Title page - International Journal of Audiology

DOES COGNITIVE IMPAIRMENT PRECEDE SELF-REPORTED POOR HEARING? RESULTS FROM THE ENGLISH LONGITUDINAL STUDY OF AGEING

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ABSTRACT

Objective: To investigate whether cognitive impairment precedes self-reported poor hearing in adults aged 50 and older over a 14-year period.

Design: Biennial longitudinal study.

Study sample: The data came from the English Longitudinal Study of Ageing (ELSA) carried out in England between the years of 2002 and 2016, with 11,391 individuals aged 50 years and older. For this study, ELSA participants who had a positive perception of hearing at the beginning of the analysis in 2002 (n = 8,895) were eligible. The dependent variable was self-reported poor hearing and the exposure measure was cognitive impairment. The analyses were performed using Generalized Estimation Equations (GEE) and adjusted for gender, age, educational level, household wealth, smoking, alcohol consumption, depressive symptoms, ADL/IADL disability, physical activity level, diabetes and cardiovascular disease.

Results: The results showed 33% increased odds of self-reported poor hearing in individuals with cognitive impairment (95% CI: 1.25; 1.43). In the fully adjusted model, individuals who presented cognitive impairment in the previous wave had, over time, 10% increased odds (95% CI: 1.02; 1.19) of presenting self-reported poor hearing.

Conclusions: The exposure of cognitive impairment was associated with a subsequent self-reported poor hearing. These data represent important tools for improving the diagnosis and treatment of cognitive and hearing impairment.

Keywords: Cognitive Decline; Cognitive Dysfunction; Hearing; Elderly; Hearing Loss; Auditory Perception.

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INTRODUCTION

With ageing, physiological losses due to a gradual process occur (Assumpção et al. 2018). Such losses include sensory - sight, touch, taste, smell and hearing - and cognitive decline, compromising cognitive functioning and mental abilities. Such impairments, in turn, can negatively impact the functionality and autonomy later in life, as well as the performance of activities of daily life and, consequently, quality of life and social integration (Kamiński et al. 2017; Binder 2017).

Cognitive capacity results from multiple neuronal connections developed throughout life, influenced by participation in stimulating activities from a physical, mental and social point of view, which determine the available cognitive reserve for creating new neural networks when losses occur (Pettigrew et al. 2019). Stimulating reading, logical reasoning and social interaction have a strong potential for reducing the risk of the progression of dementia (Prince et al. 2013; Wang et al. 2017). The Global Dementia Observatory Reference Guide (2018) noted that dementia affects approximately 50 million people worldwide, spending over one trillion dollars (Hughes 2017). In England, there are projections of reaching 1.9 million cases of dementia in 2040 (Ahmadi-Abhari et al., 2017).

Hearing depends on the integrity and function of the peripheral and central auditory systems, which detect, codify, decode, and interpret auditory stimuli. Authors suggest that the presence of hearing loss, due to changes in the peripheral auditory system, compromises the auditory signals to be processed (Uchida et al. 2019; Stahl et al. 2017). That leads the individual to activate more cognitive resources for auditory-perceptual processing. Listening, thus, demands more and more effort, leading to a diversion of cognitive tasks for this purpose, depleting cognitive reserves due to the performance of a double task. This is one of the hypotheses for the connection between hearing loss and cognitive decline (Stahl et al. 2017; Martini et al. 2014; Uchida et al. 2019).

Uchida et al. (2019) raised hypotheses for the relationship between cognitive decline and hearing loss: common cause, that is, similar pathophysiology, since both conditions can arise from standard age-related neurodegenerative processes. Another potential mechanism is the cascade hypothesis: peripheral hearing loss decreases sensory input, which can potentially lead to other harmful effects, such as social isolation and depression, which can be directly or indirectly related to cognitive impairment (Uchida et al. 2019).

A recent study highlights the importance of assessing ageing beyond the metric of chronological age, estimating the burden of this process, according to the state of health and the severity of diseases in older adults, as a way of understanding the resources necessary to cope with it (Chang et al., 2019). Studies conducted by The Lancet Commission have shown that hearing loss stands out among the nine main potentially modifiable risk factors for dementia (Livingston et al. 2017). Authors additionally emphasize the importance of hearing aid usage to increase social activity and to potentially modify the onset or trajectory of dementia (Livingston et al. 2020; Dawes et al. 2015).

Although research has already identified a statistically significant correlation between hearing loss and cognitive decline (Amieva et al. 2018; Ford et al. 2018; Huber et al. 2019), the reverse has been little researched (Davies et al. 2017). The subject constitutes an open field for investigations (Littlejohn 2017; Panza 2015; Tuwaig 2016), making a new perspective necessary. Cognitive decline can represent an indicator of hearing loss detection (Jayakody et al. 2018; Uchida et al. 2019). Studies have hypothesized that cognitive decline may lead to hearing loss, as deficits in cognitive ability can alter the perceptual processing of stimuli (Maharani et al. 2020; Wayne et al. 2015).

Understanding the relationship between cognitive impairment and hearing loss represents an elementary differential in directing actions and public health policies aimed at active and healthy ageing, the prevention of dementia and the rehabilitation of hearing loss. Given the above, this study aimed to investigate whether cognitive impairment precedes self-reported poor hearing in adults aged 50 and older over a 14-year period.

METHODS

Study design and data source

The data came from the English Longitudinal Study of Ageing (ELSA), a longitudinal study that analyzed 11,391 men and women living in private households in England. Data collection is biennial and is called a wave. The first wave, i.e. baseline started in 2002. For this study, we used data from adults aged 50 years and older from waves 1 to 8.

Only individuals who self-reported good hearing (excellent/very good/good) in wave 1 (baseline) were included. Participants who self-reported fair or poor hearing at the baseline were excluded. Thus, it was possible to assess whether the change in hearing perception (outcome) throughout the 14 years was associated with cognitive impairment (primary exposure) in the previous wave. Both the cognition and self-reported hearing assessments occurred at all eight waves of ELSA and were assessed in the same visit.

Among the 11,391 original participants in the cohort, 8,895 individuals were eligible for this study, representing 78% of the total sample. Out of the initial eligible sample, 6,951 individuals were re-interviewed in wave 2 (2004), 6,000 individuals in wave 3 (2006), 5,320 individuals in wave 4 (2008), 5,073 individuals in wave 5 (2010), 4,619 individuals in wave 6 (2012), 4,031 individuals in wave 7 (2014) and 3,486 individuals in wave 8 (2016). Subjects excluded from the baseline were not included in the study in subsequent waves. Further clarifications regarding the ELSA sampling and data collection have been previously published (Steptoe et al. 2012).

Outcome variable

The dependent variable in this study was self-reported poor hearing. Although self-reporting has limitations due to its subjective character, Marini, Halpern and Aerts (2005) pointed out in their study that perception of hearing loss has a sensitivity of 81% and specificity of 70%. Therefore, it can be a reliable tool in population studies where objective clinical examinations are logistically challenging. The perception of hearing was determined using the following question: "Is your hearing [using a hearing aid as usual] (1) excellent, (2) very good, (3) good, (4) fair and (5) poor?", in the eight study waves (Davies et al. 2017; Banks et al. 2016). This variable was subsequently classified into two categories: self-

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Exposure variable

The exposure measure, i.e. cognitive status, was obtained by assessing long-term memory using the Delayed Recall Test (Swearer et al. 1998). This test is used for rapid tracking of cognitive impairment, as it analyses both processing and short-term memory. Loewenstein et al. found a sensitivity of 87.9% and specificity of 92.5% for screening of memory decline and predisposition to dementia (Loewenstein et al. 2017). The application of the delayed recall test involves reading ten words aloud at the beginning of the interview and, after twenty minutes, to ask the individual to repeat the words, after answering the other questions asked by the interviewer. The cognitive level is determined by the maximum number of words correctly recalled. Thus, the cognitive level is characterized in: "positive" cognitive impairment, when 0 to 3 words are recalled and "negative" cognitive impairment, when 4 to 10 words are recalled. Delayed recall tests are highly accurate for the diagnosis of dementia, especially in Alzheimer's cases, is widely used due to reasonable specificity and sensitivity (Prince et al. 2013; Swearer et al. 1998).

Covariates

The covariates included were gender, age, total household wealth, educational level, health behaviours such as smoking and alcohol consumption, depressive symptoms, activities of daily living and instrumental activities of daily living (ADL/IADL), physical activity level (weekly), and the self-reported doctor diagnosed diabetes mellitus (yes/no) and cardiovascular disease (yes/no) (stand-alone category).

Age was classified into four categories (whole years): 50-59, 60-69, 70-79 and over 80 years old. ELSA has collected detailed information on different dimensions of wealth both at baseline and in each follow-up interview. We used total net non-pension household wealth, a summary measure of the value of financial, physical and housing wealth owned by the household (i.e., a single respondent or a responding couple and any dependent individuals) minus any debt. The estimation of this variable was based on 22 different wealth and debt components. Wealth was divided into quintiles, calculated by the Institute for Fiscal Studies, UK (Steptoe et al. 2012). In the United Kingdom, the 3-way education division is qualified to a level lower than “O-level” or equivalent (typically 0-11 years of schooling; i.e. low), qualified to a level lower than “A-level” or equivalent (typically 12-13 years of education; i.e. medium), and a higher qualification (usually>13 years of schooling; i.e. high). Smoking status was categorized into two groups: current smoker (yes/no). Self-reported alcohol consumption was categorized as follows: daily, weekly and never.

Depressive symptoms were measured using the eight-item version of the Center for Epidemiologic Studies Depression Scale (CES-D). Items capture information on symptoms of negative affect and somatic complaints experienced in the past week (White et al. 2016). The total score, ranging from 0 (no symptoms) to 8 (all eight symptoms), was categorized with a cut-off point of 0-3 (no) 4-8 (yes). Regarding the basic and instrumental activities of daily living disability (ADL/IADL) (yes/no), the questions were as follows for ADL: dressing (including putting on shoes and socks), eating (such as cutting up your food), using the toilet (including getting up and down), bathing and showering, getting in and out of bed, and walking across a room. IADL were as follows: preparing a hot meal, shopping for groceries, making telephone calls, taking medications, and managing your money, such as paying your bills and keeping track of expenses. Individuals who had disability in at least one ADL/IADL on the ELSA list were classified as "yes".

The level of physical activity was assessed every wave by asking participants how often they took part in vigorous-intensity (e.g. running/ jogging, swimming, cycling, aerobics/gym workout, tennis, and digging with a spade), moderate-intensity (gardening, cleaning the car, walking at moderate pace, dancing) and low-intensity (laundry and home repairs) physical activity, using prompt cards with different activities to help them interpret different physical activity intensities. Response options were: more than once a week, once a week, one to three times a month, and hardly ever/never. At each time point physical activity was further categorized into four groups: inactive; only light activity at least once a week (but no moderate or vigorous); moderate activity at least once a week (but no vigorous), and vigorous activity at least once a week. Then light to moderate physical activity were grouped into one category (light/moderate).

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Statistical Analysis

The probabilities of transitions (the change from one category to the other for the categorical variables over time) for all the variables were calculated using xttrans command. xttrans counts transitions from each observation to the next once the observations have been put in t order within i participants. The number of observations in each category was included together with the probabilities of transitions in Table two. A temporal relation was established between exposure (cognitive impairment) and outcome (self-reported poor hearing) through two-year interval models, with cognitive impairment in the previous wave being related to the self-reported poor hearing in the next wave.

We used Generalized Estimating Equations (GEE) to model the association between cognitive impairment and self-reported poor hearing. GEE is an extension of the generalized linear model that accounts for the within-subject correlation across repeated measurements, allows for within-subject missing data, and is appropriate to estimate population-averaged effects over time using longitudinal data such as ELSA (Liang and Zeger 1986). The GEE approach was used because the assumption of observation independence needed to calculate coefficients in a traditional regression cannot be satisfied when using repeated measures (for example, when we have repeated measurements of the exposure and the outcome in the same individuals over time). GEEs accommodate the modelling of repeated data over time and consider the variance within individuals and between individuals. Because the repeated observations within one subject are not independent of each other, a correction must be made for these within-subject correlations. With GEE, this correction is carried out by assuming a priori a specific 'working' correlation structure for the repeated measurements of the outcome variable. Not all the individuals included attended each of the eight time points, the minimum was one time point, the average was 4,1 and the maximum was 7. It was not necessary to attend consecutive waves to be included, some individuals might have attended wave one, have missed wave two and have returned to attend wave three and still be included in the model. Any pair of two consecutive time points available was used in the lagged model. When time was included in the model the results did not change.

Due to the dichotomous outcome, the link function was a logit function of the binomial family. The least restrictive within-group correlation structure (unstructured) was chosen, and a robust variance estimator that allowed covariates inclusion was used. The

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analyses were adjusted for gender, age, household wealth, educational level, smoking, alcohol consumption, depressive symptoms, ADL/IADL disability, physical activity level, diabetes and cardiovascular disease, included simultaneously in the adjusted analysis. Crude and adjusted odds ratios (OR) and their respective 95% confidence intervals (95% CI) were estimated. A p value of $p<0.05$ was considered statistically significant. The analyses were performed using the STATA software, version 14.0 (*StataCorp*, Texas, USA).

Ethical approval and informed consent

The English Longitudinal Study of Ageing received approval from the National Research Ethics Service (London Multicentre Research Ethics Committee [MREC/01/2/91]), and all participants signed a statement of informed consent. The authors confirm that approved guidelines and regulations performed all research and methods.

RESULTS

Of the 8.895 (78.08%) ELSA participants selected for self-reported good hearing at the time of wave 1, a more significant proportion of participants in the 60 to 69 age group across the waves. As expected, the participation of older adults aged 50 to 59 decreased over the years, while the participation of those aged 80 and over increased. The majority of the sample (57.68%) was female, with a medium level of education (47.82,%) and the percentage of individuals in the lowest quintile decreased over the years, going from 20.06% in wave 1 to 15.66% in wave 8. Regarding self-perception of hearing, it was possible to verify that the reports of poor hearing increased over the years, going from 10.08% in wave 2 to 20.51% in wave 8. Cognitive impairment had an average prevalence of 30% in the studied time frame (Table 1). The individuals excluded due to missing data were older, current smokers, poorer, had lower schooling and reported more chronic conditions in comparison to the individuals included in the present study (data not shown).

Table 2 shows the probability transitions occurred, on average, for health and risk behaviours of participants during the 14 years. Transitions between categories were observed over the years for all the variables analysed. Every two years (or in each wave of interviews), 90.5% of the persons that did not report poor hearing at that time remained like that in the next wave; the remaining 9.5% became with self-reported poor hearing. Although the persons with no self-reported poor hearing had a 9.5% chance of becoming with poor hearing in each wave, the persons that already reported poor hearing had only a 43.0% chance of becoming (or returning to) not having a poor hearing. Regarding self-reported hearing, the probabilities of transitions between categories were close to 50% for all types.

Regarding cognition, it was observed a probability of 17,16% of becoming with cognitive impairment (recalling less than three words correctly) and a chance of 39,9% of returning to not presenting this condition (identifying 4-10 words correctly). Regarding cardiovascular diseases and diabetes, few transitions were observed, with most of the participants remaining in the same category for most of the observations over time. The chance of starting to report cardiovascular diseases was around 10%, and the chance of stopping reporting this condition was only 4.63%. For diabetes, the chance of beginning to report cardiovascular diseases was even lower (1,76%), and the chance of stopping reporting this condition was only 6.44% (Table 2).

Concerning alcohol consumption, the probability of increasing consumption (changing from "never" to "weekly" or "daily") was 20.08%, and the likelihood of reducing consumption (changing from "daily" to "weekly" or "never") was 26.6%. The non-smokers remained predominantly like that (99.3%); on the other hand, the smokers had a probability of 18.59% quitting (Table 2).

Table 3 shows the crude and adjusted analyses of the association between self-reported poor hearing and cognitive impairment. A 33% increased odds of self-reported poor hearing were observed in individuals with cognitive impairment compared to the category without cognitive impairment. In the adjusted analysis, individuals who presented cognitive impairment in the previous wave had, over time, on average, 10% increased odds of reporting self-reported poor hearing in the next wave (Table 3).

DISCUSSION

In the present study, an association was found between cognitive impairment and self-reported poor hearing in 50 years or older. It was also observed that the presence of cognitive impairment in the previous wave increased the odds of reporting self-reported poor hearing throughout the 14 years of the study.

Several studies have pointed out the interrelation between hearing loss and cognitive decline (Amieva et al. 2018; Ford et al. 2018; Loughrey et al. 2018; Livingston et al. 2017). Loughrey et al. (2018) conducted a systematic review and metanalysis to investigate the association between age-related hearing loss (presbycusis) and three outcomes: cognitive function, cognitive impairment and dementia. Individuals presenting with hearing loss were more likely to show cognitive impairment and dementia. However, the authors pointed out that the causal mechanisms that link hearing loss and cognitive decline remain uncertain.

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The study developed by Kiely et al. (2012), carried out with data from the Australian Longitudinal Study of Aging (ALSA) and Blue Mountains Eye Study (BMES), concluded that faster rates of decline in hearing are predicted by probable cognitive impairment and hypertension, suggesting the possibility of reverse causality in studies that investigated hearing loss and cognitive function, primarily when the older adults are investigated (Kiely et al . 2012). Our results are also corroborated with the study of Maharani et al. (2020), carried out with ELSA data (Wave 1-7), whose purpose was to characterize latent cognitive trajectories in recall memory and identify their association with subsequent risk of hearing impairment. The authors concluded that Long-term changes in cognitive ability predict hearing impairment. In addition, in a 5-year follow-up study, Golob, Irimajiri & Starr (2007) demonstrated that both P50 amplitude and P300 latency, elicited in an oddball auditory task, increase with mild cognitive impairment.

Other studies suggest the opposite of cognitive decline preceding self-perceived hearing impairment (Lin et al. 2013; Deal et al. 2017; Davies et al. 2017; Curhan et al. 2019; Golub et al. 2019). Hearing loss is highly prevalent among older adults (Rodríguez-Valiente et al. 2020) and is independently associated with cognitive decline (Davis, Lin et al. 2016), thus making it one of the most important risks factors deserving the attention of health care professionals serving this population. Samelli et al. (2016) also stated that the difficulty in the central processing of the auditory stimulus, due to presbycusis, represents an important confounding factor in older people with cognitive decline, since the consequences of both outcomes involve social isolation and depression. A systematic review (Ismail et al. 2017) pointed out that the prevalence of depression in individuals with cognitive impairment is high, and this can lead to social isolation, favoring the subsequent presentation of hearing deficits.

A study conducted by Rutherford et al. (2018) highlighted the role of conceptual and behavioral mediators that cause hearing loss to directly interfere in the cognitive decline and in the dementia of the older adults, due to the decrease in cognitive reserve; and, indirectly, due to the need to activate more cognitive resources due to the difficulty in discriminating speech, leading to social isolation, decreased physical activity and fragility, predisposing individuals to depressive conditions. The study by Mattiazi et al. (2016) showed that the greater the degree of hearing loss, the greater the cognitive requirement for understanding speech. Thus, the hypotheses for a relationship between hearing loss and cognitive decline (cognitive load, common cause and cascade) are not mutually exclusive and can occur simultaneously, making it difficult to identify the underlying mechanism of this association (Lin et al. 2013; Uchida et al. 2019).

As already mentioned, the strategy proposed by The Lancet Commission highlights that the use of hearing aids represents an important ally to prevent dementia (Livingston 2020). In this perspective, it is worth mentioning that there are few estimates of population representativeness regarding access to hearing health services. Additionally, these services encompass actions that should include, along with the provision of technologies for amplification, adaptation support and auditory training, cognitive stimulation and communication strategies and periodic monitoring to ensure success in the rehabilitation process, especially in the older adults with hearing loss (Nieman et al. 2017).

Some key elements must be considered when interpreting the results of this research. First, the use of self-reported measures can be considered a limitation, especially when it comes to hearing loss perception measures, as these reflect the perceptions of individuals, and may be underestimated. However, although the self-report has limitations due to its subjective character, authors pointed out that the perception of hearing loss has high values of sensitivity and specificity and can be a reliable tool in population studies (Marini et al. 2005; Oosterloo et al. 2020; Torre et al. 2006).

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With regards to the strengths of the present study, ELSA constitutes a nationally representative sample of community dwelling older English individuals aged 50 and older. The methods used by ELSA are also a positive aspect of the study, emphasizing that health surveys are an important method of collecting epidemiological data, capable of producing information that subsidize public policies and promote advances in scientific knowledge. The longitudinal statistical methods used in the present study, which allows the temporal relationship with the exposition preceding the outcome, is another strength point. For the future, we suggest conducting research that includes, in its analysis, objective measures of hearing. Through the results found in our research, we highlight the importance of assessing the hearing function of older adults with cognitive impairment in clinical practice, to screen and identify early patients with risk for possible hearing impairment.

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The writing and revision process of the final version of the manuscript was carried out at the Scientific Article Writing Workshop, in the Graduate Program of Public Health at the Federal University of Santa Catarina, funded by CAPES-PRINT. We thank teachers Marco Aurélio Peres and Eleonora d'Orsi who facilitated the workshop and our colleagues for their suggestions. We thank the English Longitudinal Study of Ageing (ELSA) team for granting access to the data.

Conflict of Interests

The authors report no conflict of interest.

Funding

Funding for the English Longitudinal Study of Ageing is provided by the National Institute of Aging [grant RO1AG017644] and a consortium of UK government departments coordinated by the Office for National Statistics. AS is supported by the British Heart Foundation. The funders had no role in the study design; in the collection, analysis and interpretation of data; in writing of the report; or in the decision to submit the paper for publication. The developers and funders of ELSA and the Archive do not bear any responsibility for the analyses or interpretations presented here.

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Table 1. Sample characteristics throughout the eight study waves. English Longitudinal Study of Ageing, 2002-2016.

Variables	Wave 1 (%)	Wave 2 (%)	Wave 3 (%)	Wave 4 (%)	Wave 5 (%)	Wave 6 (%)	Wave 7 (%)	Wave 8 (%)
Eligible Participants	8,895	6,951	6,000	5,320	5,073	4,619	4,031	3,486
Age								
50–59	39.90	31.94	25.35	14.58	5.90	-	-	-
60-69	30.60	34.07	35.90	41.53	46.57	46.95	39.87	32.78
70-79	20.75	23.41	25.93	29.29	31.34	33.66	38.56	41.73
≥80	8.75	10.58	12.82	14.60	16.19	19.39	21.57	25.49
Gender								
Male	42.32	-	-	-	-	-	-	-
Female	57.68	-	-	-	-	-	-	-
Educational Level								
High (>13 years of schooling)	12.21	-	-	-	-	-	-	-
Medium (12-13 years of schooling)	47.82	-	-	-	-	-	-	-
Low (0-11 years of schooling)	39.97	-	-	-	-	-	-	-
Household Wealth*								
1st	20.06	20.02	20.00	20.00	20.00	15.25	14.97	15.66
2nd	19.94	19.98	20.00	20.02	20.00	17.73	16.70	18.42
3rd	20.00	20.03	20.02	20.02	20.00	22.10	21.82	21.57
4th	20.13	19.99	20.02	19.98	20.02	21.57	23.59	21.19
5th	19.87	19.98	19.96	19.98	19.98	23.35	22.92	23.16
Self-reported poor hearing**								
No	100.00	89.92	87.35	86.77	84.70	82.62	82.04	79.49
Yes	-	10.08	12.65	13.23	15.30	17.38	17.96	20.51
Hearing self-reported								
Excellent	28.78	24.14	21.11	19.61	17.96	16.97	15.33	14.23
Very Good	33.09	32.37	29.77	31.45	31.60	29.42	29.30	27.94
Good	38.13	33.41	36.47	35.71	35.15	36.22	37.41	37.32
Fair	-	8.79	11.02	11.28	12.83	14.38	14.74	16.61
Poor	-	1.29	1.63	1.95	2.46	3.01	3.22	3.90
Cognitive impairment								
No (4-10 words correctly recalled)	66.16	69.95	71.81	71.70	70.72	73.11	68.77	68.17
Yes (0-3 words correctly recalled)	33.84	30.05	28.19	28.30	29.28	26.89	31.23	31.83
Cardiovascular Disease***								
No	49.13	42.90	38.73	35.54	42.71	42.79	42.03	49.96
Yes	50.87	57.10	61.27	64.46	57.29	57.21	57.97	50.04
Diabetes***								
No	93.36	91.98	90.44	89.46	87.83	89.38	88.99	95.32
Yes	6.64	8.02	9.56	10.54	12.17	10.62	11.01	4.68

Alcohol Consumption								
Never	11.31	10.34	11.26	11.74	12.93	14.47	14.41	14.81
Weekly	60.09	65.27	64.99	64.58	64.76	70.00	71.38	71.24
Daily	28.60	24.39	23.75	23.68	22.31	15.54	14.21	13.95
Smoking								
No	82.75	88.07	90.73	92.34	92.05	95.23	96.25	93.12
Yes	17.25	11.93	9.27	7.66	7.95	4.77	3.75	6.88
ADL/IADL disability								
No	75.42	73.27	73.54	71.83	74.12	70.87	72.54	69.72
Yes	24.58	26.73	26.28	28.17	25.88	29.13	27.46	30.28
Depressive symptoms								
No	85.22	85.25	86.20	86.05	86.02	88.47	87.86	88.34
Yes	14.78	14.75	13.80	13.95	13.98	11.53	12.14	11.66
Physical activity level (weekly)								
None	9.21	7.50	8.97	10.91	11.29	10.87	11.09	11.10
Light/moderate	61.88	63.79	63.42	62.11	62.87	62.79	63.48	64.80
Vigorous	28.91	28.71	27.61	26.98	25.84	26.34	25.43	24.10

* Total net non-pension household wealth, which is a summary measure of the value of financial, physical and housing wealth owned by the household (i.e., a single respondent or a responding couple along with any dependent individuals) minus any debt, divided into quintiles calculated by the Institute for Fiscal Studies, UK.
** No: excellent / very good / good; Yes: fair / poor.
*** Self-reported doctor diagnosed.

Table 2. Transitions of responses over time. The English Longitudinal Study of Ageing, 2002-2016.

Variables	Remained in the same category Number of observations %	Changed category Number of observations %
Self-reported poor hearing*		
	27,578	2,895
No	90.50	9.50
	2,057	1,555
Yes	56.95	43.05
Hearing self-reported		
	3,755	3,664
Excellent	50.61	49.39
	4,857	5,893
Very Good	45.18	54.82
	6,467	5,837
Good	52.56	47.44
	1,418	1,686
Fair	45.68	54.32
	193	315
Poor	37.99	62.01
Cognitive impairment		
	19,974	4,138
No (4-10 words correctly recalled)	82.84	17.16
	5,310	3,526
Yes (0-3 words correctly recalled)	60.10	39.90
Cardiovascular**		
	16,376	1,991
No	89.16	10.84
	22,681	1,102
Yes	95.37	4.63
Diabetes**		
	30,943	554
No	98.24	1.76

	204	2,962
Yes	6.44	93.56
Alcohol		
	2,293	576
Never	79.92	20.08
	16,394	1,865
Weekly	89.79	10.21
	4,807	1,742
Daily	73.40	26.60
Smoking		
	45,940	324
No	99.30	0.70
	3,433	784
Yes	81.41	18.59
ADL/IADL disability		
	22,287	3,440
No	86.63	13.37
	5,852	2,514
Yes	69.95	30.05
Depressive symptoms		
	26,152	2,241
No	92.11	7.89
	2,000	2.163
Yes	48.04	51.96
Physical activity level (weekly)		
	1,336	1,323
None	50.24	49,76
	16,744	4,672
Light/moderate	78.18	21,82
	3,771	6,118
Vigorous	38.13	61.87

* No: excellent / very good / good; Yes: fair / poor.
** Self-reported doctor diagnosed.

Table 3. Crude and adjusted analysis of the association between self-reported poor hearing and cognitive impairment. The English Longitudinal Study of Ageing, 2002-2016.

Variable	Crude OR (95% CI)	Crude P-Value	Adjusted OR* (95% CI)	Adjusted P-Value
Cognitive impairment**		**<0.001**		**0.010**
Without Cognitive impairment	Ref.		Ref.	
With Cognitive impairment	1.33 (1.25-1.43)		1.10 (1.02-1.19)	

95% CI: 95% confidence interval.
*Adjusted for gender, age, household wealth, educational level, smoking, alcohol consumption, diabetes, cardiovascular disease, ADL/IADL disability, depressive symptoms and physical activity level.
**Without cognitive impairment (4-10 words correctly recalled), with cognitive impairment (0-3 words correctly recalled).