Longitudinal Relationship Between Hearing Aid Use and Cognitive Function in Older Americans

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OBJECTIVES: To test whether hearing aid use alters cognitive trajectories in older adults.
DESIGN: US population-based longitudinal cohort study
SETTING: Data were drawn from the Health and Retirement Study (HRS), which measured cognitive performance repeatedly every 2 years over 18 years (1996–2014).
PARTICIPANTS: Adults aged 50 and older who who took part in a minimum of 3 waves of the HRS and used hearing aids for the first time between Waves 4 and 11 (N=2,040).
MEASUREMENTS: Cognitive outcomes were based on episodic memory scores determined according to the sum of immediate and delayed recall of 10 words.
RESULTS: Hearing aid use was positively associated with episodic memory scores (β=1.53, p<.001). Decline in episodic memory scores was slower after (β=–0.02, p<.001) than before using hearing aids (β=–0.1, p<.001). These results were robust to adjustment for multiple confounders and to attrition, as accounted for using a joint model.
CONCLUSIONS: Hearing aids may have a mitigating effect on trajectories of cognitive decline in later life. Providing hearing aids or other rehabilitative services for hearing impairment much earlier in the course of hearing impairment may stem the worldwide rise of dementia. **J Am Geriatr Soc 2018.**

Key words: hearing aid use; cognition; longitudinal analysis

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Neurodegenerative dementias such as Alzheimer's disease are a major health problem in the aging worldwide population. The number of people living with dementia is projected to increase by 57% in the next 2 decades, from 46 million in 2015 to 72 million in 2050.[1,2] This rising global prevalence, combined with the lack of effective curative treatment, has made the prevention of dementia a public health concern.

A recent study showed that intervention on risk factors not including hypertension might prevent 35% of dementia cases[3] and that the strongest midlife risk factor for dementia is hearing impairment. It showed that approximately 9% of dementia cases are attributable to hearing loss in midlife. Our previous study, using 3 longitudinal surveys on aging health, showed that individuals with hearing and visual impairments had lower episodic memory scores and a worse trajectory of decline in memory scores with age than those with no impairment. The relationship between hearing impairment and poorer cognitive ability in later life has also been reported in numerous cross-sectional[4–6] and longitudinal studies.[7–9] Because hearing impairment is prevalent, alleviating it might delay the point that older adults cross the critical threshold of impairment into dementia.

Hearing impairment is not only a greater risk factor for dementia than other individual midlife risks, but is also relevant to many individuals because of its relatively high prevalence in middle and old age. At least 10% of individuals aged 40 to 69 show some degree of measurable hearing impairment,[10] and this proportion increases with age. The prevalence of hearing impairment increases to 30% of individuals aged 65 and older, and between 70% and 90% individuals aged 85 and older experience some hearing loss.[11,12] Although hearing impairment is highly prevalent, it remains largely undertreated.[13] Only 1 in 7 adults aged 50 and older with hearing impairment use hearing aids, and this figure declines to fewer than 1 in 20 for working-aged adults (50–59).[11]

The effect of hearing aid interventions on cognitive function is poorly understood. Cross-sectional studies

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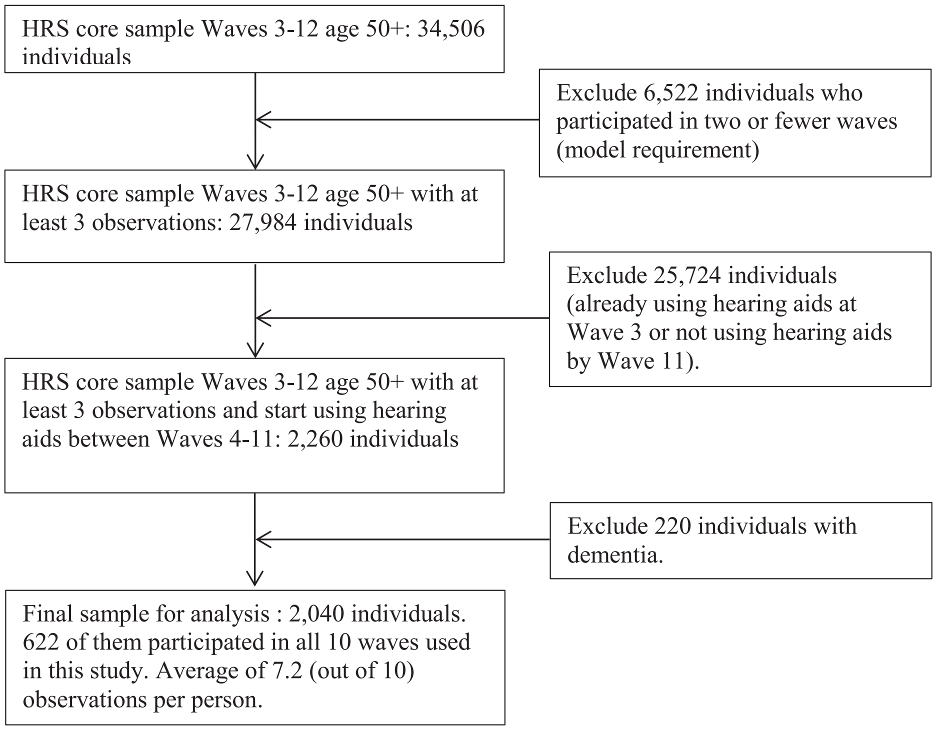

Figure 1. Procedure for selection of sample (N=2,040) from Health and Retirement Study core sample Waves 3–12.

from the United States[4] and United Kingdom[14] have reported that hearing aid use is associated with better cognitive scores, although a study using a cross-sectional cohort from the Baltimore Longitudinal Study of Aging found no significant relationship between hearing aid use and cognitive ability.[15] The insignificant effect of hearing aid use on cognitive function was also shown in several small longitudinal studies of short duration.[7–9,16,17]

We used an 18-year follow-up of the Health and Retirement Study (HRS) cohort to assess the consequences of hearing aid use on long-term age-related decline in episodic memory. Using a self-reported measure of hearing aid use, the association between hearing impairment and cognitive trajectories over 18 years was investigated in a community-based cohort of older adults, and the trajectories of the individuals before using hearing aids were compared with their trajectories after beginning to use hearing aids.

METHODS

This study forms part of the SENSE-Cog multi-phase research program, funded by the European Union Horizon 2020 program. SENSE-Cog aims to promote mental well-being in older adults with sensory and cognitive impairments (http://www.sense-cog.eu/). The goal of the first work package of this project is to better understand the links between sensory, cognitive, and mental health in older Europeans.

Study population

Our empirical analysis used the HRS Waves 3 (1996–97) to 12 (2014–15). The HRS is an ongoing biennial investigation of U.S. adults aged 50 and older that started in 1992. Sponsored by the National Institute of Aging and performed by the Institute for Social Research at the University of Michigan, the HRS provides information on demographic and socioeconomic factors and health.

We used Wave 3 and later of the HRS because the episodic memory scores using 10 words were first available in the Wave 3. We restricted the sample to respondents aged 50 and older who responded to at least 3 waves of the HRS, had no dementia in the baseline, and used hearing aids for the first time between Waves 4 and 11. This gave a sample of 2,040 individuals, with the selection procedure as illustrated in Figure 1. We describe the characteristics of the HRS core sample from Waves 3 to 12, the HRS core sample with at least 3 observations, and the final sample in Supplementary Table S1, which shows that the average age and episodic memory scores of the core sample from Waves 3 to 12 and the final sample are similar.

Measures

The measures of cognitive ability in the HRS are the outcomes of simple tests (e.g., immediate and delayed word recall (episodic memory), serial 7's, backward count starting from 20, and date naming). In our analysis, we focused on 1 cognitive domain available in all HRS waves used in this study: episodic memory. We were particularly interested in episodic memory scores because they are more age sensitive than other cognitive measures,[18] do not experience floor or ceiling effects,[19] have a mechanism in common with cognitive control variables,[13] and have a strong association with dementia. After allowing for established risk factors for dementia, the odds of dementia in members of the reference (disadvantaged) trajectory were 5 times as high as in those in the most advantaged trajectory of episodic memory.[20] In the HRS memory test, the interviewer read a list of 10 simple nouns (e.g., book, child, hotel) once, and participants were asked to repeat those nouns immediately after the words were read (immediate recall) and after a short interval (delayed recall). We calculated the episodic memory score as the sum of the number of target words recalled at the immediate and the delayed recall phase (range 0–20).[19]

When hearing aids were used for the first time was based on participants' response to the question: "Do you ever wear a hearing aid?" Based on the first time that a respondent answered yes to that question, we constructed a dummy variable for hearing aid use (1 for the wave the first time the respondents used hearing aids and after, 0 for the wave before the respondents used hearing aids). In total, 2,260 respondents used hearing aids for the first time during the 14-year period.

We included an extensive set of covariates identified as risk factors for cognitive decline in prior studies.[21–24] Demographic covariates included age and sex. Socioeconomic covariates included education (<high school, high school, ≥college), marital status (married or cohabiting, not married), and wealth (tertiles of income each wave). The lifestyle behavior covariates included smoking, drinking, and physical activities. For smoking, respondents were classified as nonsmokers, past smokers, and current smokers. We used number of units per week to measure drinking behavior. Depressive symptoms were assessed using the 8-item Center for Epidemiologic Studies Depression Scale.[25] Number of comorbidities was included as the sum of several chronic diseases: heart disease, high blood pressure, lung diseases, diabetes mellitus, stroke, and cancer.

Statistical analysis

To model trajectories in episodic memory scores, we used hierarchical linear regression analysis, which is designed for the analysis of longitudinal data. In this regression analysis, intra-individual correlation was modelled using an individual-specific random intercept and an individual-specific random slope. This analysis thus takes into account multiple observations within individual and intra-individual correlation. In addition, it allows for adjustment of potential confounding variables. We used a spline model with a knot at the beginning of hearing aid use and assessed whether the slope before using hearing aid differed from the slope after hearing aid use. We included the hearing aid variable (coded as 1 after using a hearing aid and 0 before using a hearing aid) and its interaction with the slope term (age) to test the differences in cognitive trajectories before and after beginning to use a hearing aid. The associations between hearing aid use, age, age interaction with hearing aid use, and episodic memory scores were quantified in the first model. Demographic and socioeconomic determinants (age, sex, education, marital status, wealth) and the variables representing lifestyle behavior, depression, and number of chronic diseases were added in the final model.

Sensitivity analysis

For the first sensitivity analysis, we conducted 2 separate hierarchical linear regression analyses with immediate and delayed word recall as the outcomes; the second analysis focused on attrition. The HRS, like other longitudinal studies on aging, is subject to attrition, in which respondents are prone to selective dropout due to death or poor health.[26,27] Ignoring those dropouts can result in bias in the analysis. We tested the sensitivity of our results to attrition by using a joint model.[28] This resultant division into 2 parts, the growth curve model and the survival model, allowed the random effects to influence episodic memory and attrition. Finally, we examined the role of sex in the association between hearing aid use and cognitive function by conducting separate analyses for women and men. The models were constructed using Stata version 14 (Stata Corp., College Station, TX) and Latent Gold 5.1 (Statistical Innovations, Belmont, MA).

RESULTS

Table 1 shows the descriptive statistics of 2,040 HRS sample respondents who used hearing aids for the first time between Waves 4 and 11 at the first wave observed. The episodic memory score has a distribution close to the normal distribution, with a sample mean of 10.4 and a standard deviation of 3.2. On average, respondents used hearing aids for the first time at 62 years old. Sixty-one percent of respondents were male, 45% had completed college or higher, and 81% were married. The bivariate regression model (Table 1, second and third columns) shows that age, depression score, and number of comorbidities have a significant association with episodic memory scores. Being relatively well educated, drinking alcohol, and engaging regularly in physical activities are positively associated with episodic memory scores.

The parameter estimates for the slope of episodic memory scores before and after beginning to use hearing aids in an initial model are presented in Table 2. Episodic memory declined significantly with the addition of age, but the rate of the decline was slower after beginning to use hearing aids (β=–0.03, p<.001) than before (β=–0.11, p<.001). The difference in the coefficient between those two slopes is 0.08 (p<.001). In this model, hearing aid use was associated with higher memory scores (β=2.13, p<.001). The association between hearing aid use and episodic memory scores remained significant when we included the risk factors in the second model (β=1.53, p<.001). In this second model, slopes for the decline of episodic memory scores were steeper before beginning hearing aid use (β=–0.1, p<.001) than after (β=–0.02, p<.001).

In the second model, there were significant associations between several potential confounders and sociodemographic characteristics and episodic memory scores. Being female, having attained a higher level of education, having a higher income, drinking alcohol, and engaging in regular physical exercise were positively associated with episodic memory scores. Depression scores and chronic diseases were associated with lower memory scores.

Figure 2 illustrates change in episodic memory scores over time. The graph is centered at the first time an individual used hearing aids. The lines to the left of the center of the graph show the rate of change in episodic memory

Table 1. Characteristics of Health and Retirement Study Sample of Hearing Aids Users (Using Hearing Aids for First Time Between Wavea 4 and 11) at Baseline at First Wave Observed

Characteristic	Value	Association with Episodic Memory Scores	
		Cofficient (Standard Error)	P-Value
Episodic memory score, mean ± SD	10.4 ± 3.2		
Age, mean ± SD	62.8 ± 7.7	–0.08 (0.00)	<.001
Female, %	38.0	1.11 (0.14)	<.001
Education, %			
≤Primary school	24.2	Reference	
Secondary school	30.2	1.68 (0.19)	<.001
≥College	45.6	2.52 (0.17)	<.001
Married, %	81.7	0.28 (0.18)	.13
Smoking behavior, %			
Nonsmoker	38.5	Reference	
Past smoker	47.3	–0.26 (0.16)	.10
Current smoker	14.2	–0.38 (0.23)	.10
Drinking, units/week, mean ± SD	2.9 ± 6.1	0.00 (0.01)	.58
Doing vigorous physical activity	51.2	0.53 (0.14)	<.001
Depression score, mean ± SD	1.14 ± 1.72	–0.24 (0.04)	<.001
Number of comorbidities, mean ± SD	0.87 ± 0.94	–0.38 (0.07)	<.001

SD = standard deviation.

score in the years leading up to beginning hearing aid use, and the lines to the right of the center of the graph show the rate of change in episodic memory after the beginning of hearing aid use. The model is adjusted for demographic and socioeconomic characteristics, lifestyle behavior, and health status. For all individuals, there is a decline in episodic memory leading up to hearing aid use. Episodic memory scores continue to decline after beginning to use hearing aids, but the rate of decline is less steep.

The first sensitivity analysis shows that immediate and delayed word recall scores declined significantly before using hearing aids and that this significant decline diminished after beginning to use hearing aids (Supplementary Table S2, Supplementary Figure S1). For the second sensitivity analysis (Supplementary Table S3, Supplementary Figure S2), the slope of cognitive decline before and after beginning to use hearing aids in the joint model is similar to that in the growth curve model, indicating that our findings are robust. Our final sensitivity analysis showed that, although women performed better than men on the episodic memory test, they had similar rates of cognitive decline before and after using hearing aids for the first time (Supplementary Table S4, Supplementary Figure S3).

Table 2. Hearing Aid Use and Episodic Memory Scores, Coefficients and Standard Errors: Health and Retirement Study 1996–2014

Factor	Coefficient (Standard Error) P-Value	
	Model 1	Model 2
Intercept	17.89 (0.36) <.001	15.32 (0.4) <.001
Age (before using hearing aid)	–0.11 (0.00) <.001	–0.1 (0.00) <.001
Age (after using hearing aid)	–0.03 (0.00) <.001	–0.02 (0.00) <.001
Hearing aid use	2.13 (0.41) <.001	1.53 (0.41) <.001
Female		1.11 (0.09) <.001
Married		0.16 (0.07) .04
Education (reference <high school)		
High school		0.97 (0.12) <.001
≥College		1.84 (0.11) <.001
Wealth tertile (reference 1 (poorest))		
2		0.33 (0.07) <.001
3 (wealthiest)		0.58 (0.08) <.001
Smoking (reference nonsmoker)		
Past smoker		0.08 (0.09) .36
Current smoker		–0.05 (0.13) .68
Drinking behavior		0.01 (0.00) .001
Vigorous physical activity		0.17 (0.05) .001
Depression score		–0.11 (0.01) <.001
Number of comorbidities		–0.13 (0.03) <.001

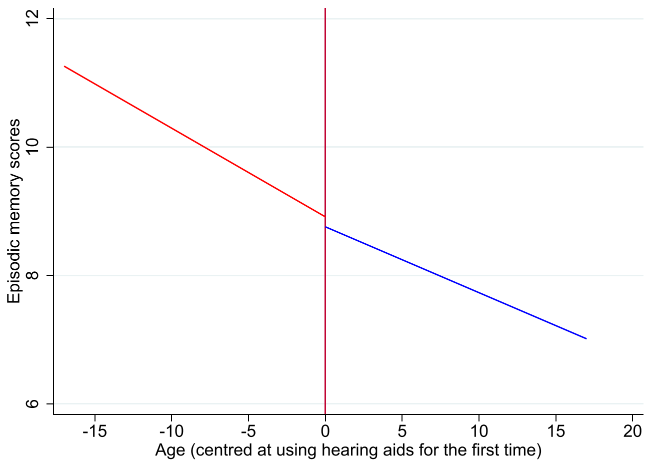

Figure 2. Predicted values of episodic memory before and after beginning to use hearing aids (time centered at using hearing aids).

DISCUSSION

Using a national representative survey spanning 18 years, our study shows a less steep decrease in episodic memory performance after beginning to use hearing aids than before using hearing aids. The slower rate of decline after beginning hearing aid use remained significant after taking attrition into account. From the theoretical point of view, this finding provides new evidence to disentangle the relationship between cognitive function and hearing impairment. In prior studies, 2 main hypotheses were posited to explain this relationship. The common cause hypothesis posits that hearing impairment and cognitive decline share common age-related change factors such as degeneration of the central nervous system.[29,30] The cascade hypothesis claims that prolonged reduction in hearing function leads to insufficient stimulation, which may cause cognitive decline in later life.[7,14,31,32] These hypotheses lead to different predictions regarding the effect of hearing aid use on cognition. According to the common cause hypothesis, hearing aids may not affect cognition given that degeneration of central nervous system affects cognitive function regardless of maintenance of good hearing.

The slower rate of cognitive decline in those with hearing impairment who have begun using a hearing aid supports the cascade hypothesis. According to this hypothesis, hearing aids may allow better hearing input and delay cognitive decline by preventing the adverse effects of auditory deprivation or facilitating lower levels of depression symptoms, greater social engagement, and higher self-efficacy, which protect cognitive function. Prior studies have reported that hearing aid users experience less anxiety and depression[33,34] and have better-quality social engagement after beginning to use hearing aids; lack of social engagement and depression are independently associated with cognitive decline.[36–38] Another mechanism through which hearing aids may reduce the rate of cognitive decline is by enhancing self-efficacy, the belief in one's ability to accomplish tasks or succeed in specific situations,[39] which in turn improves scores on cognitive tests and memory function.[40,41] Further research is needed to confirm the mechanism by which hearing aid use affects rate of cognitive decline in later life.

The strengths of this study lie in its long-term follow-up, which may have allowed a longer time for the accumulation of the benefits of hearing aid use to appear, although the longer follow-up period also introduced greater individual differences that may have influenced cognitive function because of the effects of aging and disease. In addition, the population-based nature of the HRS sample makes the results of the study generalizable and enhances their external validity. Our findings could thus have substantial public health implications, especially due to the large prevalence of age-related hearing impairment and poor hearing aid aid uptake among those with hearing impairment. Approximately one-third of U.S. adults aged 50 and older with hearing impairment[42] and 40% of those with moderate hearing impairment use hearing aids.[43] A report from the National Academies of Sciences, Engineering, and Medicine found that many individuals with hearing impairment do not seek or receive hearing health care, mainly because of their lack of awareness of hearing impairment, limited accessibility of the care, and high costs for hearing technologies. It recommended a set of actions to improve accessibility and affordability of hearing health care, including strengthen hearing healthcare promotion and provide access to care of poor people.[44] Our findings support the proposition that timing of beginning hearing aid use is crucial for the success of hearing aids as an intervention in old age.[45] Hearing impairment has been found to be the most prominent midlife risk factor for dementia,[3] with 55 being the youngest average age at which hearing impairment was shown to be associated with risk of dementia.[46] Preventing hearing loss, screening individuals for hearing function, and providing hearing aids may preserve cognitive function in older age.

An important limitation of our study is that hearing aid use was identified based on individuals reporting whether they ever wear hearing aids. No information on frequency of use, adequacy of amplification, or satisfaction with hearing aids was available. Up to 40% of hearing aids dispensed are never or rarely used.[47] Differing durations and extents of rehabilitative procedures may also lead to different effects on cognitive function. These differences may mask the magnitude of the effect of hearing aid use on cognitive function in this study. Because there is high interindividual variability in hearing aid use, future studies should consider this factor in their models. Another limitation of our study was that the episodic memory tests in the HRS were all presented orally, and better hearing may facilitate better performance on those tests, but our analysis of the visually presented letter cancellation test available in the English Longitudinal Study on Ageing Wave 5 shows that respondents with hearing impairment perform worse than those with no impairment (Supplementary Table S5).

In sum, we observed a slower decline in episodic memory performance in HRS participants with hearing impairment after they began to use hearing aids. This association was shown to be independent of risk factors for cognitive impairment and remained significant when we considered attrition in the analysis. Public health efforts to increase access to quality hearing health care might delay the onset of cognitive impairment and prove a successful preventive intervention to reduce the impending dementia epidemic.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article.

Table S1. Descriptive statistics of full sample, sample with at least 3 observations and final sample of HRS Waves 3–12.

Table S2. Hearing aid use and immediate and delayed word recalls, coefficients and standard errors. Source: HRS 1996–2014.

Figure S1. Predicted values of immediate and delayed memory before and after beginning to use hearing aids (time centered at using hearing aids).

Table S3. Joint model predicting episodic memory scores. Source: HRS 1996–2014.

Figure S2. Predicted values of episodic memory using joint model before and after beginning to use hearing aids (time centered at using hearing aids).

Table S4. Hearing aid use and episodic memory scores by gender, coefficients and standard errors. Source: HRS 1996–2014.

Figure S3. Predicted values of episodic memory before and after beginning to use hearing aids (time centered at using hearing aids) by gender.

Table S5. The comparison of letter cancellation performance between respondents with different sensory function. Source: ELSA Wave 5 (2010).