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Multiple Sensory Impairment and Quality of Life

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Abstract

PURPOSE—To evaluate the independent impact of vision, hearing, and olfactory impairment on quality of life.

METHODS—Subjects (n=1854, mean age = 67 years) were participants in the 1998–2000 and 2003–05 examinations of the Epidemiology of Hearing Loss Study and Beaver Dam Eye Study, population-based, prospective studies set in Beaver Dam, Wisconsin. Sensory capacities were measured in 1998–2000 and quality of life was measured in 2003–05. Vision impairment was assessed using current binocular visual acuity and contrast sensitivity. Hearing impairment was defined by the pure tone threshold average and word recognition scores in competing message and olfaction was measured with the San Diego Odor Identification Test. The Short Form 36 Health Survey (SF-36) was used to assess quality of life.

RESULTS—Significant independent effects of vision impairment and hearing impairment on the SF-36 social functioning domain score were observed ($P<0.01$). The adjusted mean social functioning score for participants with vision and hearing impairment was 5.9 units lower than the mean score in participants with no vision and hearing impairment. A significant independent effect of vision impairment was also observed for the physical functioning and mental health domains ($P<0.01$). Olfaction impairment was not significantly associated with the SF-36 indices.

CONCLUSIONS—Impairments in vision and hearing demonstrated independent effects on quality of life. The impact was observed for physical and emotional health (vision) and social functioning (vision and hearing). Evaluation and rehabilitation of sensory deficits may contribute to an improvement in functioning and well-being in the later years of life.

Keywords

vision loss; hearing loss; olfactory loss; quality of life; sensory impairment

INTRODUCTION

A substantial proportion of the information that we use to function is captured through multiple senses and must be centrally combined and integrated to provide a coherent observation.[1] Impairments in the capture of information are highly prevalent, particularly among the older population.[2–4] In the Epidemiology of Hearing Loss Study (EHLS), the prevalence of audiometrically measured hearing loss was 46% among adults 48 to 92 years of age and the

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overall rate of progression from baseline was 53% in the 5 year follow-up.[5,6] The cumulative incidence of visual impairment in subjects 75 years of age or older was 25% in a 15 year follow-up of the Beaver Dam Eye Study (BDES).[7] Findings from the 1993–97 National Health Interview Survey (NHIS) included prevalence rates of 27% for vision impairment and 42% for self-reported hearing loss among adults age 70 and over.[8] Among the ’97-’02 NHIS cohort, approximately 17% of those aged 80 and over reported dual loss.[9] Olfactory impairment has been shown to be common in the old, with reported prevalences of 60–75% in those 80 years and older.[10,11]

Previous work has revealed that hearing[12,13] and vision impairments[14–17] are associated with a decline in physical and social functioning among the old. Moreover, a significant trend in the association between severity of hearing loss and quality of life measures has been reported.[12,13] Similarly, in the BDES, an association between age-related macular degeneration (AMD) and poorer quality of life scores and a significant negative correlation between vision and frailty measures has been observed.[14,18] The Salisbury Eye Evaluation (SEE) Project and the Alameda County Study have also reported a dose response relationship between vision measures and everyday functioning.[16,19] Other studies evaluating the role of dual (vision and hearing) sensory impairment on quality of life have exhibited variability in the findings, particularly with respect to hearing loss.[20–23] There have been no population-based studies of olfactory impairment and quality of life.

The objective of the present investigation was to evaluate the independent impact of vision, hearing and olfactory impairments on quality of life in a population-based, prospective study with impairment measured 5 years prior to quality of life. Vision and hearing capacities were each objectively assessed with two standard measures, i.e. current binocular visual acuity and contrast sensitivity for vision and pure-tone air conduction thresholds and word recognition in competing message for hearing. Previous studies have primarily assessed each capacity using one measure or used self-report and have not included olfaction measures.[8,9,13,19–22]

MATERIALS AND METHODS

Study Population

Subjects were participants in the EHLS and the BDES, population-based studies of age-related sensory impairments among the residents of Beaver Dam, Wisconsin. In 1987–88, all persons aged 43 through 84 years residing in the city or township of Beaver Dam (n=5,924) were invited to take part in the BDES. Of these, 4,926 (83%) participated in the baseline phase of BDES during 1988–90. Five years later, in March 1993-July 1995, the baseline EHLS examination (EHLS-1) was conducted concurrent with the first follow-up of the BDES. Table 1 displays the time period and participation rate associated with each phase of the EHLS. Additional details of the BDES and EHLS have been reported.[5,24,25] The studies were performed according to the guidelines of the Declaration of Helsinki and have Institutional Review Board approval by the Health Sciences Institutional Review Board of the University of Wisconsin. Informed consent was obtained at baseline and at all follow-ups.

Measurements

Sensory Capacities—All sensory capacity data were obtained from the BDES-3 or EHLS-2 study. Visual acuity was measured using the Early Treatment of Diabetic Retinopathy Study chart R, modified for a 2-m distance with subjects using both eyes and wearing current correction.[25] Pelli-Robson letter charts were used to assess contrast sensitivity for each eye and results were reported as log contrast sensitivity units based on triplet scores.[26]

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Pure-tone air-conduction thresholds were assessed at 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz in each ear following guidelines of the American Speech Language and Hearing Association (ASHA).[27] Equipment was initially calibrated and recalibrated every 6 months in accordance with American National Standards Institute (ANSI) standards.[28] Ambient noise levels were also monitored to maintain compliance with ANSI standards.[29] Word recognition tests using the female talker version of the NU-6 test (50 words) were conducted in quiet and in competing message (single male talker at 8dB below the female voice).[30,31] Only the competing message test results were evaluated. Details regarding the audiometric testing have been published.[5,31]

The San Diego Odor Identification Test (SDOIT), using eight odors frequently experienced in the home, measured olfactory function.[32] Prior to administration of the SDOIT, participants were asked to identify items on a picture board containing the eight odorants and 12 distracters. If the participant was unable to do so after multiple attempts, the SDOIT was not given. The odorants were introduced randomly and participants, with their eyes closed, were asked to identify the odor either verbally or by pointing to the item on the picture board. To control for adaptation, stimuli were presented at 45 second intervals.[33]

Quality of Life—Health-related quality of life (QOL) data collected in EHLS-3 were used. The data included the Mental and Physical Component Summary scales (MCS&PCS) and the eight domain scores of the Short Form 36 Health Survey (SF-36).[34,35] Standardized scores were used and ranged from 0 to 100.

Covariates—Covariate information was obtained from the BDES-3 or EHLS-2 (birth date and education were from BDES-1). Possible confounders included in the analysis were age, sex, education (< 12 years, 12 years, 13–15 years, 16+ years), marital status (currently married, not married), smoking history (never, past, current), history of heavy alcohol use (four or more alcoholic beverages daily at any time in life), body mass index (≤ 25, > 25 and < 30, ≥ 30 and < 35, ≥ 35 kg/m^2), and self-report of any of 10 conditions. These included arthritis, cancer (non-skin), cardiovascular disease (myocardial infarction, stroke and angina), hypertension, diabetes, asthma, emphysema, epilepsy, hip fracture, and Parkinson's disease.

Impairment Definitions

Vision impairment was considered to be present if the participant presented with a current binocular visual acuity of 20/40 or worse and/or a contrast sensitivity of less than 1.55 units. Participants were classified as being hearing impaired if their pure-tone threshold average (PTA) (at 0.5, 1, 2 and 4 kHz in the better ear) was greater than 25 dB Hearing Level (HL) and/or their word recognition score in competing message was less than 40%. Vision and hearing impairment cut points were chosen to correspond with previously reported work or, in the case of word recognition, to capture a proportion of subjects within age groups similar to the contrast sensitivity cut point. Olfaction impairment was defined as the correct identification of less than six of the eight odorants. Six was selected as the cut point for olfaction impairment in the EHLS after a review of scores showed that among our youngest EHLS participants (53–59 years of age), 95% had scores of 6, 7 or 8. In addition, in a group of healthy adults, ages 20 to 40 years, the < 6/8 cut point was approximately 2 standard deviations lower than the mean score.[11]

Statistical Analyses

The Pearson chi-square test and the unpaired t-test were used to test differences in the characteristics between those with and without any sensory impairment. For modeling, indicator variables were created for all independent variables, including the sensory impairments, with the exception of age which remained as continuous. Vision and olfaction

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impairment were 2 level class variables (present or absent) while hearing impairment was a 4 level class variable with the following categories: 1) neither $PTA_{0.5,1,2,4\ kHz,\ better}$ > 25 dB HL nor word $recognition_{competing\ message}$ < 40%, 2) $PTA_{0.5,1,2,4\ kHz,\ better}$ > 25 dB HL only, 3) word $recognition_{competing\ message}$ < 40% only, and 4) both $PTA_{0.5,1,2,4\ kHz,\ better}$ > 25 dB HL and word $recognition_{competing\ message}$ < 40%. To test for age-sex interaction and interaction between the sensory impairments, variables were created which were equal to the product of the age and sex variables or the individual sensory impairment indicator variables.

The joint effects of the sensory impairments were modeled by fitting general linear models adjusted for age, sex, education, marital status, smoking history, alcohol use, BMI, and any chronic disease history of the 10 conditions listed above. The significance of each sensory impairment effect and interaction term was based on the parameter estimate's F value and Bonferroni adjustment was applied because of the large number of tests. Adjusted group means were estimated by the least square means and t-tests were used to identify significant differences. All analyses were performed using SAS software, version 9.1 (SAS Institute, Inc., Cary, NC).

RESULTS

There were 1854 subjects (83% of eligible), ages 53 to 94 years (mean=67 yr), with complete information for the sensory impairments, the SF-36, and the covariates. The overall prevalence of vision impairment was 21.6%, hearing impairment was 35.5%, and olfaction impairment was 17.3% (Table 2). Only vision impairment was present in 7.7%, only hearing impairment in 18.4%, and only olfaction impairment in 5.0%. Almost all of the participants with only vision impairment had a contrast sensitivity of less than 1.55 C.S. units (7.6%). Among those with only a hearing impairment, 9.3% had a $PTA_{0.5,1,2,4\ kHz,better}$ > 25 dB HL, 2.8% had a word $recognition_{competing\ message}$ < 40%, and 6.4% had both. The prevalence of having two sensory impairments, i.e. vision and hearing, hearing and olfaction, or vision and olfaction, were all significantly ($P < 0.001$) greater than expected if the conditions were independent of one another.

There were 938 participants with any sensory impairment and 916 with no impairment. As shown in Table 3, those with sensory impairment (mean age = 71 yr, s.d. = 8) were significantly ($p < 0.001$) older than those with no impairment (mean age = 63 yr, s.d. = 6). There was a significant association between the presence of any impairment and gender, education, marital status, and chronic disease history.

Unadjusted means and standard deviations for the SF-36 indices by impairment status are presented in Table 4. Among the participants with a vision impairment, for all SF-36 indices except the mental component scale and the mental health domain, the mean scores were lower in those with one or both vision impairments than in those with neither. With respect to hearing, for all indices the mean scores were lower in those with a PTA > 25 dB HL, either alone or with a word recognition < 40%, than in those with no hearing impairment. Mean scores for the mental component scale, bodily pain, social functioning and role-emotional were higher among the participants with a word recognition < 40% only, i.e. with a PTA < 25 dB HL, than among the participants with no impairment. Participants with olfaction impairment had lower mean component and domain scores compared to participants without olfaction impairment.

The results of the modeling of the joint effects of the sensory impairments on SF-36 scores are given in Table 5. There were no statistically significant ($P_{Bonferroni\ adjusted}$ <0.01) age-sex or sensory impairment interactions. Among the SF-36 indices, sensory impairment explained the greatest amount of variation for the physical component score ($R^2 = 0.058$), and the physical functioning ($R^2 = 0.086$), role-physical ($R^2 = 0.040$) and social functioning ($R^2 = 0.044$)

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domains. After adjustment for all covariates, visual impairment was independently associated with significantly lower mean scores for physical and social functioning and mental health ($P < 0.01$). For these indices, differences in the adjusted means between participants with and without vision impairment ranged from 2.5 (mental health) to 4.0 (physical functioning) units. Hearing impairment had a marginally significant independent effect only on the social functioning domain ($P = 0.01$). Those with both a $PTA_{0.5,1,2,4\ kHz,better} > 25$ dB HL and a word recognition $_{competing\ message}$ score < 40% had an adjusted mean score 3.2 units lower than those with no hearing impairment. Olfaction impairment did not have a significant independent effect on the SF-36 indices.

As noted, the social functioning domain was significantly impacted by both vision and hearing impairment. The adjusted mean social functioning score for those with dual vision and hearing impairment was 5.9 units lower as compared to those with no vision and hearing impairment.

DISCUSSION

High prevalence rates of vision, hearing, and olfactory impairment were observed in our population aged 53 to 94 years. The prevalence of sensory loss in our population was somewhat similar to previously reported rates. In the Blue Mountains Eye Study (BMES) (mean age=70 years), 9% of subjects presented with a binocular visual acuity of less than 20/40 while 40% had a $PTA_{better\ ear}$ greater than 25 dB HL.20 In the SEE project (age 65 years and over), close to 7% of the subjects presented with a current binocular visual acuity worse than 20/40.[17] Testing of the Framingham cohort in exam cycle 18 (ages 63 to 95) revealed that 42% of the cohort had a $PTA_{better\ ear}$ greater than 26 dB HL.[2] The higher visual impairment rates observed in SEE and BMES compared to this study may be related to the fact that the cohorts were older. Regarding olfaction, in a Swedish population study, 19.1% of the participants, age 20 years and over, exhibited some level of olfactory impairment which was similar to the finding in a clinic-based study of patients (mean age 42 years), where 20% of the patients demonstrated olfaction impairment.[38,39] Olfactory testing in these studies differed from our method.

In our study, vision and hearing loss exhibited independent effects on social functioning while vision loss also demonstrated a significant effect on physical and emotional health. There were no observed effects of olfactory impairment on quality of life as measured by the SF-36. Our study results are consistent with previously reported findings. In earlier studies of the BDES data, associations between vision loss and the risk of falls, fractures, and nursing home placement were observed.15 In the SEE cohort, presenting binocular acuity of worse than 20/40 was shown to be related to performance on physical mobility tasks, and frequency of social activities.16,17 Results from the BMES suggested that having either a vision or hearing impairment was associated with significantly lower SF-36 scores.[20] Having both vision and hearing impairment (n=31) resulted in average scores lower than those observed in subjects with one impairment. In the Alameda County Study, vision impairment had a more extensive impact on quality of life, but hearing impairment, even at mild levels, had a significant impact on social functioning.[19] Effective social functioning involves communication, both oral and written, while physical functioning is somewhat more concentrated on visually dependent activities. Impairment in the capture of information necessary to perform daily living activities will lead to decreased levels of functioning.

Among the participants with a hearing impairment, we observed that those with only a word recognition $_{competing\ message}$ score < 40% had a higher adjusted mean social functioning score (93.9) than those with no hearing impairment (90.7). Since these participants only had an impairment in word recognition, it would appear that hearing capacity was not appreciably impaired but ability to recognize words under a challenging condition (competing message)

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was impaired. Yet it did not diminish their social functioning score. The impairment definition cut point for word recognition may have impacted these results.

Our study has four major strengths. First, information on olfaction was available in a population of considerable size. Second, we had sensory impairment data measured 5 years prior to quality of life measurements. Many of the reported studies are either cross-sectional or prospective with 1 or 2 year follow-up. Third, sensory capacities were measured using standard, objective methods. Much of the previous work has been based on self-report which has the potential for introducing bias. Fourth, two sets of vision and hearing measurements were available for all subjects. For hearing, we were able to examine differences in associations with the SF-36 indices between the two hearing measures. Because of small numbers, we were not able to do this with the two vision measures.

Close to 400 EHLS-3 subjects were excluded from our study due to incomplete data. These subjects were significantly older and less educated and had significantly higher prevalence rates of vision and hearing impairment at EHLS-1. The removal of the subjects may have lowered our prevalence estimates but it is unlikely that it has impacted the effect estimates. To do so, the relationship between sensory impairment and quality of life would have to differ in the study and the excluded subjects. Another limitation of our study is the absence of information on current and past depression. Depression is a possible confounder in the sensory impairment and physical health relationship and we were not able to adjust for its effect.[40] Finally, other limitations of our study are that word recognition in competing message tests were performed at only 1 speech to competing message level and we had a very small number of subjects (n=47) with impaired visual acuity.

Data from our study suggests that multiple sensory impairments have a long-term impact on the quality of life in the older population. Our results have extended previous work to include the effects of olfactory impairment and the simultaneous effects of vision, hearing, and olfaction deficits. Sensory deprivation can result in a diminished quality of physical, emotional and social functioning for years to come. The negative effects of sensory impairment are independent of the influence of physical and mental health co-morbidities and may be abated through appropriate intervention. The overall results support thorough assessment and rehabilitation of sensory impairments which have the potential to make a positive impact on the later years of life.

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Table 1

EHLS Participation by Study Phase*

Study Phase			Participation	
EHLS	**BDES**	**Time Period**	**# Eligible**	**# Participants**
1	2	1993–1995	4541	3753 (82.6%)
2	3	1998–2000	3407	2800 (82.2%)
3	4	2003–2005	2516	2231 (88.7%)

*EHLS = Epidemiology of Hearing Loss Study; BDES = Beaver Dam Eye Study

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Table 2

Vision, Hearing and Olfaction Impairments Prevalence Rates (%) and 95% Confidence Intervals (C.I.) by Gender

Impairment	All Subjects (N=1854) N	All Subjects (N=1854) Prevalence % (95% C.I.)	Male (N=772) N	Male (N=772) Prevalence % (95% C.I.)	Female (N=1082) N	Female (N=1082) Prevalence % (95% C.I.)
Vision Only*	143	7.7 (6.5,9.0)	30	3.9 (2.6,5.5)	113	10.4 (8.7,12.4)
Current binocular visual acuity ≤ 20/40 only	2	0.1 (0.0,0.4)	0	0	2	0.2 (0.0,0.7)
Contrast sensitivity < 1.55 C.S. units only	136	7.3 (6.2,8.6)	29	3.8 (2.5,5.3)	107	9.9 (8.2,11.8)
Acuity ≤ 20/40 **and** contrast sensitivity < 1.55 C.S. units	5	0.3 (0.1,0.6)	1	0.1 (0.0,0.7)	4	0.4 (0.1,0.9)
***Hearing Only**+*	341	18.4 (16.6,20.2)	200	25.9 (22.8,29.1)	141	13.0 (11.1,15.2)
$PTA_{0.5,1,2,\&4\ kHz}$ > 25dB HL only	172	9.3 (8.0,10.7)	83	10.8 (8.6,13.1)	89	8.2 (6.7,10.0)
Word $recognition_{competing\ message}$ < 40% only	51	2.8 (2.0,3.6)	34	4.4 (3.1,6.1)	17	1.6 (0.9,2.5)
PTA > 25 dB HL **and** Word recognition < 40%	118	6.4 (5.3,7.6)	83	10.8 (8.6,13.1)	35	3.2 (2.3,4.5)
Olfaction Only						
(< 6/8 correctly identified odors)	92	5.0 (4.0,6.0)	42	5.4 (3.9,7.3)	50	4.6 (3.4,6.0)
***Vision and Hearing**†*	134	7.2 (6.1,8.5)	54	7.0 (5.3,9.0)	80	7.4 (5.9,9.1)
Vision and Olfaction	45	2.4 (1.8,3.2)	16	2.1 (1.2,3.3)	29	2.7 (1.8,3.8)
Hearing and Olfaction	104	5.6 (4.6,6.8)	88	11.4 (9.2,13.8)	16	1.5 (0.8,2.4)
Vision, Hearing and Olfaction	79	4.3 (3.4,5.3)	38	4.9 (3.5,6.7)	41	3.8 (2.7,5.1)
VISION TOTAL	401	21.6 (19.8,23.6)	138	17.9 (15.2,20.8)	263	24.3 (21.8,27.0)
HEARING TOTAL	658	35.5 (33.3,37.7)	380	49.2 (45.6,52.8)	278	25.7 (23.1,28.4)
OLFACTION TOTAL	320	17.3 (15.6,19.1)	184	23.8 (20.9,27.0)	136	12.6 (10.6,14.7)

* Includes either current binocular visual acuity ≤ 20/40 or contrast sensitivity < 1.55 C.S. units or both

+ PTA = Pure Tone Average; Hearing impairment includes either PTA > 25 dB HL or word recognition < 40% or both

† For prevalences of multiple impairments, includes either or both measures of hearing and vision impairment

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Table 3

Study Population Characteristics By Any Sensory Impairment* N (%) or Mean (s.d.)+

Characteristic	Any Sensory Impairment Yes (n=938)	Any Sensory Impairment No (n=916)	p-value
Age (mean & s.d.)	70.6 (8.2)	62.9 (6.4)	< 0.001
Men	468 (49.9)	304 (33.2)	< 0.001
Education (years)			
< 12	191 (20.4)	72 (7.9)	
12	469 (50.0)	456 (49.8)	< 0.001
13–15	138 (14.7)	181 (19.8)	
16+	140 (14.9)	207 (22.6)	
Married currently	616 (65.7)	698 (76.2)	< 0.001
Smoking history			
Never	425 (45.3)	452 (49.3)	
Past	422 (45.0)	362 (39.5)	0.06
Current	91 (9.7)	102 (11.1)	
History of heavy alcohol use	150 (16.0)	119 (13.0)	0.07
Body mass index (BMI) group			
≤ 25 kg/m^2	148 (15.8)	183 (20.0)	
> 25 and < 30 kg/m^2	329 (35.1)	303 (33.1)	0.07
≥ 30 and < 35 kg/m^2	305 (32.5)	268 (29.3)	
≥ 35 kg/m^2	156 (16.6)	162 (17.7)	
Chronic disease history†	768 (81.9)	627 (68.4)	< 0.001
# conditions (mean & s.d.)†	1.6 (1.1)	1.1 (1.0)	< 0.001

*Includes any hearing, vision or olfaction impairment.

+s.d. = standard deviation

†Chronic conditions included arthritis, cancer (non-skin), cardiovascular disease (myocardial infarction, stroke and angina), hypertension, diabetes, asthma, emphysema, epilepsy, hip fracture, and Parkinson’s disease.

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Table 4

SF-36 Indices by Vision, Hearing, and Olfaction Impairment* N of Participants, Means and Standard Deviations, Unadjusted

	Vision Impairment+				Hearing Impairment†				Olfaction Impairment	
SF-36 Index	**Both**	**Acuity < 20/40**	**C.S. < 1.55**	**Neither**	**Both**	**PTA > 25dB HL**	**WRec < 40%**	**Neither**	**Yes**	**No**
N of Participants	38	9	354	1453	266	308	84	1196	320	1534
Composite Scales										
Physical Component Scale	36.2 (12.5)	37.9 (13.2)	40.1 (11.2)	44.9 (10.4)	40.9 (10.9)	41.4 (11.0)	43.5 (10.3)	45.1 (10.6)	41.7 (10.5)	44.2 (10.8)
Mental Component Scale	57.4 (5.8)	58.7 (4.8)	55.6 (7.6)	56.7 (6.7)	55.7 (7.6)	56.5 (7.2)	57.5 (6.0)	56.6 (6.6)	56.3 (7.2)	56.5 (6.8)
Domains										
Physical Functioning	50.6 (31.7)	59.4 (30.9)	59.3 (27.0)	73.7 (24.2)	61.9 (27.1)	63.6 (27.8)	68.0 (25.8)	74.2 (24.0)	64.5 (26.9)	71.6 (25.3)
Role-Physical	53.3 (38.6)	44.4 (41.0)	62.1 (40.2)	76.4 (35.2)	64.3 (38.8)	67.1 (39.0)	73.2 (35.3)	76.5 (35.5)	67.3 (37.2)	74.2 (36.7)
Bodily Pain	68.2 (24.9)	68.7 (26.9)	66.3 (24.6)	71.7 (22.1)	69.2 (24.0)	68.0 (23.8)	73.5 (20.7)	71.3 (22.3)	69.2 (23.5)	70.9 (22.6)
General Health	57.1 (19.3)	68.2 (18.9)	64.6 (19.7)	70.1 (18.5)	64.6 (18.4)	65.4 (19.3)	67.7 (18.7)	70.6 (18.7)	65.3 (19.5)	69.4 (18.7)
Vitality	51.0 (23.9)	58.9 (19.0)	56.8 (20.1)	63.8 (19.6)	56.4 (20.4)	60.3 (19.8)	63.2 (18.5)	63.9 (19.9)	60.1 (19.9)	62.6 (20.0)
Social Functioning	82.9 (22.2)	83.3 (29.3)	85.1 (20.3)	91.7 (16.3)	84.8 (20.6)	87.5 (20.0)	93.2 (13.5)	91.9 (16.0)	86.7 (19.6)	90.9 (17.0)
Role-Emotional	92.1 (18.1)	92.6 (22.2)	89.8 (24.8)	94.5 (19.3)	90.7 (24.0)	91.3 (23.9)	97.2 (13.9)	94.5 (19.0)	90.6 (23.2)	94.1 (19.9)
Mental Health	83.4 (12.1)	87.1 (6.6)	78.8 (15.8)	83.1 (13.3)	80.8 (15.1)	81.8 (14.3)	82.0 (15.4)	82.8 (13.3)	82.1 (15.6)	82.4 (13.5)

*SF-36 = Short Form 36 Health Survey

+C.S. = Contrast Sensitivity

†PTA = Pure Tone Average; WRec = Word Recognition

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Table 5

Models of Joint Effects of Vision, Hearing & Olfaction Impairment on SF-36 Indices* Coefficients of Determination (R^2), F Values, and Adjusted Means +

	Model Statistics			Adjusted Means										
	Unadjusted†	Adjusted#		Vision Impairment			Hearing Impairment^					Olfaction Impairment		
SF-36 Index	R^2	R^2	F#	Yes	No	p-value	Both	PTA > 25 dB HL	WRec < 40%	Neither	p-value	Yes	No	p-value
Summary Scales														
Physical Component Scale	0.058	0.237	31.73	42.9	44.1	0.045	43.4	43.5	43.5	44.0	0.79	43.9	43.8	0.89
Mental Component Scale	0.005	0.026	2.73	55.8	56.7	0.05	55.5	56.4	57.4	56.7	0.09	56.4	56.5	0.86
Domains														
Physical Functioning	0.086	0.304	44.52	67.3	71.3	< 0.01	68.3	69.1	68.2	71.4	0.16	70.5	70.4	0.94
Role-Physical	0.040	0.127	14.78	68.9	74.2	0.02	71.0	72.7	73.6	73.6	0.81	73.6	72.9	0.75
Bodily Pain	0.012	0.089	9.98	70.0	70.7	0.60	70.9	70.1	72.4	70.5	0.86	70.7	70.6	0.95
General Health	0.031	0.128	14.97	67.4	69.1	0.14	67.9	68.0	68.0	69.2	0.72	68.2	68.8	0.60
Vitality	0.035	0.132	15.47	60.7	62.6	0.12	59.2	62.9	63.0	62.6	0.08	63.3	62.0	0.29
Social Functioning	0.044	0.079	8.70	87.6	90.9	< 0.01	87.5	89.3	93.9	90.7	0.01	89.5	90.3	0.47
Role-Emotional	0.014	0.035	3.71	92.2	93.9	0.20	91.6	92.2	97.0	94.1	0.11	91.8	93.9	0.12
Mental Health	0.013	0.049	5.25	80.4	82.9	< 0.01	81.0	82.1	81.6	82.8	0.41	82.9	82.2	0.45

* SF-36 = Short Form 36 Health Survey

+ Adjusted for hearing impairment, vision impairment, olfaction impairment, age, sex, education, marital status, smoking history, history of heavy alcohol use, body mass index (BMI) and chronic disease history.

† Unadjusted R^2 is the coefficient of determination for vision, hearing and olfaction impairment without covariate adjustment.

Adjusted R^2 is the coefficient of determination for the full model with vision, hearing and olfaction impairment and all covariates. All F Values were significant, $P < 0.001$

^ PTA = Pure Tone Average; WRec = Word Recognition