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Visual and Medical Risk Factors for Motor Vehicle Collision Involvement among Older Drivers

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Abstract

Aims—To identify visual and medical risk factors for motor vehicle collisions (MVCs).

Methods—Data from four cohorts of older drivers from three states were pooled (n=3,158). Health information was collected at baseline, and MVC data were obtained prospectively. Cox proportional hazards regression was used to estimate rate ratios (RRs) and 95% confidence intervals (CIs) for associations between medical characteristics and MVCs.

Results—A total of 363 MVCs were observed during the study period (1990-1997), of which 145 were at-fault and 62 were injurious. Falls and impaired useful field of view (UFOV[1]) were positively associated with overall MVCs. At-fault MVCs were also positively associated with falls and UFOV impairment, and inversely with cancer. Injurious MVCs were positively associated with arthritis and neurological disease, and inversely with hypertension.

Conclusions—These findings show similarities and differences across the risk factors for all, at-fault, and injurious MVCs, and point to the need for verification and possible interventions.

[1]UFOV is a registered trademark of Visual Awareness Inc.

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Keywords

automobile driving; data pooling; elderly; vision

Older drivers are the fastest growing group of drivers in the United States, in terms of number and annual mileage (1). Their motor vehicle collision (MVC) rate per-mile-driven is similar to that of young drivers whose MVC rate exceeds that of all age groups. Older drivers involved in an MVC are more likely to incur a disabling or fatal injury (1). Interventions that enhance older driver safety are needed, as driving is the preferred means of travel among older adults in the United States (2).

Various manifestations of vision impairment have been identified that place older drivers at higher risk for MVCs, most notably including severe visual field loss (3) and a restricted useful field of view (UFOV) (3-4), which takes into account visual processing speed and higherorder processing skills such as divided visual attention. Evidence suggests that among older drivers, visual acuity is not associated with MVCs despite being ubiquitously used for licensure (3). However, the evidence regarding whether other aspects of vision (e.g., contrast sensitivity, disability glare) are associated with MVCs remains unclear (3).

Cognitive and medical characteristics also have been examined for their association with MVCs, but evidence is largely inconsistent partly due to methodological issues (5-7). For example, studies have used self-report or administrative records for the identification of MVCs, and some have focused on injurious or at-fault MVCs. Little is known about whether risk factors for crash involvement regardless of injury also apply to injurious crashes. Thus, research comparing risk factors across types of MVC events may shed light on conflicting results observed in the literature. Moreover, although many studies have specifically evaluated visual or medical risk factors for MVC involvement, few have included data on both.

MATERIALS AND METHODS

Study Design

This study involves the analysis of pooled data from four cohorts of older drivers (n=3,158) from three different states (Kentucky, Maryland, Alabama).

Study Participants

Alabama Cohort I—This cohort has been described elsewhere (8). In brief, subjects were identified by the Alabama Department of Public Safety and enrolled in 1990 for a case-control study on visual and medical risk factors for MVC involvement. The sample was age-stratified to include equal numbers of drivers in each half decade from 55 to 85+ years old, and was about evenly split between those who had and had not been involved in a MVC five years prior to enrollment. The final sample (n=306) was followed prospectively for police-reported MVCs through 1996.

Alabama Cohort II—A description of this cohort is available elsewhere (9); briefly, this cohort was assembled in 1994-1995 to investigate the association between mobility and cataract. It was comprised of one group with and one without cataract. Subjects were recruited from ten ophthalmology practices and two optometry clinics in Birmingham through a medical record review of patients seen in the past year. Study participants (n=385; 274 with cataract) were followed prospectively for police reported MVCs until February, 1997.

Kentucky Cohort—A description of this cohort has been previously presented (10). In short, the cohort (n=456) was comprised of those aged 48-94 years from Warren County to investigate

whether a cognitive re-training or a simulator-training intervention affected driving. Subjects were recruited from 1993 to 1995 via multiple sources, including the Kentucky Department of Transportation, newspaper advertisements, and church and civic groups. Inclusion criteria were a valid driver's license, current driver, logMAR acuity ≤0.5, Pelli-Robson contrast sensitivity ≥1.35, and sufficient peripheral vision. Subjects with an impaired UFOV (≥ 30% reduction) were recruited into the intervention program; the control group consisted of older drivers without an impaired UFOV, and all were followed prospectively for police reported MVCs until March, 1997.

Maryland Cohort—The design of the Salisbury Eye Evaluation (SEE) Project has been reported previously (11). In brief, intended as a population-based study to investigate vision impairment among persons aged 65 to 84 years beginning in 1993, subjects were recruited from the Health Care Financing Administration (HCFA) Medicare Database for Salisbury. Study participants (n=2,520) were followed prospectively for MVCs through 1996.

After excluding those who were not driving at their respective baseline evaluation, the aggregated sample size was reduced from 3,668 to 3,158 participants.

Variable Definition and Measurement

Demographic, Medical and Cognitive Characteristics—In addition to information on demographic characteristics, self-reported information on numerous chronic medical conditions was available across all cohorts. Additionally, cognitive function was measured by the Mattis Organic Mental Syndrome Screening Examination (MOMSSE) in the Alabama cohorts and the Mini Mental State Exam (MMSE) in the Kentucky and Maryland cohorts.

Visual Function—Visual acuity was measured using the ETDRS chart and expressed as log minimum angle resolvable (logMAR). Contrast sensitivity was measured with the Pelli-Robson chart using the modified scoring system, and is expressed as the reciprocal of the log minimum contrast threshold for letters (12). For both acuity and contrast sensitivity, the binocular measures were used because vision in everyday life is typically performed with both eyes. However, for the Alabama Cohort II, binocular acuity measurements were not available, so the better eye measure was used. Similarly, for the Alabama II and Maryland cohorts, contrast sensitivity was not available, thus the better contrast sensitivity value was used. Also, for the Alabama II cohort, post-surgery values for acuity and contrast sensitivity were used for participants who had cataract surgery. Visual processing speed and visual attention were assessed with the UFOV test. Performance on this test is a function of: 1) the minimum target duration required to perform the central discrimination task, 2) the ability to divide attention between central and peripheral tasks, and 3) the ability to filter out distracting stimuli. Overall performance is expressed as a composite score calculated as a percent reduction (range 0-90) of a maximum 30-degree field size (maximum field size of the test apparatus' screen at the viewing distance).

MVC Involvement—Information on MVC involvement was obtained from the respective state agency. Only those MVCs occurring prospectively from each subject's date of enrollment were collected. Three outcomes of interest were defined: 1) involvement in at least one police-reported MVC, irrespective of fault or injury; 2) at-fault MVC according to the police accident report; and 3) injurious MVC according to the police accident report.

Statistical Analysis—Many variables had a small number of missing observations (<3%) but, in aggregate, the extent of missing data was deemed sufficient to warrant the use of multiple imputation. The Markov Chain Monte Carlo method (13) was used to impute values for missing observations using known values for demographic, medical, and visual function characteristics.

Cox proportional hazards models were used to estimate the association between demographic, medical, and visual function characteristics and all, at-fault, and injurious MVC involvement. For these analyses person-time was defined as the period from each participant's enrollment date to the final follow-up date for the participant's respective site, the date of driving cessation, or the date of death, whichever came first. Person-miles of travel represent the total amount of travel during the follow-up period and was calculated as the product of person-time and each participant's reported average annual mileage. To account for repeated events and the associated within-participant correlation, a marginal approach was used (14), which considers each event as a separate process but conditions subsequent events on prior ones. All participants were considered at risk for all events regardless of how many they experienced. *P*-values of $\leq$ 0.05 (two-sided) were considered statistically significant.

RESULTS

Table 1 presents overall and site-specific demographic, medical, and visual characteristics. On average, participants were in their early 70s and had 12 years of education. There were approximately equal proportions of males and females, and the majority was white. With minor exceptions, the prevalence of selected medical conditions was largely consistent across sites and with estimates from population-based studies. Differences in the site-specific prevalence of falls and cognitive impairment may be attributed to how specific sites measured these variables and enrolled subjects. For example, the higher prevalence of cataract for the Alabama II site can be attributed to the focus on cataract surgery in the original study.

Table 2 presents site-specific and overall crash rates for all, injury, and at-fault MVCs. A total of 363 MVCs was experienced by the cohort overall during the study period, of which 62 were injurious and 145 were at-fault.

Table 3 presents multivariate adjusted RRs and 95% CIs for the association between all, injurious, and at-fault MVC rates and demographic, medical, and visual characteristics. With respect to demographic characteristics, age and education demonstrated no significant relationship with MVC rates. There was no gender difference for overall and at-fault MVC involvement; however, males had a lower rate of injurious MVCs. Whites had lower rates for all types of MVCs, though this was only statistically significant for all and at-fault MVCs.

With respect to medical characteristics, arthritic participants demonstrated significantly higher rates for injurious MVCs. Cancer and hypertension were associated with lower at-fault and injurious MVC rates, respectively, though no such reductions were observed for other MVC types. Participants reporting neurological disease had a significantly elevated rate of injurious MVCs, though not overall or at-fault MVCs. A history of falls was associated with increased rates for all types of MVCs but this was only significant for overall and at-fault MVCs.

No eye diseases (cataract, glaucoma, macular degeneration, and diabetic retinopathy) were significantly associated with any type of MVC; this was true even when measures of visual function (acuity, CS, UFOV) were omitted (result not shown). There were no clear patterns of association for acuity or contrast sensitivity. Further, UFOV impairment was associated with a consistent increase in the overall MVC rate, though significant associations were only observed for those with 35% and greater impairment. Stronger associations were observed for at-fault MVCs, however, this relationship was only statistically significant for those experiencing a 45% or greater reduction in |UFOV|.

DISCUSSION

Consistent with past research (3,15), there was no association between MVC involvement rates and visual acuity. Though some studies have found a weak association (16), many are dated

and did not adjust for driving exposure. Earlier research on the older population also suggested that impaired contrast sensitivity is associated with MVC involvement (16), but more recent studies that account for driving exposure and adjust for the potentially confounding effects of medical conditions do not demonstrate a significant association (4). Also consistent with the results presented herein, other research (4) has reported a strong association between UFOV and MVC involvement. Further, these results lend support to the ideas that UFOV testing may be an effective screening tool for driver safety, and that those with a deficiency may benefit from visual processing speed training (19).

Consistent with some prior research (6,18-19), there was no significant association between any of the eye diseases examined (cataract, glaucoma, macular degeneration, diabetic retinopathy) and MVC involvement rates. This may not be surprising given their wide ranging impact on visual function.

Though there appears to be little research on the effects of arthritis on driving performance, at least one study reported that arthritic females experienced a higher at-fault crash risk, (18) while others found no association (6,19). This study found that those with arthritis have an elevated rate of injurious MVCs, even after adjusting for confounding factors, which suggests that arthritis may increase the vulnerability to injury during an MVC. This presents a fertile area of research for rheumatologists to further investigate the relationship and design interventions. We are surprised by the results that cancer is associated with lower rates of at-fault MVCs, which is difficult to explain and perhaps attributed to unmeasured exposures.

The results presented herein suggest that depression is associated with elevated MVC involvement rates, though not significantly so. Prior research has also suggested an association between depression (6) or using antidepressant medications (5) and MVCs, though at least one study (19) did not observe such associations. Possible reasons for this discrepancy include different measures of depression, failure to adjust for relevant confounding characteristics, and insufficient follow-up time. Though not significant, the elevated RRs for all MVC types points to the need to further investigate whether this association is a result of concomitant functional impairments related to late life depression, the use of antidepressant medications, or symptoms of the depression itself.

Some research suggests that diabetes (20) or anti-diabetic medication use (21) is associated with an increased MVC risk, while other studies do not (22). Similar to the current investigation, studies (6,18-19) that account for driving exposure and potentially confounding medical factors and visual impairments generally do not support the notion that diabetes increases the risk of MVC involvement. Taking these factors into account, the current results lend further support to the notion that diabetes does not pose an undue risk.

The current study found that heart disease had no significant association with any type of MVC, and hypertension was related to a significantly lower risk of an injurious MVCs. Likewise, some research found no significant relationship between cardiovascular disease (23), hypertension (6), or heart disease (6) and MVC risk, while other studies documented increased MVC involvement among those with heart disease (18) or those with greater orthostatic systolic blood pressure drop (19). Some research has found associations between heart disease and hypertension with cognitive impairment (24), so it is plausible that heart disease and hypertension impact MVCs through these pathways. Consistent with past research (6,18), this study found that neurological impairment (multiple sclerosis, Parkinson's, or a stroke) is associated with increased risk for all types of MVCs, but only significantly for injurious MVCs; thus, neurologists should be diligent in educating their older patients about driving safely. The respective bodies of research on falls (6,19) and cognitive impairment (7) with MVC risk are small, but are also generally consistent with the current findings.

The results of this study should be interpreted in light of several limitations. The study was limited by sample selection and is thus not generalizable to older drivers in general. Also, information on medical conditions was obtained by self-report. As such, participants may forget or be unwilling to share certain information, though past research demonstrates that there is excellent agreement between self-report and medical record diagnosis (25).

In conclusion, the findings in this study lend further credence to the lack of associations between MCV involvement and visual acuity or contrast sensitivity in the general older adult population. At the same time, however, the positive associations found between overall and at-fault MVC involvement and UFOV point to the need to attempt to develop interventions to improve UFOV and public policy that addresses this relationship. There is significant licensing variability across states with respect to vision testing requirements (26-27). A serious need exists for evidence-based research to develop a battery of vision tests to identify high-risk drivers. Until then, it has been recommended that the Iowa Department of Transportation's policies be adopted, which allow visually-impaired individuals to demonstrate their ability to drive safely(27).

Finally, positive associations between falls and neurological deficits with certain types of MVCs bolster previous findings in the literature, while other medical associations with MVC involvement (e.g., arthritis, cancer, hypertension) raise areas in need of further research. In addition, in this study we were unable to disentangle the association between MVC involvement and each medical condition compared with a medication being taken to treat it, which would be another fruitful avenue for future research.

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REFERENCES

1. Insurance Institute for Highway Safety. Status Report: Special Issue: Older Drivers September 8;2001 36(8):1–7.
2. Jette AM, Branch LG. A ten-year follow-up of driving patterns among the community-dwelling elderly. Hum Factors 1992;34:25–31. [PubMed: 1577500]
3. Owsley C, McGwin G. Vision Impairment and Driving. Surv Ophthal 1999;43(6):535–550.1999
4. Owsley C, Ball K, McGwin G Jr. Sloane ME, Roenker DL, White MF, Overley ET. Visual processing, impairment and risk of motor vehicle crash among older adults. JAMA 1998;279:1083–1088. [PubMed: 9546567]
5. Hu PS, Trumble DA, Foley DJ, Eberhard JW, Wallace RB. Crash risks of older drivers: a panel data analysis. Accident Analysis and Prevention 1998;30(5):569–581. [PubMed: 9678211]
6. Sims RV, McGwin G Jr, Allman RM, Ball K, Owsley C. Exploratory study of incident vehicle crashes among older drivers. J Geron 2000;55(1):M22–M27.
7. McGwin G Jr, Sims RV, Pulley S, Roseman JM. Relations among chronic medical conditions, medications, and automobile crashes in the elderly: a population-based case-control study. Am J of Epidemiol 2000;152(5):424–431. [PubMed: 10981455]
8. Ball K, Owsley C, Sloane ME, Roenker DL, Bruni JR. Visual attention problems as a predictor of vehicle crashes in older drivers. Invest Ophthalmol Vis Science 1993;34(11):3110–3123.
9. Owsley C, Stalvey B, Wells J, Sloane ME. Older drivers and cataract: driving habits and crash risk. J Geront 1999;54A(4):M203–M211.
10. Roenker DL, Cissell GM, Ball KK, Wadley VG, Edwards JD. Speed-of-performance and driving simulator training result in improved driving performance. Human Factors 2003;45(2):218–233. [PubMed: 14529195]

11. West SK, Munoz B, Rubin GS, Schein OD, Bandeen-Roche K, Zeger S, German PS, Fried LP, the SEE Project Team. Function and Visual Impairment in a Population-Based Study of Older Adults. Invest Ophthalmol Vis Sci 1997;38(1):72–82. [PubMed: 9008632]
12. Pelli DG, Robson JG, Wilkins AJ. The design of a new letter chart for measuring contrast sensitivity. Clin Vis Sci 1988;2(3):187–199.
13. Shafer, JL. Analysis of Incomplete Multivariate Data. Chapman Hall/CRC Press; London: 1997.
14. Wei LJ, Lin DY, Weissfeld L. Regression analysis of multivariate incomplete failure time data by modeling marginal distribution. J Amer Stat Assoc 1989;84:1065–1073.
15. Keeffe JE, Jin CF, Weih LM, McCarty CA, Taylor HR. Vision impairment and older drivers: who's driving? Br J Ophthalmol 2002;86:1118–1121. [PubMed: 12234890]
16. Marottoli RA, Richardson ED, Stowe MH, et al. Development of a test battery to identify older drivers at risk for self-reported adverse driving events. J Am Geriatr Soc 1998;46:562–8. [PubMed: 9588368]
17. Clay OJ, Wadley VG, Edwards JD, Roth DL, Roenker DL, Ball KK. Cumulative meta-analysis of the relationship between useful field of view and driving performance in older adults: current and future implications. Opt Vis Sci 2005;82(8):724–731.
18. McGwin G Jr. Sims RV, Pulley L, Roseman JM. Relations among chronic medical conditions, medications, and automobile crashes in the elderly: a population-based case-control study. Am J Epidemiol 2000;152:424–31. [PubMed: 10981455]
19. Margolis KL, Kerani RP, McGovern P, Songer T, Cauley JA, Ensrud KE. Risk factors for motor vehicle crashes in older women. J Geront 2002;57A:M186–91.
20. Koepsell TD, Wolf ME, McCloskey L, Buchner DM, Louie D, Wagner EH, Thompson RS. Medical conditions and motor vehicle collision injuries in older adults. J Am Geriatr Soc 1994;42:695–700. [PubMed: 8014341]
21. Hemmelgarn B, Lévesque LE, Suissa S. Anti-diabetic drug use and the risk of motor vehicle crash in the elderly. Can J Clin Pharmacol 2006;13:112–20.
22. Sims RV, McGwin G, Allman RM, Ball K, Owsley C. An exploratory study of incident vehicle crashes among older drivers. J Gerontol 2000;55:M22–7.
23. Guibert R, Potvin L, Ciampi A, Loiselle J, Philibert L, Franco ED. Are drivers with CVD more at risk for motor vehicle crashes? Study of men aged 45 to 70. Can Fam Physician 1998;44:770–6. [PubMed: 9585850]
24. Nash DT, Fillit H. Cardiovascular disease risk factors and cognitive impairment. Am J Cardiol 2006;97:1262–5. [PubMed: 16616038]
25. Colditz GA, Martin P, Stampfer MJ, et al. Validation of questionnaire information on risk factors and disease outcomes in a prospective cohort study of women. Am J Epidemiol 1986;123:894–900. [PubMed: 3962971]
26. Shipp MD, Penchansky R. Vision testing and the elderly driver: is there a problem meriting policy change? J Am Optom Assoc 1995;66:343–351. [PubMed: 7673593]
27. Brinig MF, Wilkinson ME, Daly JM, Jogerst GJ, Stone EM. Vision standards for licensing and driving. Optometry 2007;78:439–445. [PubMed: 17765855]

Table 1

Demographic, Medical, and Visual Characteristics Overall and by Site, 1990-1997

	ALABAMA I N=297	ALABAMA II N=373	KENTUCKY N=451	MARYLAND N=2,037	TOTAL N=3,158
Demographic					
Age, mean	71.0	70.2	68.8	73.0	71.9
Male, %	53.3	52.6	41.2	47.8	47.9
White, %	81.4	86.1	94.9	78.9	82.3
Education (years), mean	12.3	13.1	13.0	11.6	12.0
Medical					
Arthritis	49.9	63.0	43.3	51.4	51.5
Cancer	13.2	5.9	9.8	14.1	12.4
Depression	12.8	10.5	5.8	7.8	8.3
Diabetes	14.6	12.3	16.9	15.9	15.5
Heart disease	23.2	31.1	14.1	25.4	24.2
Hypertension	32.1	37.0	24.0	53.3	45.2
Neurological	6.1	7.2	3.8	8.4	7.4
Fall	13.1	32.2	2.1	27.5	23.1
Cognitive Impairment	18.3	9.1	1.9	17.1	14.1
Eye and Visual					
Cataract	35.8	71.9	21.2	34.2	36.9
Glaucoma	7.3	7.0	6.0	8.6	7.9
Macular degeneration	1.0	6.7	1.6	2.6	2.8
Diabetic retinopathy	1.4	3.8	0.9	3.8	3.1
Binocular acuity					
20/20 or Better	44.1	31.1	45.4	67.9	58.1
Worse 20/20 & Better 20/40	42.1	59.5	52.6	30.0	37.9
20/40 or Worse	13.8	9.4	2.0	2.1	4.0
Binocular CS					
≥ 1.675	60.3	8.6	41.1	21.9	26.7
≥ 1.575 & < 1.675	21.5	11.0	42.0	28.2	27.5
≥ 1.450 & < 1.575	6.8	32.7	11.3	33.5	27.8
< 1.450	11.4	47.7	5.6	16.4	18.1

	ALABAMA I N=297	ALABAMA II N=373	KENTUCKY N=451	MARYLAND N=2,037	TOTAL N=3,158
UFOV[e]					
< 22.5	24.4	23.3	47.0	19.7	24.5
≥ 22.5 & < 35.0	12.2	29.5	26.7	22.5	23.0
≥ 35.0 & < 45.0	25.9	32.4	20.8	28.4	27.6
≥ 45.0	37.6	14.8	5.4	29.4	25.0

CS, contrast sensitivity; UFOV, useful field of view

Table 2

Site-Specific and Overall Rates for All, Injury, and At-Fault Motor Vehicle Collisions.

	N	All Crashes	Person-years All Crash Rate	Person-miles All Crash Rate	Injury Crashes	Person-years Injury Crash Rate	Person-miles Injury Crash Rate	At-Fault Crashes	Person-years At-Fault Crash Rate	Person-miles At-Fault Crash Rate
Alabama I	297	137	8.06	8.85	17	1.00	1.10	59	3.47	3.81
Alabama II	373	54	9.00	9.06	5	0.83	0.84	35	5.84	5.87
Kentucky	451	77	5.25	3.96	11	0.75	0.57	0	0.00	0.00
Maryland	2,037	95	2.11	2.63	29	0.64	0.80	51	1.13	1.41
Total	3,158	363	4.39	4.72	62	0.75	0.81	145	1.75	1.88

Table 3

Multiple Adjusted Rate Ratios (RRs) and 95% Confidence Intervals (CIs) for the Association between Demographic, Medical, and Visual Characteristics and MVC Involvement.

Variable[a]	Any MVC		Injurious MVC		At-Fault MVC	
	RR	95% CI	RR	95% CI	RR	95% CI
Demographic						
Age	1.01	0.99-1.02	1.04	0.99-1.09	1.02	0.99-1.05
Male	1.08	0.86-1.35	0.43**	0.25-0.75	0.91	0.64-1.30
White	0.55***	0.41-0.73	0.64	0.31-1.32	0.57**	0.37-0.87
Education	1.04	1.00-1.08	1.01	0.92-1.10	1.02	0.96-1.07
Medical						
Arthritis	1.16	0.93-1.45	2.35**	1.33-4.17	1.42	1.00-2.02
Cancer	0.94	0.67-1.31	1.41	0.69-2.85	0.51*	0.27-0.97
Depression	1.23	0.85-1.77	1.39	0.64-3.02	1.26	0.73-2.17
Diabetes	0.86	0.47-1.57	1.29	0.50-3.37	1.11	0.62-2.01
Heart disease	1.00	0.77-1.31	0.94	0.49-1.77	0.82	0.54-1.25
Hypertension	0.87	0.69-1.10	0.53*	0.30-0.94	1.05	0.74-1.49
Neurological	1.14	0.75-1.73	4.12***	2.07-8.19	1.18	0.63-2.21
Fall	1.58**	1.19-2.09	1.23	0.66-2.29	1.59*	1.07-2.35
Cognitive Impairment	1.51	1.05-2.18	1.65	0.70-3.88	1.25	0.78-2.03
Eye and Visual						
Cataract	1.21	0.94-1.55	1.50	0.85-2.64	1.01	0.69-1.49
Glaucoma	1.18	0.81-1.72	0.63	0.19-2.06	0.91	0.48-1.72
Macular degeneration	0.57	0.23-1.39	0.90	0.11-7.44	0.95	0.35-2.56
Diabetic retinopathy	0.60	0.26-1.38	0.95	0.18-4.92	0.32	0.08-1.17
Binocular acuity						
20/20 or Better	1.00		1.00		1.00	
Worse 20/20 & Better 20/40	1.00	0.78-1.29	0.54	0.28-1.01	1.08	0.72-1.62
20/40 or Worse	1.24	0.74-2.09	0.55	0.11-2.80	1.37	0.66-2.82
Binocular CS						
≥ 1.675	1.00		1.00		1.00	
≥ 1.575 & < 1.675	0.91	0.68-1.23	0.62	0.31-1.26	0.94	0.56-1.58

Variable[a]	Any MVC		Injurious MVC		At-Fault MVC	
	RR	95% CI	RR	95% CI	RR	95% CI
≥ 1.450 & < 1.575	0.72	0.49-1.05	0.71	0.32-1.56	0.87	0.49-1.56
< 1.450	1.01	0.66-1.53	0.49	0.16-1.49	1.27	0.68-2.37
UFOV[e]						
< 22.5	1.00		1.00		1.00	
≥ 22.5 & < 35.0	1.02	0.72-1.45	0.99	0.41-2.42	1.56	0.80-3.05
≥ 35.0 & < 45.0	1.61**	1.19-2.19	1.30	0.60-2.81	1.83	0.98-3.45
≥ 45.0	1.82**	1.26-2.61	1.08	0.45-2.56	2.64**	1.37-5.11

CS, contrast sensitivity; UFOV, useful field of view

* p <.05

** p < .01

*** p < .001

[a] Main and interactive effects of site also included (results discussed in text).