Measures of Visual Function and Their Association with Driving Modification in Older Adults

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PURPOSE. Older drivers may place restrictions on their driving by reducing their mileage and avoiding high-risk driving situations in an effort to improve safety. This project identifies what types of visual function loss are associated with subsequent driving modifications.

METHODS. Data were used from the baseline and 2-year follow-up rounds of the Salisbury Eye Evaluation project, a cohort study of 2520 older adults. Measures of visual function tested were visual acuity, contrast sensitivity, visual fields, and glare sensitivity. Driving information was self-reported. Among drivers at baseline who continued to drive at follow-up, multiple logistic regression was used to estimate the odds of incident driving modification by visual function status.

RESULTS. Worse baseline scores in acuity, contrast sensitivity, and central and lower peripheral visual fields were individually associated with an increased odds of reduced mileage 2 years later (linear trend $P < 0.05$). Worse baseline scores in contrast sensitivity and central and lower peripheral visual fields were individually associated with a greater odds of cessation of night driving 2 years later, whereas worse baseline acuity scores were associated with an increased odds of cessation of driving in an unfamiliar areas 2 years later (linear trend $P < 0.05$).

CONCLUSIONS. Older drivers with worse visual function were more likely to modify their driving by reducing mileage and avoiding high-risk driving situations. Furthermore, these modifications to driving differed depending on what type of visual function was affected. (*Invest Ophthalmol Vis Sci.* 2006;47: 514–520) DOI:10.1167/iovs.05-0934

Older adults are the fastest growing age group in the U.S. population, and they tend to continue to drive an automobile through late life.[1,2] Although responsible for a small percentage of overall crashes, older people have crash rates that are four times higher than those of middle-aged adults, after adjustment for mileage.[3,4] Studies suggest that these higher crash rates are due in part to deteriorating vision.[5–9] Therefore, for assessing driver safety it is important to understand whether and how older adults change their driving behavior after experiencing visual decline.

Older adults may place restrictions on their driving once their visual function has become compromised, presumably in an effort to improve their safety.[10–14] Examples include the reduction of mileage,[12,13] the avoidance of high-risk driving situations,[10–12] or driving cessation[13,14] altogether. Many of the studies that have examined vision and driving behavior have been cross sectional[10–14]; were not able to address temporality; have grouped avoidance strategies together,[10–12] which may have hidden the possibility that different avoidance strategies have different visual predictors; and have not commented on potential effect modifiers.[10,11,13,14]

We have recently found that several types of visual function, including acuity, contrast sensitivity, and central and lower peripheral visual fields were associated with driving cessation over an 8-year time period.[15] In this analysis, we hypothesized that these four measures of visual function plus glare sensitivity would be related to three driving modifications (a reduction in mileage, cessation of night driving, and cessation of driving in unfamiliar areas) in those who did not stop driving over the initial 2 years of the study. These vision measures were chosen because of previous literature that described an increased crash risk or worse driving performance on closed-circuit tracks or simulators.[5,8,9,16–20] In addition, factors such as gender, cognitive impairment, and the presence of other drivers in the house were examined to determine whether they modified the relationships between visual function and modification of driving habits.

METHODS

Study Population

The Salisbury Eye Evaluation (SEE) project is a prospective study of a random sample of 2520 older adults living in Salisbury, Maryland, in 1993.[21] The sample was selected from the Health Care Financing Administration Medicare database. The following were eligibility criteria: age between 65 to 84 years, residence in the Salisbury area, not in a nursing home, able to communicate, and a score of greater than 17 on the Mini Mental State examination. Of the 3906 eligible persons, 2520 completed both the home questionnaire and the medical examination (65% response rate). The study population was composed of 1062 men and 1458 women. Of the subjects, 26% were African-American, and the remaining 74% were white. The study adhered to the tenets of the Declaration of Helsinki and was approved by the Joint Committee on Clinical Investigation at Johns Hopkins University. Informed consent was obtained for all participants.

Because we were interested in the new occurrence, or the incidence, of each driving modification outcome, those who were not at risk for the given outcome at baseline or who had stopped driving by the 2-year follow-up were excluded. For example, for the analysis of the reduction of miles to less than 3000, nondrivers at baseline, those who were already driving less than 3000 miles at baseline, and those who stopped driving by follow-up were excluded.

There were 1772 (70%) individuals at baseline who were still driving and were at risk for at least one of the three driving modification outcomes. Of those, 1605 (91%) people returned for the 2-year follow-up visit, and this sample formed the population of interest for these analyses. The reasons for not returning to follow-up were death (51%) and relocation or refusal (49%).

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Questionnaire

At baseline and follow-up, interviewer-administered questionnaires were given to participants in the home. Information was obtained on demographic information, medical history, health behavior, and driving history. The questions on driving history inquired about having ever driven, the miles driven in the past year (by memory), and driving at night and in unfamiliar areas.

Cognition was assessed with the Mini Mental State Examination[22] and depressive symptoms with the General Health Questionnaire Part D.[23] Participants were asked to complete a detailed health questionnaire, which was validated at baseline, and included questions on whether a physician had diagnosed certain conditions in them, such as stroke or diabetes.

Vision

Measurement. Visual function was evaluated both at baseline and follow-up during a 20-minute examination performed at the SEE clinic, as described previously.[21] Study staff who administered the driving questionnaire were unaware of vision scores and those who tested vision were unaware of driving status. Presenting (or habitual) visual acuity was scored as the number of letters read correctly on the Early Treatment of Diabetic Retinopathy (ETDRS) chart and then converted to logMAR (log minimum angle resolution) units.[24] The luminance of the chart was 130 cd/m^2, back illuminated. Contrast sensitivity was measured in each eye with a Pelli-Robson chart that was illuminated at approximately 100 cd/m^2. Measures for the better eye were used in analyses. Visual field was measured in each eye with an 81-point single-threshold (24 dB), full-field (60°) screen (Humphrey; Carl Zeiss Meditec, Inc., Dublin, CA). Binocular visual fields were estimated from a composite of the more sensitive of the two visual field locations for each eye.[25] Ninety-six visual field locations composed the binocular visual field. The binocular central visual field (≤20° radius) was measured at 56 centrally located points, whereas the binocular lower peripheral visual field (>20°and ≤60°) was measured at 22 points. The remaining 18 points represent the binocular upper peripheral visual field, which was not examined in this analysis, as preliminary analyses (data not shown) and the existing literature led us to conclude that it would not be informative. Finally, glare sensitivity, a measure of the reduction of the contrast of the retinal image caused by light-scatter, was examined with a brightness acuity tester,[26] an illuminated (medium setting, 350 cd/m^2) white hemisphere with an aperture for the participant to look through to read a test chart. Participants first read a Pelli-Robson chart with no glare source and then read a different Pelli-Robson chart with the brightness acuity tester. The score was the number of letters read correctly without glare minus the number of letters read correctly with glare.

Participants with reduced vision were advised to get new glasses if the cause was refractive error or to see an ophthalmologist if there were other causes. Those who expressed concern about driving fitness were referred to their eye care provider.

Definitions. Both baseline visual function and 2-year visual function loss were evaluated for their potential association with the driving modifications. Baseline visual functions for acuity, contrast sensitivity, central and peripheral visual fields, and glare sensitivity were examined as three-level categorical variables. The cutoff points for acuity were chosen so that the most severe category was 20/40 or worse, which is the legal binocular acuity requirement for unrestricted driving in Maryland,[27] and the middle cutoff point was 20/25 to give an adequate number for analysis. The cutoff points for the other four vision measures were based approximately on the 50th and 90th percentiles of the distribution.

Visual function changes in acuity, contrast sensitivity, central and peripheral visual fields, and glare sensitivity were examined by taking the difference between scores from baseline and follow-up so that positive scores were consistent with worse loss, while negative scores indicated a gain in function. From these values, dichotomous variables were created. Those who gained vision or who had vision loss less than the cutoff point were in the reference group, whereas those who lost vision beyond the cutoff point were in the exposed group. Cutoff points were chosen so as to achieve losses that we thought would be functionally significant (more than just noise) while maintaining an adequate number for analysis. Decline in presenting visual acuity was defined as having lost >1 line of visual acuity between rounds 1 and 2, as visual acuity can be ascertained only within ±1 line with 95% confidence.[28] Contrast sensitivity loss was defined as ≥4 letters of loss in the better eye between baseline and follow-up, as a significant change is considered to be ± 0.18 log units (± 3.6 letters).[29] Reliability estimates are not known for visual field or glare sensitivity and so cutoff points for these were chosen to be the most extreme values that assured an adequate number for analysis. Central visual field loss was defined as an increase of ≥2 in the number of points missed from baseline to follow-up, whereas lower peripheral visual field loss was defined as an increase of ≥5 in the number of points missed. Finally, glare sensitivity loss was defined as ≥2 letters of loss in the better eye in glare sensitivity scores between baseline and follow-up. Additional confirmatory analyses were also performed with continuous measures of visual function.

Outcomes

There were three outcomes for this analysis. The first outcome was the reduction of miles to fewer than 3000 per year at follow-up among drivers who were driving 3000 or more miles per year at baseline. The choice of 3000 miles has been used previously and reflects an average of fewer than 10 miles of driving per day.[12] The second outcome was the cessation of night driving by follow-up among those who were driving at night at baseline, and the third was the cessation of driving in unfamiliar areas by follow-up among those who were driving in unfamiliar areas at baseline.

Statistical Analysis

The characteristics of those drivers at baseline who did not return for follow-up were examined and compared with those of drivers who returned, to identify possible bias. Descriptive statistics for the vision variables were calculated, to examine the distributions.

Cross-tabulations were performed with each of the vision variables and each of the outcomes. Tests for statistically significant differences were done with χ^2 tests. Also, to determine whether any associations were due solely to the effect of age, age-adjusted probabilities were calculated by logistic regression. The baseline visual function categories were entered in a continuous form to obtain linear trend probabilities.

To further adjust for other demographic and health factors, separate logistic regression models were created for each of the five vision variables (acuity, contrast sensitivity, central and lower peripheral visual fields, and glare sensitivity) with each of the three outcomes (reduction in mileage to fewer than 3000 per year, cessation of night driving, and cessation of driving in unfamiliar areas). Models were adjusted for demographic (age, sex, race) and health (cognition, diabetes, stroke, general health status) variables. All vision variables were then entered into the same model in an attempt to ascertain their independent effects.

We checked for interactions between each vision variable with gender, other drivers in the house, and cognitive impairment through stratification and then through the inclusion of interaction terms into the model if interaction appeared possible by the stratified results.

Results

There were 178 (16%) of 1109 participants who were driving 3000 miles or more at baseline who decreased their mileage to fewer than 3000 miles by follow-up. Those who decreased mileage were more likely to be older, female, and African-American ($P < 0.05$) and were somewhat more likely to be cognitively impaired and in fair or worse reported health than

Table 1. Percentage of Drivers in Given Demographic or Health Category Who Had Modified Driving Habits within 2 Years

Vision Measure	Reduced Mileage to <3000 *n* = 178/1109 (16%)	Stopped Night Driving *n* = 145/1255 (12%)	Stopped Driving In Unfamiliar Places *n* = 225/748 (30%)
Age category (%)			
65–69 y	13	8	28
70–74 y	15	10	30
75–79 y	19	16	34
80–84 y	27*	26*	30
Gender (%)			
Male	8	6	22
Female	28†	18†	42†
Race (%)			
White	14	11	30
African-American	24†	12	30
General health status (%)			
Excellent or good	15	10	30
Fair or poor	20	18	30
Mini-mental score (%)			
≥24	16	11	30
<24	24	17	46
History of Stroke (%)			
No	16	11	30
Yes	18	14	33
History of Diabetes (%)			
No	16	11	30
Yes	18	16	32

* $P < 0.05$.
† Age-adjusted $P < 0.05$.

those who drove 3000 or more miles per year ($P < 0.10$; Table 1). There were 145 (12%) of 1255 participants who were driving at night at baseline but had stopped by follow-up. Those who stopped night driving were more likely to be older and female ($P < 0.05$), and were somewhat more likely to have diabetes and to be in worse reported health ($P < 0.10$) than those who continued to drive at night (Table 1). Finally, there were 225 (30%) of 748 participants who drove in unfamiliar areas at baseline but had stopped by follow-up. Those who stopped driving in unfamiliar areas were more likely to be female ($P < 0.05$; Table 1).

Several baseline measures of visual function were associated with the driving modification outcomes 2 years later, even after age adjustment (Table 2). Worse baseline acuity, contrast sensitivity, and central and peripheral visual field scores were associated with a reduction in driving mileage to fewer than 3000 miles per year (age-adjusted linear trend $P < 0.05$). Worse baseline contrast sensitivity and central and peripheral visual field scores were associated with the cessation of night driving, whereas worse baseline scores for acuity were associated with a cessation of driving in unfamiliar areas (age-adjusted linear trend $P < 0.05$). Glare sensitivity, objectively measured, was unrelated to any of the outcomes. However, in secondary analyses, participants who reported moderate or extreme difficulty with oncoming headlights on night driving at baseline were more likely to report a cessation of night driving at follow-up (OR = 2.0; 95% CI = 1.3–3.0) (data not shown).

Loss of vision over the 2-year period was generally not related to driving modifications (Table 2). Only those drivers with central visual field loss were more likely to stop night driving, after age adjustment (age-adjusted linear trend $P < 0.05$). The rest of the 2-year vision loss variables were not associated with any of the outcomes. These null associations were confirmed using continuous measures of vision change instead of dichotomous variables.

For each of the three driving modifications, multiple regression models were created that adjusted for age, gender, race, cognitive status, self-report of general health, and history of diabetes and stroke. Separate regression models were created for each measure of visual function by each outcome variable (Table 3). The inferences from the full regression models were unchanged from the age-adjusted results in Table 2 with the exception that 2-year central visual field loss was no longer associated with cessation of night driving ($P = 0.08$).

Many of the vision variables correlated moderately (Pearson's $r = 0.3$–0.6). When all the baseline measures of visual function were entered simultaneously into the same models, only acuity was related to reduction in mileage (OR = 2.76; 95% CI = 1.25–8.16) and lower peripheral fields was related to cessation of night driving (OR = 2.15; 95% CI = 1.03–4.52) in a statistically significant manner (Table 4).

Having no other drivers in the house was not significantly associated with any of the driving outcomes, although it showed a slight association with mileage <3000, in that those with no other drivers in the house were less likely to reduce their mileage to <3000 at follow-up (hazard ratio [HR]= 0.7; 95% CI = 0.4–1.1).

Finally, no interactions with gender, cognitive impairment, or other drivers in the house were detected. For example, those with acuity worse or equal to 0.3 logMAR were more likely to reduce their mileage both without other drivers in the house (HR = 2.3; 95% CI = 0.4–15.3) or with other drivers in the house (HR = 2.8; 95% CI = 0.5–14.5), compared with those with acuity better than 0.3 logMAR.

To determine whether selection bias could affect our results, the characteristics of those who did not return for follow-up were compared (Table 5). Of the 1772 drivers who were at risk for at least one of the three driving modification outcomes at follow-up, there were 167 (9%) who did not return and therefore had to be excluded because of lack of

Table 2. Percentage of Drivers at Baseline in a Given Vision Category Who Had Changed Driving Habits within 2 Years

Vision Measure	Reduced Mileage to <3000 *n* = 177/1106	Stopped Night Driving *n* = 145/1255	Stopped Driving in Unfamiliar Places *n* = 225/748
Baseline acuity (%)			
<0.1 LogMAR	15	11	28
≥0.1 and <0.3 LogMAR	17	15	38
≥0.3 LogMAR	44*	21	50*
Baseline contrast sensitivity (%)			
≥36 Letters correct	13	9	28
≥32 and <36 Letters	19	14	33
<32 Letters correct	27*	22*	38
Baseline central visual fields (%)			
≤1 Point missed	14	10	28
>1 and ≤8 Points	16	12	34
>9 Points missed	33*	25*	37
Baseline peripheral visual fields (%)			
≥9 Points missed	13	9	28
>9 and ≤18 Points	18	12	35
>18 Points missed	30*	26*	31
Baseline glare sensitivity (%)			
≤2 Points difference	16	11	30
3–4 Points difference	17	12	29
≥5 Points difference	16	14	32
Acuity Loss (%)			
≤1 Line	16	10	30
>1 Lines	15	15	32
Contrast sensitivity loss %			
<4 Letter	16	11	30
≥4 Letter	18	13	30
Central visual field loss (%)			
<2 Points	15	10	29
≥2 Points	21	17*	36
Peripheral visual field loss (%)			
<5 points	15	11	29
≥5 points	20	13	33
Glare sensitivity loss (%)			
<2 points	15	11	29
≥2 points	18	13	34

*Age-adjusted (linear) $P < 0.05$.

information on visual function loss and driving status. Those who did not return for follow-up were older; more likely to be male, to have reported worse health, and to have worse contrast sensitivity at baseline; and less likely to be driving at night and in unfamiliar areas at baseline than were those who returned.

Discussion

To summarize, a variety of measures of visual function were associated with driving modification 2 years later. In addition, baseline visual function was associated with driving modification 2 years later whereas 2-year vision loss was not. Finally, different types of visual function were associated with different types of driving modifications.

Visual acuity was associated with reduced mileage but not with cessation of driving at night. Because driving at night requires the ability to see at low luminance levels, a better measure of visual acuity for predicting cessation of driving at night may be low luminance visual acuity. Future studies should explore the relationship between visual acuity measured at low luminance and cessation of driving at night. Visual acuity was associated with a cessation of driving in unfamiliar areas. This association is intuitive, because driving in unfamiliar areas may involve the ability to read signs, for which good acuity is necessary.

Contrast sensitivity and visual fields were associated with both reduced mileage and cessation of night driving, suggesting that these types of visual function play a particularly important role in routine driving behavior. It is unclear why contrast sensitivity and visual fields were not associated with cessation of driving in unfamiliar areas as well. Perhaps, individuals with poor scores in contrast sensitivity or visual fields but with good acuity scores do not find it any more difficult to drive in unfamiliar areas than in familiar areas.

Only worse glare sensitivity scores were not associated with any of the driving modification outcomes. The lack of an association with glare sensitivity may indicate that older adults can compensate for this type of poor vision through the use of sunglasses or by driving at a time of day when glare is less of a problem. Alternatively, the measure of glare sensitivity we used, which was an objective measure of how much worse an individual's contrast sensitivity was in the presence of a glare source, may not measure a form of visual function that is associated with driving modification. Some researchers believe that a subjective measure of sensitivity to glare is also an important one.[18] Indeed, we found in secondary analyses that a subjective measure of sensitivity to glare was related to cessation of night driving.

When the baseline vision variables were simultaneously entered into the same model, acuity was associated with reduced mileage, and lower peripheral visual fields with cessa-

Table 3. Separate Logistic Regression Models Giving Odds Ratios for Each Baseline Measure of Visual Function

	Reduced Mileage to < 3000		Stopped Night Driving		Stopped Driving in Unfamiliar Places	
Baseline Visual Function	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Acuity (logMAR)						
<0.1	1.00		1.00		1.00	
≥0.1 and <0.3	0.98	0.59–1.62	1.26	0.76–2.08	1.43	0.90–2.27
≥0.3	3.20*	1.25–8.16	1.26	0.39–4.09	2.79*	0.97–8.01
Contrast sensitivity						
≥36 Letters correct	1.00		1.00		1.00	
≥32 and <36 Letters	1.61	1.10–2.37	1.60	1.05–2.43	1.32	0.91–1.93
<32 Letters correct	2.11*	1.11–4.03	2.34*	1.17–4.69	1.76	0.85–3.65
Central visual fields						
≤1 Point missed	1.00		1.00		1.00	
>1 and ≤8 Points	0.97	0.64–1.49	1.09	0.70–1.72	1.26	0.84–1.89
>9 Points missed	2.12*	1.17–3.84	2.16*	1.12–4.17	1.35	0.69–2.66
Lower peripheral visual fields						
≤9 Points missed	1.00		1.00		1.00	
>9 and ≤18 Points	1.25	0.85–1.83	1.21	0.79–1.85	1.33	0.92–1.93
>18 Points missed	2.18*	1.20–3.97	2.92*	1.57–5.41	1.07	0.53–2.13
Glare sensitivity						
≤2 points difference	1.00		1.00		1.00	
3–4 points difference	1.34	0.91–1.98	1.12	0.73–1.71	0.96	0.66–1.39
≥5 points difference	1.37	0.74–2.55	1.58	0.84–2.96	1.16	0.67–2.00

Data are adjusted for demographic and health factors. All models adjusted for age, sex, race, cognitive status, general health status, history of stroke, history of diabetes, and relevant visual function loss (example: model for acuity adjusted for 2-year acuity loss). Note that the models are not adjusting for other baseline measures of visual function.

* Linear trend $P < 0.05$.

tion of night driving, indicating that these variables were still significant even after adjustment for the other vision variables. However, the variables that were statistically significant in the separate models but not in the model with the other vision variables should not be considered unrelated to the driving modifications. This is because several of the visual function variables correlated moderately with one another including acuity and contrast sensitivity ($r = 0.44$) and central and lower peripheral visual fields ($r = 0.55$). Given this degree of correlation, it is difficult to tease out their independent effects completely.

It is interesting that 2-year loss of vision in any of the measures was not associated with the three driving-modification outcomes, yet we had found earlier that 2-year losses in

Table 4. Logistic Regression Model Results with Simultaneous Adjustment for Other Measures of Baseline Visual Function and Demographic and Health Covariates

	Reduced Mileage to <3000		Stopped Night Driving		Stopped Driving in Unfamiliar Places	
Baseline Visual Function	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Acuity (logMAR)						
<0.1	1.00		1.00		1.00	
≥0.1 and <0.3	0.86	0.51–1.45	1.00	0.58–1.71	1.36	0.84–2.20
≥0.3	2.76*	1.25–8.16	0.91	0.29–1.87	2.10	0.68–6.46
Contrast sensitivity						
≥36 Letters correct	1.00		1.00		1.00	
≥32 and <36 Letters	1.39	0.95–2.03	1.24	0.82–1.87	1.14	0.72–1.65
<32 Letters correct	1.50	0.73–3.09	1.53	0.72–3.26	1.19	0.53–2.65
Central visual fields						
≤1 Point missed	1.00		1.00		1.00	
>1 and ≤8 Points	0.87	0.55–1.37	0.88	0.44–1.43	1.28	0.83–1.97
>9 Points missed	1.59	0.73–1.47	1.44	0.66–3.15	1.35	0.59–3.05
Lower peripheral visual fields						
≤9 Points missed	1.00		1.00		1.00	
>9 and ≤18 Points	1.23	0.81–1.85	1.11	0.79–1.85	1.14	0.77–1.71
>18 Points missed	1.47	0.68–3.19	2.15*	1.03–4.52	0.78	0.34–1.81
Glare sensitivity						
≤2 Points difference	1.00		1.00		1.00	
3–4 Points difference	1.26	0.86–1.85	1.04	0.69–1.57	0.90	0.62–1.29
≥5 Points difference	1.06	0.57–1.95	1.26	0.67–2.37	1.02	0.59–1.76

All models adjusted for age, sex, race, cognitive status, general health status, history of stroke, history of diabetes, and other measures of baseline vision.

* Linear trend $P < 0.05$.

Table 5. Characteristics of Drivers at Baseline Who Were Eligible for at Least One of the Three Outcomes by Whether They Returned for Follow-up

Characteristic	Returned for Follow-up $n = 1605$	Did Not Return for Follow-up $n = 167$
Mean age (y)	73	74*
Gender (%)		
Male	51	64†
Female	49	36
Race (%)		
White	80	78
African-American	20	22
Baseline acuity (mean logMAR)	−0.01	0.01
Baseline contrast sensitivity (mean correct letters)	36	35†
Baseline central visual fields (mean points missed)	2.3	3.5
Baseline lower peripheral visual fields (mean points missed)	9.3	10.2
Baseline glare sensitivity (mean; higher score is worse)	1.6	1.9
General health status (%)		
Excellent or good	79	64†
Fair or poor	21	36
Mini-mental score (%)		
≥24	94	92
<24	6	8
Drove <3000 miles/year at baseline (%)	19	21
Did not drive at night at baseline (%)	12	23
Did not drive in unfamiliar areas at baseline (%)	45	52†

* $P < 0.05$.
† Age-adjusted $P < 0.05$.

acuity, contrast sensitivity, and lower peripheral fields were associated with driving cessation over an 8-year period.[15] It may be that 2-year vision loss would lead to driving modifications at a later time than the 2-year follow-up.

The lack of association between 2-year visual function losses and driving modifications at follow-up was not due to low statistical power. We had 80% power to detect odds ratios of 1.7 to 1.8 for mileage <3000, odds ratios of 1.7 to 1.9 for cessation of night driving, and odds ratios of 1.7 to 1.9 for cessation of driving in unfamiliar areas. It is possible that more modest odds ratios escaped our detection, particularly an association between contrast sensitivity loss and cessation of night driving (OR = 1.56; 95% CI = 0.96–2.53), but the other odds ratios for visual function losses were under 1.50 indicating a small association, if any.

Our results extend the observations of Gallo et al.,[11] who found that those who simply reported impaired vision were more likely to report having made an adaptation to their driving. Our results are also consistent with Stutts,[12] who found that worse low-contrast acuity, contrast sensitivity, and peripheral visual fields scores were associated with low mileage, whereas worse acuity and contrast sensitivity were associated with high-risk avoidance, such as avoidance of night driving. Finally, our results that worse contrast sensitivity and central and lower peripheral visual fields scores were associated with cessation of night driving is not consistent with those of Ball et al.,[10] who found that groups with a greater number of vision problems, which included contrast sensitivity, central and peripheral visual fields, eye health, and useful field of view, did not report more avoidance of night driving than a group with no vision problems. However, it is difficult to directly compare our results because the vision problems in the Ball et al. analysis were grouped together (0, 1–2, 3–4) and high-risk avoidance was measured on a five-unit ordinal scale.

Our results could reflect information bias if people who knew that they had worse vision were more likely to self-report driving modifications because they felt that it was the more socially desirable answer. However, this bias was probably minimized, because the participants filled out the questionnaire on driving before they had their vision examined. The use of the self-report of driving behavior likely resulted in some misclassification, but we do not expect that it differed by vision status. Studies are needed on how the self-report of driving behavior agrees with objective measures of driving behavior.

This was a prospective study that allowed us to measure baseline vision and then assess its relationship to incident driving modification 2 years later. However, 2-year vision change was measured at the same time as incident driving modification, and therefore, it was not possible to establish firmly the temporality of these visual exposures.

There were 167 drivers (9%) at baseline who were eligible for at least 1 of the 3 driving modification outcomes who did not return for follow-up, which precluded us from measuring how their driving and vision had changed. It is unlikely that these excluded individuals caused the positive associations that we report. Those who did not return for follow-up tended to have worse baseline vision and to be older and in worse health, all predictors of making driving modifications, so if anything, they were probably more likely to have made driving modifications (Table 5). Thus, exclusion of these individuals probably weakened the observed positive associations. It is unlikely that the missing data for these people could be responsible for the null associations that we report between glare sensitivity and all three outcomes, acuity and cessation of night driving, and contrast sensitivity and visual fields and cessation of driving in unfamiliar areas. First, the rate of missing data is only 9%. In addition, even if we assume that all those who did not return for follow-up had the respective outcome, the null associations between the baseline vision variables and each driving outcome are essentially unchanged.

We present prospective data that indicate that older drivers with worse visual function changed their driving by reducing mileage and avoiding high-risk driving situations. Furthermore, the changes to driving depended on which type of visual function was affected. Therefore, grouping modifications together may mask these different relationships. Finally, we did not find subgroups of people (such as those with cognitive impairment) with poor visual function who were not likely to modify their driving.

These results indicate that older adults with poorer function in a variety of vision measures modified their driving in different ways, presumably in an attempt to stay safe. One study has found that an educational program designed to encourage older drivers with vision problems to modify their driving did not have any impact on crash rates, despite resulting in reports of reduced mileage and greater avoidance strategies.[30] However, it is possible that the reported driving modifications in the intervention group were not in agreement with actual driving modifications, or it is possible that the intervention group did not modify enough to reduce crash risk. Additional research is needed to evaluate whether modifications of driving habits actually reduce crash risk.

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