The Association of Multiple Visual Impairments with Self-Reported Visual Disability: SEE Project

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Purpose. This report examines the relationship between psychophysical measures of visual impairment and self-reported difficulty with everyday visual tasks in a population-based sample of individuals 65 years of age and older.

Methods. Community-dwelling residents ($n = 2520$) of Salisbury, MD, between the ages of 65 and 84 were recruited for the study. Visual acuity under normal and low luminance, contrast and glare sensitivity, stereoacuity, and visual fields were measured. Subjective physical disability was assessed with the Activities of Daily Vision Scale (ADVS).

Results. In multiple regression analyses adjusted for demographic factors, cognitive status, depression, and number of comorbid medical conditions, each of the vision tests except low luminance acuity was independently associated with lower ADVS scores. The analyses indicate that a factor of 2 reduction in visual acuity or contrast sensitivity, comparable with that observed in mild to moderate lens opacity, was associated with a three- to fivefold odds of reporting difficulty with daily tasks. Although age alone was a significant risk factor for disability, it was not associated with overall ADVS score, once visual impairment and other chronic medical conditions were taken into account.

Conclusions. Visual acuity, contrast and glare sensitivity, stereoacuity, and visual fields are significant independent risk factors for self-reported visual disability in an older population. Visual impairment defined by acuity alone is not the only dimension of the association with subjective disability. Additional vision measures are required to understand the impact of vision loss on everyday life. (*Invest Ophthalmol Vis Sci.* 2001; 42:64–72)

Men and women 65 years of age and older are a rapidly growing segment of the population. It was estimated that more than 20% of the United States population would be aged 65 or more by 2000.[1] Although the majority continue to live independently, and many do so alone, one study found that more than 40% of people aged more than 65 years report difficulty in performing their usual activities.[2] A community-based study in Ohio showed that 20% of people aged 65 to 75 were physically dependent.[3]

An important component of physical disability is visual impairment. Several studies have demonstrated that visual impairment is associated with dependency in daily activities,[4–10] reduced physical activity,[11,12] social isolation,[7,12] and even mortality[6,12] in older individuals. Until recently, such studies had equated visual impairment with reduced visual acuity. Acuity measures the eye's ability to resolve fine detail at high contrast. Although good acuity is necessary for some activities, such as reading fine print, it is only weakly associated with ability to see large low-contrast objects, such as nearby faces,[13] or to navigate safely and independently in unfamiliar environments.[14,15] Other measures may provide important additional information about visual function that may decline with pathologic changes before decline occurs in visual acuity.

Contrast sensitivity is one such measure that has received considerable attention in recent years. In a healthy human eye, contrast sensitivity and visual acuity are highly correlated. For example, reduced visual acuity due to ametropia causes a predictable reduction of contrast sensitivity.[16,17] However, contrast sensitivity may be markedly reduced despite near-normal visual acuity.[19] Contrast sensitivity has been shown to be important for predicting reading speed in patients with severe visual impairment[19,20] and in older individuals who are free from obvious ocular disease.[21] Contrast sensitivity is also associated with postural stability[22] and mobility performance[15] in patients with low vision. Older observers require higher contrast to recognize real-world images such as traffic signs[23] and faces,[24] presumably because of reduced contrast sensitivity at medium to high spatial frequencies.

Similarly, some subjects with excellent visual acuity report particular difficulty seeing objects in the presence of glare. Disability glare refers to the reduced visibility of a target due to the presence of a light source elsewhere in the visual field. Any disorder that increases intraocular light scatter, such as lens opacity, may cause problems due to disability glare. Glare testing of patients with cataract can predict the reduction in visual acuity out of doors when facing the sun[25] or in direct overhead sunlight.[26] For normal elderly observers, glare sensitivity measurements are correlated with simulated nighttime driving performance and correspond to subjective reports of glare from oncoming headlights.[27] However, other studies of disability glare in patients with mild to moderate cataracts have failed to detect an association between glare symptoms and scores on disability glare tests.[28,29]

Visual acuity is almost always measured with bright targets. There is evidence that the reduction in acuity at low luminance may be especially detrimental for older observers. In a study of the effects of luminance,[30] it was reported that acuities for younger observers (up to age 45) decreased from 20/20 at 35 candelas [cd]/m^2 to 20/30 at 0.35 cd/m^2, whereas older observers (65–75 years of age) decreased from 20/30 to 20/50. These two luminance levels are comparable to a low level of room illumination and night driving on a rural road, respectively. Although the number of lines lost at low luminance is comparable for the two age groups, there may be significant functional implications for the decline of visual acuity below 20/40 at night in older observers. A survey of vision problems across age group[31] found that self-reported difficulty in performing visual tasks increased two- to sixfold with age, and dim

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lighting was identified as a particular problem by older respondents. Night-driving studies have determined that older drivers must be 30% to 50% closer to traffic signs than young observers to read them and that this distance effect is predicted by differences in visual acuity at low luminance.[32,33]

There are limited data on the relationship of visual field loss to disability. The status of the central field is an independent predictor of reading performance in patients with severe visual impairment, even after adjustment for visual acuity.[34,35] Patients with scotomas in the central 10° (diameter) field seldom read faster than 35 to 50 words per minute, regardless of visual acuity, whereas patients with intact central vision often read 100 to 200 words per minute, despite greatly reduced acuity. Studies of visually impaired patients have shown that both central and lower midperipheral visual fields are important for mobility performance.[14,36] The relationship of visual field loss and driving skills has received considerable attention.[37–39] In a California study of 10,000 drivers, binocular field loss was associated with an increased accident and driving conviction rate, although only 4% of those with visual field loss reported coexisting loss of visual acuity.[37]

It is often presumed that loss of stereoscopic depth perception is related to disability. Although there is a vast array of research on the underlying mechanisms of stereopsis and on its relation to other aspects of depth perception and other aspects of visual function, there has been almost no work on the implications of poor stereopsis on daily activities. We have reported[40] that stereoacuity was unrelated to self-reported difficulty with daily activities in a sample of 220 older adults. However, Nevitt et al.[41] found that stereoacuity was a significant risk factor for recurrent falls in the elderly.

One of the primary purposes of the Salisbury Eye Evaluation (SEE) study has been to develop a more comprehensive assessment of visual impairment to better predict physical disability and its impact on quality of life. We have shown[42] that contrast sensitivity, visual fields, glare sensitivity, and stereoacuity decline with advancing age. In this study, we examined the relationship between these psychophysical measures of declining visual function and self-reported difficulty with everyday visual activities, such as reading and driving.

Methods

Subjects

The study sample consisted of 2520 individuals tested from September 16, 1993, through September 26, 1995. A detailed description of the sampling procedure has been published previously.[43] Briefly, the sample was drawn from the Health Care Financing Administration (HCFA) Medicare eligibility lists of individuals living in the Salisbury, MD, metropolitan area aged 65 to 84 years. This sample included 100% of the identified African American residents and an age-stratified random sample of 58% of identified white residents. No other ethnic groups were represented. To be eligible for the study, the participant had to score more than 17 on the Mini Mental State Examination (MMSE[44]) and be able to travel to the SEE clinic for examination. Informed consent was obtained (in accordance with the Declaration of Helsinki) using forms approved by the institutional human experimentation committee, and a 2-hour in-home interview was administered, followed by a 4- to 5-hour clinic examination. The overall participation rate was 65%, excluding those who were ineligible. Approximately half the eligible subjects who refused to participate in the study agreed to answer a brief subset of the home questionnaire. Details on differences between refusals and participants have been published elsewhere.[45]

Vision Tests

A detailed description of the vision tests has been published elsewhere.[42] All vision tests were administered by trained technicians using strict forced-choice testing procedures.

Visual Acuity. Visual acuity was tested with Early Treatment Diabetic Retinopathy Study (ETDRS) charts.[46] The acuity charts were transilluminated with a light box (The Lighthouse, New York, NY) that maintains chart luminance at 130 cd/m^2. Acuity was measured monocularly and binocularly, with habitual refractive correction and best correction after subjective refraction. Only the binocular acuity with habitual correction was used in the current study. Visual acuity was scored as the total number of letters read correctly and converted to $\log_{10}$ minimum angle resolution (logMAR), according to the method recommended by Bailey et al.[47] Participants who failed to read any letters ($n = 5$) were arbitrarily assigned an acuity of 1.7 logMAR (20/1000).

Acuity was first measured under low luminance conditions by placing neutral density filters (U23 sunshades; NoIR Medical Technologies, South Lyon, MI) in front of both eyes. The filters reduced the luminance to 5.2 cd/m^2. The observer adjusted to the low luminance for approximately 2 minutes while the vision tests were described. After the low-luminance acuity measurement, the filters were removed, and acuity testing continued at normal luminance. The low-luminance acuity score was the difference between number of letters correct in normal and low luminance.

Contrast Sensitivity. Contrast sensitivity was measured with the Pelli–Robson letter sensitivity test.[48] The test was administered at 1 m under controlled room illumination (~100 cd/m^2) Contrast sensitivity was scored letter by letter[49] and for reporting purposes was converted to log contrast sensitivity ($\log_{10}$ 1/contrast of letters at the threshold of visibility).

Glare Sensitivity. Glare sensitivity was measured with a brightness acuity tester (BAT; Mentor, Norwell, MA) in conjunction with the Pelli–Robson letter sensitivity test. Contrast sensitivity was measured first without and then with the glare light turned on (medium setting, 350 cd/m^2). The glare sensitivity score was the number of letters correctly identified without glare minus the number of letters identified with glare.

Stereoacuity. Stereoacuity was tested with the Randot Circles test (Stereo Optical, Inc., Chicago, IL). The test consists of a series of 10 panels that form a graded disparity series from a maximum of 457 to a minimum of 17 seconds of arc when viewed at a distance of 36 cm. The panels were tested in order, beginning with the largest disparity and continuing until there was an incorrect response. The participant's score was the disparity (in $\log_{10}$ seconds of arc visual angle) of the panel before the first incorrect response.

Visual Fields. Visual fields were tested separately for each eye using the 81-point, single-intensity screening test strategy on a field analyzer (Humphrey, San Leandro, CA). This strategy tests points in a 60° (radius) field with a single target intensity of 24 dB. If the fixation losses, false-negative responses, or false-positive responses exceeded 20%, the test was stopped and the participant reinstructed before undertaking a new test. Field tests were scored by separately counting the number of points missed in the central 30° and the peripheral 30°. The square root of the number of points missed was used for analysis.

Visual Disability Questionnaire

Visual disability was assessed during the home interview with the Activities of Daily Vision Scale (ADVS).[50] The original ADVS was a 22-item questionnaire used to assess difficulty performing a range of vision tasks that were judged to be important to patients with cataract. Trained interviewers administered the ADVS as originally published, excluding one question on the use of bus service, which is not available in Salisbury. For each item, it was determined whether the participant had done the activity within the past 3 months, and if not, whether it was because of vision problems. Activities that had not been engaged in recently for reasons unrelated to vision were not scored. The remaining items were scored according to level of difficulty: 1, unable to perform because of vision problems; 2, extreme difficulty; 3,

moderate difficulty; 4, a little difficulty; and 5, no difficulty). The scoring procedures for the ADVS are described in the Data Analysis section.

Baseline Variables

Demographic variables, including age at the time of the clinic examination, gender, race, and years of education, were compiled from the home interview. Cognitive status was assessed with the MMSE, and the number of comorbidities was elicited with a structured medical history questionnaire, both administered during the home interview. Comorbidities included arthritis, broken hip, cardiovascular disease, hypertension, diabetes, emphysema, asthma, Parkinson's disease, cancer, and stroke. Depression was assessed with the depression scale of the General Health Questionnaire as part of the clinic examination.

Data Analysis

Except when indicated, all statistical analyses were conducted with SAS JMP software (ver. 3.2.1; SAS, Cary, NC). To test for differences in demographic characteristics between participants and refusals and to test for difference in vision or disability status between participants and the subset of refusals who agreed to answer the screening questionnaire, χ^2 tests were used. Simple bivariate correlation analyses were used to check for collinearity between pairs of vision tests.

The original ADVS was standardized and validated in a sample of 330 patients with cataract. We have published elsewhere an evaluation of the psychometric properties of the ADVS based on data from the SEE study.[51] Our study determined that the overall ADVS scale and the originally published night-driving and far-vision subscale exhibit adequate content validity, internal consistency, and discriminability. The scales were calculated as described in the original publication. The original near-vision subscale contained two items that were determined to be unsuitable for use in the subscale analyses. Sixty-seven percent of participants reported not playing cards, and 59% of male participants reported not threading needles during the past three months. After elimination of these two items, the near-vision subscale contained seven items. Except for activities avoided for reasons unrelated to vision, each item was given a score according to the described scale of 1 to 5. The overall and subscale scores were computed by averaging all relevant scored items and rescaling to a range of 0 to 100 where 0 = unable to perform all activities because of vision, and 100 = no difficulty with any activity. Our validation study determined that the original day-driving and glare subscales had insufficient internal consistency and were limited by items that were not applicable to a large proportion of our participants. These two subscales were not used in the analyses.

ADVS data were missing for three of the 2520 participants who completed the clinic examination. Of the remaining 2517 participants, 977 (38.8%) reported no night driving during the past 3 months. The night-driving subscale score was not computed for those participants, even though one of the items (difficulty reading street signs at night) was administered and contributed to the overall ADVS score.

Scale and Subscale Score Analyses. Overall and subscale score distributions are graphed as histograms in Figure 1. Because all the score distributions were severely skewed, they were trichotomized to approximate grouping into the highest median, the lowest decile, and the remainder. This led to consistent definitions for the overall scale and the near- and far-vision subscales (100–94, least disabled; 93.99–72, moderately disabled; and 71.99–0, most disabled). These score definitions had to be modified for the night-driving scale, because there was a substantial group of participants with very low scores (100–98, least disabled; 97.99–26, moderately disabled; and 25.99–0, most disabled). Key analyses were also performed with five-level polytomous scales and the results were consistent with those obtained from three-level scales.

Separate polytomous logistic regression analyses[52] were conducted with the CATMOD procedure (ver 6.12; SAS) to determine the association between individual psychophysical measures of visual impairment and each of the ADVS scales and subscales. This method describes associations between vision tests and self-reported vision disability as odds ratios, separately for high versus low functioning and medium versus low functioning. The odds ratios are the factors by which the odds of having higher functioning are increased among persons with less visual impairment. To describe the strengths of associations, we chose differences between less and more impaired that were judged to be clinically meaningful: 0.3 logMAR (three lines or a factor of 2 increase) for visual acuity, six letters (0.3 log contrast units or a factor of 2 increase) for contrast sensitivity and glare sensitivity, 0.3 log seconds of arc disparity (a factor of 2) for stereoacuity, and a factor of 2 for number of visual field points missed. To determine the independent association of vision measures with self- report of vision

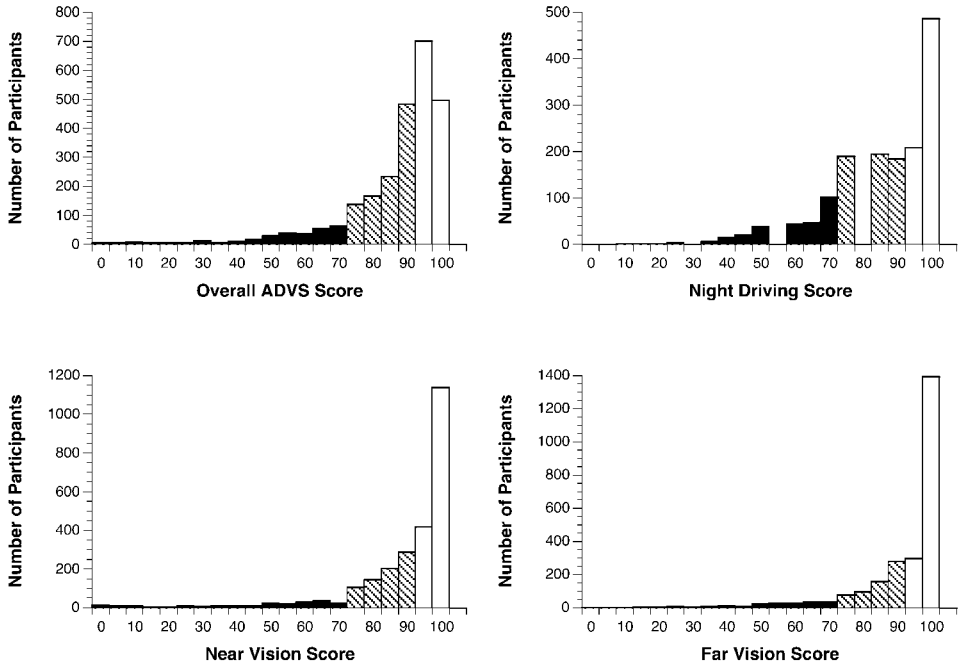

FIGURE 1. Distributions of scores for the ADVS are shown separately for the overall scale (*top left*) and for the night-driving (*top right*), near-vision (*bottom left*), and far-vision (*bottom right*) subscales. Bar shading is indicative of the trichotomous scheme used for data analyses.

disability, additional analyses were performed in which all the vision measures were simultaneously entered into the model. All analyses were adjusted for age, race, gender, mental status, years of education, number of comorbid conditions, and depression score. Greater statistical power can be obtained by using an ordinal regression procedure instead of polytomous regression, provided that the data do not violate the proportional odds assumption. Ordinal regression models were also fit to the data using the LOGISTIC procedure (ver. 6.12; SAS) but the models did violate the proportional odds assumption. Therefore, only the results from the polytomous regression analyses are reported.

Two additional analyses were performed to determine the contribution of multiple vision impairments to vision disability. The first of these was designed to further explore the extent to which impairments other than visual acuity loss contribute to disability as reflected by the overall ADVS score. The number of additional impairments was determined using the following definitions: contrast sensitivity less than 1.3 log units, glare sensitivity greater than six letters lost, stereoacuity worse than 500 seconds of arc, and missing more than 20 points (of a possible 51) in the central 30° of the visual field test. The cutoffs for contrast and glare sensitivity were based on previously published norms for these tests.[53–55] Cutoffs for the stereoacuity and visual field tests were arbitrary, but subsequent analyses that used other cutoffs did not alter the conclusions. The number of additional impairments was entered as a continuous variable into a polytomous logistic regression model along with the same set of baseline variables. Visual acuity and its interaction with the number of additional impairments were also included in the model to control for the possibility that additional impairments simply reflect greater severity of acuity loss.

The purpose of the second additional analysis was to evaluate whether multiple visual impairments represent one or more underlying dimensions of impairment insofar as they have an impaction overall ADVS. We performed a principal components analysis with the SAS FACTOR procedure using acuity at normal luminance, contrast sensitivity, glare sensitivity, stereoacuity, and central visual field scores. The components were rotated (using the VARIMAX feature), and the SCREE plot was examined to determine the number of components to retain. The retained components were entered into a polytomous regression model along with baseline variables. Exploratory analyses were also conducted to evaluate interactions between principal components and individual vision measures.

Item-Specific Analyses. To the extent that the ADVS subscales represent unidimensional constructs, averaging scores for all items within a subscale is a reasonable way to summarize the participant's self-perceived visual disability within that dimension. Although our previous evaluation of the ADVS subscales[51] indicated that each of the subscales used for this study was internally consistent, the far-vision subscale score was only weakly differentiated from the other subscale scores, and there was a suggestion of multidimensionality among items within that subscale. Therefore, we undertook individual item analyses to determine whether the risk factors identified for the subscales were related in the same fashion to all items within the subscales.

The items of the ADVS have ordinal scales. Therefore, proportional odds models[56] were used to analyze item responses. These produce odds ratios for association between each risk factor and having less versus more visual disability. The odds ratios are presumed not to depend on the rating level used to define less versus more disability (proportionality assumption). Because responses to many of the items are highly correlated with one another, an analysis that accounted for item correlations was needed to obtain correct and efficient inferences for comparing strength of associations across items. Therefore, we analyzed the relationships between individual ADVS item scores and vision impairment scores with a procedure that adapts generalized estimating equations (GEEs) for clustered ordinal measurements. Extensive plotting of residuals (tailored to the ordinal scale[57]) and fitted values was performed to check that the model fit to the data was appropriate, including production of cumulative log–odds plots to check the proportionality assumption. There was no indication of widespread or serious violations regarding any aspect of the fitted model. Model checking and other technical details of the application are provided elsewhere.[58]

Results

Table 1 lists baseline characteristics of the study sample. Average scores (mean ± SD) for each of the seven vision variables are listed in Table 2, stratified by age and race. Visual acuity, contrast sensitivity, glare sensitivity, and visual fields decreased at an approximately constant rate with age, whereas stereoacuity remained constant into the mid-70s and declined at an accelerating rate thereafter. African Americans had worse acuity, contrast sensitivity, stereoacuity, and visual fields, but better glare sensitivity than whites. After adjustment for age, there were small but clinically insignificant differences in low-luminance acuity and stereoacuity between men and women. A more in-depth analysis of the vision test results has been published previously.[42]

The 21 items used in the vision questionnaire are briefly described in Table 3 along with the subscales to which they contributed. The number of participants who gave difficulty scores for each item is also listed. Except for three participants for whom vision questionnaire data were missing, the remaining participants reported not doing the activity in question for reasons unrelated to vision. The two items with the lowest participation rates were driving in unfamiliar areas (60%) and playing cards (33%). In this population-based study, most of the participants are healthy older adults and their self-assessment reflects a high level of functioning. This is apparent from the distribution of ADVS overall and near- and far-vision scales (Fig. 1) on which more than 50% of the population scores 95 to 100. For only two of the items (driving at night with oncoming headlights and threading a needle) did at least 25% of the respondents report moderate to severe difficulty. Moderate to severe difficulty was next most common for the remaining night-driving items (driving at night, 22%; seeing moving objects while driving at night, 19%; and reading street signs at night, 16%). At least some difficulty was reported for seeing faces in bright sunlight, 29%; driving in unfamiliar areas, 22%; and reading print in newspapers, 24%, and on medicine bottles, 24%). Fewer than 20% of participants reported any difficulty with the remaining items.

Association of Visual Impairment with Disability

Scale and Subscale Analyses. Table 4 gives the results of separate polytomous logistic regressions for each of the seven

Table 1. Baseline Characteristics of Sample

Number of participants	2520
Age at time of recruitment	
65–69	36.8%
70–74	31.3%
75–79	21.0%
80–84	10.9%
Gender	
Male	42.1%
Female	57.9%
Race	
White	73.6%
African american	26.4%
Education level*	11.2 ± 3.4
Mini mental state exam score*	27.2 ± 2.6
Number of chronic medical conditions*	2.4 ± 1.6
Depression score*	0.20 ± 0.75
Vision status*†	7.7 ± 2.0

* Data are expressed as means ± SD.
† 10, excellent; 0, blind.

TABLE 2. Vision Test Scores by Race and Age

Age	African American	White
Visual acuity (logMAR)		
65–69	0.03 ± 0.26	−0.03 ± 0.15
70–74	0.05 ± 0.19	0.01 ± 0.14
75–79	0.11 ± 0.27	0.07 ± 0.19
80–85	0.22 ± 0.33	0.15 ± 0.28
Low luminance acuity (letters lost compared with normal luminance)		
65–69	12.6 ± 5.5	12.2 ± 4.7
70–74	13.5 ± 5.6	12.5 ± 4.9
75–79	13.6 ± 5.1	13.0 ± 5.6
80–85	13.8 ± 5.7	13.0 ± 5.7
Contrast sensitivity (log contrast)		
65–69	1.55 ± 0.32	1.67 ± 0.16
70–74	1.51 ± 0.26	1.61 ± 0.20
75–79	1.47 ± 0.30	1.54 ± 0.20
80–85	1.33 ± 0.44	1.46 ± 0.26
Glare sensitivity (letters lost with glare)		
65–69	0.3 ± 2.3	1.6 ± 2.4
70–74	1.1 ± 3.3	2.0 ± 2.9
75–79	0.7 ± 2.2	2.0 ± 3.0
80–85	1.5 ± 2.4	2.8 ± 2.6
Stereoacuity (log seconds of arc disparity)		
65–69	1.94 ± 0.53	1.82 ± 0.44
70–74	1.98 ± 0.55	1.86 ± 0.47
75–79	2.12 ± 0.58	2.02 ± 0.53
80–85	2.18 ± 0.58	2.14 ± 0.56
Central visual field (square root of points missed)		
65–69	2.36 ± 1.57	1.51 ± 1.28
70–74	2.78 ± 1.44	1.92 ± 1.34
75–79	3.01 ± 1.41	2.42 ± 1.51
80–85	3.56 ± 1.36	2.89 ± 1.41
Peripheral visual field (square root of points missed)		
65–69	3.58 ± 1.02	3.20 ± 0.90
70–74	3.80 ± 0.97	3.53 ± 0.89
75–79	3.93 ± 0.94	3.78 ± 0.89
80–85	4.10 ± 0.94	4.07 ± 0.67

vision measures. All models were adjusted for age, race, gender, education, cognitive status, depression, and number of comorbidities. Adjusted odds ratios along with 95% confidence limits are listed for each ADVS scale. In each case, the odds ratio is per unit improvement in vision score.

The results in Table 4 demonstrate that visual acuity at normal luminance, contrast sensitivity, glare sensitivity, stereoacuity, and central visual field were individually associated with overall ADVS score as well as the night-driving and near- and far-vision subscale scores. Peripheral visual field was associated with all but the night-driving score. Low-luminance acuity, defined as the reduction in acuity at low luminance compared with normal luminance, was not associated with any of the ADVS scores. Had we simply used acuity measured at low luminance instead of the difference score, the results would have been nearly identical with those obtained for high-luminance acuity. This is explained by the very high correlation between the normal- and low-luminance acuity scores ($r = 0.80$).

There were significant correlations among most of our vision measures. Therefore, a multiple logistic regression analysis was conducted to determine whether each vision test result was independently associated with ADVS score. Models were simultaneously adjusted for all vision measures and for baseline variables. Because low-luminance acuity, as defined, was not a significant predictor on its own, it was not included in any of the multiple regression models. Preliminary analyses also indicated that peripheral visual field was not an independent predictor if central visual field was included in the model, and peripheral field scores were therefore eliminated from the final analyses. The results are shown in Table 5. Visual acuity, contrast sensitivity, and stereoacuity were significant independent predictors for each of the ADVS scales. Glare sensitivity and central visual field were significant independent predictors of overall ADVS score and the night-driving and near-vision subscale scores.

Ninety-six percent of participants (2412) had visual impairment data on all measures. Of these, 6% (144) had binocular acuities worse than 0.3 logMAR (20/40). Twenty-three percent (564) had one or more additional visual impairments. After adjustment for baseline variables and binocular visual acuity, each additional impairment decreased the odds of reporting best versus worst ADVS score by a factor of 2.58 (95% confidence interval [CI]: 2.08–3.20) and the odds of reporting mid versus worst ADVS score by a factor of 1.20 (95% CI: 1.04–1.39). There was no interaction between binocular acuity and the number of additional impairments. These results support the notion that although visual acuity is an important determi-

TABLE 3. Items Included in the SEE Administration of the Activities of Daily Vision Scale

Activity	Respondents*	Subscales†
How difficult is		
Driving at night	1737	N
Seeing moving objects while driving at night	1739	N
Driving at night with oncoming headlights	1737	N
Reading street signs at night	1927	N, F
Driving during the day	1986	§
Driving in unfamiliar areas	1014	§
Reading street signs in daylight	2366	F
Walking down steps during daylight	2372	F
Walking down steps in dim light	2157	F
Seeing faces across the street in bright sunlight	2439	§
Watching television	2515	F
Reading numbers on the television screen	2476	§
Reading ordinary print in newspapers	2410	R
Reading directions on medicine bottles	2342	R
Reading the ingredients on food cans	2194	R
Writing checks	2079	R
Threading a needle without a device	1734	R
Using a ruler, yardstick, or tape measure	1969	R
Using a screw driver	1906	R
Preparing meals	2199	R
Playing cards	834	§

* Participants who reported doing the activity within the past 3 months or were unable to perform this activity because of vision problems. Excludes those who avoided the activity for reasons unrelated to vision. Total participants, 2520.

† N, night driving; R, near vision; F, far vision; §, not included in subscale analyses.

TABLE 4. Polytomous Logistic Regression of Vision Variables on ADVS Scales

			Far Vision	Near Vision	Night Driving	Overall Score
Vision Test	**Unit**	**Comparison**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Visual acuity	3 lines	Best vs. worst	5.17 (4.07, 6.56)	5.78 (4.49, 7.46)	3.32 (2.52, 4.36)	5.21 (4.08, 6.66)
		Mid vs. worst	2.81 (2.24, 3.52)	3.08 (2.44, 3.90)	2.79 (2.26, 3.46)	2.96 (2.38, 3.66)
Low-luminance acuity	3 lines	Best vs. worst	1.29 (0.86, 1.95)	1.29 (0.86, 1.95)	0.72 (0.45, 1.15)	1.39 (0.92, 2.1)
		Mid vs. worst	1.45 (0.94, 2.26)	1.27 (0.82, 1.98)	1.39 (0.89, 2.16)	1.41 (0.94, 2.13)
Contrast sensitivity	6 letters	Best vs. worst	4.38 (3.45, 5.54)	5.05 (3.86, 6.62)	3.46 (2.67, 4.48)	5.24 (4.04, 6.79)
		Mid vs. worst	2.87 (2.25, 3.68)	3.36 (2.56, 4.4)	2.18 (1.79, 2.66)	3.09 (2.44, 3.91)
Glare sensitivity	6 letters	Best vs. worst	2.14 (1.52, 3.01)	2.77 (1.93, 3.99)	1.76 (1.29, 2.39)	2.81 (2.00, 3.95)
		Mid vs. worst	1.51 (1.06, 2.15)	2.25 (1.54, 3.28)	1.34 (1.05, 1.72)	2.07 (1.47, 2.91)
Stereoacuity	Disparity doubling	Best vs. worst	1.64 (1.51, 1.79)	1.86 (1.70, 2.04)	1.36 (1.25, 1.46)	1.76 (1.62, 1.91)
		Mid vs. worst	1.48 (1.35, 1.61)	1.60 (1.46, 1.75)	1.29 (1.21, 1.37)	1.57 (1.45, 1.70)
Central visual field	2× points missed	Best vs. worst	1.78 (1.57, 2.00)	1.93 (1.71, 2.18)	1.76 (1.55, 1.98)	2.04 (1.81, 2.30)
		Mid vs. worst	1.47 (1.29, 1.67)	1.63 (1.44, 1.85)	1.61 (1.46, 1.78)	1.66 (1.48, 1.86)
Peripheral visual field	2× points missed	Best vs. worst	2.02 (1.51, 2.70)	2.10 (1.57, 2.80)	1.09 (0.84, 1.42)	2.20 (1.67, 2.90)
		Mid vs. worst	1.73 (1.27, 2.35)	1.79 (1.32, 2.41)	1.2 (0.95, 1.51)	1.83 (1.38, 2.42)

Data are adjusted for age, race, gender, education, cognitive status, depression, and number of comorbidities. Odds ratio (OR) is per unit improvement in vision test score.

nant of disability, other forms of vision impairment also contribute.

The principal components analysis indicated two or three components underlying the visual impairment measurements. The first component accounted for 48% of the variance (eigenvalue 2.40) and the second component accounted for an additional 20% of the variance (eigenvalue 0.99). The third component accounted for 13% of the variance, however its eigenvalue was substantially less than 1.0 (eigenvalue 0.65). Table 6 lists the factor loading for the two- and three-factor models. The two-factor solution identified one component with strongest contributions from acuity and contrast sensitivity and somewhat less contribution from stereoacuity and central visual fields. Glare sensitivity was the only vision measure that contributed to the second component. The three-factor solution was similar except that it removed central fields from the first component to a separate third component. Coefficients derived from the two-factor solution were entered into a polytomous regression model along with baseline variables to determine their association with overall ADVS score. Both factors were significantly associated with overall ADVS score (factor 1: $\chi^2 = 226, P < 0.0001$; factor 2: $\chi^2 = 20, P < 0.0001$). Exploratory analyses including factor 1 plus individual vision measures and their interaction revealed no significant contribution from the individual vision measures or the interaction after factor 1 was taken into account.

The principal components analysis suggests that in the current study there were two, at most three, underlying factors in the visual impairment measures in our population. The first factor, which accounts for most of the variance, has contributions from visual acuity, contrast sensitivity, stereoacuity, and possibly visual field. The strong association of this factor with overall ADVS score, and the absence of separate contributions from the individual vision tests or their interactions imply that what matters most in an older population is having some form of visual impairment, regardless of the exact nature of the impairment. The association of disability with number of impairments is consistent with an additive model in which multiple visual impairments reflect greater severity of vision loss.

Individual-Item Analysis. With one notable exception, there were no consistent differences in the associations of vision tests results with task difficulty for items within subscales. The exception is depicted in Figure 2, which plots the odds ratio and 95% CI for visual acuity as a predictor of difficulty with items in the far-vision subscale. The odds ratios are adjusted for baseline variables and other vision variables. Visual acuity was strongly associated with reading street signs (day and night) and watching television but was not associated

TABLE 5. Polytomous Logistic Regression of Vision Variables (Mutually Adjusted) on ADVS Scales

			Far Vision	Near Vision	Night Driving	Overall Score
Vision Test	**Unit**	**Comparison**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Visual acuity	3 lines	Best vs. worst	2.74 (2.04, 3.67)	2.70 (1.98, 3.68)	1.89 (1.38, 2.58)	2.39 (1.77, 3.23)
		Mid vs. worst	1.72 (1.29, 2.28)	1.70 (1.27, 2.28)	1.91 (1.5, 2.45)	1.64 (1.25, 2.15)
Contrast sensitivity	6 letters	Best vs. worst	1.68 (1.23, 2.30)	1.59 (1.14, 2.22)	1.89 (1.40, 2.56)	1.85 (1.35, 2.55)
		Mid vs. worst	1.46 (1.06, 2.01)	1.43 (1.03, 1.99)	1.12 (0.88, 1.42)	1.35 (1.00, 1.83)
Glare sensitivity	6 letters	Best vs. worst	1.39 (0.96, 2.00)	1.68 (1.14, 2.48)	1.42 (1.02, 1.98)	1.84 (1.28, 2.65)
		Mid vs. worst	1.07 (0.74, 1.55)	1.51 (1.03, 2.22)	0.98 (0.75, 1.29)	1.42 (1.01, 2.01)
Stereoacuity	Disparity doubling	Best vs. worst	1.25 (1.13, 1.39)	1.42 (1.28, 1.58)	1.12 (1.02, 1.22)	1.34 (1.22, 1.48)
		Mid vs. worst	1.23 (1.10, 1.37)	1.29 (1.16, 1.44)	1.11 (1.03, 1.19)	1.29 (1.18, 1.43)
Central visual field	2× points missed	Best vs. worst	1.14 (0.98, 1.33)	1.26 (1.08, 1.46)	1.39 (1.21, 1.59)	1.37 (1.19, 1.58)
		Mid vs. worst	1.03 (0.88, 1.21)	1.18 (1.01, 1.37)	1.38 (1.24, 1.54)	1.22 (1.06, 1.40)

Data are mutually adjusted for age, race, gender, education, cognitive status, depression, and number of comorbidities. Odds ratio (OR) is per unit improvement in vision test score.

TABLE 6. Factor Analysis for Vision Variables

	Two-Factor Model		Three-Factor Model		
Vision Test	**Factor 1**	**Factor 2**	**Factor 1**	**Factor 2**	**Factor 3**
Binocular acuity	0.80	−0.01	0.83	−0.10	0.17
Contrast sensitivity	0.83	−0.23	0.73	0.18	0.41
Glare sensitivity	0.21	0.97	0.06	−0.98	0.05
Stereoacuity	0.70	0.05	0.78	−0.10	0.07
Central visual field	0.73	−0.06	0.23	−0.07	0.95

Factor loadings after VARIMAX (SAS software; Cary, NC) rotation.

with walking down steps. The finding corroborates our previous evaluation of the ADVS in which factor analysis of items suggested that the two "steps" items mapped to a separate factor from the one containing the two "signs" items.[51] It is also consistent with a parallel regression analysis we conducted using latent variables to represent far-vision function, in which visual acuity and contrast sensitivity mapped specifically to signs- and steps-related disabilities, respectively.[59]

DISCUSSION

Although it is widely recognized that visual impairment may contribute significantly to disability, most studies have limited the assessment of visual function to visual acuity or self-reported trouble seeing. We are aware of four studies that have examined the relationship between multiple vision measures and disability in patients with ocular disease. Ross et al[60] reported that near visual acuity, contrast sensitivity, and visual field were the best predictors of self-reported disability in a group of 50 patients with glaucoma. Lennerstrand and Ahlström[61] found that low-contrast acuity was better than high-contrast acuity at predicting problems with orientation and discrimination in patients with macular degeneration. Two studies looked specifically at patients with cataract. Elliott et al.[29] measured acuity, contrast sensitivity, and disability glare in 33 patients with cataract and found that contrast sensitivity and, to a lesser extent, acuity were related to responses on a visual disability questionnaire. Glare scores were not related to self-reported disability. Adamsons et al.[28] compared self-reported vision disability before and after cataract surgery. They found an association between postoperative improvement in vision disability and measured changes in acuity and contrast sensitivity. Glare sensitivity was not a significant predictor.

There have been five published population-based studies of multiple vision measures and disability. Hakkinen[13] evaluated acuity, contrast sensitivity, visual fields, and color vision in people aged 65 years or more, but did not relate any of the measures except acuity to reported disability. Nevitt et al.[41] found that stereoacuity and acuity were significant risk factors for recurrent falls in the elderly. In a study of 2100 women aged 75 and older, Dargent–Molina et al.[62] reported that poor visual acuity or contrast sensitivity were associated with physical dependence, but that depth perception was not associated with disability. Rubin et al.[40] compared self-report of vision disability with measured acuity, contrast sensitivity, glare sensitivity, and stereoacuity in a convenience sample of 222 older individuals. Reduced acuity and contrast sensitivity were independently associated with overall vision disability score. Acuity was associated with difficulty in tasks requiring good resolution and adaptation to changing light conditions, whereas contrast sensitivity was associated with difficulty in tasks requiring distance judgments, night driving, and mobility. Glare and stereoacuity were not associated with disability. The Blue Mountains Eye Study investigated visual impairment and falls in a sample of 3654 individuals aged 49 years and more.[63] They found that visual acuity, contrast sensitivity, and suprathreshold visual fields were associated with two or more falls in the previous 12 months. The prior studies, whether patient- or population-based samples, provide consistent evidence that acuity and contrast sensitivity are associated with disability. Most of those that included visual field tests also found an association with disability. The results are less clear for stereoacuity and especially for glare sensitivity.

In the present study we found that acuity, contrast sensitivity, glare sensitivity, stereoacuity, and visual fields were risk factors for self-reported difficulty with everyday activities. The associations were statistically significant even when demographic factors, cognitive status, depression, and number of other chronic medical conditions were taken into account. Comparing persons in whom visual acuity differed by three lines or contrast sensitivity differed by six letters, those with better vision had three- to fivefold higher odds of reporting least versus most vision difficulty and two- to threefold higher odds of reporting moderate versus most difficulty. These levels of difference in acuity and contrast sensitivity are comparable to that obtained after surgery for removal of a mild to moderate cataract.[55] The association of visual disability with stereoacuity and visual fields was somewhat weaker. The association with glare sensitivity was most tenuous. In the multivariate analysis (Table 5), glare sensitivity tended to be associated only with the more severe ADVS difficulty. In the principal components analysis, glare sensitivity represented a distinct underlying dimension of vision loss that was more weakly associated with visual disability than with the dimension represented by the other vision measures. Overall, the pattern of results is consistent with earlier reports.

It is worth noting that although age alone was a significant risk factor for disability, it was not associated with overall ADVS score or the near- or far-vision subscales once visual impairment and other chronic medical conditions were taken into account. Age remained a significant factor in the night-driving subscale even after inclusion of vision variables and comorbidities.

Given the significant correlation among the vision measures used in this study, it may be asked whether it is necessary to make such a comprehensive assessment of visual impairment to understand its relation to disability. The multiple regression analyses summarized in Table 5 indicate that each of the vision tests was separately and independently associated with ADVS scores. Although the associations were generally strongest for

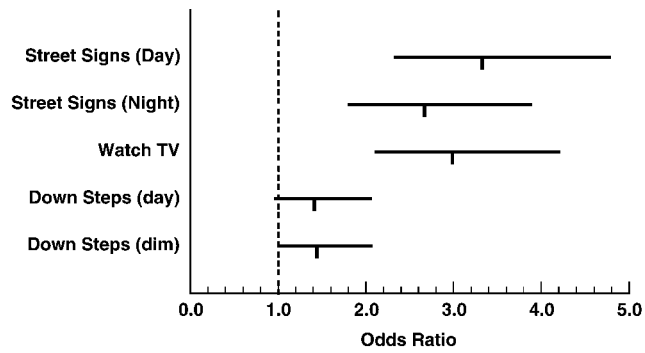

FIGURE 2. Independent association of visual acuity with individual items from ADVS are shown as odds ratios (*short vertical line*) and confidence intervals (*horizontal lines*). Odds ratios have been adjusted for demographic variables, mental status, depression, comorbid conditions and other vision measures.

acuity and contrast sensitivity, the data suggest that reductions in visual function along other dimensions also contribute to difficulty with everyday tasks.

There are several factors to keep in mind when interpreting these results. Although the sample was population based, possible selection bias from refusals could occur. The 65% response rate is as good or better than that reported for other population-based studies involving older participants and a 4- to 5-hour clinic examination.[64,65] Partial data from those who refused to participate indicates that they tended to be older and more frail than participants[45]; however, they did not differ significantly in their overall assessment of visual status. Because ADVS is correlated with self-report of overall visual status in the participants, we have no reason to presume selection bias influenced results with the ADVS.

As in all studies that rely on self-report measures of disability, the possibility of reporting bias must be considered. Participants who knew they had reduced acuity or some other form of vision loss may have overreported their disability on the ADVS. We attempted to minimize this problem by administering the ADVS at the participant's home before any of the vision tests.

Nearly 20% of participants never drove or did not drive during the year before the interview. The nondrivers were not asked why they had stopped driving, but we can presume that vision problems played a role for some and perhaps most. By treating the driving-related items as missing data we may underestimate the strength of the association between visual function and driving-related vision disability. However, the elderly population in the SEE project has a higher proportion of those still driving than other studies of older persons, thus providing us with a rich population for studying driving behavior in transition.

Finally, these data are cross-sectional, which limits the ability to attribute cause and effect. Nevertheless, within the limitations of our methods we found significant, independent associations between multiple measures of visual impairment and self-reported difficulty with everyday tasks. These results, in conjunction with other published findings of the Salisbury Eye Evaluation study, describe an aging population that is at increased risk of multiple types of visual impairment, not just the loss of acuity.[42] This visual impairment puts the older population at risk for loss of independence and a reduction in social involvement.[43] The increase in self-reported disability is also reflected in worse performance on a variety of everyday activities measured under highly standardized conditions[66] and at home.[67] Despite a very tangible impact on everyday life, many visually impaired participants in our studies did not fully use medical resources in the community to correct the causes of vision loss (e.g., spectacles and cataract surgery).[68] Although some of the barriers to eye care utilization have been identified,[69] targeted interventions to improve eye care and minimize the impact of visual impairment are urgently needed.

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