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Association of Cognition and Age-Related Hearing Impairment in the English Longitudinal Study of Ageing

Jaydip Ray, PhD, MS; Gurleen Popli, PhD; Greg Fell, BSc, MSc

Supplemental content

IMPORTANCE Evidence has linked age-related hearing impairment (ARHI) with cognitive decline; however, very few studies (none in the United Kingdom) explore this link in large well-characterized groups of community-dwelling individuals.

OBJECTIVE To investigate the link between ARHI and cognitive decline using a cohort of elderly individuals from the United Kingdom and explore untreated hearing loss and social isolation as potential explanations for the observed link.

DESIGN, SETTING, AND PARTICIPANTS This cross-sectional analysis of wave 7 (June 2014 through May 2015) of the English Longitudinal Study of Ageing (ELSA) sampled men and women 50 years or older and living in the United Kingdom in a community setting. Those with a diagnosis of dementia, Alzheimer disease, or Parkinson disease or with ear infections and cochlear implants were excluded. Data were analyzed from August 1, 2017, through May 25, 2018.

MAIN OUTCOMES AND MEASURES Memory and executive function as measures of cognitive function and hearing acuity derived from the HearCheck screener device (Siemens).

RESULTS Of a cohort of 9666 members in wave 7 of ELSA, 7385 were eligible for analysis after applying exclusion criteria (55.1% women; mean [SD] age, 67.4 [9.4] years). Of these, 3056 (41.4%) had mild hearing loss and 755 (10.2%) had severe hearing loss; 834 (11.3%) used a hearing aid; and 7155 (96.9%) were white. Hearing loss had a negative association with cognition; for those with moderate to severe loss, the score on memory assessment was a full 1 point less (−1.00; 95% CI, −1.24 to −0.76), *ceteris paribus*, relative to those with no hearing loss. However, this association was seen only in the individuals with untreated hearing loss (ie, those who did not use hearing aids) (−1.16; 95% CI, −1.45 to −0.87). Evidence suggests that social isolation acts as a mediating factor.

CONCLUSIONS AND RELEVANCE Although hearing loss and cognition are linked, untreated hearing loss drives the association. Social isolation is a mediating factor in the link for those who have untreated hearing loss. Cognitive decline associated with ARHI is probably preventable by early rehabilitation and increased opportunistic screening for the elderly.

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Author Affiliations: Regional Department of Neurotology, Ear Nose and Throat Department, Sheffield Teaching Hospitals, Glossop Road, Sheffield, United Kingdom (Ray); Department of Economics, University of Sheffield, Sheffield, United Kingdom (Popli); Sheffield City Council, Sheffield, United Kingdom (Fell).

Corresponding Author: Gurleen Popli, PhD, Department of Economics, University of Sheffield, 9 Mappin St, Sheffield S1 4DT, United Kingdom (g.popli@shef.ac.uk).

Age-related hearing impairment (ARHI) is the most common sensory abnormality of the elderly population[1,2] and is ranked as the fifth leading cause of years lived with disability, above diabetes and dementia.[3] The World Health Organization[4] estimates that more than 328 million adults experience disabling hearing loss; this not only affects interpersonal communication but also health, independence, well-being, quality of life, and daily function[5] and can lead to social isolation, depression, and possibly cognitive impairment.[6-8]

Speculation about the association between cognitive decline and ARHI has grown,[7] with research pointing toward hearing loss as an independent risk for cognitive decline as measured by the Mini-Mental State Examination.[9] A prospective study of 639 elderly people in the United States[7] found that the rate of cognitive decline and risk of mild cognitive impairment increased linearly with the severity of hearing loss; furthermore, the risk of developing all-cause dementia increased linearly with the severity of baseline hearing loss. The research suggested that mild, moderate, or severe hearing loss was associated with a 2-, 3-, or 5-fold increased risk of progression to dementia, respectively. Research suggests several mechanisms having potential causal links between hearing loss and dementia, including sensory degradation or deprivation, cognitive resource allocation or depletion, and social isolation or depression.[10]

Various studies[11-14] have also looked at the link between baseline hearing and cognition; however, the evidence is mixed. Gurgel et al[11] used US data for 4463 patients and found 16.3% of those who had hearing loss at baseline developed dementia compared with 12.1% without hearing loss. Another study[12] (again using US data) reported that baseline hearing acuity had no major effect on cognitive ability at a 5-year follow-up, suggesting that little evidence indicated that hearing impairment leads to cognitive decline in otherwise healthy elderly individuals. Similarly, studies have found no association between hearing loss and dementia.[13] A meta-analysis[14] suggested that hearing impairment is associated with cognitive problems but highlighted that conclusions may be premature owing to small sample sizes, failure to control for premorbid factors, and diversity within studies. Large well-characterized population studies have been suggested to overcome these weaknesses. Regardless, the National Institute for Health and Care Excellence[15] recognizes hearing loss and social isolation as potentially modifiable risk factors for dementia.

With a rising elderly population and the concomitant increase in the number of people with ARHI,[8] a test of this hypothesis using a larger community-dwelling population is crucial. In this study, we aimed to test the hypothesized link between ARHI and cognitive decline in a well-characterized, healthy, community-dwelling elderly population living in England. Furthermore, we explored whether simply the hearing loss or the untreated hearing loss drives the observed negative association between hearing loss and cognitive decline, whereby treated hearing loss is captured by the use of hearing aids. We also explored the role of social isolation as a potential mechanism for this link.

Key Points

Question Does untreated hearing loss and social isolation explain the link between age-related hearing loss and cognitive decline?

Findings In this cohort study of persons 50 years or older from the United Kingdom, hearing loss had a negative association with cognition; however, this association was observed only in the individuals with untreated hearing loss. Evidence suggests that social isolation acts as a mediating factor.

Meaning Cognitive decline associated with age-related hearing loss is probably preventable by early hearing rehabilitation and opportunistic screening of persons older than 50 years.

Methods

The English Longitudinal Study of Ageing (ELSA)[16,17] is the only United Kingdom–based, ongoing longitudinal survey of the aging population. The ELSA population is a representative sample of men and women 50 years and older living in England. The data for the first wave of ELSA were collected in 2002 to 2003; in total, 7 waves were collected, with the latest available wave (wave 7) collected from June 2014 through May 2015. The multidisciplinary nature of ELSA allows us to explore the complex associations between health and quality of life in old age, making these data the most appropriate for our analysis. Ethics board approval was not needed for this secondary analysis.

For the analysis in this report, we performed a cross-sectional analysis using data from wave 7 of ELSA because this is the only wave in which an objective test for hearing acuity was performed. Other relevant information that ELSA includes on the main variables of interest are measures of cognitive abilities and functioning, a range of background demographic characteristics of the individuals, and information on social participation and social support. ELSA also has sufficient information to create an index of social isolation.[18] In the Other Confounders section, we provide a description of the key variables of interest, further details of which are available from the ELSA guide.[17]

Objective Hearing Acuity Test

A hearing test was performed on all participants, unless they had an ear infection or a cochlear implant, using a simple handheld screener device (HearCheck; Siemens) validated for use in checking hearing acuity in low-cost settings.[19,20] Participants were asked to remove their hearing aid, if wearing any. For the HearCheck test, fixed series of 3 pure high-frequency sounds (3 kHz) at decreasing intensities (75, 55, and 35 dB) and 3 midfrequency sounds (1 kHz) at decreasing intensities (55, 35, and 20 dB) were administered to each ear separately. The hearing performance on each ear can then be used to classify hearing acuity as good (heard all 6 tones), mild hearing difficulty (heard 3-5 tones), and moderate to severe hearing difficulty (heard 0-2 tones). For our analysis, we combined the best hearing test result from both ears and classified hearing acuity as good (good acuity in both ears), mild difficulty (mild difficulty in both or either ear), and moderate to severe difficulty (moderate to severe difficulty in both or either ear).

Cognitive Functions

Cognitive functions were measured based on simple tests of memory and executive function. For the memory assessment tests, the participants were read a list of 10 unrelated words that they had to recall immediately and with delay. The word list can be read out by the computer or the interviewer depending on the participant's choice; in either case, before the assessment starts, the interviewer confirms that the participant can hear properly and that the volume is adjusted accordingly. The score for the memory assessment ranges from 0 to 20 and is treated as a continuous variable, with higher score indicating better cognition. The executive function test involves the participants naming as many animals as they can in 60 seconds. The test score can range from 0 to 100, with higher scores indicating better function. The construct validity of both tests has been previously established in other cohort studies and in the ELSA population.[21]

Social Isolation

We created an index of social isolation[22] from 5 different questions in ELSA. A respondent was assigned 1 point each if they were unmarried and not cohabiting; had less than monthly contact with each child, other family members, and friends; and did not participate in any social organizations. Scores ranged from 0 to 5, with higher scores indicating greater social isolation. From this index, we created a binary variable indicating social isolation if the index had a score of at least 2.

Other Confounders

In our statistical analysis, we controlled for a range of confounders, including age in years and dummy variables for sex, nonwhite race, and whether the person lives alone, uses hearing aid, works, has O-level educational qualifications or higher, is a current smoker, and has diabetes or hypertension. Participants were asked about their living arrangement, and anyone saying they live alone was classified as such. Other alternatives included living as a couple, living with children alone or as a couple, and living with extended family. The hearing aid question asked the respondent if they use a hearing aid. The possible answers for the respondent include yes, all the time; yes, sometimes; or no. Everyone responding yes was classified as using a hearing aid. Anyone having educational attainment higher than O-levels is classified as having attained a higher educational level. Smoking status is self-reported as a current smoker. For health conditions, such as diabetes and hypertension, the participants are asked whether they have been diagnosed with a specific health condition; if the participant in earlier waves had specified that they had the diagnosis, then in wave 7 they were simply asked to confirm the diagnosis.[17]

Statistical Analysis

Data were analyzed from August 1, 2017, through May 25, 2018. We started our analysis by looking at the association between hearing loss and cognition, controlling for age and a range of confounders. We then split the sample of all individuals between those who did and did not use hearing aids to see whether the association between cognitive decline and hearing loss still held among these 2 separate groups. To understand the mechanism via which hearing loss might be associated with cognition, we consider social isolation as a mediating variable. The model we estimate is

$$Y_i = \beta_1 HL_i + \beta_2 SI_i + \beta_3 X_i + \varepsilon_i$$

and

$$SI_i = \alpha_0 + \alpha_1 HL_i + \alpha_2 X_i + \eta_i$$

where Y_i is cognition, HL_i is hearing loss, SI_i is social isolation, and X_i represents confounders (these are mentioned above and include age and use of hearing aids) for the individual respondent i; β and α are the parameters to be estimated; and ε_i and η_i are the error terms. β_1 gives us the direct association between hearing loss and cognition, and β_2 gives us the association between social isolation and cognition. α_1 In equation 2 gives us the direct association between hearing loss and social isolation. For social isolation to work as a mediating variable, β_1 and β_2 should be statistically significant (ie, both hearing loss and social isolation should have a significant association with cognition). Furthermore, hearing loss should have a significant association with social isolation (ie, α_1 should be statistically significant). The indirect association between hearing loss via social isolation, and cognition is then given by $\alpha_1 \times \beta_2$, which makes the total association between hearing loss and cognition as $\beta_1 + \alpha_1 \times \beta_2$.

Measures of cognition (memory assessment and executive function) are continuous variables, so equation 1 is estimated using multivariable regression models. Social isolation is a binary outcome, so equation 2 is estimated using a logit model. The models are estimated in Mplus (version 7.3).[23]

Results

Number of cohort members in wave 7 of ELSA is 9666. We excluded from our analysis all those with a diagnosis of dementia, Alzheimer disease, and Parkinson disease; we also exclude those with ear infections and cochlear implants. After applying the exclusion criteria, 7385 cohort were member eligible for analysis. **Table 1** gives the descriptive statistics for all 7385 individuals in our sample (4072 [55.1%] women and 3313 [44.9%] men; mean [SD] age, 67.4 [9.4] years). Sample selection is given in the eTable in the Supplement. Eight hundred thirty-four participants (11.3%) used a hearing aid. We split the sample by hearing aid use. People who used hearing aids were significantly different from those who did not (Table 1). People using hearing aids had lower mean scores on cognitive functioning; for memory assessment, the difference was 1.68 points (95% CI, 1.42-1.93; Cohen effect size, 0.5); for executive function, the difference was 1.46 points (95% CI, 0.98-1.94; Cohen effect size, 0.2). A higher proportion of people using hearing aids had moderate to severe hearing loss; they tended to be older (difference, −8.65 years; 95% CI, −9.32 to −7.97 years), white (difference, −2.56%; 95% CI, −3.32 to −1.81), living alone (difference, −7.00%; 95% CI, −10.41% to −3.93%), and had hypertension (difference, −13.00%; 95% CI, −16.57% to −9.51%).

Table 1. Individual Characteristics of the Analyzed Sample From ELSA by Hearing Aid Use

Characteristic	All Participants (N = 7385)	Participants by Hearing Aid Use: Nonuse (n = 6551)	Participants by Hearing Aid Use: Use (n = 834)	Difference Between Hearing Aid Nonuse and Use (95% CI)
Cognition score, mean (SD)				
Memory test	11.00 (3.43)	11.19 (3.37)	9.52 (3.51)	1.68 (1.42 to 1.93)
Executive function	21.96 (6.76)	22.12 (6.77)	20.66 (6.61)	1.46 (0.98 to 1.94)
Objective hearing test result, No. (%)				
No loss	3574 (48.4)	3543 (54.1)	31 (3.7)	50.37 (48.6 to 52.1)
Mild loss	3056 (41.4)	2676 (40.8)	380 (45.6)	−4.71 (−8.3 to −1.1)
Moderate to severe loss	755 (10.2)	332 (5.1)	423 (50.7)	−45.65 (−49.1 to −42.2)
Age, mean (SD), y	67.44 (9.42)	66.46 (8.97)	75.11 (9.36)	−8.65 (−9.32 to −7.97)
Binary covariates, No. (%)[a]				
Female	4072 (55.1)	3705 (56.6)	367 (44.0)	13.00 (8.97 to 16.12)
White	7155 (96.9)	6328 (96.6)	827 (99.2)	−2.56 (−3.32 to −1.81)
Lives alone	1673 (22.7)	1431 (21.8)	242 (29.0)	−7.00 (−10.41 to −3.93)
Employed	2510 (34.0)	2403 (36.7)	107 (12.8)	24.00 (21.30 to 26.41)
Educational qualification above O level	3152 (42.7)	2809 (42.9)	343 (41.1)	2.00 (−1.80 to 5.30)
Smoker	775 (10.5)	733 (11.2)	42 (5.0)	6.00 (4.48 to 7.82)
Diabetes	719 (9.7)	613 (9.4)	106 (12.7)	−3.00 (−5.72 to −0.98)
Hypertension	2245 (30.4)	1895 (28.9)	350 (42.0)	−13.00 (−16.57 to −9.51)
Social isolation	3011 (40.8)	2672 (40.8)	339 (40.6)	0 (−3.40 to 3.68)

Abbreviation: ELSA, English Longitudinal Study of Ageing.

[a] Presented covariate is scored as 1; opposite or other, 0.

Table 2. Association Between Cognitive Decline and Hearing Loss

Cognitive Assessment[a]	Coefficient (95% CI)[b]: All Participants (N = 7385)	Participants With Hearing Aid Nonuse (n = 6551)	Participants With Hearing Aid Use (n = 834)
Memory			
Mild hearing loss	−0.52 (−0.65 to −0.39)	−0.51 (−0.64 to −0.38)	−0.06 (−0.97 to 0.86)
Moderate to severe hearing loss	−1.00 (−1.24 to −0.76)	−1.16 (−1.45 to −0.87)	−0.25 (−1.18 to 0.67)
Use hearing aid	0.01 (−0.21 to 0.23)	NA	NA
Social isolation	−0.61 (−0.74 to −0.48)	−0.55 (−0.69 to −0.42)	−1.07 (−1.47 to −0.67)
Executive function			
Mild hearing loss	−0.38 (−0.65 to −0.11)	−0.41 (−0.69 to −0.13)	0.86 (−1.53 to 3.25)
Moderate to severe hearing loss	−1.56 (−2.07 to −1.06)	−1.60 (−2.23 to −0.97)	−0.35 (−2.77 to 2.08)
Use hearing aid	0.89 (0.45 to 1.34)	NA	NA
Social isolation	−1.06 (−1.32 to −0.80)	−0.98 (−1.25 to −0.70)	−1.65 (−2.38 to −0.92)

Abbreviation: NA, not applicable.

[a] Treated as continuous variables. In each case, higher scores indicate better cognition.

[b] Estimated using ordinary least squares regression. In all specifications, the following covariates are used: cubic in age and dummy variables for sex, nonwhite race, and whether the person lives alone, works, has high educational qualifications, is a current smoker, and has diabetes and hypertension.

Among the proportion of those not using the hearing aid, more were women (difference, 13%; 95% CI; 8.97% to 16.12%) and employed (difference, 24.00%; 95% CI, 21.30% to 26.41%).

Table 2 presents the association among cognitive functioning, hearing loss, and social isolation across all 3 samples (all, those who used hearing aids, and those who did not use hearing aids). Herein we have controlled for the full range of confounders. For all individuals in the sample, we found a negative association between cognitive functioning (for memory assessment and executive function) and hearing loss. For those with mild loss and holding everything else constant, the mean score on memory assessment is a half point (−0.52; 95% CI, −0.65 to −0.39) lower than those with no hearing loss; for those with moderate to severe loss, the score is 1 point less (−1.00; 95% CI, −1.24 to −0.76). The use of a hearing aid was associated with higher executive functioning (difference, 0.89; 95% CI, 0.45-1.34), but we could not demonstrate the same association for memory assessment (difference, 0.01; 95% CI, −0.21 to 0.23).

Table 2 also presents the separate results for those who did and did not use hearing aids. We found that those who did not use hearing aids drove the negative association between hearing loss and cognitive functioning. In the sample of individuals who used hearing aids, no statistically significant association was found between hearing loss and cognitive function. For example, the difference in the score on memory assessment for those with mild hearing loss, relative to those with no hearing loss, is −0.06 (95% CI, −0.97 to 0.86). This finding seems to suggest that untreated hearing loss is linked to a decline in cognitive function and not just to hearing loss itself.

Table 3. Association Between Social Isolation and Hearing Loss

Social Isolation Variable[a]	OR (95% CI)[b] All Participants (N = 7385)	Hearing Aid Nonuse (n = 6551)	Hearing Aid Use (n = 834)
Mild hearing loss	1.15 (1.04-1.26)	1.17 (1.06-1.29)	0.89 (0.45-1.74)
Moderate to severe hearing loss	1.53 (1.28-1.83)	1.36 (1.09-1.70)	1.43 (0.72-2.82)
Use of hearing aid	0.71 (0.60-0.83)	1 [Reference]	1 [Reference]

Abbreviation: OR, odds ratio.

[a] Treated as a binary variable.

[b] Reported from a logit model. In all specifications, the following covariates are used: quadratic in age and dummy variables for sex, nonwhite race, and whether the person lives alone, works, has high educational qualifications, is a current smoker, and has diabetes and hypertension.

Social isolation also has a negative association with cognition seen in the entire sample and the 2 subsamples as well. To check whether social isolation acts as a mediating variable, we first tested whether hearing loss has an association with social isolation (equation 2); results for this test are reported in **Table 3**. We found significant evidence for this factor, whereby hearing loss is associated with higher odds of social isolation. Holding all other variables at a fixed value, the odds of being socially isolated for an individual with mild hearing loss, relative to someone with no hearing loss, are 1.15 (95% CI, 1.04-1.26); the same odds increase to 1.53 (95% CI, 1.28-1.83) for a person with moderate to severe loss. Further, this association was seen only in the subsample of respondents who did not use hearing aids; for the sample of participants using hearing aids, the odds ratio is not statistically different from 1.00.

In **Table 4**, we report the direct and the indirect associations between hearing loss and cognition. The direct association between mild hearing loss and memory test was −0.52 (95% CI, −0.65 to −0.39; this association is the same as the estimated coefficient reported in Table 2); the association between social isolation and memory test was −0.61 (95% CI, −0.75 to −0.47). From Table 3, we know that mild hearing loss also has a negative association on social isolation (the estimated coefficient underlying the odds ratio of 1.15 reported in Table 3 is 0.14); the indirect association between mild hearing loss and memory test is thus given by $0.14 \times (-0.61) = -0.08$. This formula gives us the total association between mild hearing loss and memory test as $-0.52 + (-0.08) = -0.61$ (95% CI, −0.75 to −0.47). In all cases, we found statistically significant indirect associations between hearing loss and cognition via social isolation, which then increases the total association between hearing loss and cognition. Again, this association seems to be driven by the sample of respondents who did not use hearing aids.

Diagnostic checks were performed on all estimated regression. For the linear specification (equation 1, with results reported in Table 2), the following tests were performed: checking for the normality of the residuals; homoscedasticity of the residuals; the multicollinearity test; and model specification tests for omitted variables. For the logistic regressions (equation 2, with results reported in Table 3), the multicollinearity test and model specification tests for omitted variables were performed. All regressions passed the regression diagnostics. Some of the regressions had a potential issue of heteroscedasticity in the residuals, so we therefore used the White corrected SEs throughout.[24]

Discussion

Although quite a few prospective studies on hearing loss and incident dementia have been performed, the study populations have been relatively small, and many confounding variables were not well controlled for. The Maastricht Aging Study[25] compared decline in hearing and vision with cognitive function and found a weak association on only 1 domain of a battery of tests. Another study failed to find any difference in cognitive function between hearing aid users and nonusers.[26] The largest number of analyses have been performed on various subsets of the Baltimore Longitudinal Study of Aging by Lin and colleagues.[7,27,28] The need for larger population-based studies of hearing and social isolation has been highlighted.[29,30]

To our knowledge, ours is the first study looking at the association of cognition with ARHI in the elderly using large longitudinal survey data representative of the English population. This study not only corroborates the initial findings in the literature using a larger cohort but also tests the hypothesis on a different cohort.

Many explanations exist for concomitant decline in hearing and cognition in elderly populations. One possibility is that the association may be bidirectional. Common factors such as aging, hypertension, and educational level could affect hearing and cognitive function. However, research[27] has shown an independent contribution of hearing loss on cognitive function and suggests a few mechanistic pathways through which hearing loss may mediate the effects on cognitive function.[7] First, peripheral hearing loss means that greater cognitive resources are needed to process the signal; thus, increased cognitive load will then have a detrimental association with other cognitive processes.[31] In addition, in individuals with hearing impairment, a change in brain structure, such as accelerated rates of brain atrophy in regions important for language and memory, may occur.[7] Another mechanism is thought to be social isolation associated with withdrawal from social engagement owing to difficulties in communicating, which can then exacerbate the problem because reduced social-stimulatory input can lead to a reduction in general cognitive function.[7] The Lancet Commissions report[32] estimates that 35% of risk factors for incident dementia in a life-course model are modifiable. Of these, hearing loss contributes 9% toward the possible onset or acceleration of dementia.

Findings and Recommendations

Our findings corroborate the existing evidence that hearing loss is associated with cognitive impairment, with the association

Table 4. Direct and Indirect Association of Hearing Loss With Cognition

Association With Hearing Loss[a]	Association With Cognition, Score (95% CI)	
	Memory	Executive Function
All Participants		
Mild hearing loss		
Total	−0.61 (−0.75 to −0.47)	−0.53 (−0.82 to −0.24)
Direct	−0.52 (−0.65 to −0.39)	−0.38 (−0.65 to −0.11)
Indirect via social isolation	−0.08 (−0.14 to −0.02)	−0.15 (−0.25 to −0.04)
Moderate to severe hearing loss		
Total	−1.26 (−1.53 to −0.99)	−2.01 (−2.57 to −1.46)
Direct	−1.00 (−1.24 to −0.76)	−1.56 (−2.07 to −1.06)
Indirect via social isolation	−0.26 (−0.38 to −0.14)	−0.45 (−0.67 to −0.23)
No Hearing Aid Use		
Mild hearing loss		
Total	−0.60 (−0.74 to −0.45)	−0.57 (−0.86 to −0.27)
Direct	−0.51 (−0.64 to −0.38)	−0.41 (−0.69 to −0.13)
Indirect via social isolation	−0.09 (−0.15 to −0.03)	−0.16 (−0.26 to −0.05)
Moderate to severe hearing loss		
Total	−1.33 (−1.65 to −1.01)	−1.90 (−2.57 to −1.22)
Direct	−1.16 (−1.45 to −0.87)	−1.60 (−2.23 to −0.97)
Indirect via social isolation	−0.17 (−0.30 to −0.04)	−0.30 (−0.53 to −0.06)
Hearing Aid Use		
Mild hearing loss		
Total	0.08 (−1.06 to 1.20)	1.06 (−1.35 to 3.46)
Direct	−0.06 (−0.97 to 0.86)	0.86 (−1.53 to 3.25)
Indirect via social isolation	0.13 (−0.59 to 0.86)	0.20 (−0.91 to 1.31)
Moderate to severe hearing loss		
Total	−0.64 (−1.78 to 0.51)	−0.93 (−3.37 to 1.51)
Direct	−0.25 (−1.18 to 0.67)	−0.35 (−2.77 to 2.08)
Indirect via social isolation	−0.38 (−1.13 to 0.36)	−0.60 (−1.76 to 0.59)

[a] Direct indicates the association of hearing loss with cognitive function (memory and executive function) that is not mediated by social isolation; this value is the estimate of the coefficient on hearing loss (β_1) in the equation 1 regression in the text. Indirect indicates the association of hearing loss with cognitive function mediated by social isolation; this value is given by $\alpha_1 \times \beta_2$, where α_1 is the coefficient on hearing loss in the regression of social isolation in equation 2 in the main text and β_2 is the coefficient on social isolation in equation 1.

of moderate to severe loss being higher than mild loss. However, the association between hearing loss and cognition is seen only in the individuals who do not use hearing aids; for the sample of respondents who used hearing aids, we found no evidence of association between hearing loss and cognition. Social isolation significantly reduces cognition; this association was seen in the sample of respondents who used hearing aids and those who did not. Evidence suggests that social isolation acts as a mediation factor. Hearing loss is associated with higher social isolation, which in turn has a negative association with cognition. We found this indirect association of hearing loss via social isolation only in those who did not use hearing aids. The main recommendation that follows from our analysis is that persons older than 50 years are screened opportunistically in primary care for hearing loss and mild cognitive impairment. A more prominent public health campaign is needed to increase awareness and knowledge among those who need hearing rehabilitation and in those provided hearing rehabilitation.

Limitations

One weakness of our study is the use of screening estimates of hearing levels and not pure-tone audiometry performed in sound-treated booths. However, the HearCheck screener is a validated tool for field testing of hearing levels. The other weakness arises from the fact that hearing and cognition levels were measured as point prevalence, taking ELSA wave 7 data as baseline. The gradient of progression of hearing and cognition levels cannot be assessed from the single wave. We also must consider the potential self-selection in the use of hearing aids; those who have a higher need or desire for social interaction and/or have better cognition may succeed in getting hearing aids. Future longitudinal data collections of objective hearing test results, use of hearing aids, and cognition would allow us to address this weakness.

Conclusions

Although hearing loss and cognition are linked, untreated hearing loss drives the association. Social isolation is a mediating factor only for those who have untreated hearing loss. We found that cognitive decline associated with ARHI is probably preventable by early rehabilitation and increased opportunistic screening for the elderly.

ARTICLE INFORMATION

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Concept and design: All authors.
Acquisition, analysis, or interpretation of data: Ray, Popli.
Drafting of the manuscript: Ray, Popli.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Popli.
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REFERENCES

1. Gates GA, Mills JH. Presbycusis. *Lancet*. 2005; 366(9491):1111-1120. doi:10.1016/S0140-6736(05)67423-5

2. Heine C, Browning CJ. Communication and psychosocial consequences of sensory loss in older adults: overview and rehabilitation directions. *Disabil Rehabil*. 2002;24(15):763-773. doi:10.1080/09638280210129162

3. Ärnlöv J, Larsson A; Global Burden of Disease Study 2013 Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2015;386(9995):743-800. doi:10.1016/S0140-6736(15)60692-4

4. World Health Organization. Deafness and hearing loss. WHO factsheets. http://www.who.int/mediacentre/factsheets/fs300/en/. Updated February 2017. Accessed December 2017.

5. Hearing loss: an important global health concern. *Lancet*. 2016;387(10036):2351. doi:10.1016/S0140-6736(16)30777-2

6. Dalton DS, Cruickshanks KJ, Klein BE, Klein R, Wiley TL, Nondahl DM. The impact of hearing loss on quality of life in older adults. *Gerontologist*. 2003;43(5):661-668. doi:10.1093/geront/43.5.661

7. Lin FR, Albert M. Hearing loss and dementia—who is listening? *Aging Ment Health*. 2014;18(6):671-673. doi:10.1080/13607863.2014.915924

8. Lin FR, Ferrucci L, Metter EJ, An Y, Zonderman AB, Resnick SM. Hearing loss and cognition in the Baltimore Longitudinal Study of Aging. *Neuropsychology*. 2011;25(6):763-770. doi:10.1037/a0024238

9. Uhlmann RF, Larson EB, Rees TS, Koepsell TD, Duckert LG. Relationship of hearing impairment to dementia and cognitive dysfunction in older adults. *JAMA*. 1989;261(13):1916-1919. doi:10.1001/jama.1989.03420130084028

10. Fulton SE, Lister JJ, Bush AL, Edwards JD, Andel R. Mechanisms of the hearing-cognition relationship. *Semin Hear*. 2015;36(3):140-149. doi:10.1055/s-0035-1555117

11. Gurgel RK, Ward PD, Schwartz S, Norton MC, Foster NL, Tschanz JT. Relationship of hearing loss and dementia: a prospective, population-based study. *Otol Neurotol*. 2014;35(5):775-781. doi:10.1097/MAO.0000000000000313

12. Gennis V, Garry PJ, Haaland KY, Yeo RA, Goodwin JS. Hearing and cognition in the elderly: new findings and a review of the literature. *Arch Intern Med*. 1991;151(11):2259-2264. doi:10.1001/archinte.1991.00400110105021

13. Hong T, Mitchell P, Burlutsky G, Liew G, Wang JJ. Visual impairment, hearing loss and cognitive function in an older population: longitudinal findings from the Blue Mountains Eye Study. *PLoS One*. 2016;11(1):e0147646. doi:10.1371/journal.pone.0147646

14. Taljaard DS, Olaithe M, Brennan-Jones CG, Eikelboom RH, Bucks RS. The relationship between hearing impairment and cognitive function: a meta-analysis in adults. *Clin Otolaryngol*. 2016;41(6):718-729. doi:10.1111/coa.12607

15. National Institute for Health and Care Excellence. *Dementia, Disability and Frailty in Later Life—Mid-Life Approaches to Delay or Prevent Onset*. London, UK: National Institute for Health and Clinical Excellence; 2015.

16. English Longitudinal Study of Ageing (ELSA). http://www.elsa-project.ac.uk/. Accessed September 2016.

17. Banks J, Batty GD, Nazroo J, Steptoe A. The dynamics of ageing: evidence from the English Longitudinal Study of Ageing 2002-15 (wave 7). https://www.ifs.org.uk/publications/8696. Published October 13, 2016. Accessed December 2017.

18. McHugh JE, Kenny RA, Lawlor BA, Steptoe A, Kee F. The discrepancy between social isolation and loneliness as a clinically meaningful metric: findings from the Irish and English Longitudinal Studies of Ageing (TILDA and ELSA). *Int J Geriatr Psychiatry*. 2017;32(6):664-674. doi:10.1002/gps.4509

19. Parving A, Sørensen MS, Christensen B, Davis A. Evaluation of a hearing screener. *Audiol Med*. 2008;6:115-119. doi:10.1080/16513860801995633

20. Davis A, Smith PA, Booth M, Martin M. Diagnosing patients with age-related hearing loss and tinnitus: supporting GP clinical engagement through innovation and pathway redesign in audiology services. *Int J Otolaryngol*. 2012;2012:290291. doi:10.1155/2012/290291

21. Zheng F, Yan L, Yang Z, Zhong B, Xie W. HbA_{1c}, diabetes and cognitive decline: the English Longitudinal Study of Ageing. *Diabetologia*. 2018;61(4):839-848. doi:10.1007/s00125-017-4541-7

22. Steptoe A, Shankar A, Demakakos P, Wardle J. Social isolation, loneliness, and all-cause mortality in older men and women. *Proc Natl Acad Sci U S A*. 2013;110(15):5797-5801. doi:10.1073/pnas.1219686110

23. Muthén L, Muthén B. *Mplus User's Guide*. 6th ed. Los Angeles, CA: Muthén & Muthén; 2010.

24. White H. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*. 1980;48(4):817-830.

25. Valentijn SA, van Boxtel MP, van Hooren SA, et al. Change in sensory functioning predicts change in cognitive functioning: results from a 6-year follow-up in the Maastricht Aging Study. *J Am Geriatr Soc*. 2005;53(3):374-380. doi:10.1111/j.1532-5415.2005.53152.x

26. Dawes P, Cruickshanks KJ, Fischer ME, Klein BE, Klein R, Nondahl DM. Hearing-aid use and long-term health outcomes: hearing handicap, mental health, social engagement, cognitive function, physical health, and mortality. *Int J Audiol*. 2015;54(11):838-844. doi:10.3109/14992027.2015.1059503

27. Lin FR, Yaffe K, Xia J, et al; Health ABC Study Group. Hearing loss and cognitive decline in older adults. *JAMA Intern Med*. 2013;173(4):293-299. doi:10.1001/jamainternmed.2013.1868

28. Lin FR, Metter EJ, O'Brien RJ, Resnick SM, Zonderman AB, Ferrucci L. Hearing loss and incident dementia. *Arch Neurol*. 2011;68(2):214-220. doi:10.1001/archneurol.2010.362

29. Blazer DG, Domnitz S, Liverman CT, eds. *Hearing Healthcare for Adults: Priorities for Improving Access and Affordability*. Washington, DC: National Academic Press; 2016.

30. Mick P, Pichora-Fuller MK. Is hearing loss associated with poorer health in older adults who might benefit from hearing screening. *Ear Hear*. 2016;37(3):e194-e201. doi:10.1097/AUD.0000000000000267

31. Tun PA, McCoy S, Wingfield A. Aging, hearing acuity, and the attentional costs of effortful listening. *Psychol Aging*. 2009;24(3):761-766. doi:10.1037/a0014802

32. The Lancet Commissions. Dementia prevention and care. http://www.thelancet.com. Published July 20, 2017. Accessed November 20, 2017.