Longitudinal Associations of Sensory and Cognitive Functioning: A Structural Equation Modeling Approach

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Abstract

Objectives: Although visual and hearing impairments have been found to be associated with cognitive decline in the old age, the mechanism underlying this relationship remains unclear. This study aimed at assessing the predictive role of visual and hearing difficulties on subsequent cognitive functioning.

Method: From the cohort of the first (2002) and fifth waves (2010) of the English Longitudinal Study of Ageing (ELSA), 3,508 individuals aged 60 and older were included in the study. Five self-reported visual and hearing functioning items were used to assess sensory functioning at baseline. Cognition was assessed 8 years later by means of four measured tests covering immediate and delayed recall, verbal fluency, and processing speed. A Multiple Indicators Multiple Causes approach was used to assess the longitudinal associations of visual and hearing functioning with cognitive difficulties. A multigroup longitudinal measurement invariance was used to estimate latent change in cognitive difficulties across groups of participants presenting either visual, hearing, or dual sensory impairment (i.e., those reporting difficulties in both visual and hearing functioning items).

Results: Visual (β = 0.140, p < .001) and hearing (β = 0.115, p < .001) difficulties predicted cognitive difficulties 8 years later. The latent increase in cognitive difficulties was steeper in people with visual impairment (d = 0.52, p < .001), hearing impairment (d = 0.50, p < .001), and dual-sensory impairment (d = 0.68, p < .001) than those non-impaired (d = 0.12, p < .001).

Discussion: Visual and hearing difficulties were identified as predictors of subsequent cognitive decline in the old age. Interventions to prevent visual and hearing difficulties may have a substantial impact to slow down subsequent age-related cognitive decline.

Keywords: Cognition, Hearing impairment, Vision impairment

Aging is a multidimensional process comprising cumulative damages of molecular and cellular structures over time (Beard et al., 2016), resulting in a gradual degradation of several physical and mental capacities. Age-related declines in cognitive and sensory functioning are well documented in the literature (Roberts & Allen, 2016).
Diverse aspects of fluid cognition, such as spatial visualization, inductive reasoning, episodic memory, or processing speed show a significant decline over time (Salitouse, 2004, 2009). Age-related cognitive decline is associated with relevant health-related outcomes, such as disability (Nikolova, Demers, & Beland, 2009; Olaya et al., 2016), mortality (MacDonald, Hultsch, & Dixon, 2011; Wilson, Segawa, Hizel, Boyle, & Bennett, 2012), or well-being (Wilson et al., 2013).

Similarly, visual and hearing functioning also decline with age. In fact, age-related hearing impairment (HI) is the most common sensory impairment among the older population (Van Eyken, Van Camp, & Van Laer, 2007), and it is associated with several adverse health-related outcomes, such as depression, social isolation, or loss of self-esteem (Gates & Mills, 2005). Likewise, visual functioning declines with advancing age, yielding adverse changes in different visual processes, like visual acuity (Kaido et al., 2011), motion perception (Hutchinson, Arena, Allen, & Ledgeway, 2012), or temporal resolution of vision (Culham & Kline, 2002). These declines in vision are also associated with important outcomes, such as disability (West et al., 2002) or depressive symptoms (Zheng et al., 2016).

Recent literature reviews summarize a strong body of evidence indicating a link between sensory and cognitive functioning in older adults (Humes & Young, 2016; Roberts & Allen, 2016; Wayne & Johnsruide, 2015). Although the relationship between visual and hearing functioning and cognition in older adults has been shown both cross-sectionally (S. P. Chen, Bhattacharya, & Pershing, 2017; Lindenberger & Baltes, 1994; Ong et al., 2012; Wettstein, Wahl, & Heyl, 2017) and longitudinally (Fischer et al., 2016; F. R. Lin et al., 2014; F.R. Lin et al., 2013; Lindenberger & Ghisletta, 2009; Maharani, Dawes, Nazroo, Tampubolon, & Pendleton, 2018; M. Y. Lin et al., 2004; Yamada et al., 2016), the mechanisms underlying this relationship are not clear yet. Several hypotheses have been proposed to address the sensory-cognitive relationship (Roberts & Allen, 2016). According to the sensory deprivation hypothesis, there is a causal link between sensory impairment and cognitive dysfunction. Age-related hearing and visual impairments are intricate disorders associated with both environmental and genetic factors (Bourne et al., 2014; Van Eyken et al., 2007). Thus, the quality of the sensory stimuli input is impoverished due to impairments in sensory functioning, which in a long term would produce neural atrophy in central brain structures, leading to declines in cognitive performance (Baltes & Lindenberger, 1997; F. R. Lin et al., 2014; Lindenberger & Baltes, 1994; M. Y. Lin et al., 2004; Yamada et al., 2016).

Considering the expected increase in the worldwide population aged 60 and older (Bloom et al., 2015), and the important economic burden and health care utilization expenditures of people with mild cognitive impairment (Lin & Neumann, 2013; Ton et al., 2017), it is important to assess the roles of visual and hearing functioning as predictors of subsequent cognitive decline in older population. Thus, this study aimed at assessing the longitudinal associations of visual and hearing difficulties with cognitive difficulties in a time-frame of 8 years in a nationally representative sample of 3,508 participants aged 60 and older from the English Longitudinal Study of Ageing (ELSA). In addition, change in cognitive difficulties over 8 years will be estimated at a latent level and separately for people either with visual, hearing, or dual-sensory impairment, as well as for those non-impaired, in order to assess potential differences in cognitive decline according to different types of sensory impairment.

Methods
Sample and Study Design
This study comprises a sample of 3,508 participants aged 60 and older from the first (2002) and fifth waves (2010) of ELSA (Steptoe, Breeze, Banks, & Nazroo, 2013). The ELSA is a biannual longitudinal study focused on nationally representative samples of people aged 50 and older from the English population. Participants provided informed consent, and the National Research Ethics Service granted ethical approval for all the ELSA waves (MREC/01/2/91). Further details on the specifics of the ELSA can be found elsewhere (https://www.elsa-project.ac.uk/).

Measures
Visual and hearing functioning
Visual functioning and hearing functioning were assessed at ELSA baseline (wave 1: 2002). Visual functioning was assessed by means of three self-reported items covering eyesight in far, near, and general vision. For hearing functioning, self-reported hearing functioning and presence of difficulties following a conversation with background noise were used. These original variables were five-category questions (except self-reported difficulties following a conversation that had two categories), with the following categories in all cases: “Excellent,” “Very good,” “Good,” “Fair,” and “Poor.” The full description of these items can be seen in Supplementary Table 1. For both visual and hearing functioning, participants were assessed with their visual and hearing aids if they had them.

For the purpose of this study, these variables were dichotomized, collapsing “Excellent,” “Very good,” and “Good” as “Absence of difficulties”. In the dichotomous variable created, values coded as “Fair” and “Poor” were considered as indicators of “Presence of difficulties.”

Cognitive functioning
Cognitive functioning was assessed both at ELSA baseline (wave 1: 2002) and wave 5 (2010). The assessment of cognitive functioning comprised four measured tests of verbal fluency, processing speed, and short-term and long-term memory (Steptoe et al., 2013). The verbal fluency...
task consisted in naming the maximum number of animals in 1 minute. The total score was the number of animals named by the participant. The processing speed score was obtained from a letter cancellation task where participants had to identify and mark two target letters in a page of 65 random letters. Finally, the short-term and long-term memory scores corresponded with the number of words recalled by the participant from a list of 10 common words, immediately and after a short delay, respectively. All the scores derived from the cognitive functioning tests were dichotomized using the lower quartile of each distribution as cut-off point for indicating presence of difficulties. Participants were assessed with their visual and hearing aids if they had them.

Other covariates
Participants also provided information on sociodemographic variables, including age, sex, household wealth, and possessing formal qualification. Household wealth comprised total net non-pension household wealth, including financial, physical, and housing wealth owned by the household minus all debt. Household wealth was dichotomized using the second quintile of its distribution in order to indicate the belonging to the less wealthy groups of the sample. The range of values included in the first and second quintiles of household wealth ranged from −22,946£ to 95,195£. Formal qualification was defined as having any official academic certificate recognized by the English system (from having completed primary school to university degree).

Statistical Analysis

Descriptive statistics
Descriptive statistics of the overall, the analytical, and the dropout sample were computed. Potential differences in basic sociodemographic data between the analytical and dropout sample were tested either with chi-square independence tests, or two-sample t-tests. Effect sizes were also computed: Cramer’s V for chi-square tests, and Cohen’s d for t-tests. Cramer’s V values of 0.10, 0.30, and 0.50 indicated small, medium, and high effect sizes, respectively; in the case of Cohen’s d, these cutoff points were 0.20, 0.50, and 0.80, according to Cohen’s guidelines (Cohen, 1988) in both cases. Regarding Cohen’s d values, they represent the standardized latent change in cognitive difficulties from baseline to wave 5.

Multiple Indicator Multiple Causes Structural Equation Models
Two Multiple Indicator Multiple Causes (MIMIC) Structural Equation Models to test for sensory deprivation hypothesis principles were fitted using Means Adjusted Weighted Least Squares (WLSM) estimator and tetrachoric correlations. First is a MIMIC solution to model cognitive difficulties at follow-up under the influence of hearing and visual impairment without including the effect of cognition at baseline. A second MIMIC model controlling the effect of cognitive difficulties at baseline was also fitted. In both MIMIC models, the exogenous effect of chronological age at baseline was included. The beta parameters reported in these models denote the standardized regression weight of each exogenous (independent) latent variable predicting the corresponding endogenous (dependent) latent variable. They can be interpreted as partial correlations, with higher absolute values indicating a stronger association.

On the basis of the response patterns to the self-reported difficulties, a factor defining visual impairment (VI), HI, dual-sensory impairment (DSI), and non-impairment was generated. If respondent reported at least one difficulty on any item of the visual domain, it was included in the VI group. The HI group included only participants presenting difficulties in general hearing. Those participants presenting at least one difficulty in the visual domain and in general hearing were included in the DSI group. Potential differences in basic socioeconomic variables were tested either using one-way analysis of variance (ANOVA) or chi-square independence test. Effect sizes for these comparisons were also obtained, using partial eta-squared for the ANOVA and Cramer’s V for the chi-square tests (Cohen, 1988).

Longitudinal and multigroup measurement invariance
Finally, to assess and compare the extent of cognitive decline across the four groups of sensory impairment at a latent level, it is required to achieve strong measurement invariance across time and groups in the cognitive difficulties latent factor. Thus, three nested measurement models of the cognitive difficulties factor were fitted using Structural Equation Modeling (SEM). First, an unconstrained model comprising two cognitive difficulties factors (at baseline and wave five, respectively) with free parameters across time points and groups. Second, factor loadings (λ) and thresholds (τ) of the cognitive difficulties factor were constrained to be equal across measurement occasions, but free across groups, in order to assess longitudinal measurement invariance (λ1,t=λ1,t+λ2,t, τ11=τ12=τ21=τ22=τ31=τ32=τ41=τ42). In the common factor model, the parameter represents the factor loading of an item on a specific latent factor (i.e., the direction and magnitude of the lineal relationship between the item/observed indicator and a latent factor). The tau parameter (τ) denotes the threshold of an item, which provides information on the continuous latent response underlying the proportion of individuals endorsing each response category of a categorical item (Wirth & Edwards, 2007). Finally, factor loadings and thresholds were constrained to be equal across time points and groups. This last model assures that the meaning and metric of the cognitive difficulties factor is invariant across groups and occasions, allowing for the estimation of a standardized comparable measure of cognitive change across groups (αt).
Minimal identification constraints were imposed to identify the longitudinal measurement invariance models (Widaman, Ferrer, & Conger, 2010): (a) the metric of the latent factor at the first measurement occasion was standardized, fixing its mean and variance to 0 and 1, respectively ($\lambda_{11} = \lambda_{21}$); and (b) the first factor loading was freely estimated at the first time point, whereas it was constrained to be equal at the second measurement occasion ($\lambda_{21} = \lambda_{31}$). In both models, the error terms of the same indicators were allowed to correlate across the two time points for modeling unique item effects.

The goodness-of-fit of the longitudinal and multigroup measurement invariance models was assessed according to the recommendations proposed in the literature (Hu & Bentler, 1999; Reise, Widaman, & Pugh, 1993): Comparative Fit Index (CFI) and Tucker–Lewis Index (TLI) values higher than 0.95 and root mean square error of approximation (RMSEA) value lower than 0.08 were considered as indicators of appropriate fit. The longitudinal and multigroup measurement invariance analysis was based on changes in the CFI values lower than 0.01, and on changes in RMSEA values lower than 0.015 across the three different nested models (Chen, 2007).

Results

Descriptive Statistics and Attrition Analysis

Table 1 contains the baseline sociodemographic profile of the overall sample (N = 3,508), the analytical sample (n = 2,912), and the dropout sample (n = 596), as well as the results of the attrition analysis conducted to assess potential differences between the analytical and dropout samples. The dropout sample comprised 16.99% of the overall sample and was significantly older ($p < .001$; Cohen's $d = 0.63$), with a higher percentage of people belonging to the first or second quintile of household wealth ($p < .001$; Cramer's $V = 0.09$), and less qualified ($p < .001$; Cramer's $V = 0.08$). Nonetheless, these differences were small according to Cohen's guidelines (Cohen's $d < 0.20$; Cramer's $V < 0.10$ for all differences), and therefore, it is assumed that they do not suppose a threat to the representativeness of the sample.

The presence of difficulties in visual functioning was reported by 8.27%, 10.13%, and 13.65% in far, near, and general vision, respectively. In the case of hearing functioning, a 37.51% of the sample had difficulties for following a conversation, whereas a 21.87% was considered as reporting difficulties in general hearing.

Multiple Indicator Multiple Causes Sensory Deprivation Models

The two sensory deprivation MIMIC models presented an adequate fit (Model 1: $\chi^2(31) = 392.03, p < .001$; CFI = 0.96; TLI = 0.95; RMSEA = 0.055, 90% CI (0.051, 0.060)); Model 2: $\chi^2(67) = 730.42, p < .001$; CFI = 0.97; TLI = 0.94; RMSEA = 0.053, 90% CI (0.050,0.056)). All the standardized factor loadings of the measurement models were high and statistically significant ($p < .001$) in the two MIMIC models. Standardized estimates of the MIMIC Model 2 (controlling the effect of cognitive difficulties at baseline) are presented in Figure 1. Standardized factor loadings in MIMIC Model 2 (Figure 1), ranged from 0.845 to 0.943 in the visual difficulties factor, from 0.726 to 0.972 in the hearing difficulties factor, and from 0.369 to 0.878 in the cognitive difficulties factor. Regarding the structural part of the MIMIC models, all the standardized regression weights were also statistically significant ($p < .001$).

Results from both models revealed significant direct effects of visual (Model 1: $\beta = 0.143$; Model 2: $\beta = 0.140$) and hearing (Model 1: $\beta = 0.114$; Model 2: $\beta = 0.115$) difficulties at baseline on cognitive difficulties 8 years later. It is important to note that these longitudinal effects of sensory functioning on cognition remain stable even after controlling the effect of cognitive status at baseline (Model 2, Figure 1). In addition, age-related differences in visual (Model 1: $\beta = 0.145$; Model 2: $\beta = 0.145$), hearing (Model 1: $\beta = 0.118$; Model 2: $\beta = 0.115$), and cognitive (Model 1: $\beta = 0.398$; Model 2: $\beta = 0.237$) functioning were found in both models.

Longitudinal and Multigroup Measurement Invariance

The three measurement invariance models presented an adequate fit (Table 2), with CFI and TLI values greater than 0.95, and RMSEA values less than .08. Although a

<table>
<thead>
<tr>
<th>Table 1. Baseline Characteristics of the Sample According to Participation and Nonparticipation in the Follow-up Assessment</th>
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<tbody>
<tr>
<td>Overall sample (N = 3,508)</td>
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<tr>
<td>Age, M (SD)</td>
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<tr>
<td>Male, N (%)</td>
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<td>Belonging to the first or second quintile of household wealth, N (%)</td>
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<td>Formal qualification, N (%)</td>
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Note: Cramer's V was used as effect size measure in the comparisons across categorical variables, whereas Cohen's d was used as effect size measure in the comparisons across continuous variables.
slightly significant increment in CFI was found between Models 2 and 3 (ΔCFI = 0.016), the increase in RMSEA was nonsignificant (ΔRMSEA = 0.010), and considering all the goodness-of-fit indices of the model it presented a good fit (CFI = 0.961; TLI = 0.958; RMSEA = 0.067). In addition, it should be mentioned that the cutoff point of ΔCFI = 0.01 is proposed for the sequential comparison of four levels of measurement invariance across groups with a smaller number of parameter constraints: (a) configural, (b) metric (equal loadings), (c) strong (equal loadings and intercepts), and (d) strict (equal loadings, intercepts, and residual variances). In this case, there was a larger difference in the number of parameters constrained from Model 2 to Model 3. Therefore, according to Model 3 (Figure 2), evidences of strong longitudinal and multigroup strong measurement invariance were found, and based in this model, change in cognition was estimated in each group of sensory impairment, using the standardized latent mean in the cognitive difficulties factor (α2) as effect size measure.

Table 3 contains a general sociodemographic profile of each group of sensory impairment along with the estimated standardized latent change in cognition. Statistically significant differences in all sociodemographic variables across the groups of impairments were found (p < .001). Nonetheless, according to Cohen’s guidelines, the effect sizes associated with these differences were small (partial eta-squared < 0.06; Cramer’s V < 0.10).

The estimated latent cognitive change contained in Table 3 reflects the standardized change in the latent mean of the cognitive difficulties factor from baseline to wave five. This measure is in standard deviation units, with higher values indicating worse cognitive status (i.e., more cognitive difficulties). All groups experienced a significant increase (p < .001) in cognitive difficulties at a latent level. Nonetheless, the change was larger for those with some sensory impairment. More specifically, the steeper increment in cognitive difficulties was found for those either with DSI (α2 = 0.68), VI (α2 = 0.52), or HI (α2 = 0.50), whereas the non-impaired group presented the smallest increment in cognitive difficulties (α2 = 0.12).

Discussion

In this study, visual and hearing difficulties were independently associated with a worse cognitive functioning 8 years later in a nationally representative sample of older adults from the United Kingdom. These longitudinal associations emerged even after controlling for the effect of chronological age and cognitive status at baseline. Regarding cognitive change, subjects presenting difficulties in any sensory domain showed an accelerated rate of cognitive decline, especially those with DSI.

Our results support the sensory deprivation hypothesis for explaining the link between sensory and cognitive functioning in the older age because visual and hearing difficulties predicted subsequent cognitive decline 8 years later. It is important to highlight that these relationships were not due to an advanced age nor a worse cognitive status at baseline, because these effects were controlled in the models. Moreover, unlike previous studies using single measures of cognitive functioning, we modeled the abovementioned relationships at a latent level, thus considering only the common variance shared by a wide set of...
cognitive measures assessing diverse processes. Although significant, the magnitude of these associations was relatively small, and was slightly higher for the visual than the hearing domain (accounting for 1.96% and 1.32% of the cognitive functioning variance, respectively). These results are consistent with previous cross-sectional and longitudinal studies using either objective sensory measures of threshold sensitivity (Fischer et al., 2016; F. R. Lin et al., 2014; F. R. Lin et al., 2013; M. Y. Lin et al., 2004), or self-reported questions of sensory functioning (Liu, Cohen, Fillenbaum, Burchett, & Whitson, 2016; Maharani et al., 2018b; Yamada et al., 2016).

It is important to consider results from previous studies addressing alternative hypotheses for explaining the sensory-cognitive relationship in the old age. Lindenberger and Ghisletta (2009) evidenced significant correlations between cognitive, visual, and hearing decline, suggesting common age-related mechanisms underlying these domains. However, as pointed out by the authors, these correlations were moderate in magnitude, thus suggesting the need of disentangling general and specific mechanisms of aging. In that regard, our study provides evidence on specific unidirectional long-term mechanisms by which poor sensory functioning affects subsequent cognitive decline.

We showed that people manifesting some type of sensory impairment at baseline, regardless the extent of that impairment, manifested a larger decline in cognitive functioning over 8 years. The most accelerated rate of cognitive decline was observed in people with presenting difficulties on both visual and hearing domains at baseline. Similarly, a longitudinal study comprising 1,989 nursing home residents showed that the rate of cognitive decline of those with DSI doubled the rate of those non-impaired (Yamada et al., 2016). Results were similar in another longitudinal study (M. Y. Lin et al., 2004) comprising 6,112 old women, where individuals with DSI presented the highest odds of cognitive decline. It should be noted that cognitive decline was almost equal for people either with VI or HI. This is not consistent with previous research showing nonsignificant associations of HI with worse cognitive status (M. Y. Lin et al., 2004; Yanan et al., 2018). These discrepancies might be due to the use of general screening tests of cognitive impairment as measures of cognitive functioning, as well as shorter follow-up lengths.

This study has several methodological strengths in comparison with previous research. First, our study comprised a large nationally representative sample of older adults and we conducted an attrition analysis to assess potential differences between the analytical and the dropout samples, which provides evidence on the generalizability of the results. Second, we use an SEM approach to assess the longitudinal relationships between sensory and cognitive functioning, not at an observed but at a latent level (Maharani et al., 2018b). This approach is more robust than others implemented in previous studies, because it allows for quantifying changes in a latent factor accounting for the common variance underlying a set of observed cognitive indicators, thus reducing noise in the data. In addition, instead of using a general screening test of dementia as outcome, our cognitive indicators are performance tests assessing specific cognitive processes. Finally, we quantified cognitive change at a latent level using a longitudinal multi-group measurement invariance approach, which guarantees the validity of comparisons across groups of impairments over time.

Some limitations of the study should be noted. On the one hand, the measures of visual and hearing functioning are self-reported and might be influenced by response style biases (Vaerenbergh & Thomas, 2013). In addition, there were few observed indicators for the hearing domain. On the other hand, the extent of sensory impairment was not considered in the formation of the groups of sensory impairment. In that regard, future research should be conducted to assess the impact of the magnitude of sensory impairment on both visual and hearing domains at baseline.

Figure 2. Longitudinal measurement invariance model for estimating latent change in cognitive difficulties.

Table 3. Sociodemographic Profile and Estimated Cognitive Change From the Longitudinal and Multigroup Strong Measurement Invariance Model by Group of Sensory Impairment

<table>
<thead>
<tr>
<th></th>
<th>VI (n = 416)</th>
<th>HI (n = 528)</th>
<th>DSI (n = 239)</th>
<th>NI (n = 2,325)</th>
<th>p</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, M (SD)</td>
<td>71.04 (7.03)</td>
<td>69.94 (6.48)</td>
<td>71.10 (7.22)</td>
<td>68.20 (6.14)</td>
<td>&lt;.001</td>
<td>0.04</td>
</tr>
<tr>
<td>Male, N (%)</td>
<td>120 (28.85)</td>
<td>310 (58.71)</td>
<td>117 (48.95)</td>
<td>954 (41.03)</td>
<td>&lt;.001</td>
<td>0.14</td>
</tr>
<tr>
<td>Belonging to the first or second quintile of household wealth, N (%)</td>
<td>122 (29.33)</td>
<td>108 (20.45)</td>
<td>77 (32.22)</td>
<td>369 (15.87)</td>
<td>&lt;.001</td>
<td>0.14</td>
</tr>
<tr>
<td>Formal qualification, N (%)</td>
<td>182 (43.75)</td>
<td>284 (53.79)</td>
<td>109 (45.61)</td>
<td>1,439 (61.89)</td>
<td>&lt;.001</td>
<td>0.14</td>
</tr>
<tr>
<td>Latent cognitive change (SD)</td>
<td>0.52 (0.15)</td>
<td>0.50 (0.12)</td>
<td>0.68 (0.17)</td>
<td>0.12 (0.06)</td>
<td></td>
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</tr>
</tbody>
</table>

Note: Cramer’s V was used as effect size measure in the comparisons across categorical variables, whereas partial eta-squared was used as effect size measure in the comparisons across continuous variables. DSI = dual sensory impairment; HI = hearing impairment; NI = non-impaired; VI = visual impairment.
impairment on cognitive functioning. In addition, further research could be focused on explaining different trajectories of cognition and how these trajectories could be related to trajectories of visual and hearing functioning. Moreover, specific cognitive domains could be assessed in these trajectories, exploring also long-term effects of sensory impairment on specific cognitive domains.

Some clinical implications may be derived from our results. The longitudinal association of impairments in sensory functioning and later cognitive decline suggests that visual and hearing difficulties could be early markers of the neurobiological course of brain while aging. Thus, interventions to prevent or compensate sensory impairments could be promising in slowing down the pace of age-related effects on cognitive domain. In that regard, a recent longitudinal study following 2,040 older adults have shown a positive effects of hearing aid on trajectories of cognitive performance over 18 years (Maharani et al., 2018a). To the best of our knowledge, there is no evidence suggesting a positive effect of visual aid use or cataract surgery on cognitive decline (Hall, McGwin Jr., & Owssley, 2005). Further longitudinal studies should be conducted to provide evidence on the potential benefits of visual aids on age-related cognitive decline. In addition, preventive health policies should highlight the importance of maintaining a good sensory functioning in the old age, disseminating the available evidence on the modifiable risk factors of visual (e.g., uncorrected refractive error) and hearing (e.g., noise exposure) impairment (Bourne et al., 2014; Van Eyken et al., 2007).

In conclusion, this study shows that visual and hearing functioning is associated with subsequent cognitive difficulties in the old age. Moreover, sensory-impaired older adults may experience an accelerated rate of cognitive decline than those non-impaired. Thus, visual and hearing difficulties might be used as early indicators of cognitive decline. These findings highlight the importance of preserving a good sensory functioning in the old age, not only for maintaining a good functional status (Liu et al., 2016) and well-being (Toyoshima, Martin, Sato, & Poon, 2018), but potentially also to slow down cognitive decline over time.

**Supplementary Material**

Supplementary data are available at *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences* online.

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**Conflict of Interest**

None reported.

**References**


