Ehrlich Joshua (Orcid ID: 0000-0002-0607-3564)

# Self-Reported Dual Sensory Impairment, Dementia, and Functional Limitations in Medicare Beneficiaries

**Running Title:** Sensory Impairment and Functional Limitations


| | |
|---|---|
| Lama Assi, MD MPH[1,2] | lassi@lsuhsc.edu |
| Joshua R. Ehrlich, MD MPH[3,4,5] | joshre@med.umich.edu |
| Yunshu Zhou, MS[3] | yunshuz@med.umich.edu |
| Alison Huang, MPH[1,6] | ahuang31@jhmi.edu |
| Judith Kasper, PhD[7] | jkasper1@jh.edu |
| Frank R. Lin, MD PhD[1,8,9] | flin1@jhmi.edu |
| Michael M. McKee, MD MPH[4,10] | mmmckee@med.umich.edu |
| Nicholas S. Reed, AuD[1,8,9,11] | nreed9@jhmi.edu |
| Bonnielin K. Swenor, PhD MPH[1,9,11,12] | bswenor@jhmi.edu |
| Jennifer A. Deal, PhD[1,8,9,11] | jdeal1@jhu.edu |

**Affiliations:**
1 Cochlear Center for Hearing and Public Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
2 Department of Ophthalmology, Louisiana State University Health Sciences Center, New Orleans, LA
3 Department of Ophthalmology and Visual Sciences, University of Michigan Medical School, Ann Arbor, MI
4 Institute for Healthcare Policy and Innovation, University of Michigan, Ann Arbor, MI
5 Institute for Social Research, University of Michigan Medical School, Ann Arbor, MI
6 Department of Mental Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
7 Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
8 Department of Otolaryngology-Head and Neck Surgery, Johns Hopkins School of Medicine, Baltimore, MD
9 Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD
10 Department of Family Medicine, University of Michigan Medical School, Ann Arbor, Michigan
11 The Disability Health Research Center, Johns Hopkins Bloomberg University, Baltimore, MD
12 The Wilmer Eye Institute, Johns Hopkins University, Baltimore, MD


**Funding Sources**: Dr. Deal was supported by NIH/NIA grant K01AG054693, Dr. Reed was supported by NIH/NIA grant K23AG065443, Dr. Ehrlich was supported by NIH/NEI grant K23EY027848, and Dr. Swenor was supported by NIH/NIA grant K01AG052640.

**Corresponding Author:** Lama Assi, MD, MPH
Address: Department of Ophthalmology
Louisiana State University Health Sciences Center
533 Bolivar St, Room 451B
New Orleans, LA 70112
Email: lassi@lsuhsc.edu
Twitter: @LamaAssi3

**Abstract Word Count**: 300
**Manuscript Word Count**: 3,422

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/jgs.17448

**Key Points**

- Adults with dual sensory impairment have more functional limitations than those with one or no impairment.
- Those who also have dementia have even greater limitations in daily activities.

**Why does this matter?**

Strategies to improve sensory functioning could minimize disability among older adults.

**Abstract**

**Background**: Vision and hearing impairments often co-exist with dementia, and all are independently associated with limitations in daily activities. Our aim was to examine the association of dual sensory impairment with functional limitations, and further examine the combined estimated association of sensory impairment and dementia on these functional limitations.

**Methods**: Cross-sectional analysis of the National Health and Aging Trends Study (NHATS), a population-based cohort of Medicare beneficiaries. Participants were selected from the 2015 round. Survey weighted Poisson regression models adjusted for dementia, demographics, and health status variables examined the association of self-reported dual sensory impairment (no sensory impairment, single sensory impairment, dual sensory impairment) with scores of limitations in mobility, self-care, and household activities. Models were repeated to take into account the combined effects of dual sensory impairment and dementia.

**Results**: Overall, 7,124 participants representative of Medicare beneficiaries 65 years or older were included. Of them, 43.9% were 75 years or older and 55.3% were female. Older adults with dual sensory impairment had greater limitations with mobility (prevalence rate ratio [PRR]=1.45, 95% CI=1.28-1.63), self-care (PRR=1.41, 95% CI=1.25-1.59), and household activities (PRR=1.54, 95% CI=1.37-1.72) compared with those without sensory impairment. They also had greater limitations than those with a single sensory impairment across the different activity categories. In models taking into account the combined estimated effect of both sensory impairment and dementia, those with dual sensory impairment and dementia had greater limitations than those without sensory impairment or dementia in each

category (mobility: PRR=1.85, 95% CI=1.59-2.14, self-care: PRR=1.86, 95% CI=1.59-2.18, household: PRR=2.41, 95% CI=2.09-2.77).

**Conclusions**: Older adults with dual sensory impairment had greater functional limitations compared with those without sensory impairment and those with a single sensory impairment. Strategies to improve visual and/or hearing function (e.g., sensory aids, rehabilitation) could potentially help prevent or minimize disability, even among those with dementia.

**Key words**: sensory impairment, dementia, disability, mobility, self-care

**Introduction**

In the United States (U.S.), approximately 18 million adults over the age of 65 have difficulty or receive help with self-care, mobility, or household activities.[1] Most older persons with disability receive assistance from family or friends, and use of formal care increases with disability severity.[2] Activity limitations also are associated with a broad range of negative outcomes including reduced social engagement,[3,4] nursing home entry,[5,6] and higher risk of death.[7]

Sensory impairment, both hearing and vision, are independently associated with functional limitations.[8-11] In the U.S., of adults 65 years and older, 9% are estimated to have vision impairment or blindness,[12] while more than 50% are estimated to have hearing impairment.[13] Vision and hearing impairment prevalence increases with age, and concurrent vision and hearing impairment, or dual sensory impairment, is estimated to affect 11% of adults aged 80 years and older.[14] Those with dual sensory impairment may be particularly vulnerable to the negative outcomes of sensory impairment as they may be unable to use sensory substitution strategies that rely on vision or hearing. However, few studies have investigated the association of dual sensory impairment with functional limitations.[15] The few studies that have been conducted used data limited to specific populations such as French women,[16] Dutch adults with frailty,[17] residents in Beaver Dam, Wisconsin,[18] and New York City residents 95 years and older,[19] or old national U.S. data dated from 1984.[20]

Dual sensory impairment is also associated with cognitive impairment and dementia.[21-25] The Aging, Demographics, and Memory Study (ADAMS) estimates that 22% of adults 71 years or older in the U.S. have cognitive impairment not dementia (CIND),[26] and 14% have dementia from any cause (including Alzheimer disease, vascular dementia, and other causes

of dementia).[27] Cognitive impairment and dementia are also independently associated with functional decline,[28] and people with both dual sensory and cognitive impairments could be even more likely to have functional limitations.

A study using a population-based cohort of community-dwelling adults in North Carolina found that the combinations of dual sensory or vision impairment alone and cognitive impairment were most strongly associated with difficulty performing ADLs and IADLs,[29] and another one conducted in a long-term facility in Canada reported that those with both dual sensory and cognitive impairment were the most likely to report activity limitations.[30] Recent work has shown that older Americans with both vision impairment and dementia are at higher risk for limitations in mobility and daily activities than those with vision impairment or dementia alone.[31] To our knowledge, no studies have examined the interaction of dual sensory impairment and dementia in a national study of community-dwelling adults.

With the aging of the population, understanding older adults' risk of having functional limitations is important for health care planning to ensure optimal aging and appropriate accommodations in the community and health care settings for people with sensory impairment. The present study aims to examine the association of dual sensory impairment with functional limitations in a nationally representative sample of older Medicare beneficiaries in the U.S., and then the combined estimated effects of sensory impairment and dementia.

## Methods

*Study Population*

The National Health and Aging Trends Study (NHATS) is an ongoing cohort study of a nationally representative sample of Medicare beneficiaries over the age of 65 years that aims to study late-life functioning through annual in-person interviews. Approximately 96% of older adults in the U.S. are covered by the Medicare insurance program.[32] The NHATS sample was initially drawn from the Medicare enrolment file in 2011. In these analyses, we used cross-sectional data from the 2015 NHATS round, when the sample was replenished to make it representative of the Medicare population 65 years and older once again. In total, 8,334 participants were included in the NHATS in 2015. Of the 8,334 participants, 758 did not complete or were ineligible for the sample person interview in Round 5 (e.g. deceased with proxy interview only), leaving 7,576 participants eligible for inclusion in this study. Of them, 452 were excluded due to missing data (102 missing outcome information, 116 missing sensory impairment or dementia information, and 234 missing covariate information). The final analytic sample was 7,124 (7,124 of 7,576; 94.0%). In general, those who were included in the study were more likely to be younger, non-Hispanic white, with a college degree, and with higher income than those who were excluded due to missing information. The NHATS study protocol was approved by the Johns Hopkins' Bloomberg School of Public Health's Institutional Review Board. Signed informed consent was obtained from the study participants or their proxy respondents at the time of enrollment in the study.[33]

*Functional Limitations*

The NHATS late-life disability scale was used to assess functional limitations.[34] Limitations in 3 mobility activities (going outside, going around inside, getting out of bed), 4 self-care activities (eating, dressing, toileting, bathing), and 5 household activities (doing laundry, shopping for groceries, making hot meals, paying bills and banking, keeping track of medications) were the primary outcomes of this study (Figure 1-A). For each mobility and self-care activity, participants were asked whether anyone helped with the activity and if not, whether they had difficulty doing it on their own. For household activities, participants were asked if it was performed in the past month, how it was performed (by themselves, with someone else or whether someone else did the activity for them; if someone else helped was it for health or functioning reasons), if any equipment/devices were used, and whether they had difficulty performing it (using equipment/devices when applicable). For all activities except getting out of bed, using the toilet, and eating, participants were asked about changes in the frequency of performing the activity by themselves since the past year.

Functional limitation scores for each category of activities (i.e., mobility, self-care, household) were computed based on a 4-category hierarchal scale previously described in this cohort (Figure 1-B).[35] Each activity was assigned a score from 0 to 3, where 0 indicates no limitations performing the activity (no assistance, device use, or reduced frequency), 1 indicates performing the activity with accommodation (device use or reduced frequency, but no difficulty or assistance from others), 2 indicates difficulty performing the activity (with or without accommodation), and 3 indicates receiving assistance from someone to do the activity (for health or functioning reasons for household activities) or not doing it at all. Assessing functional limitation outcomes with the 4-category hierarchical scale used may

better capture the continuum of disability than only including information about difficulty or ability to perform activities,[35] which were used by previous studies that examined the association between dual sensory impairment and dementia.[16,17,19] Summary measures for mobility, self-care, and household activities were computed by summing together the scores for individual activities within each category. Scores ranged from 0 to 9 for mobility activities, 0 to 12 for self-care activities, and 0 to 15 for household activities, where 0 indicates no limitations in any of the activities and higher scores indicating greater limitations in activities.

*Sensory Impairment*

The primary exposure was self-reported dual sensory impairment status. Self-reported sensory measures capture the day-to-day burden of sensory impairment by incorporating participants' perception and compensation mechanisms. They measure a valuable component of sensory impairment that impacts health independent of objective sensory impairment. Although different from clinically assessed sensory function, the two constructs are related. For example, compared with audiometric measures, self-reported hearing measures generally have high specificity but low sensitivity.[37] Most notably, older adults tend to underestimate their hearing impairment.[38] Self-reported vision measures are comparable to objectively assessed vision measures when they evaluate vision impairment and blindness together.[39]

Vision impairment was defined as self-reported blindness, or not being able to see across the street and/or newspaper print (despite using glasses or contacts if applicable). Hearing impairment was defined as any of the following: self-reported deafness, using a hearing aid

or other hearing device, or not being able to hear well enough to use the telephone or to carry on a conversation in a room with a radio or TV playing (using a hearing device if applicable). Dual sensory impairment status was categorized as having no sensory impairment (reference), a single sensory impairment (i.e. vision or hearing impairment), or dual sensory impairment.

*Covariates*

Variables that may confound the association between sensory impairment and functional limitations were included. Sociodemographic characteristics included age (in 5 year intervals), sex (male, female), race/ethnicity (non-Hispanic white, non-Hispanic Black, non-Hispanic other, Hispanic), educational attainment (less than high school degree, high school degree, some college, college degree or more), and family income quartiles using multiple imputation values provided by the NHATS (less than $17,000, $17,000-31,000, $31,000-60,000, $60,000 or more).

Functional and health status variables included dementia, depression, count of self-reported physician diagnosed chronic conditions reported (arthritis, cancer, diabetes, heart attack, heart disease, hypertension, lung disease, osteoporosis, and stroke), self-reported history of cataract surgery, body-mass index (BMI) computed based on self-reported height and weight, and use of a proxy respondent (reasons included dementia, a major illness, speech or hearing impairment, language barrier, and being temporarily unavailable). Dementia was defined as having probable dementia or possible dementia (i.e., cognitive impairment) using the broad definition previously described in the NHATS cohort.[40] As such, participants were considered to have dementia if they had a self- or proxy-reported physician diagnosis of

dementia or Alzheimer's disease, a score of 2 or greater on the AD8 Dementia Screening Interview administered to proxy respondents, or a score less than or equal to 1.5 standard deviations below the mean on at least 1 cognitive performance test (memory, orientation, or executive function). Clinically-significant depressive symptoms were defined as a score of 3 or greater on the 2-item Patient Health Questionnaire.[41]

*Statistical Analysis*

Cross-sectional analyses examined the association between dual sensory impairment status and limitations in mobility, self-care, and household activities. Analyses accounted for the NHATS complex survey design using the recommended approach and weights provided by the NHATS User Guide.[42] Weighted percentages and means of population characteristics were presented for the overall population and by dual sensory impairment group. Generalized linear models with a Poisson distribution and log-link function were used to examine the association between sensory impairment and scores on the mobility, self-care, and household activities, adjusting for sociodemographic characteristics and health/functional status. Models were repeated with a combined sensory impairment and dementia status variable (no sensory impairment and no dementia [reference], single sensory impairment and no dementia, dual sensory impairment and no dementia, no sensory impairment and dementia, single sensory impairment and dementia, and dual sensory impairment and dementia) to examine the estimated joint effects of sensory impairment and dementia on the functional limitation scores. Sensitivity analyses excluding participants with proxy respondents were conducted. The p-values were two-tailed with statistical significance level set at 0.05. Analyses were conducted using R, version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria).

**Results**

*Study Population*

Overall, 7,124 participants were included, representing about 38.5 million Medicare beneficiaries 65 years and older (Table 1). The majority were female (55.3%), non-Hispanic white (80.7%), and had at least a high school diploma (83.1%). Seventy-two percent reported no sensory impairment, 25.2% reported a single sensory impairment, and 3.1% reported dual sensory impairment. Overall, 1,418 (14.6%) had dementia; dementia prevalence was 11.1% among those with no sensory impairment (N=768), 21.0% among those with a single sensory impairment (N=503), and 45.1% among those with dual sensory impairment (N=147). A greater proportion of those with dual sensory impairment than without sensory impairment were 80 years and older (57.6 vs 19.3%), female (61.6 vs 57.6%), Hispanic (20.0 vs 6.1%), had a family income less than $17,000 (40.3 vs 17.7%), and had clinically-significant depressive symptoms (38.7 vs 9.9%).

*Prevalence Rate of Functional Limitations by Sensory Impairment Status*

In fully adjusted models, those with dual sensory impairment had higher prevalence rates of limitations with mobility, self-care, and household activities compared to those with no sensory impairment and those with a single sensory impairment (Table 2). The prevalence rate of greater mobility limitations was 1.19 times (95% confidence interval [CI]=1.10-1.30) higher among those with a single sensory impairment and 1.45 times (95% CI=1.28-1.63) higher among those with dual sensory impairment relative to those without sensory impairment (p-trend<.001). Compared with those without sensory impairment, those with a single sensory impairment had 1.14 times (95% CI=1.06-1.22) higher prevalence rate of greater limitations in self-care, and those with dual sensory impairment had 1.41 times (95%

CI=1.25-1.59) higher prevalence rate of limitations in self-care activities (p-trend<.001). The prevalence rate of greater limitations in household activities was 1.19 times (95% CI=1.11-1.28) higher among those with a single sensory impairment and 1.54 times (95% CI=1.37-1.72) higher among those with dual sensory impairment relative to those without sensory impairment (p-trend<.001). Inferences were unchanged when excluding study participants with proxy respondents (Supplemental Table 1).

*Prevalence Rate of Functional Limitations by the Combined Estimated Effects of Sensory Impairment and Dementia*

There was an independent association of dementia with functional limitations (Table 2). Specifically, dementia was also associated with greater limitations in mobility (PRR=1.49, 95% CI=1.38-1.61), self-care (PRR=1.46, 95% CI=1.35-1.57), and household activities (PRR=1.79, 95% CI=1.63-1.97).

Results from the models examining the combined estimated effects of sensory impairment and dementia on the prevalence rate ratios of functional limitations are presented in Figure 2. Relative to those with no sensory impairment and no dementia, those with dual sensory impairment but not dementia had 1.92 (95% CI=1.59-2.32) higher prevalence rate of limitations in mobility activities, 1.72 (95% CI=1.46-2.02) higher prevalence rate of limitations in self-care activities, and 2.05 (95% CI=1.73-2.43) higher prevalence rate of limitations in household activities, while those with both dual sensory impairment and dementia had 1.85 (95% CI=1.59-2.14) higher prevalence rate of limitations in mobility activities, 1.86 (95% CI=1.59-2.18) higher prevalence rate of limitations in self-care activities, and 2.41 (95% CI=2.09-2.77) higher prevalence rate of limitations in household activities.

Excluding participants with proxy respondents did not result in a change in the inferences (Supplemental Table 2).

**Discussion**

In a nationally representative sample of Medicare beneficiaries in the United States, we found that older adults with dual sensory impairment had greater limitations in mobility, household, and self-care activities compared with those without sensory impairment and those with a single sensory impairment, after adjusting for dementia, sociodemographic characteristics, and other functional and health status variables. Having both dual sensory impairment and dementia was associated with the highest levels of limitations in self-care and household activities.

Our findings that dual sensory impairment is associated with greater functional limitations is consistent with previous studies. In the French E3N sub-cohort of older adults, women with dual sensory impairment were found to have more limitations in IADLs (similar to household activities) compared to those without sensory impairment, and compared to those with hearing or vision impairment alone.[16] In a sample of community-living frail Dutch older adults,[17] and in a sample of adults aged 95 years or older in New York City,[19] those with dual sensory or vision impairment had similarly greater limitations in IADLs and ADLs (similar to mobility and self-care activities) compared to those with hearing or no sensory impairment. In these two studies, however, samples may have been limited to those with more severe forms of sensory impairment, including vision impairment, as they included only frail adults in one,[17] and only those aged 95 years and older in the other.[19] A study using the Longitudinal Study on Aging, a nationally representative sample of older adults in the U.S. in

1984, found that having dual sensory impairment was associated with greater limitations in ADLs or IADLs compared with not having sensory impairment.[20] Finally, a study using data from the Epidemiology of Hearing Loss Study and Beaver Dam Eye Study found that clinically assessed vision impairment was associated with lower physical functioning scores, but hearing impairment and the interaction between hearing and vision impairment were not significantly associated with physical functioning.[18]

We also found that having dual sensory impairment (relative to no sensory impairment), was associated with greater difficulty with mobility and self-care activities to a similar extent as to having dementia (relative to not having dementia) (similar magnitude of PRRs). The association with limitations in household activities was stronger with dementia (PRR=1.79. 95% CI=1.63-1.97) than with dual sensory impairment (PRR=1.54, 95% CI=1.37-1.72). Early cognitive decline is known to cause changes in daily function, especially IADLs,[43] which could explain the strong association with household activities specifically. However, when accounting for the combined estimated effects of dementia and sensory impairment, there was a 20% increase in the PRR between having dementia and no sensory impairment, and having both dementia and dual sensory impairment (relative to no dementia and no sensory impairment). Therefore, dual sensory impairment may have a comparable association to dementia when it comes to less complex or cognitively demanding activities (mobility, self-care). With more cognitively demanding activities (household activities), the odds of difficulty performing them for those with dual sensory impairment increase when they also have dementia.

Sensory impairment can be addressed to potentially help maintain functional independence among older adults using relatively low-cost, accessible strategies. Improving access to hearing and vision care services in the community could help maintain older adults' sensory function. Screening for sensory impairment in health care settings could help to detect sensory impairment and address it earlier by referring for treatment (e.g., cataract surgery), prescribing sensory aids (e.g., glasses, hearing aids), or referring for visual and/or aural rehabilitation. Some strategies have also been shown to improve or maintain function (ADLs) among people with low vision, including improving indoor lighting,[44] and participation in a health-promotion program.[45]

Importantly, among people with dementia, interventions to address vision and hearing impairments are generally considered as effective, relatively low-cost, and accessible strategies to improve function.[46] This could be especially important in the subset of people with both dual sensory impairment and dementia. A systematic review[46] identified the Memory of Reasoning Enhanced Low Vision Rehabilitation (MORE-LVR) Program as one that improved cognitive and visual function, as well as performance on ADLs.[47] In the SENSE-Cog Field Trial, providing vision and hearing support (through assessment, provision of glasses and/or hearing aids with or without sensory support therapy) improved function in people with dementia.[48] Further research could assess more interventions for their impact on daily function, especially strategies that address both vision and hearing simultaneously, as those with dual sensory impairment may be the most vulnerable to disability.

Currently, the traditional Medicare program does not cover most vision and hearing services. Even among those enrolled in Medicare Advantage plans, out-of-pocket expenses

still make up more than two-thirds of vision and hearing care costs.[49] Expanding Medicare coverage to include vision and hearing services could help optimize independence and functioning among older adults, including those with dementia. The regulation of over-the-counter hearing aids sales for the treatment of mild to moderate hearing loss under the Over-the-Counter Hearing Aid Act of 2017 is another example of a policy that could have a positive impact on this issue. However, to date the Food and Drug Administration has not released regulations governing the samples of over-the-counter hearing aids.[50]

This study has limitations that should be taken into account when interpreting the results. First, the sampling frame used to draw the sample, the Medicare enrollment file, is inclusive of more than 95% of older adults in the U.S., but a small percentage of older adults are not represented. Moreover, older participants of non-white race or Hispanic ethnicity, and those with lower income and educational attainment maybe have been underrepresented due to missing data. However, those missing data represent only a small proportion (6%) of the study population. Second, the cross-sectional analyses do not allow for establishing temporality in the association of sensory or cognitive impairments with functional limitations. However, they allow to examine the co-existence of multiple impairments and functional limitations among a growing subset of the population. Third, the severity of sensory impairment was not accounted for in the exposure variable. The association of sensory impairment with functional limitations may be different for those with mild compared to severe impairments. Finally, self-reported sensory measures may represent a correlated but distinct construct compared to clinically assessed sensory measures, and may underestimate the prevalence of sensory impairment. Nonetheless, they provide important data on the day-to-day lived sensory experience.

In conclusion, we found that dual sensory impairment was associated with functional limitations in a nationally representative sample of older community-dwelling Medicare beneficiaries in the U.S. Those with both dual sensory impairment and dementia had the highest level of functional limitations across a range of activities of regarded as important for independent daily living. Addressing sensory impairment through low-cost strategies could help improve or maintain function among older adults, including those with dementia. Further research is needed to evaluate interventions for people with dual sensory impairment specifically.

ACKNOWLEDGEMENTS

**Conflict of Interest**: Dr. Reed reports sitting on the scientific advisory boards without financial compensation of Shoebox Inc and Good Machine Studio. All other authors have no conflicts of interest.

**Author Contributions**: LA, JRE, YZ, NSR, and JAD designed the study and conducted the statistical analyses. AH, JK, FRL, MMM, and BKS contributed to the interpretation of the data. LA, JRE and JAD drafted the manuscript. YZ, AH, JK, FRL, MMM, NSR and BKS revised it for critically important intellectual content. All authors approved the final version to be published.

**Sponsor's Role**: Study sponsors had no role in study design; collection, analysis, and interpretation of data; writing the report; and the decision to submit the report for publication.

REFERENCES


1. Freedman VA, Spillman BC. Disability and care needs among older Americans. *Milbank Q.* 2014;92(3):509-541.
2. Van Houtven CH, Konetzka RT, Taggert E, Coe NB. Informal And Formal Home Care For Older Adults With Disabilities Increased, 2004-16. *Health Aff (Millwood).* 2020;39(8):1297-1301.
3. Cudjoe TKM, Roth DL, Szanton SL, Wolff JL, Boyd CM, Thorpe RJ. The Epidemiology of Social Isolation: National Health and Aging Trends Study. *J Gerontol B Psychol Sci Soc Sci.* 2020;75(1):107-113.
4. Pohl JS, Cochrane BB, Schepp KG, Woods NF. Measuring Social Isolation in the National Health and Aging Trends Study. *Res Gerontol Nurs.* 2017;10(6):277-287.
5. Wolff JL, Mulcahy J, Roth DL, et al. Long-Term Nursing Home Entry: A Prognostic Model for Older Adults with a Family or Unpaid Caregiver. *J Am Geriatr Soc.* 2018;66(10):1887-1894.
6. Gaugler JE, Duval S, Anderson KA, Kane RL. Predicting nursing home admission in the U.S: a meta-analysis. *BMC Geriatr.* 2007;7:13.
7. Pongiglione B, De Stavola BL, Kuper H, Ploubidis GB. Disability and all-cause mortality in the older population: evidence from the English Longitudinal Study of Ageing. *Eur J Epidemiol.* 2016;31(8):735-746.
8. Lin TC, Yen M, Liao YC. Hearing loss is a risk factor of disability in older adults: A systematic review. *Arch Gerontol Geriatr.* 2019;85:103907.
9. Lam BL, Christ SL, Zheng DD, et al. Longitudinal relationships among visual acuity and tasks of everyday life: the Salisbury Eye Evaluation study. *Invest Ophthalmol Vis Sci.* 2013;54(1):193-200.

10. Swenor BK, Simonsick EM, Ferrucci L, et al. Visual impairment and incident mobility limitations: the health, aging and body composition study. *J Am Geriatr Soc.* 2015;63(1):46-54.

11. Gopinath B, Schneider J, McMahon CM, Teber E, Leeder SR, Mitchell P. Severity of age-related hearing loss is associated with impaired activities of daily living. *Age Ageing.* 2012;41(2):195-200.

12. Prevent Blindness America. Vision Problems in the U.S.: Prevalence of Adult Vision Impairment and Age-Related Eye Disease in America. http://www.visionproblemsus.org. Published 2012. Accessed February 29, 2020.

13. Goman AM, Lin FR. Prevalence of Hearing Loss by Severity in the United States. *Am J Public Health.* 2016;106(10):1820-1822.

14. Swenor BK, Ramulu PY, Willis JR, Friedman D, Lin FR. The prevalence of concurrent hearing and vision impairment in the United States. *JAMA Intern Med.* 2013;173(4):312-313.

15. Alzheimer's Association. 2018 Alzheimer's Disease Facts and Figures. *Alzheimers Dement.* 2018;14(3):367-429.

16. Bouscaren N, Yildiz H, Dartois L, Vercambre MN, Boutron-Ruault MC. Decline in Instrumental Activities of Daily Living over 4-Year: The Association with Hearing, Visual and Dual Sensory Impairments among Non-Institutionalized Women. *J Nutr Health Aging.* 2019;23(8):687-693.

17. Mueller-Schotte S, Zuithoff NPA, van der Schouw YT, Schuurmans MJ, Bleijenberg N. Trajectories of Limitations in Instrumental Activities of Daily Living in Frail Older Adults With Vision, Hearing, or Dual Sensory Loss. *J Gerontol A Biol Sci Med Sci.* 2019;74(6):936-942.

18. Fischer ME, Cruickshanks KJ, Klein BE, Klein R, Schubert CR, Wiley TL. Multiple sensory impairment and quality of life. *Ophthalmic Epidemiol.* 2009;16(6):346-353.

19. Cimarolli VR, Jopp DS. Sensory impairments and their associations with functional disability in a sample of the oldest-old. *Qual Life Res.* 2014;23(7):1977-1984.

20. Brennan M, Su YP, Horowitz A. Longitudinal associations between dual sensory impairment and everyday competence among older adults. *J Rehabil Res Dev.* 2006;43(6):777-792.

21. Harithasan D, Mukari SZS, Ishak WS, Shahar S, Yeong WL. The impact of sensory impairment on cognitive performance, quality of life, depression, and loneliness in older adults. *Int J Geriatr Psychiatry.* 2020;35(4):358-364.

22. Maharani A, Dawes P, Nazroo J, Tampubolon G, Pendleton N, Sense-Cog WPG. Associations Between Self-Reported Sensory Impairment and Risk of Cognitive Decline and Impairment in the Health and Retirement Study Cohort. *J Gerontol B Psychol Sci Soc Sci.* 2020;75(6):1230-1242.

23. Mitoku K, Masaki N, Ogata Y, Okamoto K. Vision and hearing impairments, cognitive impairment and mortality among long-term care recipients: a population-based cohort study. *BMC Geriatr.* 2016;16:112.

24. Yamada Y, Denkinger MD, Onder G, et al. Dual Sensory Impairment and Cognitive Decline: The Results From the Shelter Study. *J Gerontol A Biol Sci Med Sci.* 2016;71(1):117-123.

25. Kuo PL HA, Ehrlich JR, Kasper J, Lin FR, McKee MM, Reed NS, Swenor BK, Deal JA. . Prevalence of Concurrent Functional Vision and Hearing Impairment and Association with Dementia in Community-Dwelling Medicare Beneficiaries. *JAMA Network Open.*In Press.

26. Plassman BL, Langa KM, Fisher GG, et al. Prevalence of cognitive impairment without dementia in the United States. *Ann Intern Med.* 2008;148(6):427-434.

27. Plassman BL, Langa KM, Fisher GG, et al. Prevalence of dementia in the United States: the aging, demographics, and memory study. *Neuroepidemiology.* 2007;29(1-2):125-132.

28. Delva F, Edjolo A, Peres K, Berr C, Barberger-Gateau P, Dartigues JF. Hierarchical structure of the activities of daily living scale in dementia. *J Nutr Health Aging.* 2014;18(7):698-704.

29. Liu PL, Cohen HJ, Fillenbaum GG, Burchett BM, Whitson HE. Association of Co-Existing Impairments in Cognition and Self-Rated Vision and Hearing With Health Outcomes in Older Adults. *Gerontol Geriatr Med.* 2016;2.

30. Guthrie DM, Davidson JGS, Williams N, et al. Combined impairments in vision, hearing and cognition are associated with greater levels of functional and communication difficulties than cognitive impairment alone: Analysis of interRAI data for home care and long-term care recipients in Ontario. *PLoS One.* 2018;13(2):e0192971.

31. Patel N, Stagg BC, Swenor BK, Zhou Y, Talwar N, Ehrlich JR. Association of Co-occurring Dementia and Self-reported Visual Impairment With Activity Limitations in Older Adults. *JAMA Ophthalmol.* 2020;138(7):756-763.

32. Freedman VA, Kasper JD. Cohort Profile: The National Health and Aging Trends Study (NHATS). *Int J Epidemiol.* 2019;48(4):1044-1045g.

33. NHATS Data Collection Procedures: Round 5, 2015. Available at www.nhats.org. Accessed 11/12/2020.

34. Freedman VA, Kasper JD, Cornman JC, et al. Validation of new measures of disability and functioning in the National Health and Aging Trends Study. *J Gerontol A Biol Sci Med Sci.* 2011;66(9):1013-1021.

35. Gill TM, Williams CS. Evaluating Distinctions in the Assessment of Late-Life Disability. *J Gerontol A Biol Sci Med Sci.* 2017;72(11):1538-1546.

36. Choi JS, Betz J, Deal J, et al. A Comparison of Self-Report and Audiometric Measures of Hearing and Their Associations With Functional Outcomes in Older Adults. *J Aging Health.* 2016;28(5):890-910.

37. Agrawal Y, Platz EA, Niparko JK. Prevalence of hearing loss and differences by demographic characteristics among US adults: data from the National Health and Nutrition Examination Survey, 1999-2004. *Arch Intern Med.* 2008;168(14):1522-1530.

38. Kamil RJ, Genther DJ, Lin FR. Factors associated with the accuracy of subjective assessments of hearing impairment. *Ear Hear.* 2015;36(1):164-167.

39. Rein DB, Lamuda PA, Wittenborn JS, et al. Vision Impairment and Blindness Prevalence in the United States: Variability of Vision Health Responses across Multiple National Surveys. *Ophthalmology.* 2021;128(1):15-27.

40. JD Kasper, VA Freedman, Spillman B. 2013. Classification of Persons by Dementia Status in the National Health and Aging Trends Study. Technical Paper #5. Baltimore: Johns Hopkins University School of Public Health. Available at www.NHATS.org. Accessed 11/11/2020.

41. Kroenke K, Spitzer RL, Williams JB. The Patient Health Questionnaire-2: validity of a two-item depression screener. *Med Care.* 2003;41(11):1284-1292.

42. JD Kasper, VA Freedman, Spillman B. 2020. National Health and Aging Trends Study User Guide: Rounds 1-9 Final Release. Baltimore: Johns Hopkins University School of Public Health. Available at www.NHATS.org. Accessed 11/11/2020.

43. Cornelis E, Gorus E, Beyer I, Bautmans I, De Vriendt P. Early diagnosis of mild cognitive impairment and mild dementia through basic and instrumental activities of daily living: Development of a new evaluation tool. *PLoS Med.* 2017;14(3):e1002250.

44. Falkenberg HK, Kvikstad TM, Eilertsen G. Improved indoor lighting improved healthy aging at home - an intervention study in 77-year-old Norwegians. *J Multidiscip Healthc.* 2019;12:315-324.

45. Eklund K, Sjostrand J, Dahlin-Ivanoff S. A randomized controlled trial of a health-promotion programme and its effect on ADL dependence and self-reported health problems for the elderly visually impaired. *Scand J Occup Ther.* 2008;15(2):68-74.

46. Dawes P, Wolski L, Himmelsbach I, Regan J, Leroi I. Interventions for hearing and vision impairment to improve outcomes for people with dementia: a scoping review. *Int Psychogeriatr.* 2019;31(2):203-221.

47. Whitson HE, Whitaker D, Potter G, et al. A low-vision rehabilitation program for patients with mild cognitive deficits. *JAMA Ophthalmol.* 2013;131(7):912-919.

48. Leroi I, Simkin Z, Hooper E, et al. Impact of an intervention to support hearing and vision in dementia: The SENSE-Cog Field Trial. *Int J Geriatr Psychiatry.* 2020;35(4):348-357.

49. Willink A, Reed NS, Swenor B, Leinbach L, DuGoff EH, Davis K. Dental, Vision, And Hearing Services: Access, Spending, And Coverage For Medicare Beneficiaries. *Health Aff (Millwood).* 2020;39(2):297-304.

50. Franck KH, Rathi VK. Regulation of Over-the-Counter Hearing Aids - Deafening Silence from the FDA. *N Engl J Med.* 2020;383(21):1997-2000.

**Supporting Information**

Supplemental Table S1: Multivariable-Adjusted Prevalence Rate Ratios of Functional Limitations by Sensory Impairment and Dementia Status Excluding those with Proxy Respondents, the National Health and Aging Trends Study 2015 (N=6,756)

Supplemental Table S2: Multivariable-Adjusted Prevalence Rate Ratios of Functional Limitations by Sensory Impairment and Dementia Status Excluding those with Proxy Respondents, the National Health and Aging Trends Study 2015 (N=6,756)

**Table 1: Population Characteristics by Sensory Impairment Status, the National Health and Aging Trends Study 2015 (N=7,124)**

| | Overall | No sensory impairment | Single sensory impairment | Dual sensory impairment | p-value [a] |
|---|---|---|---|---|---|
| N (weighted %) | 7124 (100.0) | 4843 (71.8) | 1988 (25.2) | 293 (3.1) | NA |
| Age in years, N (weighted %) | | | | | <.001 |
| 65-69 | 991 (29.4) | 805 (33.2) | 167 (20.0) | 19 (18.5) | |
| 70-74 | 1681 (26.7) | 1321 (28.8) | 333 (22.2) | 27 (13.6) | |
| 75-79 | 1518 (19.0) | 1097 (18.8) | 392 (20.3) | 29 (10.2) | |
| 80-84 | 1329 (12.6) | 866 (11.3) | 408 (16.0) | 55 (16.4) | |
| 85-89 | 960 (8.0) | 515 (5.9) | 377 (12.9) | 68 (19.5) | |
| ≥ 90 | 645 (4.3) | 239 (2.1) | 311 (8.6) | 95 (21.7) | |
| Female, N (weighted %) | 4113 (55.3) | 2901 (57.6) | 1027 (48.1) | 185 (61.7) | <.001 |
| Race/ethnicity, N (weighted %) | | | | | <.001 |
| Non-Hispanic white | 4992 (80.7) | 3292 (80.5) | 1510 (82.9) | 190 (67.7) | |
| Non-Hispanic black | 1500 (8.4) | 1166 (9.5) | 283 (5.2) | 51 (7.3) | |
| Non-Hispanic other [b] | 207 (3.8) | 144 (4.0) | 52 (3.1) | 11 (4.9) | |
| Hispanic | 425 (7.2) | 241 (6.1) | 143 (8.7) | 41 (20.0) | |
| Educational attainment, N (weighted %) | | | | | <.001 |
| Less than high school diploma | 1544 (16.9) | 958 (14.8) | 472 (19.9) | 114 (40.4) | |
| High school diploma | 1916 (26.0) | 1287 (25.4) | 558 (27.9) | 71 (26.4) | |
| Some college | 1535 (23.2) | 1085 (24.1) | 398 (21.5) | 52 (16.8) | |
| College degree or more | 2129 (33.9) | 1513 (35.8) | 560 (30.7) | 56 (16.3) | |
| Family income, N (weighted %) | | | | | <.001 |
| Less than $17,000 | 1772 (19.3) | 1133 (17.7) | 517 (21.4) | 122 (40.3) | |
| $17,000-31,000 | 1775 (21.6) | 1187 (20.9) | 509 (23.0) | 79 (24.7) | |
| $31,000-60,000 | 1722 (25.8) | 1181 (26.0) | 481 (25.8) | 60 (23.0) | |
| $60,000 or more | 1855 (33.3) | 1342 (35.4) | 481 (29.8) | 32 (12.0) | |
| History of cataract surgery, N (weighted %) | 3515 (41.4) | 2153 (36.9) | 1171 (52.0) | 191 (59.1) | <.001 |
| Clinically significant depressive symptoms, N (weighted %) | 956 (12.2) | 538 (9.9) | 319 (15.4) | 99 (38.7) | <.001 |
| Proxy respondent, N (weighted %) | 368 (3.5) | 124 (1.8) | 160 (5.9) | 84 (25.0) | <.001 |
| BMI, mean (SD) | 28.08 (5.82) | 28.11 (5.73) | 28.05 (5.90) | 27.77 (7.28) | 0.862 |
| Number of comorbidities, mean (SD)[c] | 2.55 (1.61) | 2.42 (1.56) | 2.79 (1.63) | 3.68 (1.74) | <.001 |
| Dementia, N (weighted %) | 1418 (14.6) | 768 (11.1) | 503 (21.0) | 147 (45.1) | <.001 |

Abbreviations: BMI, body mass index.

[a]: Based on groupwise comparisons using survey-weighted chi-square tests.

[b]: Includes American Indian, Asian, Native Hawaiian, Pacific Islander, and “other” race.

[c]: Comorbidity count includes self-reported physician diagnoses of arthritis, cancer, diabetes, heart attack, heart disease, hypertension, lung disease, osteoporosis, and stroke.

**Table 2: Multivariable-Adjusted Prevalence Rate Ratios of Functional Limitations by Sensory Impairment and Dementia Status, the National Health and Aging Trends Study 2015 (N=7,124)**

| | Mobility Activities | | Self-Care Activities | | Household Activities | |
|---|---|---|---|---|---|---|
| | PRR (95% CI) | p-value | PRR (95% CI) | p-value | PRR (95% CI) | p-value |
| **Sensory Impairment** | | | | | | |
| No sensory impairment | 1 [Reference] | NA | 1 [Reference] | NA | 1 [Reference] | NA |
| Single sensory impairment | 1.19 (1.10, 1.30) | <.001 | 1.14 (1.06, 1.22) | 0.001 | 1.19 (1.11, 1.28) | <.001 |
| Dual sensory impairment | 1.45 (1.28, 1.63) | <.001 | 1.41 (1.25, 1.59) | <.001 | 1.54 (1.37, 1.72) | <.001 |
| **Dementia** | | | | | | |
| No dementia | 1 [Reference] | NA | 1 [Reference] | NA | 1 [Reference] | NA |
| Dementia | 1.49 (1.38, 1.61) | <.001 | 1.46 (1.35, 1.57) | <0.01 | 1.79 (1.63, 1.97) | <.001 |

Abbreviations: CI, confidence interval; PRR, prevalence rate ratio; NA, not applicable.

Models adjusted for age (65-69, 70-74, 75-79, 80-84, 85-89, ≥90 years), sex (male, female), race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic other, Hispanic), education (<high school diploma, high school diploma, some college, ≥college degree), income (<%17,000, $17,000-31,000, %31,000-60,000, ≥$60,000), history of cataract surgery (yes, no), clinically-significant depressive symptoms (yes, no), proxy response (yes, no), body mass index, and number of comorbidities.

**Figure Legends**

**Figure 1 – Functional Limitation Outcomes in the National Health and Aging Trends Study**

Figure Legend:

A – Mobility, Self-Care, and Household Activities. B – Hierarchal Scores of Functional Limitations.

**Figure 2 – Multivariable-Adjusted Prevalence Rate Ratios of Functional Limitations by Combined Sensory Impairment and Dementia Status, the National Health and Aging Trends Study 2015 (N=7,124)**

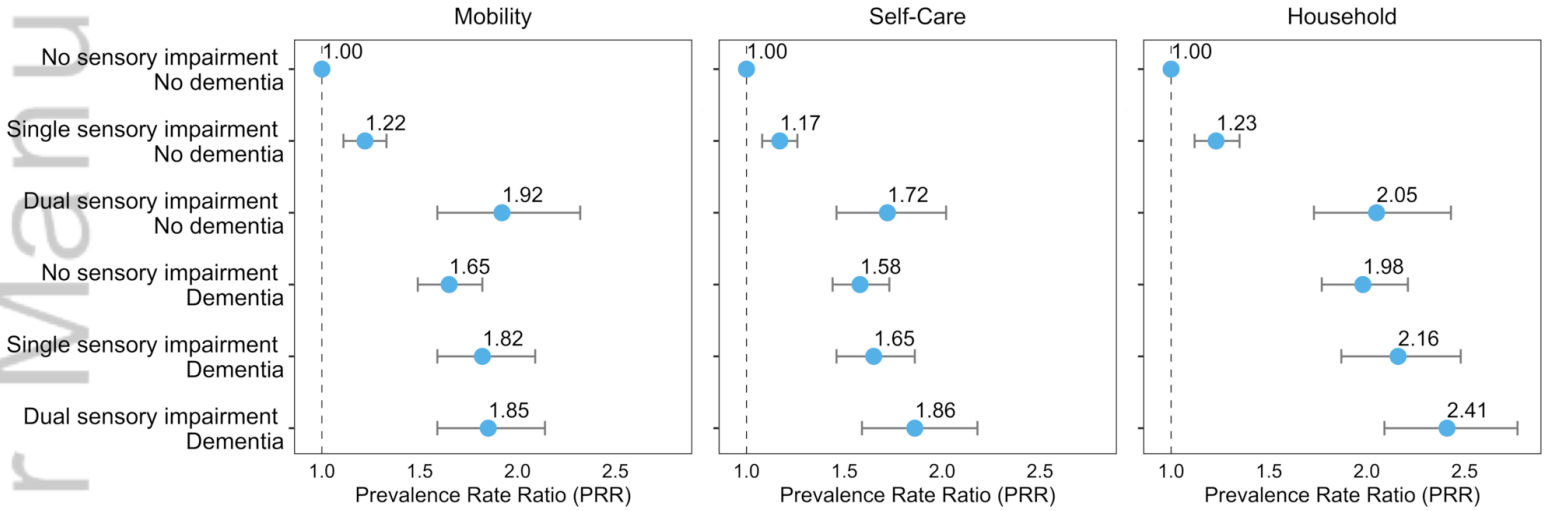
Models adjusted for age (65-69, 70-74, 75-79, 80-84, 85-89, ≥90 years), sex (male, female), race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic other, Hispanic), education (<high school diploma, high school diploma, some college, ≥college degree), income (<%17,000, $17,000-31,000, %31,000-60,000, ≥$60,000), history of cataract surgery (yes, no), clinically-significant depressive symptoms (yes, no), proxy response (yes, no), body mass index, and number of comorbidities.

A)

| Mobility | Self-Care | Household |
| --- | --- | --- |
| •Going outside<br>•Getting around inside<br>•Getting out of bed | •Eating<br>•Dressing<br>•Toileting<br>•Bathing | •Doing laundry<br>•Shopping for groceries<br>•Making hot meals<br>•Paying bills / banking<br>•Keeping track of medications |

B)

| | |
| --- | --- |
| 0 | •**No limitation**: performs the activity without devices, frequency unchanged, and without difficulty or assistance. |
| 1 | •**Successful accommodation**: accommodates for limitations by using devices (for self-care and mobility activities) or by performing the activity less frequently, but without difficulty or assistance. |
| 2 | •**Difficulty**: has difficulty performing the activity alone even with accommodations, but receives no assistance. |
| 3 | •**Assistance**: receives assistance from another person (due to health or functioning for household activities) or does not do the activity. |




JGS_17448_plot7.28.tiff