults From the Active Trial. *J Aging Health* 0(0):08982643221111205. <https://doi.org/10.1177/08982643221111205>
15. Dawes P, Emsley R, Cruickshanks KJ, Moore DR, Fortnum H, Edmondson-Jones M, McCormack A, Munro KJ (2015) Hearing loss and cognition: the role of hearing AIDS, social isolation and depression. *PLoS ONE* 10(3):e0119616
16. Deal JA, Betz J, Yaffe K, Harris T, Purchase-Helzner E, Satterfield S, Pratt S, Govil N, Simonsick EM, Lin FR (2017) Hearing impairment and incident dementia and cognitive decline in older adults: the health ABC study. *Journals Gerontol Ser A: Biomedical Sci Med Sci* 72(5):703–709
17. Fang M, Hu J, Weiss J, Knopman DS, Albert M, Windham BG, Walker KA, Sharrett AR, Gottesman RF, Lutsey PL (2025) Lifetime risk and projected burden of dementia. *Nat Med* 31(3):772–776
18. Ingram M, Marrone N, Sanchez DT, Sander A, Navarro C, De Zapien JG, Colina S, Harris F (2016) Addressing hearing health care disparities among older adults in a US-Mexico border community. *Front Public Health* 4:169
19. Jang J-W, Lee S-H, Kim T, Lee E, Park SW, Yeo NY, Kim Y-J (2025) Hearing loss and the risk of dementia: A longitudinal analysis of the Korean National Health Insurance Service Senior Cohort. *J Alzheimer's disease* 104(2):364–373
20. Jobe JB, Smith DM, Ball K, Tennstedt SL, Marsiske M, Willis SL, Rebok GW, Morris JN, Helmers KF, Leveck MD, Kleinman K (2001) ACTIVE: A cognitive intervention trial to promote independence in older adults. *Control Clin Trials* 22(4):453–479. [https://doi.org/10.1016/s0197-2456\(01\)00139-8](https://doi.org/10.1016/s0197-2456(01)00139-8)
21. Kim AS, Betz JF, Albert M, Deal JA, Faucette SP, Oh ES, Reed NS, Lin FR, Nieman CL (2022) Accuracy of self-and proxy-rated hearing among older adults with and without cognitive impairment. *J Am Geriatr Soc* 70(2):490–500
22. Lezak MD (2004) *Neuropsychological assessment*. Oxford University Press
23. Lin FR, Hazzard WR, Blazer DG (2016) Priorities for improving hearing health care for adults: a report from the National Academies of Sciences, Engineering, and Medicine. *JAMA* 316(8):819–820
24. Lin FR, Pike JR, Albert MS, Arnold M, Burgard S, Chisolm T, Couper D, Deal JA, Goman AM, Glynn NW, Gmelin T, Gravens-Mueller L, Hayden KM, Huang AR, Knopman D, Mitchell CM, Mosley T, Pankow JS,

- Reed NS, Coresh J (2023) Hearing intervention versus health education control to reduce cognitive decline in older adults with hearing loss in the USA (ACHIEVE): a multicentre, randomised controlled trial. *Lancet* 402(10404):786–797. [https://doi.org/10.1016/s0140-6736\(23\)01406-x](https://doi.org/10.1016/s0140-6736(23)01406-x)
25. Lin FR, Yaffe K, Xia J, Xue QL, Harris TB, Purchase-Helzner E, Satterfield S, Ayonayon HN, Ferrucci L, Simonsick EM (2013) Hearing loss and cognitive decline in older adults. *JAMA Intern Med* 173(4):293–299. <https://doi.org/10.1001/jamainternmed.2013.1868>
 26. Loughrey DG, Kelly ME, Kelley GA, Brennan S, Lawlor BA (2018) Association of Age-Related Hearing Loss With Cognitive Function, Cognitive Impairment, and Dementia: A Systematic Review and Meta-analysis. *JAMA Otolaryngology–Head Neck Surg* 144(2):115–126. <https://doi.org/10.1001/jamaoto.2017.2513>
 27. Maharani A, Dawes P, Nazroo J, Tampubolon G, Pendleton N, group, Bertelsen SCW, Cosh G, Cougnard-Grégoire S, A., Delcourt C (2018) Longitudinal relationship between hearing aid use and cognitive function in older Americans. *Journal of the American Geriatrics Society*, 66(6), 1130–1136
 28. Majoka MA, Schimming C (2021) Effect of social determinants of health on cognition and risk of Alzheimer disease and related dementias. *Clin Ther* 43(6):922–929
 29. Marques T, Castelhana J, Duarte IC, Pinto-Moura C, Castelo-Branco M, Miguéis A (2026) Association of Age-Related Hearing Loss with Domain-Specific Cognitive Performance in Older Adults. *J Clin Med* 15(6):2322. <https://doi.org/10.3390/jcm15062322>
 30. Meyer OL, Sisco SM, Harvey D, Zahodne LB, Glymour MM, Manly JJ, Marsiske M (2017) Neighborhood Predictors of Cognitive Training Outcomes and Trajectories in ACTIVE. *Res Aging* 39(3):443–467. <https://doi.org/10.1177/0164027515618242>
 31. Morris JN, Fries BE, Steel K, Ikegami N, Bernabei R, Carpenter GI, Gilgen R, Hirdes JP, Topinkova E (1997) Comprehensive clinical assessment in community setting: applicability of the MDS-HC. *J Am Geriatr Soc* 45(8):1017–1024. <https://doi.org/10.1111/j.1532-5415.1997.tb02975.x>
 32. Nandi A, Counts N, Bröker J, Malik S, Chen S, Han R, Klusty J, Seligman B, Tortorice D, Vigo D (2024) Cost of care for Alzheimer’s disease and related dementias in the United States: 2016 to 2060. *npj Aging* 10(1):13
 33. Pabst A, Bär J, Röhr S, Löbner M, Kleineidam L, Heser K, Hajek A, van Der Leeden C, Wiese B, Maier W (2021) Do self-reported hearing and visual impairments predict longitudinal dementia in older adults? *J Am Geriatr Soc* 69(6):1519–1528
 34. Radloff LS (1977) The CES-D Scale. *Appl Psychol Meas* 1(3):385–401. <https://doi.org/10.1177/014662167700100306>
 35. Rebok GW, Ball K, Guey LT, Jones RN, Kim HY, King JW, Marsiske M, Morris JN, Tennstedt SL, Unverzagt FW (2014) Ten-year effects of the advanced cognitive training for independent and vital elderly cognitive training trial on cognition and everyday functioning in older adults. *J Am Geriatr Soc* 62(1):16–24
 36. Reed NS, Garcia-Morales EE, Myers C, Huang AR, Ehrlich JR, Killeen OJ, Hoover-Fong JE, Lin FR, Arnold ML, Oh ES, Schrack JA, Deal JA (2023) Prevalence of Hearing Loss and Hearing Aid Use

- Among US Medicare Beneficiaries Aged 71 Years and Older. *JAMA Netw Open* 6(7):e2326320. <https://doi.org/10.1001/jamanetworkopen.2023.26320>
37. Schuh MR, Bush ML (2022) Evaluating equity through the social determinants of hearing health. *Ear Hear* 43(Supplement 1):15S–22S
 38. Simpson AN, Matthews LJ, Cassarly C, Dubno JR (2019) Time From Hearing Aid Candidacy to Hearing Aid Adoption: A Longitudinal Cohort Study. *Ear Hear* 40(3):468–476. <https://doi.org/10.1097/aud.0000000000000641>
 39. Sisco SM, Marsiske M (2012) Neighborhood Influences on Late Life Cognition in the ACTIVE Study. *J Aging Res*, 2012, 435826. <https://doi.org/10.1155/2012/435826>
 40. Terhaar S, Patel D, Fung E, Mansour F, Wallace JF, Corsten M, McDonald JT, Johnson-Obaseki S, Quimby AE (2024) Association Between Social Determinants of Health and Hearing Loss and Hearing Intervention in Older US Adults. *Otology Neurotology*. 10.1097
 41. Tsimpida D, Kontopantelis E, Ashcroft D, Panagioti M (2020) Comparison of Self-reported Measures of Hearing With an Objective Audiometric Measure in Adults in the English Longitudinal Study of Ageing. *JAMA Netw Open* 3(8):e2015009. <https://doi.org/10.1001/jamanetworkopen.2020.15009>
 42. Venkatesh S, Wong R, Corsten M, McDonald JT, Johnson-Obaseki S, Quimby AE (2026) Elucidating the relationship between hearing loss, social isolation, and dementia: data from the National Health and Aging Trends Study. *J Gerontol B Psychol Sci Soc Sci*. <https://doi.org/10.1093/geronb/gbaf276>
 43. Wilson BAC, Baddeley J, A (1985) The Rivermead Behavioral Memory Test. National Rehabilitation Services
 44. Ying G, Zhao G, Xu X, Su S, Xie X (2023) Association of age-related hearing loss with cognitive impairment and dementia: an umbrella review. *Front Aging Neurosci* 15:1241224
 45. Yu R-C, Proctor D, Soni J, Pikett L, Livingston G, Lewis G, Schilder A, Bamio D, Mandavia R, Omar R (2024) Adult-onset hearing loss and incident cognitive impairment and dementia—a systematic review and meta-analysis of cohort studies. *Ageing Res Rev* 98:102346
 46. Zhao Q, Chen F, Song X, Cai Y, Wu Y, Wan Y, Qiu P (2025) Hearing loss and cognitive impairment among older adults: findings from the China health and retirement longitudinal study. *BMC Public Health* 25(1):1588

Figures

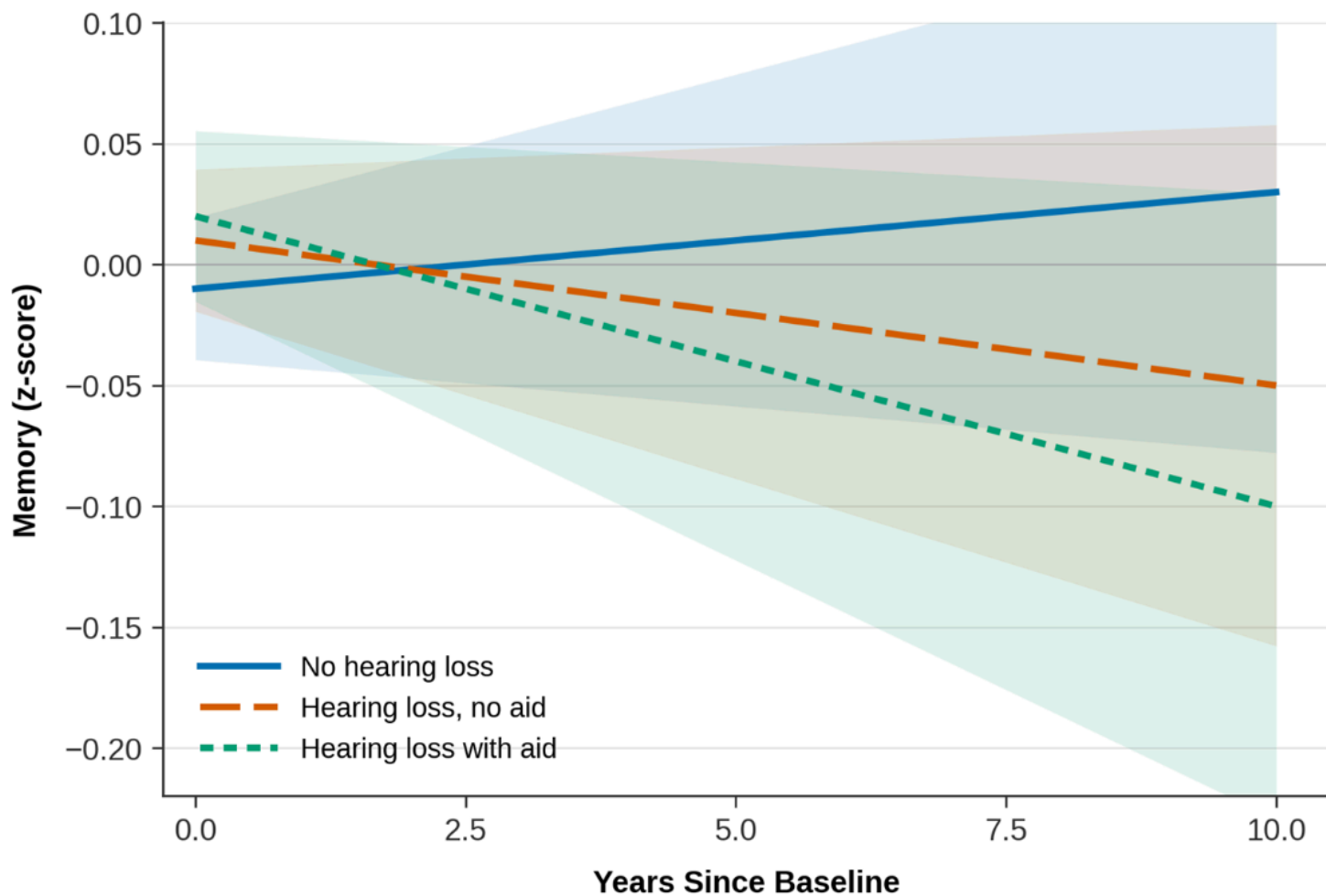


Figure 1

The association of hearing loss status with change in memory. Note. HL = hearing loss. Z-scores reflect performance relative to the full analytic sample mean; negative values indicate below-average performance relative to the overall sample and do not indicate pathological impairment.

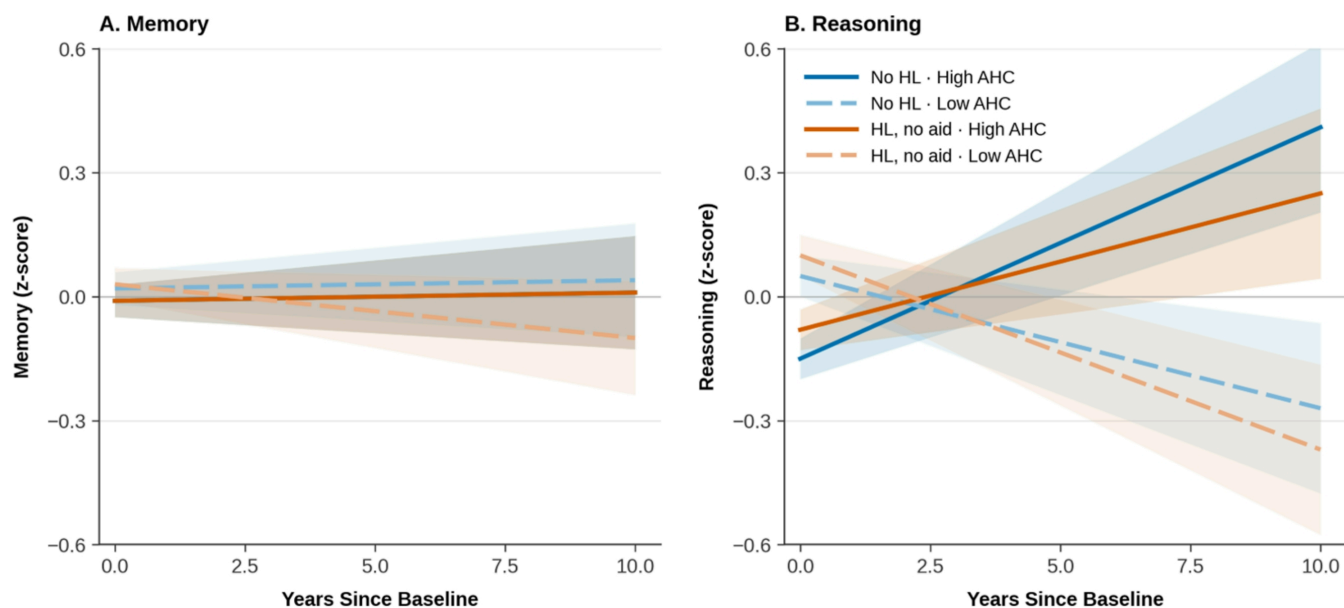


Figure 2

Association of uncorrected hearing loss status on memory and reasoning as moderated by access to healthcare. Note. AHC = access to health care. Low and high levels AHC values at -1 SD and +1 SD. In panel A, the lines depicting the high AHC groups overlap.

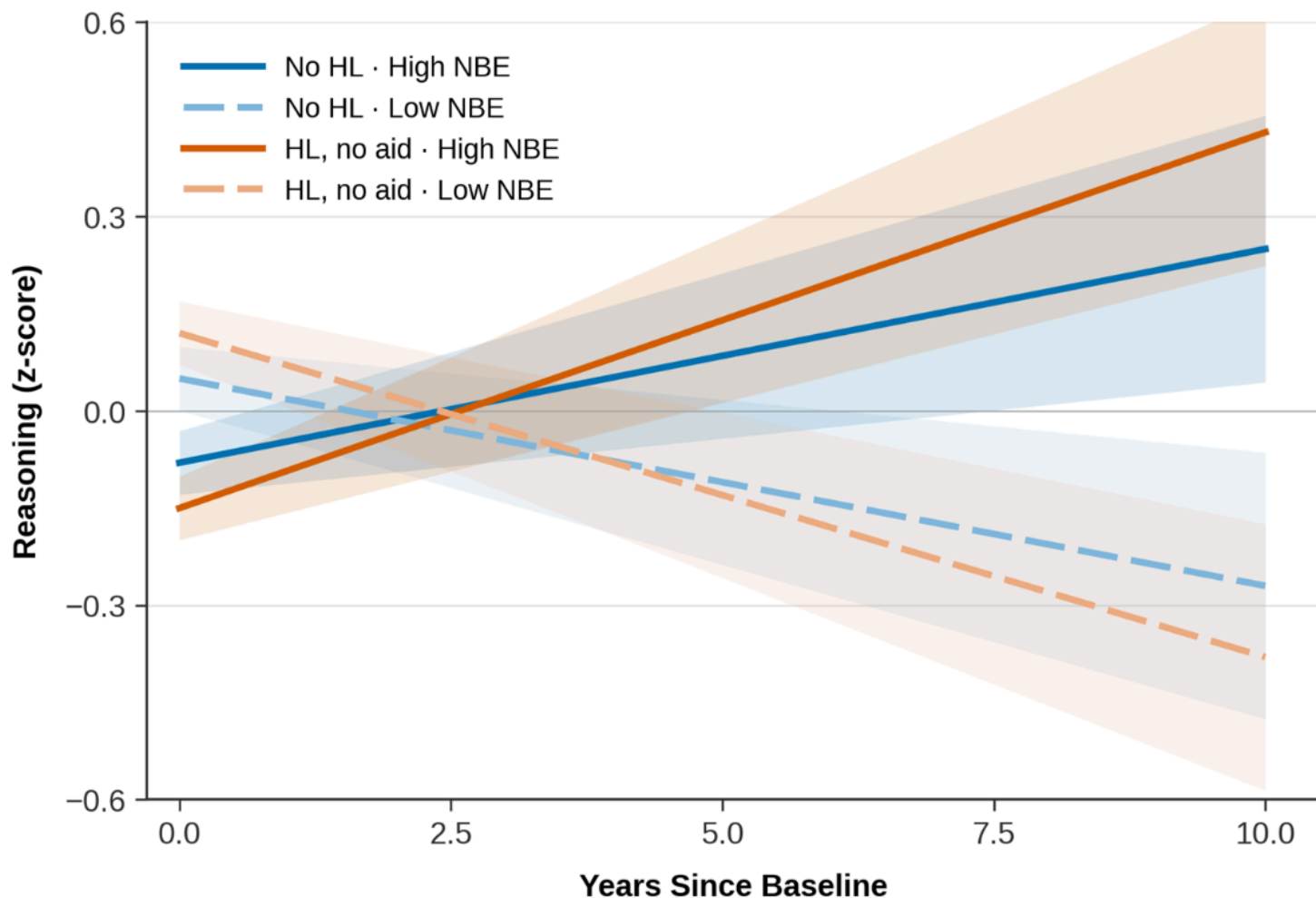


Figure 3

Association of uncorrected hearing loss status on reasoning as moderated by neighborhood and built environment. Note. NBE = neighborhood and built environment. Low and high levels NBE values at -1 SD and +1 SD.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementalTables.docx](#)