



OPEN Differential associations of longitudinal hearing and vision trajectories with dementia and mild cognitive impairment in older adults

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Hearing and vision impairments are modifiable risk factors for cognitive decline, yet their longitudinal contributions to mild cognitive impairment (MCI) and dementia remain unclear. This study examined differential associations of baseline sensory function and longitudinal sensory trajectories with cognitive status at Wave 9. Nine waves of data (2006–2022) from the Korean Longitudinal Study of Aging were analyzed, including 11,146 participants aged 45 years and older. Parallel process latent growth modeling was used to examine associations between baseline hearing and vision, their rates of change over time, and cognitive status at the final wave (cognitively normal, MCI, dementia). More rapid hearing decline was significantly associated with a higher likelihood of being classified in the dementia group. Poorer baseline vision was associated with a higher likelihood of being classified in the MCI group. In contrast, baseline hearing and longitudinal vision decline were not significantly associated with MCI or dementia classification, respectively. These findings indicate that longitudinal hearing decline shows a stronger association with dementia classification than visual impairment, whereas poorer baseline visual function may be more strongly associated with earlier-stage cognitive status.

Keywords Hearing, Vision, Latent growth modeling, Mild cognitive impairment, Dementia

As the global population aged 60 years and older continues to grow, identifying modifiable risk factors for cognitive decline has become a critical public health priority^{1–4}. Dementia imposes substantial societal and economic burdens, making even modest delays in disease onset potentially significant at the population level. Recent Lancet Commission reports have consistently identified hearing loss as the leading modifiable risk factor for dementia in midlife, with a population-attributable fraction (PAF) of 8% in 2017 and 7% in 2024^{5,6}. Vision impairment has been newly recognized as an independent risk factor in late life, accounting for an additional PAF of approximately 2%⁶. Together, these findings suggest that sensory impairments—long viewed as inevitable consequences of aging—represent critical and actionable targets for dementia prevention across the lifespan.

Much of the existing literature has either examined hearing and vision impairments separately or aggregated them into a broad dual sensory impairment construct, without jointly modeling both modalities to disentangle their independent contributions to cognitive aging^{7,8}. Although growing evidence links both sensory impairments to cognitive decline through cross-sectional^{9–11} and longitudinal studies^{12,13}, this approach provides limited insight into the relative and independent contributions of each sensory modality. Moreover, many studies rely on static baseline measures that fail to capture the dynamic, progressive nature of sensory decline. Consequently, whether hearing and vision exert distinct longitudinal effects on cognitive outcomes—when modeled simultaneously and within a framework that separates baseline status from rate of change—remains insufficiently understood.

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Several theoretical mechanisms have been proposed to explain the association between sensory impairment and cognitive decline. Hearing loss, in particular, has been linked to increased cognitive load, whereby greater neural resources are allocated to auditory perception at the expense of higher-order cognitive processes⁷. Prolonged auditory deprivation may also lead to structural and functional brain changes, including cortical reorganization, that accelerate neurodegenerative processes^{3,14}. Additionally, hearing impairment may contribute to social withdrawal and reduced cognitive stimulation, indirectly increasing dementia risk³. These mechanisms are not mutually exclusive and may operate cumulatively over time, suggesting that both baseline severity and longitudinal deterioration of hearing function may be critical in shaping cognitive trajectories¹⁴.

Hearing loss often remains untreated for 7–10 years after onset, resulting in extended periods of sensory deprivation during midlife and early older adulthood³. Lin and colleagues demonstrated a dose–response relationship between hearing loss severity and dementia risk, such that greater impairment was associated with progressively higher risk. Similarly, long-term follow-up data from the Caerphilly cohort revealed that elevated auditory thresholds in midlife were associated with more than a twofold increase in dementia risk, even after adjusting for baseline cognitive performance¹⁵. These findings suggest that subclinical or progressive hearing loss may serve as an early marker of dementia vulnerability and highlight the importance of monitoring auditory decline over time.

Recent investigations have therefore extended beyond static measures of hearing status to examine longitudinal trajectories of hearing decline. Deal et al. reported that each 10-dB increase in hearing loss was associated with a higher risk of incident dementia over 9 years ($HR = 1.14$), and that moderate to severe hearing impairment was associated with poorer baseline memory performance, though no significant differences in rates of domain-specific cognitive decline were observed¹⁴. A longitudinal study using pure-tone audiometry demonstrated that both prevalent and incident hearing loss were associated with faster decline in verbal memory, information processing speed, and executive function over a 12-year follow-up, with the onset of hearing loss preceding the onset of cognitive decline¹⁶. Importantly, increased cognitive risk was observed even among individuals with mild hearing impairment whose hearing continued to deteriorate, indicating that the rate of sensory change may be a critical determinant of cognitive outcomes.

In contrast, vision impairment is often identified and treated earlier through corrective lenses or surgical interventions, potentially attenuating its long-term cognitive impact. Nevertheless, longitudinal studies have linked visual deficits to declines across multiple cognitive domains including memory, language, attention, and visuospatial ability^{17,18}. Women with moderate to severe visual impairment have been reported to exhibit elevated risk of incident dementia compared to those without impairment¹⁹. Similarly, baseline visual deficits and persistent or worsening visual impairment over time have been associated with greater cognitive decline in a multiethnic Asian cohort²⁰. Despite these findings, the magnitude and consistency of associations between vision impairment and dementia appear less robust than those observed for hearing loss. This discrepancy may reflect differences in underlying mechanisms, timing of onset, or the extent to which visual deficits are mitigated through intervention.

Importantly, cognitive decline progresses along a continuum from normal cognition to mild cognitive impairment (MCI) and ultimately dementia^{21,22}. Risk factors that contribute to early cognitive vulnerability may differ from those associated with later-stage neurodegenerative transition²³. To the best of our knowledge, relatively few studies have differentiated stage-specific outcomes while simultaneously modeling longitudinal changes in multiple sensory systems. Distinguishing whether baseline sensory deficits or progressive sensory decline are differentially associated with MCI versus dementia classification may provide important insights into the temporal dynamics of sensory-cognitive relationships in aging.

Accordingly, there remains a need for longitudinal investigations that jointly model hearing and vision trajectories within the same analytic framework to clarify their independent and relative contributions to cognitive outcomes²⁴. A modeling approach that separates baseline sensory status (intercept) from the rate of change over time (slope) enables evaluation of whether stable impairment or progressive deterioration is more strongly associated with end-of-follow-up cognitive status. In the present study, we analyzed nine waves of data spanning 16 years from the Korean Longitudinal Study of Aging (KLoSA). Using parallel process latent growth modeling²⁵, we examined how baseline levels and longitudinal trajectories of hearing and vision were differentially associated with cognitive status at Wave 9, categorized as cognitively normal, MCI, or dementia. By modeling sensory changes dynamically and concurrently, this study aims to clarify whether the trajectory of hearing decline shows a stronger association with dementia classification relative to visual impairment, and whether baseline visual function is more strongly associated with MCI classification.

Materials and methods

Study population

This study used data from the first (2006) to the ninth (2022) waves of the Korean Longitudinal Study of Aging (KLoSA), comprising an initial baseline sample of 10,254 participants. KLoSA is a nationally representative longitudinal panel survey designed to examine the economic, health, and social conditions of community-dwelling adults aged 45 years and older in the Republic of Korea. The survey employs a multistage stratified sampling design based on geographical region and housing type to ensure representativeness. Detailed information regarding the study design, sampling procedures, and survey methodology is publicly available through the Korea Employment Information Service (<http://survey.keis.or.kr>).

The total number of individuals who participated in at least one wave across the nine waves was 11,146, including the original Wave 1 panel of 10,254 adults and 892 participants recruited in subsequent waves. Of the 11,146 participants, 6057 had available cognitive status data at Wave 9 (cognitively normal: $n = 5908$; MCI: $n = 43$; dementia: $n = 106$) and were included in the cognitive outcome analysis (Table 1). The remaining 5089 participants did not provide cognitive outcome data at Wave 9 due to death or dropout. This attrition may have

Variables	Scale	Wave 9 (N = 6057)			
		Normal (N = 5908)	MCI (N = 43)	Dementia (N = 106)	p
Age, mean (SD) [§]		72.02 (9.10)	83.33 (6.57)	84.83 (6.71)	<.001
Gender, N (%) [‡]	Male	2473 (41.9%)	14 (32.6%)	34 (32.1%)	.062
	Female	3435 (58.1%)	29 (67.4%)	72 (67.9%)	
Education, N (%) [§]	Less than elementary school graduation	2055 (34.8%)	31 (72.1%)	77 (72.6%)	<.001
	Middle school graduation	1025 (17.4%)	7 (16.3%)	12 (11.3%)	
	High school graduation	2028 (34.3%)	3 (7%)	15 (14.2%)	
	College graduation or higher	800 (13.5%)	2 (4.7%)	2 (1.9%)	
Hearing, N (%) [§]	Excellent	305 (5.2%)	0 (0%)	0 (0%)	.743
	Good	2671 (45.2%)	11 (25.6%)	10 (9.4%)	
	Fair	2404 (40.7%)	21 (48.8%)	34 (32.1%)	
	Poor	452 (7.7%)	8 (18.6%)	49 (46.2%)	
	Very poor	76 (1.3%)	3 (6.9%)	13 (12.3%)	
Vision, N (%) [§]	Excellent	146 (2.5%)	3 (6.9%)	3 (2.8%)	.057
	Good	1307 (22.1%)	13 (30.2%)	13 (12.3%)	
	Fair	2398 (40.6%)	15 (34.9%)	49 (46.2%)	
	Poor	1933 (32.7%)	12 (27.9%)	41 (38.7%)	
	Very poor	107 (1.8%)	0 (0%)	0 (0%)	

Table 1. Sociodemographic characteristics of the study sample. SD standard deviation, MCI mild cognitive impairment, Hearing and vision were assessed using a five-point Likert scale ranging from 1 (very poor) to 5 (Excellent). [‡]Chi-square test. [§]One-Way ANOVA. Seventeen participants in the cognitively normal group had missing vision data.

introduced survivorship bias, as individuals with poorer health or greater cognitive decline are more likely to die or be lost to follow-up, and is acknowledged as a major limitation of the present study.

Dependent variable: cognitive status

The primary aim of this study was to examine whether baseline sensory function and longitudinal sensory trajectories were differentially associated with cognitive status at Wave 9, operationalized as MCI or dementia. Cognitive status at the ninth wave (2022) was used as the outcome variable and categorized into three mutually exclusive groups: cognitively normal, MCI, or dementia. Because diagnostic questions were introduced at Wave 7 and information on the exact timing of diagnosis was unavailable, the present analysis examines associations between longitudinal sensory trajectories and cognitive group membership at the final wave, rather than modeling incident cognitive outcomes from a verified cognitively normal baseline. Although based on self-reported physician diagnosis, this measure reflects clinically recognized impairment and has been previously utilized in large-scale epidemiological research using KLoSa data²⁶.

Participants who reported no diagnosis of either condition were classified as cognitively normal. Those who reported a physician-diagnosed MCI were categorized as the MCI group, and those reporting a diagnosis of dementia were classified as the dementia group. Cognitive status at Wave 9 was treated as a categorical outcome variable in subsequent analyses to distinguish predictors of earlier-stage impairment (MCI) from predictors of more advanced neurodegeneration (dementia).

Independent variables: sensory loss

Hearing and vision function were assessed at each survey wave through self-reported measures. Participants rated their hearing and vision abilities using a five-point Likert scale. Responses were coded from 1 (“very poor”) to 5 (“excellent”), such that higher scores indicate better sensory functioning. Individuals who used hearing aids or corrective lenses were instructed to evaluate their sensory function while using these devices, such that hearing ratings reflected aided hearing and vision ratings reflected corrected vision. Self-reported sensory assessments have been widely used in large-scale longitudinal aging studies^{27,28}. In the present study, repeated measurements of hearing and vision across nine waves were used to estimate both baseline sensory status (intercept) and rates of change over time (slope) within a parallel process latent growth modeling framework.

Statistical analysis

Descriptive characteristics of participants at the ninth wave were compared across cognitive status groups (normal, MCI, dementia). Continuous variables were analyzed using one-way analysis of variance (ANOVA), and categorical variables were compared using chi-square tests (Table 1). All descriptive analyses were conducted using IBM SPSS Statistics (version 29.0; IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < .05$.

Hearing and vision were each assessed using a five-point Likert scale ranging from 1 (very poor) to 5 (excellent), such that higher values indicate better sensory functioning. The latent intercept represents baseline sensory status at Wave 1, with higher values reflecting better hearing or vision, and the latent slope represents

the rate of linear change per wave interval, with positive values indicating improvement and negative values indicating deterioration over time.

To examine how both baseline levels and longitudinal changes in sensory function contributed to cognitive outcomes, we conducted a parallel process latent growth modeling (PPLGM) analysis. This modeling approach allows simultaneous estimation of latent growth factors for multiple longitudinal processes—in this case, hearing and vision—thereby capturing both baseline levels (intercepts) and rates of change over time (slopes). Modeling hearing and vision in parallel enables evaluation of their independent effects while accounting for covariance between the two sensory trajectories. Linear change over time was specified given that the primary aim of the study was to link interpretable growth parameters to cognitive outcomes. Although nonlinear specifications such as quadratic models may provide a closer mathematical fit to observed trajectories, increasing model complexity renders the interpretation of growth factors progressively more ambiguous²⁹. A linear specification was therefore adopted to ensure that the intercept and slope parameters remain substantively interpretable. Correlations among all four latent growth factors were freely estimated to account for potential associations between the two sensory trajectories.

All latent growth models were estimated using Mplus (version 8.9)³⁰, applying full information maximum likelihood (FIML) estimation to handle missing data under the assumption of missing at random. Of the total 11,146 participants, 892 who were recruited after Wave 1 and lacked baseline age data were excluded from the conditional model, yielding a final analytic sample of 10,254. FIML was applied to handle missing sensory data across waves under the missing at random (MAR) assumption, allowing all available observations to contribute to parameter estimation regardless of the number of waves completed. The proportion of observed sensory data ranged from 91.8% at Wave 1–54.1% at Wave 9, reflecting cumulative attrition due to death and dropout over the 16-year follow-up period. Of the 10,254 participants, 6057 had available cognitive status data at Wave 9 (cognitively normal: $n = 5908$; MCI: $n = 43$; dementia: $n = 106$) and were included in the multinomial logistic regression. The remaining 4197 participants did not provide cognitive outcome data at Wave 9; their sensory data across earlier waves nonetheless contributed to the estimation of latent growth parameters via FIML. Time was coded in wave units (0 through 8), with the intercept representing baseline sensory status at Wave 1 and the slope representing the rate of linear change per wave interval (every 2 years) across the nine waves spanning 16 years. Model fit was evaluated using standard indices, including the comparative fit index ($CFI = 0.924$)³¹, root mean square error of approximation ($RMSEA = 0.043$)³², and standardized root mean square residual ($SRMR = 0.055$)³³. All indices met recommended thresholds for good model fit.

To investigate the effects of sensory trajectories on cognitive function, the estimated latent intercepts and slopes of hearing and vision were included as independent variables in a multinomial logistic regression model within the PPLGM framework. Hearing and vision were rated on a five-point scale where higher values indicate better sensory functioning, such that a positive slope reflects slower deterioration and a negative slope reflects faster deterioration over time. Cognitive status at Wave 9 served as the categorical outcome variable, with three levels: cognitively normal (reference group), MCI, and dementia. Accordingly, two contrasts were estimated: (1) MCI versus normal and (2) dementia versus normal. Regression coefficients were expressed as odds ratios (ORs) with corresponding 95% confidence intervals. Age and years of education were included as covariates in all models. A schematic representation of the analytical framework is presented in Fig. 1.

Results

Table 1 summarizes characteristics of participants with cognitive status data at Wave 9 ($N = 6057$), stratified by cognitive group (cognitively normal, MCI, dementia). Note that the full analytic sample for the latent growth model comprised all participants across nine waves ($N = 11,146$), of whom 6057 provided cognitive outcome data at Wave 9.

No statistically significant differences were observed across groups in sex distribution or in self-reported hearing and vision impairment (All $ps > .05$). Significant group differences were identified for age ($F = 136.52$, $p < .001$), with participants in the MCI and dementia groups being older than those in the cognitively normal group. Educational attainment also differed significantly across groups ($\chi^2 = 94.90$, $p < .001$), with lower education levels more frequently observed in the MCI and dementia groups.

Sensory trajectory associations with mild cognitive impairment

In the multinomial logistic regression model, higher baseline vision (i.e., better self-reported visual function at Wave 1, on a five-point scale where higher values indicate better functioning) was significantly associated with a lower likelihood of belonging to the MCI group compared to the cognitively normal group ($B = -1.918$, $p = .005$; Table 2). That is, individuals with poorer baseline visual function were more likely to be classified in the MCI group at Wave 9. No significant associations with MCI were observed for the slope of vision over time ($B = 15.715$, $p = .301$), baseline hearing function ($B = 0.372$, $p = .536$), or change in hearing over time ($B = -19.750$, $p = .152$).

Regarding covariates, older age at baseline was significantly associated with a higher likelihood of being classified in the MCI group compared to the cognitively normal group ($B = 0.098$, $p < .001$). Educational attainment did not significantly differ across groups (all $ps > .05$).

Sensory trajectory associations with dementia

A less steep decline in hearing over time (i.e., a higher slope value reflecting slower deterioration) was significantly associated with a decreased likelihood of being classified in the dementia group compared to the cognitively normal group ($B = -26.220$, $p = .010$; Table 2). While the unit scaling of the latent slope parameter yielded a large negative coefficient and a correspondingly small odds ratio, the unstandardized regression coefficient confirmed a robust and statistically significant association. That is, individuals whose hearing deteriorated more rapidly were more likely to be classified in the dementia group at Wave 9. In contrast, no significant associations were

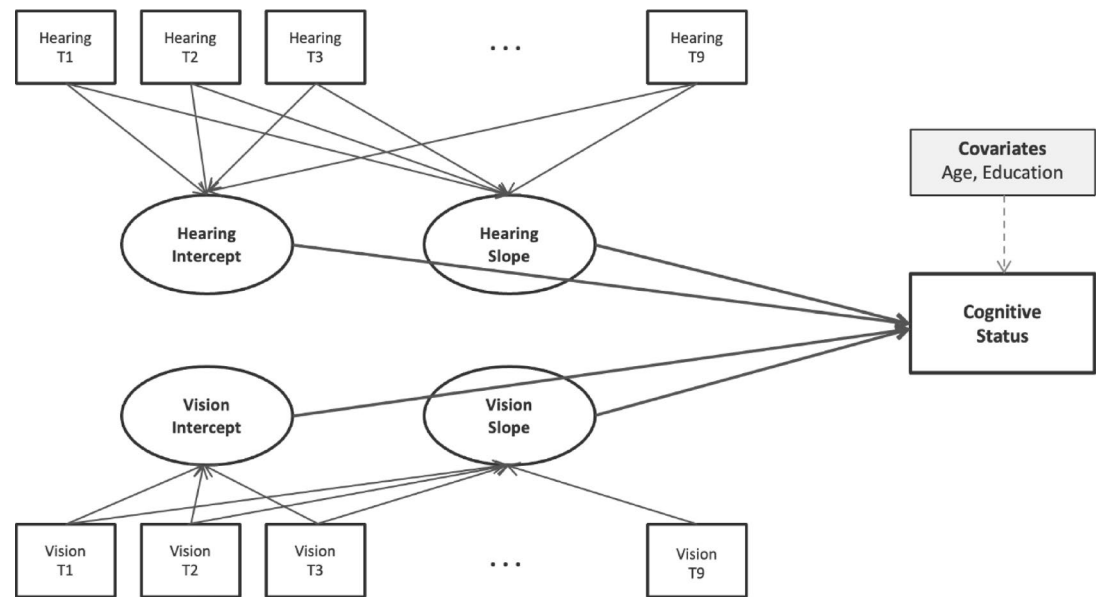


Fig. 1. Schematic representation of the parallel process latent growth model. Hearing and vision were each assessed across nine waves (T1–T9) using a five-point Likert scale (1 = very poor to 5 = excellent). Latent intercepts represent baseline sensory status at Wave 1, and latent slopes represent the rate of linear change per wave interval (approximately every 2 years) over the 16-year follow-up period. The four latent growth factors (Hearing Intercept, Hearing Slope, Vision Intercept, Vision Slope) were simultaneously estimated and included as predictors of cognitive status at Wave 9 (cognitively normal, MCI, dementia). Dashed arrows indicate the effects of covariates (age and education) on cognitive status. All reported associations are adjusted for age and years of education.

Predictor		MCI			Dementia		
		B	SE	OR	B	SE	OR
Vision	Intercept	−1.918*	0.682	0.147	−0.258	0.486	0.773
	Slope	15.715	15.193	6,682,482	14.108	11.191	1,339,759
Hearing	Intercept	0.372	0.602	1.451	−0.46	0.408	0.631
	Slope	−19.75	13.797	0.000	−26.22*	10.189	0.000
Covariates	Age (baseline)	0.098***	0.025	1.103	0.119***	0.017	1.126
	Education (Middle vs. less)	0.298	0.456	1.347	−0.212	0.354	0.809
	Education (High vs. less)	−0.49	0.568	0.613	−0.152	0.321	0.859
	Education (College vs. less)	−0.122	0.768	0.885	−1.237	0.749	0.290

Table 2. Multinomial logistic regression predicting cognitive status. B = unstandardized regression coefficient; SE = standard error; OR = odds ratio; *p* values are based on two-tailed tests; Education reference category = less than elementary school graduation. **p* < .05. ***p* < .01. ****p* < .001. Extreme OR values for slope parameters (e.g., OR > 1,000,000 or OR < 0.001) reflect quasi-separation due to the marked imbalance in outcome group sizes (Normal: *n* = 5908; MCI: *n* = 43; Dementia: *n* = 106) combined with the small variance of the latent slope parameters. These values should be interpreted with caution; the direction and significance of the unstandardized B coefficients are more informative for slope terms. Significant values are in [bold].

found for the baseline level of hearing (*B* = −0.460, *p* = .260), baseline vision (*B* = −0.258, *p* = .596), or slope in vision over time (*B* = 14.108, *p* = .207). Regarding covariates, older age at baseline was significantly associated with a higher likelihood of being classified in the dementia group (*B* = 0.119, *p* < .001). Educational attainment was not significantly associated with dementia group membership (all *ps* > .05).

Discussion

This longitudinal study examined the differential associations of hearing and vision trajectories with cognitive status at Wave 9 over a 16-year follow-up period. Our findings indicate that more rapid longitudinal hearing decline was more strongly associated with being classified in the dementia group than visual impairment, whereas poorer baseline visual function was more strongly associated with being classified in the MCI group.

Notably, it was the trajectory of hearing decline—rather than baseline sensory status—that showed the strongest association with dementia classification at Wave 9, underscoring the importance of tracking longitudinal changes in hearing function.

The association between longitudinal hearing decline and dementia classification is consistent with accumulating evidence linking auditory impairment to late-life cognitive deterioration. A linear association between baseline hearing loss severity and dementia risk has been reported, with a 27% increased risk for every 10 dB of hearing loss³⁴. A graded association between hearing loss severity and incident dementia risk has been observed, with each 10-dB increase in hearing loss associated with a 14% higher hazard of dementia¹⁴. While prior studies have largely focused on baseline hearing levels¹⁵, the present study advances this work by showing that the rate of hearing deterioration over the 16-year follow-up, rather than baseline severity alone, was more strongly associated with cognitive status at the final wave. Leveraging a PPLGM approach, we simultaneously estimated baseline sensory function and its rate of change over time. Baseline hearing loss may reflect accumulated sensory damage, whereas longitudinal decline may signal ongoing biological processes that parallel or accelerate neurodegenerative changes.

In contrast, visual impairment demonstrated a distinct pattern. Poorer baseline vision was significantly associated with increased likelihood of MCI classification, yet neither baseline vision nor longitudinal vision decline was associated with dementia classification. This dissociation suggests that visual impairment may function as an early indicator of cognitive vulnerability, though the present findings do not establish whether it independently contributes to dementia classification. Although hearing loss has consistently been identified as a key risk factor for dementia⁵, evidence linking visual impairment to incident dementia remains mixed. Several studies have reported that visual impairment is associated with increased odds of MCI among older adults³⁵, and a dose–response relationship between self-rated visual impairment and dementia risk has also been reported³⁶. In cross-sectional analyses, individuals who rated their vision as moderate or poor were approximately two to four times more likely to have dementia compared to those with normal vision. Longitudinally, among adults aged 50 to 69, moderate and poor vision at baseline predicted significantly elevated dementia risk over an average 11-year follow-up period, whereas no such association was observed in those aged 70 and older. In a comprehensive review of over 110 studies, consistent associations were observed between visual impairment and both cognitive decline and MCI, whereas the evidence linking visual impairment to dementia was mixed and less conclusive³⁷. Similarly, cataract surgery has been reported to be associated with a reduced risk of MCI, although no significant association with dementia was observed³⁸. Taken together, these patterns are consistent with a stage-specific interpretive framework, though the present design does not permit direct observation of transitions between cognitive stages: visual impairment may serve as an early signal of cognitive vulnerability, yet its association with dementia classification appears limited.

While some studies have linked visual impairment to increased risk of MCI or even dementia^{35,36} the overall evidence remains inconsistent. For instance, visual deficits have been associated with greater functional impairment and loneliness yet were not found to independently predict dementia in fully adjusted models—even after accounting for sensory loss and comorbidity³⁹. Similarly, no significant longitudinal association between vision loss and dementia onset has been observed¹³, suggesting that visual impairment may lack specificity as a predictor of later-stage cognitive decline. Taken together, these findings indicate that although visual impairment may reflect early cognitive vulnerability—such as increased odds of MCI classification—its association with dementia classification appears weaker and less consistent.

The differential findings for hearing and vision are consistent with a stage-specific hypothesis of sensory contributions to cognitive outcomes. Under this interpretive framework, visual impairment may signal early functional vulnerability characteristic of MCI, whereas progressive hearing decline may be more closely linked to neurodegenerative processes underlying dementia. However, the present analysis does not directly observe stage transitions over time, and this interpretation should be regarded as a conceptual implication rather than a demonstrated finding. Hearing function is tightly integrated with temporal processing, language comprehension, and sustained attention—domains supported by distributed cortical networks frequently implicated in dementia-related neuropathology. Progressive auditory deterioration may therefore impose sustained strain on large-scale neural systems, amplifying age-related degeneration. In contrast, visual deficits may exert more localized or compensable effects, particularly when corrective strategies are implemented.

Importantly, the present findings highlight the conceptual distinction between baseline impairment and longitudinal change. The absence of a significant association between baseline hearing and dementia classification suggests that static severity alone may not fully capture risk. Instead, progressive deterioration may serve as a more sensitive marker of ongoing pathological processes. This distinction has methodological implications. Cross-sectional studies may underestimate risk if they fail to account for the temporal dynamics of sensory decline. By separating intercept and slope parameters within a parallel growth framework, the present study demonstrates that rates of change may convey information about end-of-follow-up cognitive status beyond what baseline levels alone capture.

Beyond its clinical implications, the present study contributes to a broader theoretical understanding of sensory–cognitive interactions in aging. The modality-specific associations observed here suggest the possibility of partially distinct pathways linking hearing and vision to cognitive outcomes in later life, though drawing mechanistic conclusions from the present observational data would go beyond what the study design can support. Progressive auditory deterioration may be more closely associated with large-scale neural networks involved in memory and executive function, whereas visual impairment may exert indirect or compensable effects. This distinction may help reconcile inconsistencies in prior literature and emphasizes the need to consider sensory modalities separately rather than aggregating them into composite indices.

Several limitations warrant consideration. First, and most centrally, cognitive status was ascertained via self-reported physician diagnosis of MCI or dementia rather than standardized neuropsychological assessment

or clinical adjudication. This method of outcome ascertainment depends not only on participants' underlying cognitive status, but also on access to medical evaluation, diagnostic recognition, recall accuracy, and willingness to report a prior diagnosis. Moreover, cognitive status was analyzed only as a final categorical outcome at Wave 9, rather than being measured and modeled longitudinally from baseline. As a result, the study models longitudinal change in sensory function but not longitudinal change in cognition itself, substantially limiting inference regarding stage-specific progression from normal cognition to MCI and dementia.

Second, sensory function was assessed using self-reported measures rated under aided or corrected conditions, which may underestimate true impairment severity. Although self-report has been widely used in large-scale epidemiological studies⁴⁰ and demonstrates reasonable concordance with objective assessments^{41,42}, reliance on subjective ratings may not fully capture the complexity or progression of sensory impairment over time. Importantly, corrective lenses typically restore visual acuity more completely than hearing aids rehabilitate hearing loss, meaning that the two measures may not be directly comparable in terms of residual impairment captured. This asymmetry may have attenuated hearing-related associations relative to vision and should be considered when interpreting the modality comparisons. Future studies using audiometric and ophthalmic assessments would provide more precise estimates of sensory capacity.

Third, although age and education were included as covariates, other potentially relevant variables such as self-rated health, chronic disease burden, functional status, and depressive symptoms were not available in the analytic dataset; residual confounding from these factors cannot be excluded. Fourth, Wave 9 cognitive outcome data were unavailable for 5089 participants due to death or dropout, and individuals with poorer health or earlier cognitive deterioration may have been disproportionately underrepresented among those with available Wave 9 data, potentially biasing the observed associations toward a healthier surviving sample; this survivorship concern is regarded as a major limitation. Finally, the marked imbalance in outcome group sizes—particularly the small MCI group ($n = 43$)—raises concerns about sparse-data bias and near-separation, and multinomial estimates for the MCI category should be interpreted with caution and treated as preliminary pending replication in larger samples.

Conclusion

The present study found differential associations of longitudinal sensory trajectories with cognitive status at the final wave of the KLoSA, assessed after 16 years of follow-up. More rapid hearing decline over the follow-up period was associated with a higher likelihood of being classified in the dementia group, whereas poorer baseline visual function was associated with a higher likelihood of being classified in the MCI group. These findings underscore the importance of tracking sensory trajectories over time, rather than relying solely on static baseline measures, when examining associations with cognitive outcomes in older adults. Notably, the rate of hearing deterioration over time—rather than baseline severity alone—showed the strongest association with dementia classification, suggesting that longitudinal sensory change may carry information about cognitive outcomes beyond what single-timepoint measures can capture. The present findings are observational and based on self-reported measures, and causal or clinically actionable conclusions are not warranted from the current data. Future longitudinal studies using standardized cognitive and sensory assessments, with more balanced outcome group distributions, are needed to replicate and extend these findings.

Data availability

The data that support the findings of this study are available from the Korean Longitudinal Study of Aging (KLoSA) via the Korea Employment Information Service (KEIS). Access to the data requires registration and approval and can be obtained at <http://survey.keis.or.kr>.

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Author contributions

J.S. conceptualized the study, conducted formal analyses and drafted the manuscript. S.E.K. contributed to the data curation, formal analyses, and writing—review & editing. J.K. was responsible for data curation, investigation, and writing—review & editing. S.K. supervised the modeling approach, contributed to data interpretation, and participated in writing—review & editing. J.E.S. supervised and conceptualized the study and co-drafted the manuscript. All authors reviewed and approved the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

This study used publicly available, de-identified secondary data from the Korean Longitudinal Study of Aging (KLoSA). Therefore, Institutional Review Board approval was not required. All participants provided informed consent at the time of original data collection.

Additional information

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