SECTION EDITOR: LESLIE HYMAN, PhD

Association Between Vision and Hearing Impairments and Their Combined Effects on Quality of Life

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Objectives: To assess associations between age-related vision and hearing impairments and whether combined sensory losses magnify effects on health-related quality of life.

Methods: Seventy-five percent of survivors (n=2334) were reexamined at Blue Mountains Eye Study 5-year examinations and 86.3% (2015) attended hearing assessments. Visual impairment was defined as visual acuity less than 20/40 (better eye), and hearing impairment as average pure-tone air conduction threshold greater than 25 dB (500-4000 Hz, better ear).

Results: Persons with visual impairment, compared with those without visual impairment, had lower mean audiometric thresholds across all frequencies ($P \leq .05$). For each 1-line (5-letter) reduction in best-corrected visual acuity and presenting visual acuity, hearing loss prevalence increased by 18% and 13%, respectively. Cataract and age-related maculopathy were also associated with hearing loss (respectively, multivariate-adjusted odds ratio, 1.3 and 1.6; 95% confidence interval, 1.0-1.7 and 1.1-3.1). The association between age-related maculopathy and hearing loss was stronger at younger ages (<70 years). Combined impairments were associated with poorer health-related quality of life than were single impairments (multivariate-adjusted 36-Item Short-Form Health Survey mean physical and mental component scores; $P_{trend}=.001$ and <.001, respectively).

Conclusions: Older persons with visual impairment were also more likely to have hearing loss in this study, which suggests that these sensory impairments could share common risk factors or biologic aging markers. Combined sensory impairments also cumulatively affect health-related quality of life.

Arch Ophthalmol. 2006;124:1465-1470

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THE STRONG AGE-RELATED INcrease in sensory impairment,[1-3] particularly in the context of changes in life expectancy, has highlighted concerns about the cumulative effects of sensory impairments on disability and health-related quality of life (HRQOL) in the growing number of older adults.[4] In the 1994 National Health Interview Survey, 18% of American adults aged 70 years or older reported vision impairment, 33% reported hearing impairment, and 9% reported both vision and hearing impairment.[4] Another 2% reported blindness in both eyes, and 7% reported deafness in both ears. In the Australian Burden of Disease Study, adult-onset hearing loss was ranked as the second leading contributor to the nonfatal burden in men, after depression. In women, vision disorders were ranked seventh and adult-onset hearing loss was ranked ninth.[5]

The Beaver Dam Study investigators reported associations between hearing loss and both age-related maculopathy (ARM)[6] and cataract[7] in the Epidemiology of Hearing Loss Study (EHLS). In the National Health Interview Study, persons reporting combined vision and hearing loss had significantly poorer HRQOL, with adverse effects on physical, emotional, and social functioning; they were 3 times more likely to have difficulty walking, getting outside, getting into or out of bed or a chair, preparing meals, and managing medications.[4] They were also significantly more likely to give a self-reported history of falling in the previous 12 months, to have broken a hip, or to have a history of hypertension, heart disease, or stroke, and were significantly less likely to participate in social activities.[4]

To our knowledge, no population-based study has described whether there is an association between age-related vision and hearing impairments. Therefore, we proposed to examine the association between these 2 conditions; to assess whether hearing loss is associated with cataract and ARM, the 2 main causes of visual impairment; and to assess the cumulative effects of these sensory losses on HRQOL in an older population.

METHODS

STUDY POPULATION

The Blue Mountains Eye Study (BMES) is a population-based cohort study of vision and hearing in an older community-living population.[1] Study procedures were approved by the University of Sydney Human Research Ethics Committee and were in accord with the tenets of the Declaration of Helsinki, and written informed consent was obtained from all participants.

In 1991, the BMES baseline survey (BMES-1) identified 4433 eligible permanent residents in a door-to-door private census from a defined area in the Blue Mountains region west of Sydney, Australia. Of this target population, 3654 persons (82.4%) were examined from March 1992 to December 1994. From March 1997 to December 1999, surviving BMES-1 participants (n=3111) were invited to undergo 5-year follow-up examinations, which were performed in 2335 persons (75.1%) (BMES-2); 383 persons (10.5%) had moved from the area. This group was also invited to undergo detailed hearing examinations from 1998 to 2000. After excluding the 383 persons who had moved from the area and another 53 persons who had subsequently left the area or died, there were 2675 eligible participants, of whom 2015 (75.3%), aged 55 to 98 years, were examined.

DATA COLLECTION

Participants underwent a comprehensive medical interview, and vision and hearing examinations by trained technicians. Monocular distance logMAR (logarithm of the minimum angle of resolution) visual acuity was measured with forced-choice procedures using the retroilluminated chart with automatic calibration to 85 cd/m^2 (Vectorvision CSV-100TM; Vectorvision Inc, Dayton, Ohio) according to the Early Treatment Diabetic Retinopathy Study protocol.[1] This was conducted with habitual correction (presenting visual acuity, with current eyeglasses, if worn) and after subjective refraction (best-corrected visual acuity [BCVA]). For each eye, visual acuity was recorded as the number of letters read correctly from 0 to 70.

Cataract was diagnosed at slitlamp examination and documented with lens photography (Topcon SL-7e camera; Topcon Optical Co, Tokyo, Japan) and retroillumination (Neitz CT-R cataract camera, Neitz Instrument Co, Tokyo, Japan). Age-related maculopathy was diagnosed and confirmed by grading of stereoretinal photographs. Details of the cataract[8] and ARM[9] photography and grading used have been described. Contributing causes of visual loss were determined by the examining ophthalmologist (P.M.) during the final stage of dilated eye examination.

The hearing examination included pure-tone air-conduction audiometry conducted in a sound-treated room by an audiologist using a Madsen OB822 audiometer (Madsen Electronics, Copenhagen, Denmark). Hearing thresholds at frequencies of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz were measured and bone-conduction audiometry was performed for each ear. Hearing examination was conducted without participants wearing hearing aids. Audiometer calibration was conducted regularly and complied with International Standards Organization protocol 389 (1991).

Before the eye examination, all participants were sent a detailed questionnaire that included the Australian adapted 36-Item Short-Form Health Survey (SF-36).[10] The questionnaire contained 36 items divided into 8 dimensions of health and well-being[11] and summarized as the physical and mental component scores. Participants were asked to bring the questionnaire booklets to their examination or to return it by postage-paid mail.

DEFINITIONS

Visual impairment was defined as visual acuity less than 20/40 in the better eye. Hearing impairment was defined as the pure-tone average air-conduction hearing threshold worse than 25-dB hearing level (dB HL) in the better ear, averaged over 4 frequencies: 500, 1000, 2000, and 4000 Hz. This differed from the EHLS conducted in Beaver Dam Eye Study participants,[6] which defined hearing loss from thresholds in the ear with more impairment. Mild hearing loss was defined as worse than 25 dB HL but 45 dB HL or better, moderate hearing loss as worse than 45 dB HL but 65 dB HL or better, and marked hearing loss as worse than 65 dB HL. Conductive hearing loss was considered present when there was an air-bone gap greater than 15 dB HL at 500, 1000, or 2000 Hz.

STATISTICAL ANALYSES

Statistical Analysis System software (version 8.2 for Windows; SAS Institute Inc, Cary, NC) was used. Logistic regression models were used to assess relationships between visual and hearing impairments. Data are given as odds ratio (OR) and 95% confidence interval (CI).

Each SF-36 dimension was scored from 0 (worst possible health state) to 100 (best possible health state) by coding, summating, and transforming its relevant item scores according to the SF-36 manual.[12] Physical and mental component scores were calculated according to previous factor analysis results and were normalized using Australian population scores (mean±SD, 50±10).[13,14] Normalized component scores were used in analysis of covariance to calculate multivariate-adjusted mean scores.

RESULTS

STUDY POPULATION

Of the 2015 hearing study participants, 36 (1.8%) had incomplete visual or audiologic data and 68 (3.4) were excluded from analyses (10 had a history of hearing loss from birth, 15 had otosclerosis, and 43 had conductive hearing loss), leaving 1911 participants (94.8%). The SF-36 data were calculated from 1836 participants (91.1%) who completed the SF-36 questionnaire and both hearing and vision assessments. Mean age of participants was 69.8 years; 57.3% were women. Characteristics of hearing study participants are shown in **Table 1**.

ASSOCIATION BETWEEN VISION AND HEARING IMPAIRMENTS

Prevalence rates for presenting visual impairment and best-corrected visual impairment were 9.3% (n=178) and 2.9% (n=56), respectively. The prevalence of hearing impairment was 40.0% (N=766: 599 mild, 141 moderate, and 26 marked). Each impairment and combined sensory loss increased markedly with age (Table 1; $P_{trend}<.001$).

Age- and gender-adjusted hearing sensitivity was significantly worse (higher thresholds) for all frequencies tested in participants with visual impairment than in participants without presenting visual impairment ($P\leq.05$) (**Table 2**). A similar trend was found for best-corrected visual impairment, but this was not statistically significant.

Table 1. Characteristics of the Study Population by Age*

Characteristic	Age, y				Total
	<60	60-69	70-79	≥80	
Female gender	139 (56.3)	418 (58.4)	393 (55.7)	165 (59.3)	**1115** (57.3)
Visual impairment (<20/40)					
Presenting	5 (2.1)	23 (3.2)	66 (9.5)	84 (31.3)	**178** (9.3)
Best corrected	1 (0.4)	3 (0.4)	18 (2.6)	34 (12.6)	**56** (2.9)
Hearing impairment					
Self-reported	85 (36.8)	306 (44.1)	374 (55.0)	180 (66.2)	**945** (50.4)
>25 dB	24 (9.7)	170 (23.8)	360 (51.2)	212 (78.2)	**766** (40.0)
>45 dB	4 (1.6)	28 (3.9)	58 (8.3)	77 (28.4)	**167** (8.6)
Combined vision and hearing impairments (>25 dB)					
Using presenting visual impairment	0	8 (1.1)	39 (5.5)	69 (24.8)	**116** (6.0)
Using best-corrected visual impairment	0	1 (0.1)	9 (1.3)	30 (10.8)	**40** (2.1)
Risk factors for age-related hearing loss					
Exposure to noise at work or leisure	97 (39.8)	284 (39.7)	267 (38.1)	79 (28.4)	**727** (37.5)
Current smoking	38 (15.9)	75 (10.7)	49 (7.2)	9 (3.4)	**171** (9.1)
Diabetes	15 (6.2)	87 (12.2)	79 (11.4)	23 (8.5)	**204** (10.6)

*Data are given as number (percent).

Table 2. Age- and Gender-Adjusted Audiometric Thresholds in Better Ear by Frequency Among Participants With and Without Visual Impairment (<20/40)*

Visual Impairment	Audiometric Thresholds, dB							
	250 Hz	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz	8000 Hz
Presenting (n = 175)	19.2 (0.9)	17.9 (0.9)	20.5 (1.0)	25.9 (1.2)	37.0 (1.7)	43.4 (1.4)	52.5 (1.6)	55.5 (1.6)
No presenting (n = 1730)	16.6 (0.3)	15.8 (0.3)	16.8 (0.3)	21.9 (0.4)	32.2 (0.5)	38.8 (0.4)	48.0 (0.5)	51.4 (0.5)
P value	.004	.03	<.001	.002	.009	.002	.006	.02
Best corrected (n = 56)	16.9 (1.5)	15.3 (1.6)	18.1 (1.8)	24.5 (2.2)	34.9 (3.0)	40.9 (2.5)	52.0 (2.8)	54.1 (2.9)
No best corrected (n = 1855)	16.8 (0.3)	15.9 (0.3)	17.1 (0.3)	22.2 (0.4)	32.6 (0.5)	39.2 (0.4)	48.3 (0.5)	51.7 (0.5)
P value	.97	.68	.60	.28	.46	.50	.18	.42

*Data are given as mean (SD).

Table 3. Hearing Impairment (Better Ear) in Participants With Visual Impairment (Better Eye)*

Visual Impairment (<20/40)	Hearing Impairment, dB	Any Age			<70 y		
		No. of Participants	Age and Gender Adjusted	Multivariate Adjusted†	No. of Participants	Age and Gender Adjusted	Multivariate Adjusted†
Presenting	>25	116	1.4 (1.0-2.1)	1.4 (1.0-2.1)	8	1.5 (0.6-3.5)	1.5 (0.6-3.5)
	>45	40	1.7 (1.1-2.7)	1.6 (1.0-2.6)	28	2.2 (0.5-10.1)	2.8 (0.6-13.1)
Best corrected	>25	40	1.1 (0.6-2.2)	1.2 (0.6-2.4)	1	. . .	. . .
	>45	15	1.3 (0.7-2.6)	1.2 (0.6-2.4)	0	. . .	. . .

Abbreviation: Ellipses, there is an insufficient number of cases to do any calculations.
*Data are given as odds ratio (95% confidence interval). Odds ratio for group without visual impairment, 1.0.
†Adjusted for age, gender, diabetes, noise exposure, and smoking.

Hearing loss was present in 116 participants (65.2%) with presenting visual impairment (multivariate-adjusted OR, 1.4; 95% CI, 1.0-2.1; **Table 3**). Of these, 40 participants (22.5%) had at least moderate hearing impairment (multivariate-adjusted OR, 1.6; 95% CI, 1.0-2.6). Although persons younger than 70 years generally had higher odds, this trend was not statistically significant. Men and women with presenting visual impairment had a similar increased likelihood of hearing loss (age-adjusted OR, 1.5; 95% CI, 0.8-2.8, and OR, 1.4; 95% CI, 0.8-2.2, respectively). For each 1-line (5-letter) reduction in BCVA and presenting visual acuity, there was an 18% (95% CI, 7-31) and 13% (95% CI, 5-21) increase in the likelihood of hearing loss, respectively.

Conversely, participants with hearing loss (worse than 25 dB HL) were more likely to have presenting visual impairment (age- and gender-adjusted OR, 1.5; 95% CI, 1.0-2.1). This association was slightly stronger in subjects

with more severe hearing impairment (worse than 45 dB; age- and gender-adjusted OR, 1.6; 95% CI, 1.1-2.6).

CATARACT, ARM, AND HEARING LOSS

We further explored the association between vision and hearing impairments by assessing the relation of hearing impairment with the 2 principal causes of visual impairment in our study, cataract and ARM. The **Figure** shows the prevalence of hearing loss by principal cause of visual impairment (in either eye). Participants with any cataract were more likely to have hearing loss, after adjusting for confounders (multivariate-adjusted OR, 1.2; 95% CI, 1.0-1.5; **Table 4**). Participants younger than 70 years with any cataract, nuclear or cortical cataract, or previous cataract surgery were significantly more likely to have moderate to marked levels of hearing impairment.

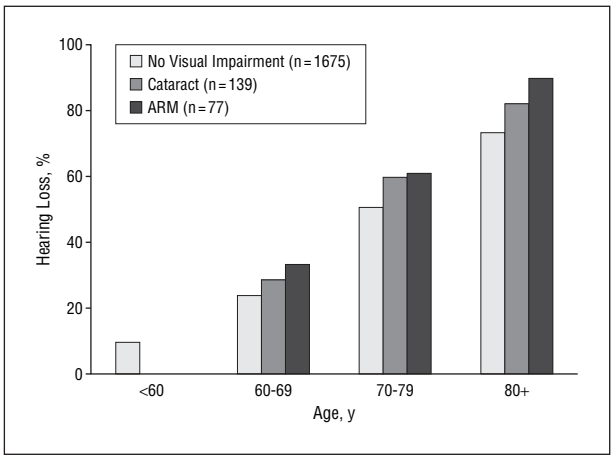

Figure. Hearing loss by principal cause of visual impairment in either eye. ARM indicates age-related maculopathy.

Participants with any ARM were also significantly more likely to have hearing loss (multivariate-adjusted OR, 1.5; 95% CI, 1.1-2.0; **Table 5**). This association was again stronger in participants younger than 70 years who had ARM, particularly for higher levels of hearing loss, and was primarily driven by the associations with early ARM. No association was found with late ARM, possibly because of the small number of participants with ARM. The gradient of the association, however, was less marked than for cataract. Hearing loss (worse than 25 dB HL) was also statistically significantly more frequent in participants with soft indistinct (>125 µm) or reticular drusen. We also explored the relationship between ARM and high-frequency hearing loss (worse than 45 dB HL at frequencies of 4000, 6000, and 8000 Hz), as in the EHLS report.[6] No associations were found at this level. However, high-frequency hearing loss of worse than 65 dB HL was associated with any ARM and early ARM (multivariate-adjusted OR, 1.5; 95% CI, 1.0-2.1, and OR 1.4; 95% CI, 1.0-2.1, respectively).

HRQOL AND COMBINED SENSORY IMPAIRMENTS

After adjusting for demographic and medical confounders, there was a significant trend for lower SF-36 scores in

Table 4. Hearing Impairment (Better Ear) in Participants With Cataract (Either Eye)*

	Hearing Impairment, dB			
	>25		>45	
Cataract	Any Age	<70 y	Any Age	<70 y
Any	1.2 (1.0-1.5) (n = 507)	1.4 (1.0-1.9) (n = 81)	1.1 (0.7-1.7) (n = 122)	2.8 (1.3-6.1) (n = 19)
Nuclear	1.3 (1.0-1.7) (n = 321)	1.4 (0.9-2.1) (n = 42)	1.6 (1.0-2.5) (n = 79)	3.9 (1.6-10.0) (n = 10)
Posterior subcapsular	0.8 (0.5-1.3) (n = 43)	. . . (n = 1)	0.5 (0.2-1.3) (n = 6)	. . . (n = 0)
Cortical	1.2 (0.9-1.6) (n = 213)	1.7 (1.1-2.6) (n = 46)	1.4 (0.9-2.2) (n = 53)	3.3 (1.4-8.0) (n = 11)
Cataract surgery	1.4 (1.0-2.0) (n = 122)	1.4 (0.6-3.5) (n = 7)	1.7 (1.1-2.6) (n = 40)	8.2 (2.4-27.8) (n = 4)

Abbreviation: Ellipses, there is an insufficient number of cases to do any calculations.
*Data are given as multivariate (age, gender, diabetes, noise exposure, and smoking)–adjusted odds ratio (95% confidence interval) (number of patients). Odds ratio for group without cataract, 1.0.

Table 5. Hearing Impairment (Better Ear) in Participants With ARM in Either Eye*

	Hearing Impairment, dB			
	>25		>45	
ARM	Any Age	<70 y	Any Age	<70 y
Any	1.5 (1.1-2.0) (n = 137)	2.0 (1.0-4.1) (n = 12)	1.2 (0.8-1.9) (n = 35)	3.1 (0.9-11.0) (n = 3)
Late	1.3 (0.6-3.1) (n = 25)	. . . (n = 0)	1.0 (0.4-2.4) (n = 7)	. . . (n = 0)
Early	1.6 (1.1-3.1) (n = 112)	2.1 (1.0-4.5) (n = 12)	1.2 (0.8-2.0) (n = 28)	3.2 (0.9-11.5) (n = 3)
Soft indistinct drusen (>125 µm, or reticular drusen)	1.4 (1.0-1.9) (n = 111)	2.3 (1.1-4.8) (n = 12)	1.2 (0.8-2.0) (n = 30)	2.3 (0.5-10.6) (n = 2)
Pigmentary changes	1.2 (0.9-1.5) (n = 187)	1.4 (0.9-2.3) (n = 30)	1.2 (0.8-1.8) (n = 47)	3.8 (1.7-8.5) (n = 10)

Abbreviations: ARM, age-related maculopathy; ellipses, there is an insufficient number of cases to do any calculations.
*Data are given as multivariate (age, gender, diabetes, noise exposure, and smoking)–adjusted odds ratio (95% confidence interval) (number of patients). Odds ratio for group without ARM, 1.0.

Table 6. Eight Dimensions and Physical and Mental Component Scores for Participants with Neither, Either, or Both Best-Corrected Visual and Hearing Impairments*

Impairment	Physical Functioning	Role Limitation Due to Physical Problems	Bodily Pain	General Health Perceptions	Vitality	Social Functioning	Role Limitation Due to Emotional Problems	Mental Health	Physical Component Score	Mental Component Score
Neither (n = 1111)	70.7 (0.8)	66.7 (1.3)	71.8 (0.8)	68.0 (0.7)	62.2 (0.7)	85.6 (0.8)	82.5 (1.1)	80.3 (0.5)	44.5 (0.3)	52.9 (0.3)
Vision or hearing (n = 694)	67.3 (1.0)†	61.4 (1.7)†	68.6 (1.1)†	66.3 (0.9)	60.9 (0.9)	81.6 (1.0)†	77.2 (1.4)†	77.9 (0.7)†	43.2 (0.4)†	51.9 (0.4)†
Vision and hearing (n = 31)	57.1 (5.0)†‡	67.9 (8.4)	66.5 (5.1)	58.3 (4.4)†	46.1 (4.4)†‡	74.5 (5.0)†	78.1 (7.3)	70.6 (3.5)†‡	40.3 (2.4)	47.9 (2.3)†
P_{trend}	.004	.05	.06	.06	.002	.003	.02	.003	.04	.03

*Data are given as multivariate (age, gender, marital status, higher qualifications, current smoking, angina, stroke, and diabetes)–adjusted mean (SE).
†Significantly different from neither impairment.
‡Significantly different from either vision or hearing impairment.

participants with both vision and hearing impairments than in those with either impairment. This trend was significant in all SF-36 dimensions ($P \leq .05$) and for the physical and mental component scores ($P_{trend} = .001$ and $P_{trend} < .001$, respectively) when using presenting visual impairment. This trend was not so marked when best-corrected visual impairment was used, but remained statistically significant in 6 of the 8 dimensions ($P \leq .05$) and for the physical and mental component scores ($P_{trend} = .04$ and $P_{trend} = .03$, respectively) (**Table 6**). The trend was of borderline significance for the remaining 2 dimensions, namely, "Bodily pain" and "General health perceptions" ($P = .06$).

COMMENT

In this older population, visual impairment was significantly associated with hearing impairment after adjusting for age and other covariables. This association was explained, in part, by the associations between hearing impairment and both cataract and ARM, the 2 major causes of visual impairment. This association suggests that both of these sensory impairments may be markers of biologic aging. They may also share common risk factors in addition to age. Irrespective of the underlying cause, combined sensory impairment had a cumulative detrimental effect on functional status, independence, and well-being, affecting both mental and physical domains.

Our findings are consistent with findings from the EHLS.[6,7] In both studies, statistically significant associations were found between hearing loss and both age-related cataract (nuclear or cortical cataract, or previous cataract surgery) and ARM. The cataract relationship was similar between the 2 studies, while, for ARM, some differences in findings between the 2 studies were evident. The EHLS[7] reported a significant association between hearing loss and any late (neovascular or atrophic) ARM (multivariate-adjusted OR, 3.17; 95% CI, 1.35-7.45) or pure neovascular macular degeneration (OR, 3.79; 95% CI, 1.25-11.48).[6] In our study, however, stronger associations were found with early ARM[9] and soft indistinct drusen (>125 μm) or reticular drusen.[9] The discrepancies between studies could be contributed by different study definitions. The EHLS defined hearing loss in the more impaired ear and did not exclude conductive hearing defects from their analyses.

The strong age-related increases in prevalence of cataract, ARM, and vision and hearing impairments have been well documented. However, the relation of these eye conditions and hearing impairment remained, even after adjustment for age, although the adequacy of this age adjustment may be debatable. Our findings suggest that they are both likely markers of aging. Inasmuch as we found that the association was generally stronger among the younger subgroup of the population (age <70 years), it seems reasonable to consider that these impairments are markers of biologic aging rather than chronologic aging.

Biologically plausible mechanisms for the association of these 2 sensory impairments include sharing of common risk factors in addition to age. Each condition has been postulated to result from somewhat similar genetic, environmental, and lifestyle factors.[15-17] Exposure to oxidative stress, cigarette smoking, and atherosclerosis and its risk factors have been linked respectively to ARM,[18-21] cataract,[16,22-24] and hearing loss.[17,25-27] Another common risk factor for cataract and visual and hearing impairments is diabetes.[28-31]

Although the effects of either age-related vision or hearing impairments have been widely explored, few studies have addressed the combined effects of these sensory impairments. Previous reports have shown that persons with both impairments have poorer physical[4,32,33] and social functioning[4] and higher rates of depressive symptoms[34] than do persons with a single impairment. Self-reported vision and hearing impairments were also reported to be significantly associated with poorer functional status and emotional well-being.[35] A possible reason for this cumulative effect is that vision and hearing impairments affect different aspects of functioning. Vision mainly affects the physical and spatial environment, while hearing affects social functioning in day-to-day interactions.[36] Inasmuch as services such as the use of sensory aids have been associated with improvements in HRQOL,[37] arguments for increased use of these services in these groups could be made.

Limitations of this study include its cross-sectional design; thus, it is not possible to establish the nature of the observed association between the 2 sensory (visual and hearing) impairments. Other limitations include possible observational bias inherent with the determina-

tion of the causes of visual impairment by a single observer, an ophthalmologist (P.M.).

CONCLUSIONS

Our study confirms some previous findings that there is a significant, modest association between vision and hearing impairments in older persons, after accounting for the effect of age. This relation was stronger among the younger subgroup and among subjects with more severe levels of hearing loss. Our data suggest that these 2 impairments could share common underlying aging or disease processes, possibly owing to common genetic, environmental, and lifestyle risk factors, that contribute to biologic aging. Irrespective of the cause of sensory impairment, these 2 impairments were found to have a cumulative effect on function and well-being, significantly affecting both physical and mental domains. Further studies are needed to understand the relationship between visual and hearing impairments in older persons and to determine whether intervention to improve these impairments could delay biologic aging.

Submitted for Publication: November 22, 2005; final revision received March 12, 2006; accepted April 23, 2006.
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Financial Disclosure: None reported.
Funding/Support: This study was supported by grants 974159, 991407, and 211069 from the Australian National Health and Medical Research Council and the Westmead Millennium Institute, University of Sydney.

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