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Measurement Article

Development of a Combined Sensory-Cognitive Measure Based on the Common Cause Hypothesis: Heterogeneous Trajectories and Associated Risk Factors

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Abstract

Background and Objectives: There is a link between sensory and cognitive functioning across old age. However, there are no integrative measures for assessing common determinants of sensory-cognitive functioning. This study aims to develop a combined measure of sensory-cognitive functioning, and to identify heterogeneous trajectories and associated risk factors.
Research Design and Methods: Two thousand two hundred and fifty-five individuals aged 60 years and over selected from the first six waves (2002–2012) of the English Longitudinal Study of Ageing completed a set of five self-reported visual and hearing functioning items and four cognitive items. Several health-related outcomes were also collected.
Results: The common cause model presented longitudinal factorial invariance (Tucker-Lewis index [TLI] = 0.989; Comparative Fit Index [CFI] = 0.991; Root Mean Square Error of Approximation [RMSEA] = 0.026). A common factor explained 32%, 36%, and 26% of the visual, hearing, and cognitive difficulties, respectively. The developed sensory-cognitive measure predicted incident dementia over 10 years (area under the curve = .80; 95% confidence interval [CI] = .75, .86). A three-trajectory model was proved to fit better, according to growth mixture modeling. Low levels of education and household wealth, disability, diabetes, high blood pressure, depressive symptoms, and low levels of physical activity were risk factors associated with the classes showing trajectories with a steeper increase of sensory-cognitive difficulties.
Discussion and Implications: A time-invariant factor explains both sensory and cognitive functioning over 8 years. The sensory-cognitive measure derived from this factor showed a good performance for predicting dementia 10 years later. Several easily identifiable socioeconomic and health-related risk factors could be used as early markers of subsequent sensory-cognitive decline. Therefore, the proposed latent measure could be useful as a cost-effective indicator of sensory-cognitive functioning.

Keywords: Sensory functioning, Cognitive functioning, Latent classes, Structural equation modeling

Aging is a multidimensional phenomenon associated with declines in both sensory and cognitive functioning. Several cross-sectional and longitudinal studies have evidenced a relationship between sensory and cognitive functioning in the older population (Baltes & Lindenberger, 1997; Humes, Busey, Craig, & Kewley-Port, 2013; Lin et al., 2013, 2014; Lin et al., 2004; Lindenberger & Ghisletta, 2009; Maharani, Dawes, Nazroo, Tampubolon, & Pendleton, 2018; Yamada et al., 2016). Although diverse hypotheses have been proposed to address this link (Humes & Young, 2016; Roberts & Allen, 2016), the causal mechanisms underlying the pattern of relationships between perception and cognition in the older age is still debatable (Whitson et al., 2018).

According to the common cause hypothesis, cognitive and sensory functioning is closely related in older persons since they both depend on the physiological integrity of the brain, which gradually declines in functioning with aging (Roberts & Allen, 2016). Thus, a common neurodegenerative factor simultaneously affecting sensory and cognitive functioning would explain the association between age-related declines in these domains. Neurobiological age-related changes have been found to affect both sensory and cognitive functioning (Chang et al., 2015; Harris & Dubno, 2017). On the other hand, the American Geriatrics Society and the National Institute on Aging highlight that the role of cardiovascular disease and inflammation as common pathways for sensory and cognitive impairment has been overlooked (Whitson et al., 2018). In that regard, a study showed a decrease in the association between sensory impairment and risk of cognitive impairment after controlling for inflammatory and cardiovascular disease and related factors (Fischer et al., 2016). Another recent study showed that visual and olfactory impairments and cardiovascular disease were associated with cumulative incidence of cognitive impairment over 10 years (Schubert et al., 2019). Despite the available evidence, the nature of the common cause and its determinants remain unclear.

Previous research highlights the potential usefulness of developing a combined measure of sensory-cognitive difficulties to explore mechanisms of brain health (Fischer et al., 2016), allowing assessing joint trajectories of sensorineurocognitive functioning across the old age. Moreover, a single measure capturing common aging pathways of sensory and cognitive functioning could be useful for predicting important health-related outcomes, especially those that have been found to be independently associated with these domains of functioning in the older population. For instance, previous research has reported independent associations of visual, hearing, and cognitive impairment with disability (Brennan, Su, & Horowitz, 2006; Cimarolli & Jopp, 2014; Fabbri et al., 2016; Mansbach & Mace, 2018), higher mortality (Gopinath et al., 2013; Wahl et al., 2013; Wilson, Segawa, Hizel, Boyle, & Bennett, 2012), and some mental disorders, like depression (Cosh et al., 2018; Kim, Liu, Cheung, & Ahn, 2018; Lawrence et al., 2019) or dementia (Deal et al., 2017; Lin et al.,

2011; Mitoku, Masaki, Ogata, & Okamoto, 2016; Panza, Solfrizzi, & Logroscino, 2015). However, none of these associations have been assessed taking into account the covariance structure underlying sensory and cognitive functioning.

Therefore, the present study had three aims. First, to assess the longitudinal invariance of a common factor accounting for the shared variance among visual, hearing, and cognitive difficulties in older population. It is important to note that although the actual common cause remains unknown, we propose a common cause model that would present factorial invariance over time. Second, we aim at developing a latent measure capturing the common variation underlying a set of individual hearing, visual, and cognitive functioning measures, assessing its ability to predict incident dementia. Third, to identify groups presenting heterogeneous trajectories of sensory-cognitive difficulties, and their associated risk factors.

Methods

Sample and Study Design

The sample comprised 2,255 participants aged 60 years and over from the first six waves (2002–2012) of the English Longitudinal Study on Ageing (ELSA) who had responded to all the self-reported items of sensory functioning and the measured test of cognition. ELSA is a biannual longitudinal study focused on nationally representative samples of people aged 50 years and over from the English population (Steptoe, Breeze, Banks, & Nazroo, 2013). All participants provided informed consent. The National Research Ethics Service granted ethical approval for all the ELSA waves (MREC/01/2/91). Further details on the specifics of ELSA can be found in the study website (https://www.elsa-project.ac.uk/).

Measures

Self-reported sensory functioning scale items and cognitive measures employed for the measurement models are given in Table 1. Visual functioning was measured by means of three self-reported items assessing 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 which had two categories), with the following categories: "Excellent," "Very good," "Good," "Fair," and "Poor." For both visual and hearing functioning, participants were assessed with their visual and hearing aids if they had them. These items were highly skewed, with a great amount of responses grouped in the "best functioning" categories. In these cases, dichotomizing the values is a habitual strategy (De La Fuente et al., 2018). Thus, these variables were dichotomized, collapsing "Excellent," "Very good," and

Table 1. Self-reported Sensory Functioning Scale Items and Cognitive Measures Employed for the Measurement Models

Vision		Excellent	Very good	Good	Fair	Poor
Far vision	How good is your eyesight for seeing things at a distance, like recognizing a friend across the street (using glasses or corrective lens as usual)?	1	2	3	4	5
Near vision	How good is your eyesight for seeing things up close, like reading ordinary newspaper print (using glasses or corrective lens as usual)?	1	2	3	4	5
General vision	How is your eyesight (using glasses or corrective lens as usual)?	1	2	3	4	5
Hearing		Excellent	Very good	Good	Fair	Poor
General hearing	How is your hearing (using a hearing aid as usual)	1	2	3	4	5
Following conversations	Do you find it difficult to follow a conversation if there is background noise, such as TV, radio, or children playing (using a hearing aid as usual)?	No 0	Yes 1			
Cognition*						
Verbal fluency	Participants are asked to name the maximum number of animals in one minute. The total score was the number of animals named by the participant.					
Processing speed	Score obtained from a letter cancellation task where participants had to identify and mark two target letters (P and W) in a page of 65 random letters set out in rows and columns within one minute.					
Immediate recall and delayed recall	Number of words recalled by the participant from a list of 10 common words. Word recall is tested immediately and after a short delay filled with other cognitive tests					

Note: *All cognitive measures are freely available in: https://www.elsa-project.ac.uk/uploads/elsa/docs_w1/booklet.pdf.

"Good" as "Absence of difficulties," and "Fair" and "Poor" as indicators of "Presence of difficulties."

The assessment of cognitive functioning comprised four measured tests of verbal fluency, processing speed, and immediate and delayed recall. The verbal fluency task consisted in naming the maximum number of animals in one 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 immediate and delayed re-call 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 cutoff point for indicating presence of difficulties.

Participants also provided information on sociodemographic variables, including age, sex, household wealth (net value of total wealth minus all debts), and formal qualification (having an academic certificate recognized by the English educational system). Level of physical activity was obtained by means of a self-reported item comprising four categories: "Sedentary," "Mild," "Moderate," and "Vigorous." Self-reported doctor-diagnosed diabetes and high blood pressure were also used.

Incident dementia in Wave 6 of the ELSA study was obtained following the three-way protocol described by Davies, Cadar, Herbert, Orrell, and Steptoe (2017).

Participants with either: (a) a physician diagnosis of dementia, (b) a score of 3.5 or higher in the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE), or (c) receiving prescriptions for N-methyl-D-aspartate receptor antagonists, anticholinesterase inhibitors, or other antidementia medications (such as galantamine, rivastigmine, memantine, donepezil, or tacrine) were categorized as presenting incident dementia if they did not present any of these characteristics in previous waves of the study.

Participants indicated the presence of difficulties to perform six activities of daily living (ADL) (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963) and six instrumental activities of daily living index (IADL) (Graf, 2008). The original variables for assessing ADL and IADL, ranged from 0 (no difficulties) to 6 (difficulties with all six activities of ADL/IADL).

The overall score of the Center for Epidemiologic Studies-Depression scale, eight-item version survey was used to assess the presence of depressive symptoms (CES-D 8) (Turvey, Wallace, & Herzog, 1999). This instrument is made up of eight items with a dichotomous (yes/no) scale of response.

Statistical Analysis

A structural equation modeling (SEM) approach was used to assess the longitudinal factorial invariance of the common cause model proposed in Figure 1 across the first five waves of ELSA. In each wave, this model comprises a second-order latent factor explaining the common variance of the visual, hearing and cognitive difficulties first-order factors.
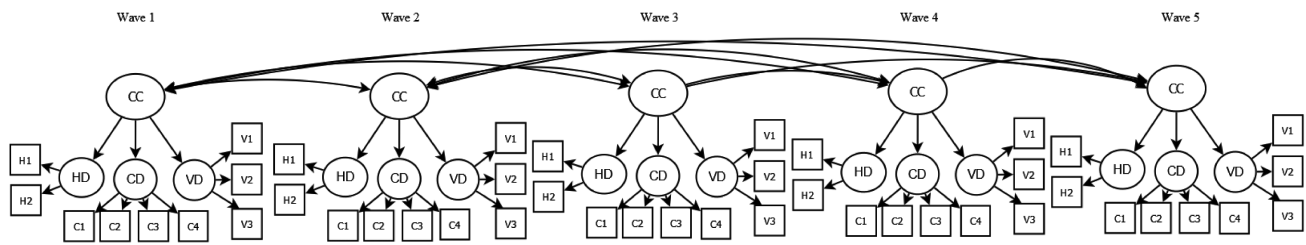
Figure 1. Common cause model for explaining the relationships between hearing, visual, and cognitive difficulties. CC = Common cause; CD = Cognitive difficulties; HD = Hearing difficulties; VD = Visual difficulties.

Two nested models were compared in terms of goodness-of-fit. An unconstrained model with free parameters across waves was first implemented to test configural invariance. Then, a constrained model with equal factor loadings and thresholds across waves was used to assess strong factorial invariance. Based on Widaman, Ferrer, and Conger (2010), the following constraints were imposed to identify the SEM models: (a) latent factors were standardized at baseline ($M = 0$, $SD = 1$); (b) the factor loading and threshold of the first indicator of each factor were freely estimated at baseline and constrained to be equal at subsequent waves. The residual variances of the same indicators were allowed to correlate across waves for modeling unique item effects. The goodness-of-fit of the SEM models was assessed using the cutoff points proposed by Hu and Bentler (1999); a model showed a good fit when Comparative Fit Index (CFI) and Tucker-Lewis index (TLI) values were greater than .95, and Root Mean Square Error of Approximation (RMSEA) values were lower than .05. The longitudinal factorial invariance analysis was based on a change in the CFI value lower than .01 between the nested models (Cheung & Rensvold, 2002). Means adjusted weighted least squares (WLSM) estimator for categorical data was used for the SEM models.

If strong factorial invariance was achieved, latent scores on the second-order common factor in each wave were predicted using the factor score regression method. To improve interpretability, these latent scores were then transformed into a 0–100 scale, where higher values indicated higher sensory-cognitive difficulties. The ability of the metric to predict incident dementia 10 years later was assessed by means of receiver operating characteristics (ROC) curves, and the area under the ROC curve (AUC). As a sensitivity analysis, we compared the ROC curves and AUCs for predicting incident dementia of the common cause metric with latent scores of visual, hearing, and cognitive functioning estimated separately. AUC values range from .5 (representing no predictive ability) to 1 (representing perfect predictive ability).

Finally, a latent class mixed model (LCMM) (Proust-Lima, Philipps, & Liquet, 2017) was conducted to identify a finite set of groups of subjects with similar sensory-cognitive trajectories. Models with increasing number of latent classes were fitted, considering age effects up to the cubic. The model with lower sample-size-adjusted Bayesian information criterion (SABIC) was selected. As additional criteria

for selecting the final model, a successful convergence, average of posterior probabilities over .70, and no less than a 5% of the overall sample in each class were considered. The highest average of the posterior probability was used for assigning class membership. A general profile of each class, comprising sociodemographic and clinical information, was obtained. One-way analysis of variances (ANOVAs) and chi-square tests were conducted to assess between-class differences in these variables. Finally, a multinomial logistic regression was conducted to identify determinants of the sensory-cognitive difficulties trajectories.

SEM analyses were conducted with the *lavaan* R package (Rosseel, 2012). Latent class mixed models were implemented with the *lcmm* R package (Proust-Lima et al., 2017). ROC curves, linear, and multinomial regressions were conducted with STATA (StataCorp, 2015).

Results

The mean age of the sample at baseline ($N = 2,555$) was 68.19 years ($SD = 6.01$), with 56.81% of them being women.

Longitudinal Factorial Invariance of the Common Cause Model

The unconstrained model for testing configural factorial invariance ($\chi^2(838) = 2,252.55$, $p < .001$; RMSEA = .024; TLI = .989; CFI = .991), and the constrained model assessing strong factorial invariance ($\chi^2(883) = 2,254.90$, $p < .001$; RMSEA = .026; TLI = .989; CFI = .991) presented an adequate fit. Longitudinal factorial invariance of the common cause model was achieved, since the difference in fit between the constrained and unconstrained models was below the cutoff point (ΔCFI < .001).

All items presented significant loadings across waves ($p < .001$) on the hearing difficulties (ranging from .75 to .96), visual difficulties (ranging from .83 to .98), and cognitive difficulties (ranging from .50 to .82) first-order factors in the constrained model. The loadings of the visual, hearing, and cognitive difficulties first-order factors on the common cause second order factor were all statistically significant (.57, .60, and .51; $p < .001$). The common cause accounted for 32%, 36%, and 26% of the visual, hearing, and cognitive difficulties factors variance, respectively.

Creation of a Sensory-Cognitive Difficulties Latent Score

The strong factorial invariance common cause model was used to estimate a sensory-cognitive difficulties latent score in each wave. The following means were obtained for the sensory-cognitive difficulties score after rescaling (ranging from 0 to 100): Wave 1: M = 31.71, SD = 15.87; Wave 2: M = 32.34, SD = 16.82; Wave 3: M = 36.78, SD = 16.21; Wave 4: M = 40.14, SD = 17.16; Wave 5: M = 45.20, SD = 16.24). According to the results from the ROC curves analyses, this metric at baseline presented a good ability to predict incident dementia at Wave 6 (AUC = .80; 95% confidence interval [CI] = .75, .86). Results from the sensitivity analysis indicated that latent scores on visual and hearing difficulties factors presented a poor ability to predict dementia over 10 years (visual difficulties: AUC = .53; 95% CI = .41, .65; hearing difficulties: AUC = .50; 95% CI = .37, .63). On the other hand, latent scores on cognitive difficulties presented an appropriate ability to predict incident dementia (AUC = .70; 95% CI = .60, .80).

Trajectories of the Common Cause Metric

Results from the LCMM indicated that the model comprising three latent classes with quadratic fixed and random effects presented the lowest SABIC value (SABIC = 67237.59). In addition, average of posterior probabilities of class membership was over .70 in every class, with no class comprising less than a 5% of the overall sample. Supplementary Table S1 contains the sample size and growth parameters of each class. A modal class comprising a 73.44% of the sample (Class 1) was identified. This class presented the lowest sensory-cognitive difficulties at baseline (intercept = 11.88, p < .001), and a significant slope with both linear (β = 1.27, p < .001) and quadratic (β = 0.02, p < .001) shape. A class presenting a stable trajectory of high sensory-cognitive difficulties was also identified (Class 2). Although this trajectory class presented the highest levels of sensory-cognitive difficulties at baseline (intercept = 39.29, p < .001), it only showed a small but significant quadratic shape (β = 0.02, p < .001). Finally, a sensory-cognitive risk trajectory class was detected (Class 3). This class presented the highest linear slope (β = 1.55, p < .001). Figure 2 displays the observed sensory-cognitive difficulties trajectories for each class.

The overall profile of the Classes identified in the LCMM is presented in Table 2. Results from multinomial logistic regressions conducted to assess baseline determinants of Class membership are presented in Table 3. Considering the modal class (Class 1) as reference, classes 2 and 3 comprised more female participants, and were associated with lower levels of education and wealth, as well as a greater presence of ADL and IADL difficulties, self-reported medical diagnoses of diabetes, lower levels of physical activity, and higher Center for Epidemiologic Studies-Depression scale (CESD) score. On the other hand, whereas Class 2 presented older participants compared with the modal class, individuals comprising Class 3 were more likely to be younger. In addition, Class 3 presented a significantly higher proportion of people with high blood pressure.

Discussion

This study presents a methodological approach for developing a combined measure of sensory-cognitive difficulties based on self-reported items of visual and hearing functioning, and a set of cognitive tests. To develop this measure, we proposed a common cause model, testing the temporal stability of a common factor accounting for the observed associations between sensory and cognitive functioning, using a sophisticated SEM approach. This measure presented a good ability to predict incident dementia 10 years later. Moreover, we identified three population groups with heterogeneous trajectories of sensory-cognitive difficulties, as well as risk factors associated with groups presenting high or increasing levels of sensory-cognitive difficulties over time.

We identified a latent factor accounting for the common variance between visual, hearing, and cognitive difficulties over 8 years. Moreover, the explanatory power of this factor as a predictor of sensory and cognitive functioning remains stable over time, accounting for 32%, 36%, and 26% of the visual, hearing, and cognitive difficulties. These results are consistent with previous research evidencing a common etiology underlying both sensory and cognitive age-related decline (Anstey, Luszcz, & Sanchez, 2001; Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994; Lindenberger & Ghisletta, 2009).

We presented a method for developing a latent measure of sensory-cognitive difficulties based on self-reported items of visual and hearing functioning, as well as a set of cognitive measured tests. Based on the proposed common cause model, this metric allows capturing individual variations in a common factor predicting both sensory and cognitive declines. As suggested previously, this factor might be reflecting senescent neurodegenerative processes affecting perceptive and cognitive functioning, in which people vary in terms of level and rate of decline (Lindenberger & Baltes, 1994; Lindenberger & Ghisletta, 2009). The estimated measure of sensory-cognitive difficulties presented an appropriate ability to predict incident dementia over 10 years. It is important to highlight that the common cause explained sensory and cognitive difficulties to a similar extent, and thus, was not overlooking any domain. The above-mentioned evidences of criterion validity regarding the metric are in line with the previous literature showing isolated associations of visual, hearing, and cognitive impairment with risk of dementia (Deal et al., 2017; Lin et al., 2011; Luo et al., 2018; Mitoku et al., 2016; Panza et al., 2015).
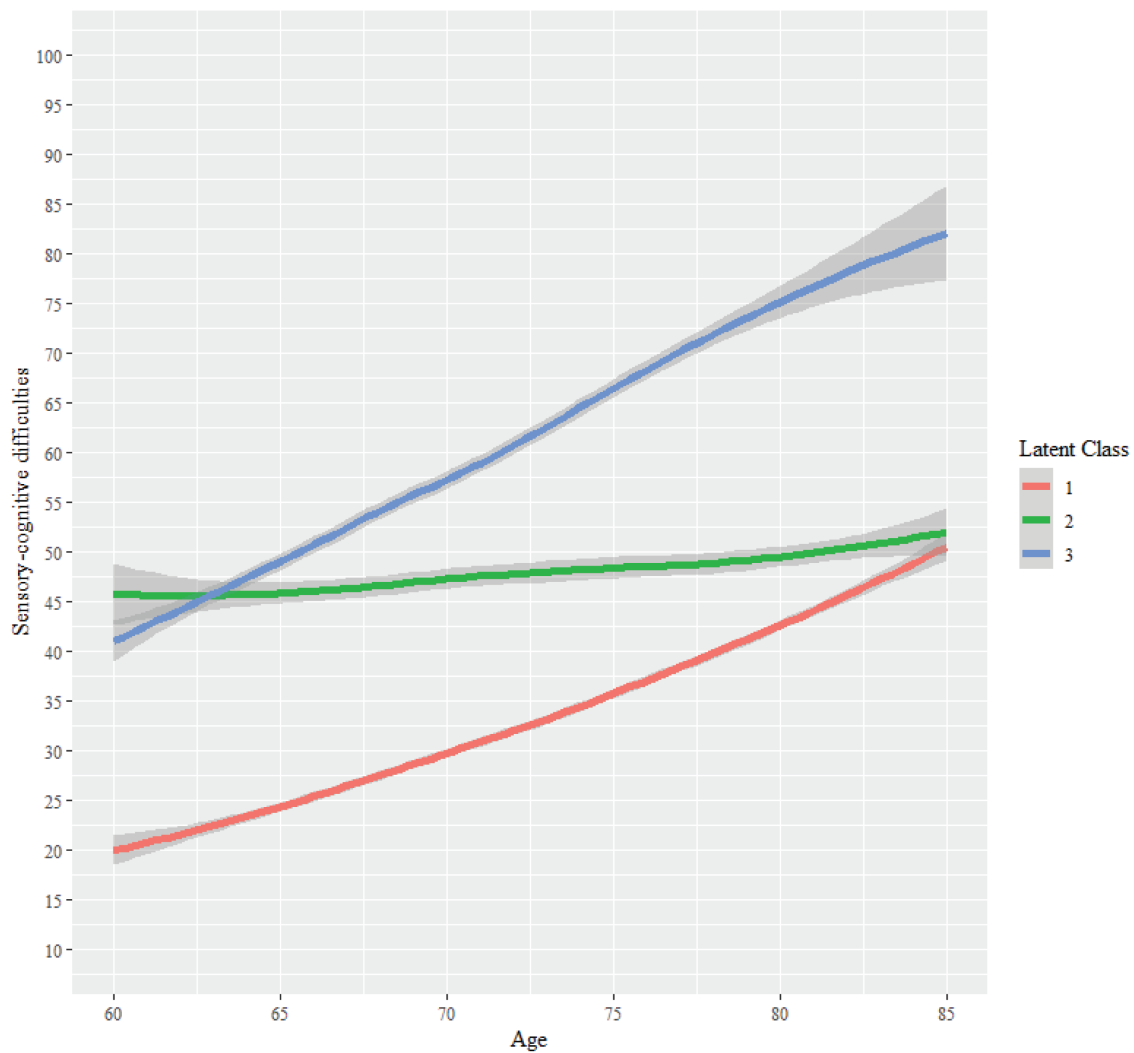
Figure 2. Trajectories of the combined sensory-cognitive difficulties latent score by class.

The LCMM-based methodology implemented in this study allowed assessing heterogeneous trajectories of sensory-cognitive difficulties. In that regard, we identified three populations groups with varying trajectories. The modal class comprising the largest proportion of the sample presented low levels of sensory-cognitive difficulties at baseline and a moderate increase over time. This class was associated with higher levels of education, household wealth, and physical activity. These results are consistent with the previous literature evidencing positive links between health status and education, income, and physical activity (De La Fuente et al., 2018). In that regard, higher education could enable people to access more qualified occupations which take place in healthier environments, thus reducing exposure to sensory-related risk factors. Similarly, a higher income might facilitate access to better healthcare services and healthy habits.

Two risk groups presenting trajectories with high levels or increases of sensory-cognitive difficulties were identified. A set of common risk factors were associated with these groups: a worse functional ability, medical-diagnose of diabetes, and depressive symptomatology. It is important to highlight that disability and depression have been previously associated with both sensory (Brennan et al., 2006; Cimarolli & Jopp, 2014; Fabbri et al., 2016; Nikolova, Demers, & Béland, 2009) and cognitive functioning (Cosh et al., 2018; Kim et al., 2018). Specific risk factors associated with the group presenting the most accelerated rates of sensory-cognitive difficulties should be noted. This group comprised younger participants, and it was associated with high blood pressure, as well as higher levels of depressive symptoms. These results are in line with previous literature suggesting that the common cause might reflect cardiovascular-related factors affecting both sensory and cognitive functioning (Fischer et al., 2016). Similarly, depression has been associated with both sensory (Cosh et al., 2018) and cognitive functioning (Kim et al., 2018).

Two major limitations of the study should be considered. First, our sample is focused on participants from the U.K. population aged 60 years and over that had

Table 2. Baseline General Profile of the Three Classes Identified in the LCMM

	Class 1 (*n* = 1,656)	Class 2 (*n* = 332)	Class 3 (*n* = 267)
Age, *M* (*SD*)	68.36 (5.97)	69.87 (6.48)	65.11 (4.24)
Male, *N* (%)	668 (40.34)	164 (49.40)	142 (53.18)
Formal qualification, *N* (%)	1,075 (64.92)	172 (51.81)	129 (48.31)
Belonging to the first to second quintile of household wealth, *N* (%)	428 (25.85)	144 (43.37)	113 (42.32)
Difficulties in ADLs, *N* (%)	220 (13.29)	86 (25.90)	82 (30.71)
Difficulties in IADLs, *N* (%)	17 (1.03)	15 (4.52)	13 (4.87)
Diabetes, *N* (%)	72 (4.35)	33 (9.94)	28 (10.49)
High blood pressure, *N* (%)	620 (37.44)	128 (38.55)	122 (45.69)
Physical activity, *N* (%)			
Sedentary	90 (5.43)	43 (12.95)	39 (14.61)
Mild	406 (24.52)	99 (29.82)	74 (27.72)
Moderate	817 (49.34)	142 (42.77)	113 (42.32)
Vigorous	343 (20.71)	48 (14.46)	41 (15.36)
CESD score, *M* (*SD*)	1.11 (1.60)	1.59 (1.91)	1.83 (2.02)

Note: ADLs = Activities of daily living; CESD = Center for Epidemiologic Studies-Depression scale; IADLs = Instrumental activities of daily living; LCMM = Latent class mixed model.

Table 3. Multinomial Logistic Regression Model for Predicting Sensory-Cognitive Classes Identified in the LCMM

	Multinomial logistic regression (reference category = Class 1)	
	Class 2 (*n* = 332)	Class 3 (*n* = 267)
	Relative risk ratio (95% CI)	Relative risk ratio (95% CI)
Age	1.03** (1.01, 1.05)	0.86*** (0.84, 0.89)
Sex (ref. male)	0.58*** (0.45, 0.74)	0.46*** (0.35, 0.62)
Formal qualification (ref. no)	0.72* (0.56, 0.94)	0.51*** (0.38, 0.68)
Belonging to the first to second quintile of household wealth (ref. no)	1.77*** (1.36, 2.31)	1.50* (1.10, 2.05)
ADLs difficulties (ref. no)	1.46* (1.06, 2.02)	2.30*** (1.61, 3.29)
IADLs difficulties (ref. no)	2.80** (1.33, 5.89)	2.77* (1.19, 6.44)
Diabetes (ref. no)	2.03** (1.29, 3.20)	1.86* (1.11, 3.09)
High blood pressure (ref. no)	0.84 (0.65, 1.09)	1.37* (1.03, 1.83)
Physical activity (ref. sedentary)		
Mild	0.60* (0.38, 0.93)	0.59* (0.36, 0.96)
Moderate	0.53** (0.34, 0.82)	0.59* (0.36, 0.94)
Vigorous	0.46** (0.28, 0.76)	0.49* (0.28, 0.84)
CES-D 8 score	1.08* (1.01, 1.17)	1.15*** (1.06, 1.24)

Note: ADLs = Activities of daily living; CESD = Center for Epidemiologic Studies-Depression scale; CI = Confidence interval; IADLs = Instrumental activities of daily living; LCMM = Latent class mixed model.
*p < .05; **p < .01; ***p < .001.

responded to all the sensory and cognitive items. Thus, participants who did not survive the time frame considered were excluded from the analyses, constraining the sample and limiting the generalizability of the results. Second, the visual and hearing domains were assessed by means of self-reported items, which can be affected by response biases, and may underestimate sensory impairment in older population (Kamil, Genther, & Lin, 2015). The underestimation of sensory impairment might reduce variability in the responses

to self-reports, attenuating the relationships between the sensory and cognitive domains. Subsequently, this attenuation might have a negative impact on the reliability and strength of the common cause factor. Therefore, the predictive ability of the common cause latent measure on incident dementia could be increased in case objective measures of sensory functioning are included in the structural model. Nonetheless, both self-reported measures of visual and hearing impairments present a high correspondence with

objective measures of visual (Whillans & Nazroo, 2014) and hearing (Sindhusake et al., 2001) functioning. That aside, the hearing domain only comprised two indicators. Further research should be conducted to assess the temporal stability of the common cause in other populations (e.g., younger cohorts, or populations exposed to sensory or cognitive environmental risk factors), as well as the psychometric properties of the sensory-cognitive measure proposed in this study. Additionally, interdisciplinary research could be useful for identifying other potential neurobiological and genetic markers of the common cause. Neuroimaging studies could help localizing structural and functional regions of interest in the brain associated with both sensory and cognitive functioning. Such findings would be potentially valuable for identifying common neurodegenerative factors associated with declines in both sensory and cognitive functioning. Genome-wide association studies could also help identifying single-nucleotide polymorphisms and genetic correlations across these domains of functioning.

In conclusion, the longitudinal factorial invariance of a common factor accounting for the observed associations between sensory and cognitive functioning is assessed to derive a sensory-cognitive measure from the model. Our results identify a latent factor accounting for the communalities among visual, hearing, and cognitive functioning. Moreover, here we show that the predictive ability of this common factor in relation to sensory and cognitive functioning remains stable over 8 years. The sensory-cognitive measure derived from this factor outperformed both sensory and cognitive functioning isolated measures at predicting dementia over 10 years. Therefore, complementing cognitive measures with a few self-reported indicators of sensory functioning proved to be useful for enhancing the assessment of risk of dementia. Three population-based groups with different trajectories of sensory-cognitive difficulties were identified. This study suggests that older people with lower education and household wealth, more disability, higher presence of diabetes, high blood pressure, and depressive symptoms, as well as lower levels of physical activity, may present a steeper decline in sensory-cognitive functioning over time, as well as a higher risk of dementia. Considering our results, the proposed measure could be useful as a cost-effective indicator of sensory-cognitive functioning among older population.

Supplementary Data

Supplementary data are available at *The Gerontologist* online.

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Conflict of Interest

None reported.

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