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Original Research Article

Self-Reported Sensory Decline in Older Adults Is Longitudinally Associated With Both Modality-General and Modality-Specific Factors

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Abstract

Background and Objectives: Self-reported sensory data provide important insight into an individual's perception of sensory ability. It remains unclear what factors predict longitudinal change in self-reported sensory ability across multiple modalities during healthy aging. This study examined these associations in a cohort of older adults for vision, hearing, taste, and smell.

Research Design and Methods: Data on self-report sensory ability were drawn from 5,065 participants of The Irish Longitudinal Study on Ageing (mean age at baseline = 61.6, *SD* = 9.5, range 32–93 years; 59% female; resident in the Republic of Ireland) across 6 waves of data collection (2009–2021). Covariates included demographics, lifestyle factors, and measures of sensory, physical, mental, and cognitive health. Independent discrete survival analyses were performed for each sensory modality.

Results: A transition to self-reported fair/poor hearing was most prevalent (21% of the sample), followed by fair/poor vision (19%), smell (11%), and taste (6%). Participants who self-reported fair/poor function in one sensory modality were likely to report fair/poor ability in another sensory modality, although not for all pairings. Only self-rated fair/poor health was associated with increased odds of self-reported fair/poor ability across all sensory modalities. Age was associated with increased odds of self-reported fair/poor hearing, smell, and taste, as was current smoker status (vision, smell, and taste). Several other sensory (e.g., eye disease, hearing aid use) and nonsensory covariates (e.g., education, depression) were associated with the odds of self-reported fair/poor ability in one or two sensory modalities only.

Discussion and Implications: Over time, older adults perceive associations in fair/poor ability for multiple sensory modalities, albeit somewhat inconsistently. Both modality-general and modality-specific factors are associated with a transition from normal to fair/poor sensory ability. These results suggest the need for more routine testing of multiple senses with increasing age.

Translational Significance: Sensory decline can have adverse consequences for the health and well-being of older adults. However, it is unclear what factors influence long-term changes in perceived sensory ability across multiple senses. Here, we found that older adults associate perceived sensory decline across sensory modalities, but inconsistently. Furthermore, perceived sensory decline is associated with multiple modality-general and modality-specific factors (spanning sensory and nonsensory categories, including perceived health, smoking, and depression). These findings further our understanding of longitudinal patterns of perceived sensory decline in aging and suggest that multiple senses should be routinely measured in clinical settings.

Keywords: Hearing, Self-report, Smell, Taste, Vision

Background and Objectives

Sensory health typically declines during the normal aging process (Armstrong et al., 2021; Cavazzana et al., 2018; Doty, 2018; Owsley, 2016; Swenor et al., 2020; Van Eyken et al., 2007), as physiological changes occur along peripheral and central sensory pathways. The extent and pattern of this sensory change can be shaped by several interlinked factors, including individual differences in demographics (e.g., participant sex and education), broader health, environment, and lifestyle habits (Doty, 2018; Owsley, 2016; Swenor et al., 2020; Van Eyken et al., 2007). In addition to exploring the biological changes that occur within aging sensory systems, there is a pressing need to understand the functional consequences of such changes; that is, how sensory decline impacts upon an older adult's intrinsic ability to successfully interact with his/her external environment and maintain his/her normal, everyday routine. Indeed, sensory decline is associated with an increased risk of adverse outcomes, including malnutrition, frailty, falls, depression, social isolation, and mortality (e.g., Appollonio et al., 1995; Doty, 2018; Frank et al., 2019; Owsley, 2016; Tan et al., 2020; Van Eyken et al., 2007; Yu & Liljas, 2019), underscoring the importance of investigating sensory health in aging populations.

Whether an age-related change in one sensory modality is linked with changes in other modalities is uncertain. Significant associations in suboptimal sensory functioning across modalities have been reported (Boesveldt et al., 2011; Chia et al., 2006; Correia et al., 2016; Hoffman et al., 1998; Kaneda et al., 2000; Schneck et al., 2012). This implies that common mechanisms may underpin general age-related sensory decline ("common-factor theory"; Correia et al., 2016), potentially leading to concurrent impairments across the senses ("global sensory impairment"; Correia et al., 2016; Pinto et al., 2017). Conversely, others have reported evidence more compatible with the so-called "specific-factor theory" (Cavazzana et al., 2018; Gadkaree et al., 2016; Humes et al., 2009), which proposes that sensory loss is linked with modality-specific etiological mechanisms. Accordingly, a pattern of decline could arise in one sensory system while another remains comparatively preserved.

Investigations into the longitudinal risk factors associated with suboptimal sensory ability in aging have typically focused on a single modality (e.g., Frank et al., 2019; Kiely et al., 2012; Schubert et al., 2011), while studies involving multiple modalities are largely cross-sectional in nature (e.g., Cavazzana et al., 2018; Chia et al., 2006; Correia et al., 2016; Gadkaree et al., 2016; Hämäläinen et al., 2021; Hoffman et al., 1998; Humes et al., 2009; Kaneda et al., 2000; Pinto et al., 2017; Schneck et al., 2012). There is a paucity of research investigating both the longitudinal relationship in functioning across the senses, which is needed to understand long-term changes in sensory function in aging, and the broader factors that are associated with longitudinal change in sensory function across multiple sensory modalities in older adults.

To address this knowledge gap, we investigated incidents of perceived fair/poor ability for vision, hearing, smell, and taste among community-dwelling older adults drawn from The Irish Longitudinal Study on Ageing (TILDA; Whelan & Savva, 2013). The current study focused on self-reported sensory function, which was available across six waves (12 years, 2009–2021) of the TILDA study (see Author Note 1). Self-report is a commonly used and easy-to-administer index of sensory function. Furthermore, self-report provides insight into older adults' perceptions of their sensory abilities, which is important for identifying if an individual might seek help and obtain objective clinical assessments should sensory decline occur. Self-report evaluations of sensory ability are also potentially more representative of everyday sensory experiences compared with objective tests, which are more domain-specific (Brennan et al., 2006; Tremblay et al., 2015). Questions of sensory ability are likely to prompt responses that reflect how successfully an older adult can typically interact with his/her external environment (e.g., have a conversation or food intake), thus capturing the functional, "lived" reality of sensory health in aging. Despite the importance of self-perceived sensory functioning, it remains unclear if older adults perceive concomitant declines in sensory ability across modalities and, if so, whether specific modalities tend to be more strongly associated than others. Given that older adults may experience declining sensory ability before this is detected through formal assessments, it is also important to understand what factors shape these perceptions and, by extension, if these factors generalize across sensory modalities. As such, we examined what factors predict the self-reported transition from normal to fair/poor ability in vision, hearing, taste, and smell over time. The factors we explored included demographics, lifestyle factors and measures of sensory, physical, mental, and cognitive health.

Research Design and Methods

Study Population

Participants were drawn from Waves 1 to 6 (2009–2021) of TILDA, a population-representative sample of 8,504 individuals resident in the Republic of Ireland (for sampling details, see Whelan & Savva, 2013). The waves occurred approximately every 2 years. The study was approved by the Trinity College Dublin Faculty of Health Sciences Research Ethics Committee and complied with relevant data protection legislation. All participants provided informed consent at every testing wave. Our analysis concentrated on participants who partook in at least Waves 1 and 2 (N = 7,285). To mitigate data loss, data from participants who dropped out of the study over time were retained; data were included from the waves prior to their attrition.

Sensory Ability

All participants completed a computer-assisted personal interview from Waves 1 through 5 of TILDA, wherein a trained interviewer delivered a standardized set of questions in the participants' homes. Due to the COVID-19 pandemic, a computer-assisted telephone interview was conducted at Wave 6. At all six waves, the participants were asked to rate their vision ("Is your eyesight (using glasses or contact lenses if you use them)…"), hearing ("Is your hearing…"), smell ("Is your sense of smell…"), and taste ("Is your sense of taste…") on a 5-point Likert scale (Excellent, Very good, Good, Fair, or Poor). For hearing, from Waves 1 through 4, all participants were asked to rate their hearing "with or without a hearing aid." For Waves 5 and 6, hearing aid users were asked to rate their hearing with a hearing aid and separately without a hearing aid, and we included ratings for unadjusted hearing only in our primary analysis (see Author Note 2). Self-reported fair/poor ability was classified as a response of "fair" or "poor" (or "registered blind" in the case of vision) and self-reported "normal" ability was classified as a response of "excellent," "very good," or "good" (Whillans & Nazroo, 2014; Yu & Liljas, 2019). For the purpose of our analyses, participants reporting such fair/poor vision (n = 582), hearing (an additional n = 738), smell (an additional n = 452), and/or taste (an additional n = 47) at Wave 1 were not included, as it would not be possible to observe changes toward fair/poor ability in these individuals.

Covariates

Time-fixed covariates (i.e., those whose values would remain consistent over time) included participant sex (*male*, female) and socioeconomic status (SES) based on the father occupation (*unemployed*, unknown, farmer, manual, non-manual, professional/managerial).

Time-varying covariates (i.e., those whose values potentially change across time) were selected based on the availability and consistency in the measurement of variables over the testing waves. These were as follows, with the reference levels for categorical covariates indexed by italicized font: age (years), highest education level (*primary*, secondary, tertiary), self-reported eye disease (cataract(s), age-related macular degeneration, glaucoma, diabetic retinopathy; *no*, yes), self-reported hearing aid use (*no*, yes), self-reported sensory function for each of the nontarget sensory modalities (*normal*, fair/poor; for example, if modeling the transition from normal to fair/poor ability for vision, the model includes hearing, smell and taste function as covariates), self-rated ability to follow a group conversation (with or without a hearing aid; *yes*, no/with difficulty), self-rated health (measured with the same Likert scale as the sensory questions; *normal,* fair/poor), self-reported doctor (i.e., clinical) diagnoses of cardiac-related diseases (hypertension, angina, heart attack, stroke, ministroke, heart murmur, atrial fibrillation, diabetes/high blood sugar; 0, 1, 2+), self-reported doctor (i.e., clinical) diagnoses of noncardiac diseases (chronic lung disease, asthma, cancer, Parkinson's disease, rheumatoid arthritis; 0, 1, 2+), smoking status (*nonsmoker*, former smoker, current smoker), weekly physical activity (≥150 min of moderate activity/75 min of vigorous activity/an equivalent combination of moderate and vigorous activity; *no*, yes), depression (≥9 on the short-form Centre for Epidemiological Depression scale; *no*, yes) and cognitive function (*normal,* impaired; based on verbal fluency (timed animal naming), immediate recall and delayed recall performance (of verbally presented words), where a score ≤1.5 *SD*s below the mean qualified for impaired performance). Time was split into discrete intervals corresponding to the testing waves and time interval (interval 1 [Waves 1–2; 2009–2012], interval 2 [Waves 2–3; 2012–2015], interval 3 [Waves 3–4; 2015–2016], interval 4 [Waves 4–5; 2016–2018], and interval 5 [Waves 5–6; 2018–2021]) was also included as a covariate. For time-varying covariates, covariate values for each interval were based on the most recent wave within that interval (e.g., in interval 1 [Waves 1–2], values were based on Wave 2 data, reflecting the most recent variable status for that interval).

Analysis

Given the discrete nature of the testing waves, we performed discrete survival analysis (Austin, 2017) using multivariable regression models (see Author Note 3) to

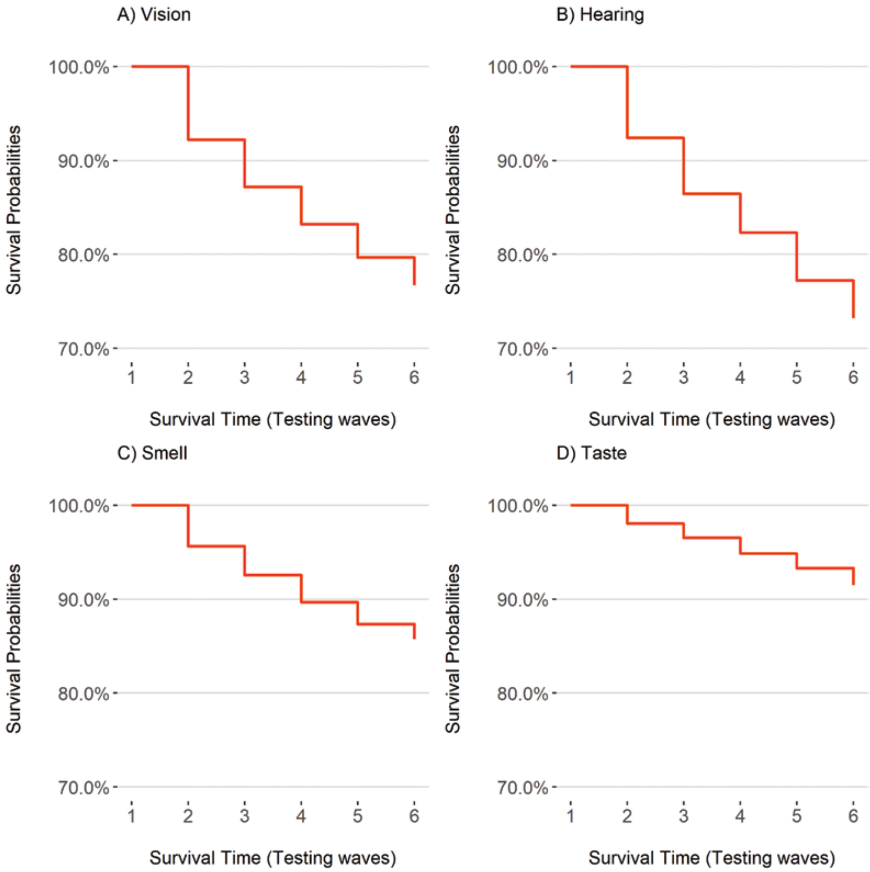

Figure 1. Plot showing the unadjusted survival probabilities for (A) fair/poor vision, (B) fair/poor hearing, (C) fair/poor smell, and (D) fair/poor taste across The Irish Longitudinal Study on Ageing testing waves. Each drop in survival indicates the percentage of the sample at each wave showing a transition from normal to fair/poor ability in that wave.

estimate the longitudinal association between covariates of interest and the transition from normal to fair/poor sensory ability across time intervals. These analyses were performed for each sensory modality, resulting in four independent regression models, that is, one each for vision, hearing, smell, and taste.

All analyses were conducted using R (R Core Team, 2019) via RStudio (RStudio Team, 2021). Multivariable regression models were fitted using the "stats" package (R Core Team, 2019), the "glm()" function, and the logit link (Austin, 2017). Model coefficients were exponentiated to yield odds ratios (ORs; Austin, 2017). For each independent regression model, we verified that each statistically significant covariate (automatically indicated by the Wald test in the "glm()" output) was a significant contributor to the overall model fit. To do so, we conducted likelihood ratio tests, which are conservative tests of statistical significance, wherein the fit of models with and without the covariate of interest was compared (while holding all other model terms constant). Thereafter, the "Holm–Bonferroni" correction was implemented as multiple likelihood ratio tests were performed for each independent regression model, and corrected p values following these tests are reported. Full model results can be found in Supplementary Tables S3–S6 and Supplementary Figures S1 and S2.

Results

After removing missing data across waves, the final analysis sample consisted of 5,065 participants (mean age at Wave 1 = 61.6, SD = 9.5, range 32–93 years; 95% [n = 4,824] aged 50 years and over; 59% female); all of these participants had complete data for Waves 1 and 2 and 2,523 (50%) had complete data for all six waves. Descriptive baseline characteristics of the sample, stratified by self-report function across modalities, are available in Supplementary Table S1. Over time, approximately 19% (n = 940) of participants transitioned from a response of normal to fair/poor vision, 21% (n = 1,057) to fair/poor hearing, 11% (n = 569) to fair/poor smell, and 6% (n = 319) to fair/poor taste. Figure 1 displays Kaplan–Meier plots for the unadjusted survival probability across each of the four target sensory modalities. These data are derived from the number of participants "at risk" of transitioning to fair/poor ability (i.e., those whose data are available at each specific wave and have not yet reported fair/poor ability) and the number of confirmed first instances of fair/poor ability reported within each time interval (Table 1).

Vision

Higher odds of transitioning from self-reported normal to fair/poor vision were significantly associated with self-reported eye disease (OR = 2.75, 95% confidence interval [CI] [2.33, 3.23]; $\chi^2_{(1)}$ = 136.48, $p < .001$), fair/poor health (OR = 2.68, 95% CI [2.26, 3.18]; $\chi^2_{(1)}$ = 121.50, $p < .001$), fair/poor hearing (OR = 2.49, 95% CI [2.03, 3.03]; $\chi^2_{(1)}$ = 74.20, $p < .001$), fair/poor smell (OR = 1.68, 95% CI [1.29, 2.18]; $\chi^2_{(1)}$ = 13.95, $p < .001$), a current smoker status only (OR = 1.40, 95% CI [1.14, 1.73]; $\chi^2_{(2)}$ = 9.85, $p = .02$), or depression (OR = 1.43, 95% CI [1.15, 1.76]; $\chi^2_{(1)}$ = 10.37, $p = .005$). Lower odds of transitioning from self-reported normal to fair/poor vision were significantly associated with a higher SES (as indicated by professional/managerial father occupation: OR = 0.60, 95% CI [0.44, 0.83]; and manual father occupation: OR = 0.73, 95% CI [0.56, 0.96]; $\chi^2_{(5)}$ = 13.48, $p = .039$), with higher education levels (secondary: OR = 0.81, 95% CI [0.68, 0.97]; tertiary: OR = 0.77, 95% CI [0.63, 0.93]; $\chi^2_{(2)}$ = 7.44, $p = .039$) and with time (interval 2, OR = 0.65, 95% CI [0.54, 0.77]; interval 3, OR = 0.57, 95% CI [0.46, 0.70]; interval 4, OR = 0.50, 95% CI [0.40, 0.63]; interval 5, OR = 0.43, 95% CI [0.33, 0.56]; $\chi^2_{(4)}$ = 70.52, $p < .001$), as shown in Figure 2A.

Hearing

Higher odds of transitioning from self-reported normal to fair/poor hearing were significantly associated with the use of a hearing aid (OR = 3.05, 95% CI [2.43, 3.81]; $\chi^2_{(1)}$ = 87.76, $p < .001$), difficulty following a group conversation (OR = 8.23, 95% CI [7.14, 9.49]; $\chi^2_{(1)}$ = 850.90, $p < .001$), fair/poor vision (OR = 2.46, 95% CI [1.99, 3.02]; $\chi^2_{(1)}$ = 66.09, $p < .001$), fair/poor health (OR = 1.66, 95% CI [1.38, 2.00]; $\chi^2_{(1)}$ = 27.30, $p < .001$), fair/poor taste (OR = 1.68, 95% CI [1.15, 2.41]; $\chi^2_{(1)}$ = 7.19, $p = .02$), or older age (OR = 1.24, 95% CI [1.15, 1.35]; $\chi^2_{(1)}$ = 29.76, $p < .001$). Lower odds of transitioning from self-reported normal to fair/poor hearing were significantly associated with being female (OR = 0.75, 95% CI [0.65, 0.86]; $\chi^2_{(1)}$ = 15.47, $p < .001$) and with time (interval 3, OR = 0.68, 95% CI [0.55, 0.84]; interval 5, OR = 0.72, 95% CI [0.56, 0.92]; $\chi^2_{(4)}$ = 16.05, $p = .01$) as shown in Figure 2B.

Smell

Self-reported taste was not included as a covariate in the regression model (see Author Note 4) due to a high collinearity with self-reported smell at all testing waves based on Spearman rank correlations (all $r > .76$, $p < .001$). Higher odds of transitioning from self-reported normal to fair/poor smell were significantly associated with fair/poor hearing (OR = 1.64, 95% CI [1.28, 2.09]; $\chi^2_{(1)}$ = 14.56, $p < .001$), difficulty following a group conversation (OR = 1.47, 95% CI [1.19, 1.81]; $\chi^2_{(1)}$ = 12.77, $p = .001$), fair/poor vision (OR = 1.87, 95% CI [1.45, 2.40]; $\chi^2_{(1)}$ = 21.57, $p < .001$), fair/poor health (OR = 1.46, 95% CI [1.15, 1.83]; $\chi^2_{(1)}$ = 9.82, $p = .003$), or a current smoker status only (OR = 1.50, 95% CI [1.15, 1.94]; $\chi^2_{(2)}$ = 9.33, $p = .009$). As expected, the odds also increased with age (OR = 1.23, 95% CI [1.11, 1.35]; $\chi^2_{(1)}$ = 16.15, $p < .001$). Lower odds of transitioning from self-reported normal to fair/poor smell were significantly associated with being female (OR = 0.72, 95% CI [0.60, 0.86]; $\chi^2_{(1)}$ = 13.43, $p < .001$) and time (interval 2, OR = 0.70, 95% CI [0.56, 0.88]; interval 3, OR = 0.67, 95% CI [0.52, 0.85]; interval 4, OR = 0.51, 95% CI [0.39, 0.67]; interval 5, OR = 0.35, 95% CI [0.24, 0.49]; $\chi^2_{(4)}$ = 51.57, $p < .001$) as shown in Figure 3A.

Taste

Self-reported smell was not included as a covariate in the regression model (see above). Higher odds of transitioning from self-reported normal to fair/poor taste were significantly associated with fair/poor health (OR = 3.12, 95% CI [2.39, 4.08]; $\chi^2_{(1)}$ = 65.55, $p < .001$), fair/poor hearing (OR = 1.98, 95% CI [1.44, 2.69]; $\chi^2_{(1)}$ = 17.39, $p < .001$), fair/poor vision (OR = 1.87, 95% CI [1.37, 2.51]; $\chi^2_{(1)}$ = 14.83, $p < .001$), a current smoker status only (OR = 1.93, 95% CI [1.39, 2.66]; $\chi^2_{(2)}$ = 17.68, $p < .001$), depression (OR = 1.68, 95% CI [1.24, 2.26]; $\chi^2_{(1)}$ = 10.68, $p = .004$), or being older in age (OR = 1.25, 95% CI [1.09, 1.42]; $\chi^2_{(1)}$ = 10.72, $p = .004$), as shown in Figure 3B. Lower odds of transitioning from self-reported normal to fair/poor taste were significantly associated with higher physical activity (OR = 0.74, 95% CI [0.58, 0.96]; $\chi^2_{(1)}$ = 5.18, $p = .046$).

Table 1. Number of Participants at Risk of Reporting Fair/Poor Sensory Ability with Number of First Reported Incidents of Fair/Poor Sensory Ability

Sensory Ability	Interval 1 (W1–W2)	Interval 2 (W2–W3)	Interval 3 (W3–W4)	Interval 4 (W4–W5)	Interval 5 (W5–W6)
Vision	5,065 (396)	3,874 (210)	3,182 (141)	2,639 (113)	2,064 (76)
Hearing	5,065 (386)	3,888 (250)	3,163 (151)	2,638 (163)	2,043 (107)
Smell	5,065 (222)	4,000 (129)	3,354 (104)	2,816 (73)	2,234 (41)
Taste	5,065 (99)	4,102 (64)	3,502 (61)	2,992 (49)	2,404 (46)

Notes: W = wave. Number of first reported incidents of fair/poor ability within each time interval is presented in parentheses.

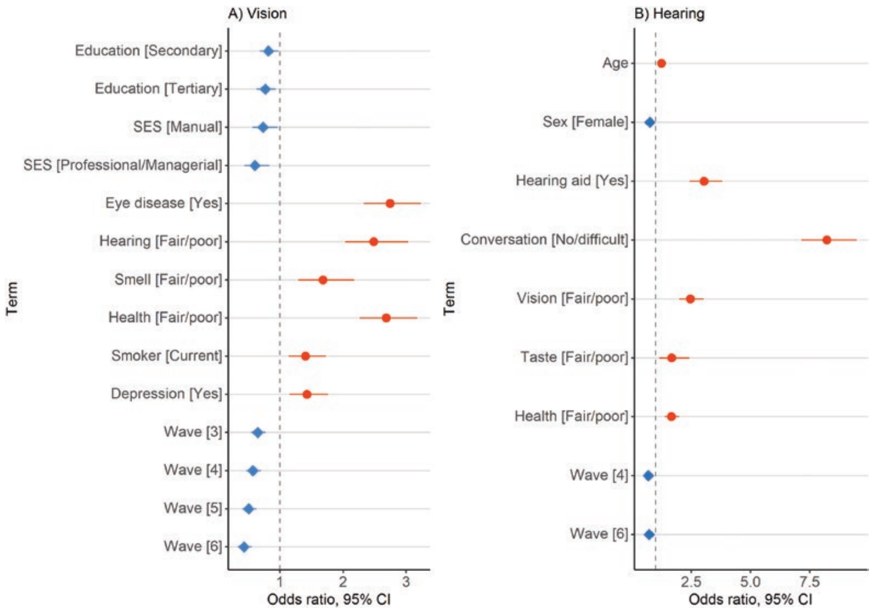

Figure 2. Plot showing odds ratios for (A) fair/poor vision and (B) fair/poor hearing with 95% confidence intervals (CIs). Odds ratios to the left of the vertical dashed line (blue diamonds) indicate a reduced odds of reporting fair/poor ability. Odds ratios to the right of the vertical dashed line (red circles) indicate increased odds of reporting fair/poor ability. Plot shows only statistically significant covariates, based on corrected *p* values from likelihood ratio tests.

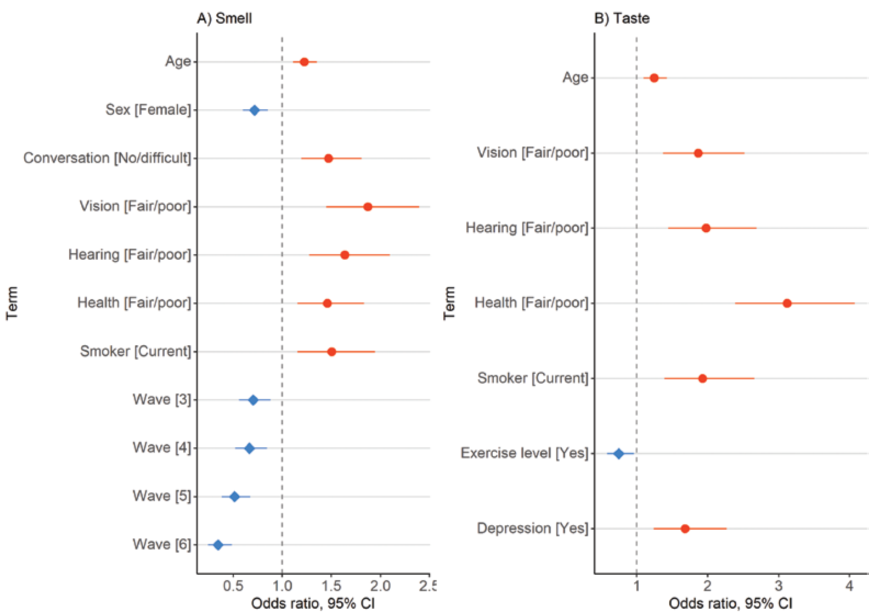

Figure 3. Plot showing odds ratios for (A) fair/poor smell and (B) fair/poor taste with 95% confidence intervals (CIs). Odds ratios to the left of the vertical dashed line (blue diamonds) indicate a reduced odds of reporting fair/poor ability. Odds ratios to the right of the vertical dashed line (red circles) indicate increased odds of reporting fair/poor ability. Plot shows only statistically significant covariates, based on corrected *p* values from likelihood ratio tests.

Discussion and Implications

This study aimed to provide a better understanding of what factors predict the transition from self-reported normal to fair/poor sensory ability in vision, hearing, taste, and smell within a sample of community-dwelling older adults ($N = 5{,}065$), including if function in one sensory modality predicts function in another. The results of our analyses are summarized in Figure 4.

Cross-modal Associations

A longitudinal transition from normal to fair/poor ability was most frequently reported for hearing, followed by vision, smell, and taste. A higher prevalence of fair/poor hearing than vision and a relatively lower prevalence of fair/poor ability in the chemical senses forms a pattern that is broadly consistent with the findings of other studies involving older adults (Armstrong et al., 2021; Brennan et al., 2006; Cavazzana et al., 2018; Chia et al., 2006; Hämäläinen et al., 2021; Schneck et al., 2012; Yu & Liljas, 2019). A particularly high prevalence of fair/poor hearing among older adults may stem from numerous factors; for example, difficulties encountered in specific, everyday scenarios that can be attributed to hearing, such as difficulty following group conversations (which increased the odds of self-reporting fair/poor hearing more than eight-fold [OR = 8.23] in this cohort). A relatively lower frequency of hearing examinations compared to vision, poor uptake and inconsistent use of hearing aids, temporary hearing loss (e.g., due to an ear infection), and/or repeated exposure to common risk factors (e.g., high noise levels) may also play a role. In contrast, a comparatively low prevalence of fair/poor taste may reflect a genuine preservation of this sense in aging or greater difficulty in subjectively rating the sense of taste, perhaps given that there are few salient contexts for evaluating taste experiences (and, in the case of eating, suboptimal taste can often be "explained away" or sufficiently masked). Nevertheless, prevalence rates for fair/poor sensory ability reported over time were reasonably low among these older adults (<25% across sensory modalities). This may reflect the fact that this cohort is still relatively young and high-functioning and that we are modeling the transition from normal to fair/poor self-reported sensory ability, as opposed to more subtle declines in sensory function.

Studies utilizing objective sensory measures have yielded evidence for cross-modal links in sensory functioning in aging (e.g., Boesveldt et al., 2011; Chia et al., 2006; Correia et al., 2016; Hämäläinen et al., 2021; Kaneda et al., 2000; Schneck et al., 2012; Stevens et al., 1998). We were interested in whether self-reported decline in one sensory modality was likely to predict self-reported decline in another, therefore supporting a generalized perception of self-reported sensory function. Similar to previous findings (e.g., Cavazzana et al., 2018; Hämäläinen et al., 2021; Hoffman et al., 1998; Tremblay et al., 2015), our analyses revealed significant associations between self-reported ratings of sensory function across modalities, although there was variability here. Fair/poor vision was strongly predictive of fair/poor hearing (and vice versa); for example, 37% (n = 345) of older adults who transitioned to fair/poor vision also reported fair/poor hearing. Fair/poor taste and smell were not significant predictors of the probability of fair/poor vision and hearing, respectively, while the opposite associations did reach significance. This might indicate that if individuals self-report declines in vision and hearing specifically, they might well generalize these perceptions to other sensory modalities. This may reflect the fact that vision and hearing are mutually informative for several everyday behaviors (e.g., socialization, entertainment, navigation, obstacle detection, and avoidance, etc.) and are, therefore, particularly amenable to subjective evaluation, thus strongly shaping perceptions of sensory health more broadly (also note that Cavazzana et al. [2018] reported good correspondence between subjective and objective measures of vision and hearing, but not for other senses, among older adults). Interestingly, we could not include smell and taste as mutual predictors in our models due to their highly correlated responses. For example, 62% (n = 199) of older adults who transitioned to fair/poor taste also reported fair/poor smell. This suggests

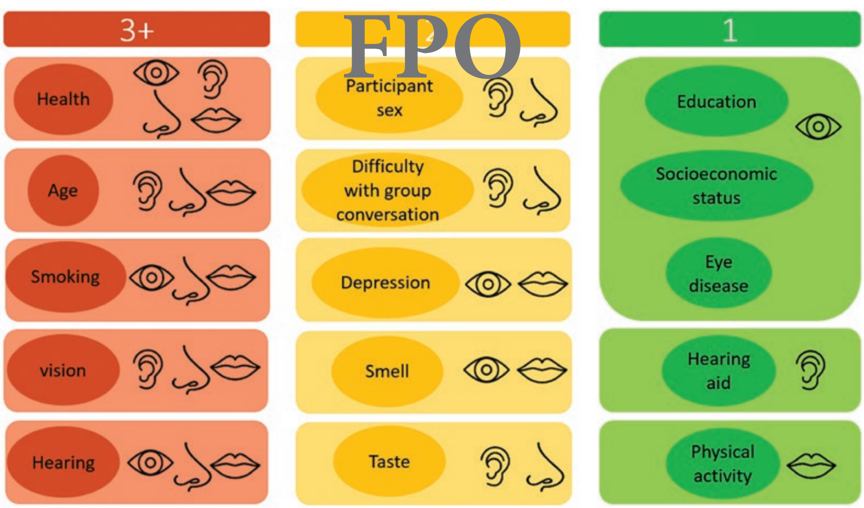

Figure 4. Summary of the covariates associated with a transition from normal to fair/poor self-report sensory ability for vision, hearing, taste, and smell.

that older adults strongly associate perceived functioning across the chemical senses. This was not unexpected, given the interrelated functional (e.g., food intake) and physiological nature of these sensory systems.

Overall, significant but inconsistent associations across modalities as well as asymmetric prevalence rates of sensory decline appear consistent with the findings of Stevens et al. (1998), who reported significant cross-modal correlations in (objectively measured) sensory function in aging while also observing that the senses declined at different rates. Given this variability in patterns of decline across the senses and evidence for *both* common and distinct mechanisms shaping perceptions of sensory function, our findings overall suggest that the concept of "global" sensory impairment alone does not fully capture subjective sensory decline in the present cohort. Importantly, many of the observed associations between sensory and nonsensory factors and perceived sensory function here are compatible with the findings of other studies using self-report and/or objective measures of sensory function with older adults, suggesting a degree of consistency in results across these cohorts. Moreover, this highlights the genuine potential for accessible self-report assessments to provide valuable insight into sensory function in aging. Given the complexity of these patterns, reflecting the complexity of sensory health in aging, our findings call for the objective examination of multiple senses in clinical settings to better understand the nature of the sensory decline in older adults.

Modality-General Factors

To begin with, a relationship was found for self-rated fair/poor health and an increased probability of self-reported sensory decline across modalities but particularly for vision and taste. Self-rated health is considered a valid proxy measure of health, sensitive to physical and cognitive decline as well as mortality (Bond et al., 2006). Reduced sensory function is also significantly associated with several health issues, including frailty, cognitive decline, and disease, as well as an elevated risk of mortality (Appollonio et al., 1995; Doty, 2018; Frank et al., 2019; Owsley, 2016; Tan et al., 2020; Yu & Liljas, 2019). Thus, it is unsurprising that we observed robust correspondences between perceived health and ratings for vision, hearing, smell, and taste. That these findings are consistent with those of previous studies involving older adults (Brennan et al., 2006; Rawal et al., 2016; Yu & Liljas, 2019) suggests that perceptions of sensory function are an important facet of perceptions of health in older adults (see Author Note 5), underscoring the importance of profiling sensory health across the sensory modalities in older adults. Incidentally, the overall prevalence of self-rated fair/poor health declined over time. While the reasons for this are beyond the scope of this study (see Turner et al., 2018), improved perceptions of health may account for the significant decrease in the odds of perceived fair/poor ability for vision, hearing, and smell over subsequent testing waves (while the relative rarity of fair/poor taste may explain the absence of a time effect for this modality). It is also important to consider whether the sample attrition over time, an expected consequence of longitudinal studies involving older adults, can account fully for the decrease in self-reported incidents of fair/poor ability across the waves. We did not observe a sizeable difference in the overall sample characteristics of those who started the study and those who remained across all six waves (Supplementary Table S2), while the declining trends already emerged by Wave 3 (approximately 4 years post-baseline). Furthermore, the pattern of decline in self-report incidents of fair/poor ability was not uniform across modalities (where hearing did not show a consistent decrease in reported incidents of fair/poor ability with time). Therefore, although significant sample attrition is evident in this cohort, such is unlikely to fully account for the current findings.

Increasing age was associated with 24%, 23%, and 25% increased odds of reporting fair/poor hearing, smell, and taste, respectively, consistent with evidence for age-related declines in these sensory modalities (e.g., Armstrong et al., 2021; Correia et al., 2016; Hoffman et al., 1998; Humes et al., 2009; Pinto et al., 2014; Stevens et al., 1998). Importantly, these relationships emerged when controlling for potential mediators such as physical and cognitive health, implying an independent role of the aging process (e.g., potentially reflecting mechanisms such as cellular senescence, slower neuronal conduction velocity, etc.) on perceived sensory function. No such relationship was found between age and visual decline, consistent with the findings from a previous cross-sectional study involving the TILDA cohort (Hirst et al., 2019) but at odds with substantial evidence for age-related visual decline reported in several other studies (e.g., Armstrong et al., 2021; Correia et al., 2016; Gadkaree et al., 2016; Hämäläinen et al., 2021; Pinto et al., 2014). However, this relationship was only statistically nonsignificant after adjusting for covariates such as eye disease and self-rated health (see Author Note 6). This suggests that declining perceptions of visual function with increasing age can be entirely accounted for by such health-based factors. Nevertheless, age-related visual decline can be insidious and it is possible that some older adults lack full awareness of their vision loss or have habituated to suboptimal vision over time, accounting for the absence of an independent relationship between vision and age in the fully-adjusted model (Foreman et al., 2017; however, see Whillans & Nazroo, 2014). Moreover, the widespread availability and uptake of typically successful interventions for vision loss (e.g., glasses) and the benefit such could have for the "oldest" older adults in the present sample (Chen et al., 2016) is particularly important to consider, given that the participants here were always asked to rate their eyesight "using glasses or contact lenses if you use them."

Smoking, a modifiable risk, was associated with an increased probability of self-reported fair/poor vision, taste, and smell (but not hearing, consistent with Kiely et al., 2012). Altered function within these senses among older adult smokers versus nonsmokers has been previously documented (Doty, 2018; Klein et al., 2008; Murphy et al., 2002; Nolan et al., 2012; Sødal et al., 2021). For example, current smoker status has been associated with lower macular optical pigment density, which is detrimental to healthy visual function, in the TILDA cohort (Nolan et al., 2012; see also Klein et al., 2008), as well as poorer olfactory identification abilities (Murphy et al., 2002) and more frequent experiences of unpleasant oral sensations (Sødal et al., 2021). Importantly, only current smokers showed increased odds of reporting fair/poor ability across these modalities (see also Murphy et al., 2002 and Nolan et al., 2012 for compatible findings). This suggests that an adverse effect of smoking on perceived sensory function may not be permanent, underlining the continued value of public health campaigns to reduce smoking.

Females had lower odds of reporting fair/poor hearing and smell than males (but not for vision or taste). Older adult males typically self-report, and exhibit, a more extensive decline in hearing (particularly for high frequencies) compared to females (Armstrong et al., 2021; Brennan et al., 2006; Correia et al., 2016; Hämäläinen et al., 2021; Pinto et al., 2014; Villavisanis et al., 2020; Yu & Liljas, 2019). The possible reasons for this sex difference require further research but may include lifestyle differences, greater occupational exposure to noise in males, and hormonal influences, with emphasis on the influence of estrogen levels on auditory function (Villavisanis et al., 2020). Similarly, poor olfactory function in older adult males compared to females has been reported (Boesveldt et al., 2011; Murphy et al., 2002). The mechanisms underpinning the association between the sex of the participant and sense of smell are also unclear, but may include lifestyle differences, physiological differences in the olfactory system, and neuroendocrinological influences (Sorokowski et al., 2019). Given the potential adverse consequences of sensory decline in aging, further work is certainly needed to better understand these sex differences and help design/implement effective strategies, perhaps differentially tailored to males and females, to mitigate such decline.

Depression was associated with 43% and 68% increased odds of reporting fair/poor vision and taste, respectively. Our findings are consistent with reported evidence for links between depression and less healthy vision (Carrière et al., 2013; Frank et al., 2019) and taste (Hoffman et al., 1998; Hur et al., 2018) function among older adults, which are likely to be bi-directional in nature. That is, depression may increase the risk of developing fair/poor vision or taste due to neglected self-care or anhedonia, while the psychological burden of sensory loss and resulting limitations to independent functioning could increase the risk of depression (Carrière et al., 2013; Frank et al., 2019; Hur et al., 2018; Yu & Liljas, 2019). Depression was not independently associated with an increased probability of fair/poor hearing or smell (see Author Note 5), although other studies have reported these associations (Boesveldt et al., 2011; Hoffman et al., 1998; Hur et al., 2018; Kiely et al., 2012; although see Pronk et al., 2013). Further work is needed to clarify the reasons why independent associations between depression and perceived sensory decline in older adults are evident for certain sensory modalities. Nevertheless, our findings underscore the importance of recognizing the relationship between mental health and sensory function in aging, particularly for the appropriate design and implementation of effective interventions for functional decline.

A significant association was observed between an inability to follow a group conversation and increased odds of reporting fair/poor hearing (as expected; see also Hämäläinen et al., 2021) and smell. The latter finding may reflect links between olfactory abilities and cognitive health (Sohrabi et al., 2012), given that cognitive function (e.g., divided attention, inhibition, etc.) can facilitate the comprehension of relevant speech in complex, noisy contexts, particularly as hearing declines (e.g., Anderson et al., 2013). In this respect, the contribution of cognitive as opposed to sensory factors alone to the relationship with hearing ability also remains to be investigated. Interestingly, these associations emerged when controlling for verbal fluency and recall in both models. This indicates that any potential cognitive facets associated with smell and hearing function are quite domain-specific. These links are also potentially clinically meaningful, although additional work is needed to explore the associations between cognitive health and particular aspects of sensory ability with greater specificity. Unlike previous studies (Guthrie et al., 2022; Hämäläinen et al., 2021; Kiely et al., 2012; Valsechi et al., 2022), we found no standalone associations between sensory decline and cognitive function (although Hämäläinen et al., 2021 did not observe associations between cognition and self-reported sensory abilities after adjusting for behavioral measures of sensory function). The limited number of cognitive measures longitudinally available for the present analysis and the relatively low incidence of impaired performance across these measures may explain the absence of significant associations in this cohort.

Modality-Specific Factors

Higher education levels were protective against a self-reported decline in vision, as previously reported (Chen et al., 2016; Hämäläinen et al., 2021). For example, higher macular pigment optical density has been documented in the more highly educated older adults in the TILDA cohort (Nolan et al., 2012). These older adults may engage in healthier lifestyle habits (e.g., have a better diet) and experience a lower prevalence of comorbidities relative to their less well-educated counterparts (Nolan et al., 2012), thereby helping to better preserve their visual functioning. A higher SES category (based on the father's occupation) was also protective against the development of fair/poor vision, possibly reflecting better childhood health and healthier lifestyles which can persist into adulthood (Cohen et al., 2010; see also Hämäläinen et al., 2021 and Rahi et al., 2009 for evidence linking SES factors with visual function in older adults). Interestingly, Rahi et al. (2009) reported that markers of childhood socioeconomic deprivation are associated with significantly increased odds of impaired visual acuity in middle-aged adults. While the association in the current study for reduced odds of fair/poor vision and SES was strongest for the highest SES category (professional/managerial father occupation), we cannot account for why those reporting a manual (but not nonmanual) occupation of their father also showed reduced odds of visual decline (although manual occupation was much more prevalent than nonmanual occupation among this cohort). Regardless, these two findings collectively reinforce the significant benefit of access to education services and better health in childhood for healthy visual functioning in later life. We also found that higher physical activity was mildly protective against taste decline; further work will be needed to establish if this represents a direct relationship between taste and physical functioning (Gauthier et al., 2020; Hoffman et al., 1998) or reflects healthier lifestyle preferences/characteristics more broadly for active older adults (e.g., improved dietary intake or reduced weight; Jeon et al., 2021; Rohde et al., 2020).

The odds of self-reported visual decline were almost three times greater for older adults with an eye disease (compared to those without an eye disease): this was unsurprising as eye disease is the leading global cause of blindness in older adults (GBD 2019 Blindness and Vision Impairment Collaborators & Vision Loss Expert Group of the Global Burden of Disease Study, 2021), highlighting the importance of increasing awareness of the symptoms of eye disease in older adults as well as designing, implementing and making available effective screening tools and treatments for such diseases. The odds of self-reported fair/poor hearing were also greater for hearing aid users than nonhearing aid users, which was expected. This relationship was still statistically significant, albeit weaker, when considering ratings for *adjusted* hearing in the final two waves, when hearing was evaluated separately with and without a hearing aid for hearing aid users. As we cannot interpret whether hearing aid users consistently rated their hearing with or without the use of a hearing aid across all waves, caution is needed when drawing conclusions about hearing aid efficacy based on this finding.

Strengths and Limitations

The strengths of the current study include the longitudinal design, the inclusion of multiple covariates in our analyses, and the availability of self-reported data for multiple sensory modalities in a large sample of older adults. Nonetheless, the absence of longitudinal objective measures of sensory function is a limitation of this study in terms of validating the self-report data and quantifying the extent of sensory loss in these participants. Moreover, further work will be needed to clarify whether the associations presented here reveal causal links between sensory and nonsensory factors and sensory decline in older adults. We also note that there is no self-report assessment of other sensory modalities, such as the tactile or vestibular modality, in this study, therefore precluding a more comprehensive investigation of sensory function in this cohort across time. In addition, further empirical work will be necessary to explore the factors associated with concomitant declines in multiple modalities (e.g., dual sensory impairment) in this cohort. The absence of parallel objective tests precludes an interpretation of whether our findings reflect a subjective generalization of sensory ability only or suggest genuine cross-modal associations in sensory decline, as the accuracy of self-report evaluations in capturing actual sensory decline is unclear (Cavazzana et al., 2018; Hämäläinen et al., 2021; Murphy et al., 2002; Pinto et al., 2014; Whillans & Nazroo, 2014). For example, subjective reports can suggest global patterns of sensory decline that are not apparent in objective tests (Cavazzana et al., 2018). These discrepancies may be due to the functional specificity of objective measures (e.g., visual acuity or contrast sensitivity), in contrast to the broader nature of self-reported assessments (Brennan et al., 2006). We also cannot rule out the possibility that the cross-modal associations reported here were influenced by the sequential presentation of the sensory questions in the TILDA assessment (i.e., questions on self-rated health, vision, hearing, smell, and taste were administered in that same, fixed order across participants).

Nonetheless, our findings are broadly consistent with those of other studies of aging, in terms of the prevalence of fair/poor sensory ability in older adults and regarding the observed associations between particular covariates and the probability of perceiving declines across sensory systems. This suggests that self-report assessments of sensory function can provide important insight into sensory function in older adults. Given the complexity and multidimensionality of sensory decline in aging, we argue that there is a need to include routine measures of sensory function across the senses in older adults, both objective and subjective in nature. This combined approach would offer a comprehensive account of the extent of the sensory decline in aging populations and help to distinguish those with objective impairments. Moreover, a record of self-reported sensory changes with aging would provide valuable insight into how older adults' everyday experiences are impacted by such decline. As such, this dual approach may help to optimize the design and implementation of effective interventions to meaningfully improve the quality of life of older adults experiencing declining sensory health.

The statistical models presented here are by no means exhaustive but provide important insight into key factors that can inform perceptions of sensory function across multiple sensory modalities in older adult populations.

Conclusion

We investigated what factors longitudinally predict the odds of transitioning from perceived normal to fair/poor vision, hearing, smell, and taste in a large sample of community-dwelling older adults. We found significant albeit inconsistent associations between self-reported declines across modalities, indicating that older adults' perceptions of sensory function tend not to be confined to a single sense. Furthermore, we observed sensory and nonsensory factors associated with the probability of reporting fair/poor ability in multiple senses versus a specific sensory modality. As such, our findings further contribute to our understanding of cross-modal associations between perceived sensory decline and the broader factors that significantly shape these perceptions during healthy aging and also reinforce the need for routine, objective measures of sensory function across the senses in older adults.

Supplementary Material

Supplementary data are available at *Innovation in Aging* online.

Author Notes

1. Visual acuity (LogMAR Chart) and contrast sensitivity (F.A.C.T.) tests were administered at Waves 1 and 3 only. The Whispered Voice Test was administered at a pilot wave only. No objective assessments of smell or taste were conducted.
2. When including ratings *with a hearing aid* for these waves, there was still a significant, albeit weaker, effect of hearing aid use on the odds of reporting fair/poor hearing (OR = 1.44 (95% CI [1.11, 1.85], p = .03).
3. Generalized logistic mixed-effects regression models were fitted first with a random intercept across participants, similar to frailty survival models (Austin, 2017). However, singular fit warnings were generated due to negligible variance in the intercept. Therefore, the final models were fitted without a random term.
4. If included in the smell regression model, the odds ratio for fair/poor taste was 30.20 (95% CI [22.95, 39.74]). If included in the taste regression model, the odds ratio for fair/poor smell was 27.87 (95% CI [21.67, 35.92]).
5. In regression models unadjusted for self-rated health, (1) the odds of self-reported fair/poor vision were significantly higher in those reporting noncardiac disease (2+: OR = 1.32, 95% CI [1.11, 1.57]; p = .03) and (2) the odds of self-reported fair/poor smell were significantly higher in those reporting depression (1: OR = 1.40, 95% CI [1.05, 1.83]; p = .02).
6. In regression models adjusted only for age and time interval, the odds of self-reported fair/poor vision were significantly higher with increasing age (OR = 1.25, 95% CI [1.17, 1.34]; p < .001).

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Conflict of Interest

None declared.

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Access to the TILDA data set is available upon request (see https://tilda.tcd.ie/data/accessing-data/ for further information). The computer-assisted personal interviews from Waves 1–4 are available at https://tilda.tcd.ie/data/documentation/. The R script for data preparation and analysis is available at https://osf.io/cqa34/?view_only=6920b4fab26449e5bf1d3f9b3293f4a5. This study was not pre-registered.

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