Vision and Commercial Motor Vehicle Driver Safety

Volume 2 – Appendix G

Presented to

Federal Motor Carrier Safety Administration

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Prepared for

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Evidence reports are sent to the Federal Motor Carrier Safety Administration's (FMCSA) Medical Review Board (MRB) and Medical Expert Panels (MEP). The MRB and MEP make recommendations on medical topics of concern to FMCSA.

FMCSA will consider all MRB and MEP recommendations, however, all proposed changes to current standards and guidance (guidelines) will be subject to public-notice-and-comment and relevant rulemaking processes.

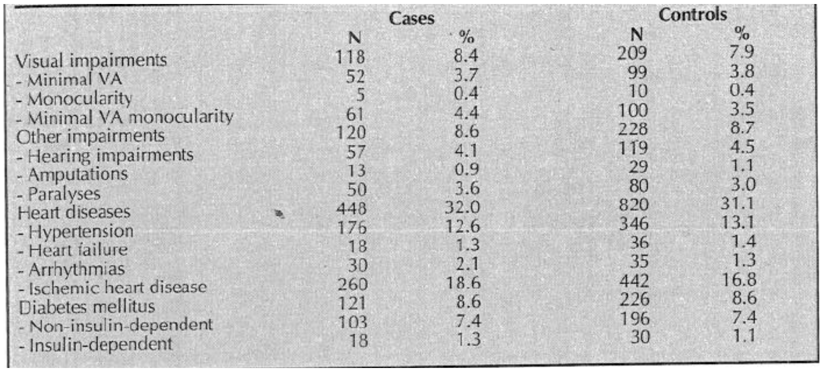
Appendix G

Study Summary Tables for Key Question 1

<table>
<tr><td colspan="3">Gresset J, Meyer F. Risk of Automobile Accidents Among Elderly Drives with Impairments or Chronic Diseases. Revue Canadienne De Sante Publique 1994; Vol 85, NO. 4; 282-5.</td></tr>
<tr><td>Key Questions Addressed</td><td colspan="2"><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td>√</td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>Research Question</td><td colspan="2">What is the influence of visual conditions which just meet minimal VA (VA) on the risk of “accidents” among 70 year-old drivers?</td></tr>
<tr><td>Study Design</td><td colspan="2">Case-Control</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td>Cases:
Quebec residents who held passenger vehicle permits (class 5 driver’s permit)
Drivers who were involved in crashes during their 70th year in 1988 or 1989
Controls:
Randomly selected drivers who were not involved in crashes during their 70th year in 1988 and 1989</td></tr>
<tr><td>Exclusion Criteria</td><td>Cases:
Male drivers involved in fatal crashes (causing death of at least one of the individuals involved in the crash) and in crashes causing severe bodily damage (requiring hospitalization of at least one of the individuals involved
Controls:
Individuals missing medical records</td></tr>
<tr><td>Study population Characteristics</td><td><table><tr><td>Characteristics</td><td>Case</td><td>Control</td></tr><tr><td>Population (n)</td><td>1400</td><td>2636</td></tr><tr><td>Gender (male, %)</td><td>100%</td><td>100%</td></tr><tr><td>Age</td><td>70</td><td>70</td></tr></table>Refer to Table G- 1 for complete details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td>Unclear</td></tr>
<tr><td>Methods</td><td colspan="2">All drivers involved in crashes that involved mild bodily injury were selected for this study
Controls were randomly selected from the 30,000± male drivers who were involved in crashes during their 70th year
Information on subjects vision and/or impairments obtained from the SAAQ
Information on mileage and prevailing driving conditions obtained through questionnaire mailed to study subjects
4 a priori confounding variables considered: demerit points, mileage, number of hours driven and frequency of driving during rush hour</td></tr>
<tr><td>Statistical Methods</td><td colspan="2">Multiple logistic regression was used to obtain odds ratios (OR) while controlling for confounding factors
95% CI were obtained from the standard error of the beta coefficients</td></tr>
<tr><td rowspan="2">Quality assessment</td><td>Study quality</td><td><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr><tr><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>NR</td><td>Y</td></tr></table></td></tr>
<tr><td>Low</td><td><table><tr><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="2">Risk of road crash for drivers with chronic medical conditions and/or impairments</td></tr>
<tr><td>Results</td><td colspan="2">• Prevalence of impairments including vision presented in Table G- 1.
Drivers with at least 1 demerit point had a statistically significant higher risk of crash (OR;2.41, CI: 2.01-2.88)
Response rate to questionnaire was 39.9%
Proportion of those who responded did not differ significantly between cases and controls according to impairment or disease status
Respondents to questionnaire, relative risk of crash increased by 12% per 10,000 km/year (OR=1.12, CI: 1.00-1.24); driving during ≥9 hours per week was associated with relative risk of crash of 1.31 (Ci: 1.06-1.62)
Drivers of more than 14 hours per week during rush hours had a relative risk of 1.24 (CI: 1.03-1.55)
• Risk of crash for individuals with minimal VA (VA) presented and OR of 0.99, CI: 0.71-1.40 (Table G- 2).
• Drivers with combined VA and monocularity, non-statistically significant increase in risk of crash observed as OR=1.16, CI: 0.83-1.60 (Table G- 2).</td></tr>
</table>

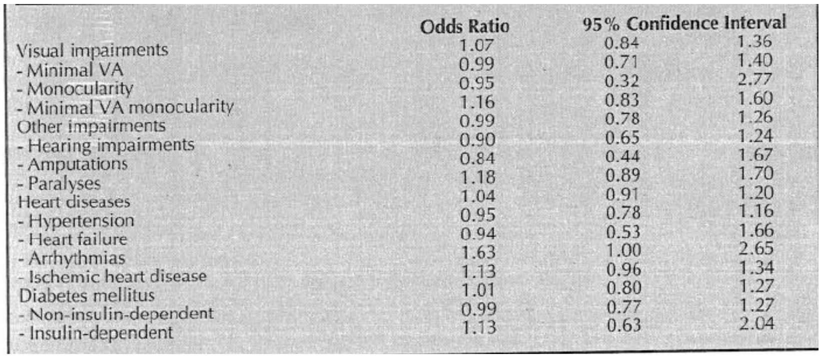
Authors' Comments	• It is possible that this study failed to identify truly increased risks of crashes associated with the various impairments and medical conditions • "our study did not address the relationship between impairments or chronic diseases and the risk of accidents cause death or severe bodily injury" • The result from another study conducted in Quebec revealed that relative risks associated with visual impairments were similar for crashes with or without bodily injury

Table G- 1 Prevalence of Chronic Impairments and Diseases among 1,400 Cases and 2,636 Controls



	Cases		Controls	
	N	%	N	%
Visual impairments	118	8.4	209	7.9
- Minimal VA	52	3.7	99	3.8
- Monocularity	5	0.4	10	0.4
- Minimal VA monocularity	61	4.4	100	3.5
Other impairments	120	8.6	228	8.7
- Hearing impairments	57	4.1	119	4.5
- Amputations	13	0.9	29	1.1
- Paralyses	50	3.6	80	3.0
Heart diseases	448	32.0	820	31.1
- Hypertension	176	12.6	346	13.1
- Heart failure	18	1.3	36	1.4
- Arrhythmias	30	2.1	35	1.3
- Ischemic heart disease	260	18.6	442	16.8
Diabetes mellitus	121	8.6	226	8.6
- Non-insulin-dependent	103	7.4	196	7.4
- Insulin-dependent	18	1.3	30	1.1

Table G- 2 Odd Ratios of Accidents and Related 95% Confidence Intervals for Chronic Impairments and Diseases Among 70-year-old Drivers



	Odds Ratio	95% Confidence Interval	
Visual impairments	1.07	0.84	1.36
- Minimal VA	0.99	0.71	1.40
- Monocularity	0.95	0.32	2.77
- Minimal VA monocularity	1.16	0.83	1.60
Other impairments	0.99	0.78	1.26
- Hearing impairments	0.90	0.65	1.24
- Amputations	0.84	0.44	1.67
- Paralyses	1.18	0.89	1.70
Heart diseases	1.04	0.91	1.20
- Hypertension	0.95	0.78	1.16
- Heart failure	0.94	0.53	1.66
- Arrhythmias	1.63	1.00	2.65
- Ischemic heart disease	1.13	0.96	1.34
Diabetes mellitus	1.01	0.80	1.27
- Non-insulin-dependent	0.99	0.77	1.27
- Insulin-dependent	1.13	0.63	2.04

Keeney A, Garvey J, Brunker G. Current experience with the monocular drivers of Kentucky. American Association for Automotive Medicine Proceedings, October 1-3, 1981, San Francisco

Key Questions Addressed	1	2	3	4	5
	✓				

Research Question	Risk of crash for monocular drivers		
Study Design	Retrospective Cohort		
Population	**Inclusion Criteria**	Monocular drivers enrolled in Kentucky's Driver Limitation Program from 1976 to 1980	
	Exclusion Criteria		
	Study population Characteristics	Variable N	Value 52
	Generalizability to CMV drivers	Unclear	
Methods	o Monocularity is defined as best corrected vision in one eye of 20/200 or worse A request by Kentucky State Police or Division of Driver Licensing is made for a physical exam for driver limitation. Reasons for this request Include: 1. Has been involved in three or more reportable motor vehicle crashes within a 24 month period 2. Has received three or more convictions for operating a motor vehicle while under the influence of intoxicants or drugs within the last five years 3. Has indicated that he/she "blacked out" or lost consciousness prior to a reportable motor vehicle crash 4. Has been named in an affidavit by at least 2 witnesses as being incapable of properly operating a motor vehicle due to physical or mental infirmities 5. Has been reported by a physician as being incapable of driving safely due to physical or mental condition or due to medication prescribed for an extended time 6. Has been reported by a law enforcement officer after being observed driving or behaving in an erratic or dangerous manner which indicates a possibility of physical or mental infirmity 7. Applicant for initial license or for renewal of same has obvious physical or mental impairment 8. Has an official record kept by the Bureau of Vehicle Regulation indicating a possibility of physical or mental impairment o Frequency and characteristics of traffic violations, driver license restrictions, physical data and associated disease information was obtained from driver records. o Crash type, severity and frequency were obtained from crash reports.		
Statistical Methods	Between group analyses		

Quality Assessment	**Internal Validity**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Score:										
	Category: Moderate	S	Y	Y	N	N	Y	Y	N	NR	Y

Relevant Outcomes Assessed	Risk of crash
Results	o During the period 1976-1980, monocular drivers had significantly more crash ($p<0.05$) with a rate of almost twice that of the general driving population (Figure G-1). Note: rates determined by extrapolation to 1000 subjects o Monocular drivers had significantly more ($p<0.05$) reckless driving violations, at a rate greater than one and a half times that of their binocular counterparts (Figure G-2). o In a subgroup analysis of drivers with blindness in left or right eye, drivers with a right blind eye demonstrated significantly more ($p<0.05$) traffic violations that those with a left blind eye, with a rate almost five times higher (466 vs 95) (Figure G-3).
Authors' Comments	Monocular drivers have an increased risk of crash versus the general driving public and significantly more driving violations versus binocular drivers. In addition, drivers blind in the right eye had significantly more traffic violations than drivers with a blind eye in the left.

Figure G-1: Rate of Crash by Monocular Drivers vs General Driving Population of Kentucky (1976-1980)

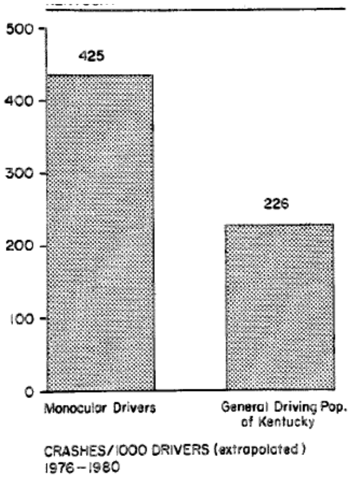


Figure G-2: Rate of Reckless Driving Violations by Monocular Drivers vs General Driving Population of Kentucky (1976-1980)

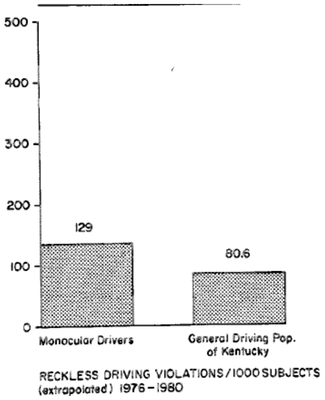
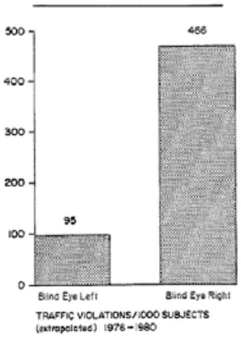


Figure G-3: Rate of Traffic Violations Comparing Right vs Left Eyed Blindness



McCloskey L, Koepsell T, Wolf M, Buchner D. Motor Vehicle Collision Injuries and Sensory Impairments of Older Drivers. Age and Aging 1194: 23: 267-273

Key Questions Addressed	**1**	**2**	**3**	**4**	**5**
	√				

Research Question	To evaluate the roles of impaired static VA, ocular disorders and impaired hearing as potential risk factors for motor vehicle injury collisions
Study Design	Case-Control

Population	**Inclusion Criteria**	Cases: Drivers treated for injuries sustained in a police-reported collision that occurred in 1987 or 1988 Controls: Drivers who experienced no such injury during the study years; matched to cases by age, gender and county of residence *All subjects were HMO members who were licensed drivers age ≥65 residing in Washington state counties; received medical care through Group Health System (GHC) facilities in King, Pierce, Snohomish, Thurston or Kitsap county*
	Exclusion Criteria	Cases/Controls: NR
	Study population Characteristics	

Measurement	**Cases**	**Controls**
Population (n)	235	448
Gender (m/f)	117/118	224/224
Age (years)	65-80	65-80

Refer to Table G-6 for complete details

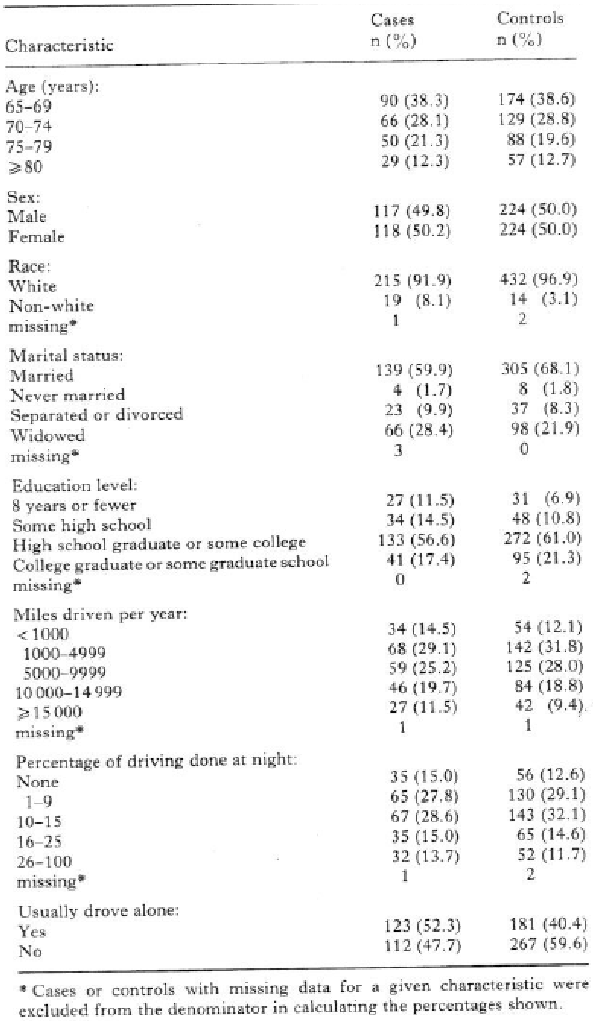
	Generalizability to CMV drivers	**Unclear**

Methods	Cases were driver who sought medical care within 7 days for injuries sustained in a motor vehicle collision (MVC); reported to police when ≥65 year of age Cases utilized that date of the index MVC; controls it was the reference date for the corresponding case Cases were initially identified from police reports for MVCs in 1987-8 and then confirmed by examining GHC medical records Controls were randomly selected from a pool of eligible subjects who had not been injured in a police reported MVC during the calendar year of the reference date 2 controls sought for each case and matched for gender, age (within 1 year) and county of residence) Information collected from 4 sources for analyses: GHC clinic records, survey from Washington State Department of Licensing, Drivers Services Division, and Washington State Patrol records (for cases only) Health history abstracted for all subjects' medical records from routine visits Subjects completed a survey questionnaire that included questions about driving habits, number of miles driven, ownership pattern, formal educations, hearing aid, lifestyle factors and demographics Failed responses were called and invited to interview by phone Surrogate interview conducted with family members a/o close friends for cases who were either deceased or otherwise unable mentally, physically to complete survey Controls were matched to surrogate interviews Additional analyses were performed using a subject of cases who were considered at fault in the index collision; controls matched
Statistical Methods	Odds ratios used throughout as estimates of relative risk Most analyses utilized dichotomous measures of exposure and employed Mantel-Haenszel techniques for stratified data, each matched set forming a single stratum For analyses of exposure variables with more than two levels or for analyses conditional logistic regression used Unmatched logistic regression models used in few instances when the numbers of subjects having valid data were too small to accomplish a matched analysis

Quality assessment														
	Study quality	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
		Y	Y	N	N	N	Y	Y	NR	Y	N	Y	Y	Y
	Low	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	

Relevant Outcomes Assessed	• Motor vehicle collision risk for individuals with impaired vision • Risk of injury for individuals with visual impairments
Results	• Non-whites were at a greater risk for an MVC (relative risk (RR) 2.3; 95% confidence interval (CI) 12-4.6 • Statistical significance in trend for cases to have less formal education than the controls (p-value for trend=0.02) • 3 variable examined that characterized driving styles: o Number of miles driven o Percentage of driving in one night o Those who drove alone were more likely to have an injury producing MVC (RR 1.8; 95% CI 1.2-2.5) • See Table G- 4 for the association between various ophthalmological conditions and the risk of MVC injury • Cases had shorter time interval between their most recent optometry examination and their reference date—a mean of 22.4 months for cases (range 0-144; SD 24.2) versus a mean of 24.7 months for controls (range 0-228; SD 28.0); no statistical significance (p value = 0.3) • Table G-5 summarized the relative risk of collision injury associated with levels of visual impairment; levels of impairments of unaided VA were associated with elevated risk estimates but none statistically significant; no linear trend (p=.07) • Analysis of five levels of aided VA; we found a greater inverse association at each successive level of impairment, except for the highest level that had an elevated risk estimate (RR 4.3; 95% CI 0.5-40.3) • For aided visual acuities of 20/50 or 20/60 did the confidence interval exclude 1.0 (RR 0.3; 95% CI 0.1-0.9); no significant linear trend (p value=0.15)
Authors' Comments	• "A case-control design is not particularly well suited to the study of rare exposures, as it tends to produce wide confidence intervals around the risk estimates, frequently allowing estimates to fall short of statistical significance • There may be several reasons for negative findings with respect to VA and ocular diseases: o Most individuals in population with severe impairment of VA (20/70 or greater) had already open screen out either by license testing protocols or by voluntary cessation of driving o Drivers may have responded to visual impairments with slower and more cautious driving behaviors that more than offset any increased risk ensuring from mild visual limitations; as vision deteriorates to 20/70 and beyond, perhaps cautious driving can no longer compensate o It is possible that some individuals may not have sought timely medical evaluations of their visual problems and were thereby misclassified with regard to the extent of their visual impairment at reference date o Individuals with same ocular diagnosis or the same level of full-illumination static VA may have had unmeasured differences in their functional visual capability

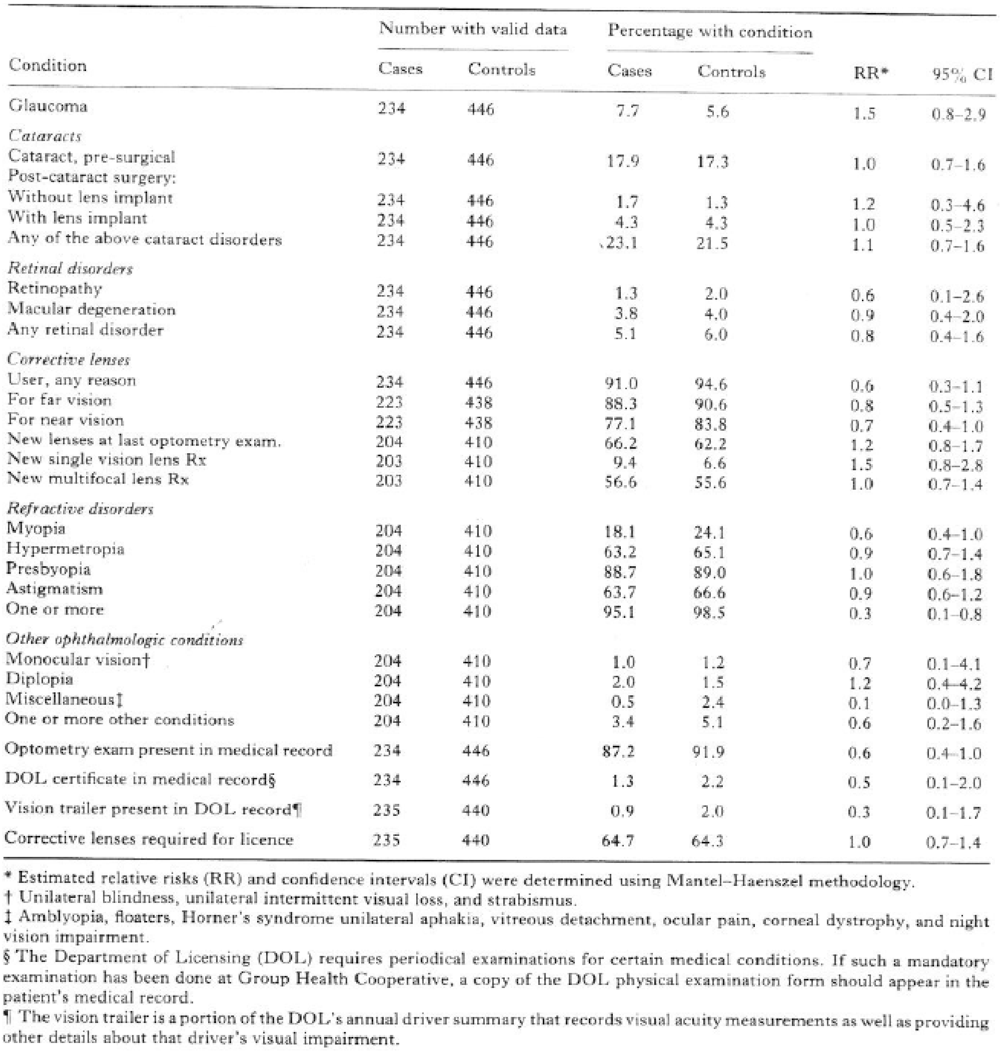
Table G- 3 **Demographic and other Characteristics of cases and controls**



Characteristic	Cases n (%)	Controls n (%)
Age (years):		
65–69	90 (38.3)	174 (38.6)
70–74	66 (28.1)	129 (28.8)
75–79	50 (21.3)	88 (19.6)
≥80	29 (12.3)	57 (12.7)
Sex:		
Male	117 (49.8)	224 (50.0)
Female	118 (50.2)	224 (50.0)
Race:		
White	215 (91.9)	432 (96.9)
Non-white	19 (8.1)	14 (3.1)
missing*	1	2
Marital status:		
Married	139 (59.9)	305 (68.1)
Never married	4 (1.7)	8 (1.8)
Separated or divorced	23 (9.9)	37 (8.3)
Widowed	66 (28.4)	98 (21.9)
missing*	3	0
Education level:		
8 years or fewer	27 (11.5)	31 (6.9)
Some high school	34 (14.5)	48 (10.8)
High school graduate or some college	133 (56.6)	272 (61.0)
College graduate or some graduate school	41 (17.4)	95 (21.3)
missing*	0	2
Miles driven per year:		
<1000	34 (14.5)	54 (12.1)
1000–4999	68 (29.1)	142 (31.8)
5000–9999	59 (25.2)	125 (28.0)
10 000–14 999	46 (19.7)	84 (18.8)
≥15 000	27 (11.5)	42 (9.4)
missing*	1	1
Percentage of driving done at night:		
None	35 (15.0)	56 (12.6)
1–9	65 (27.8)	130 (29.1)
10–15	67 (28.6)	143 (32.1)
16–25	35 (15.0)	65 (14.6)
26–100	32 (13.7)	52 (11.7)
missing*	1	2
Usually drove alone:		
Yes	123 (52.3)	181 (40.4)
No	112 (47.7)	267 (59.6)

* Cases or controls with missing data for a given characteristic were excluded from the denominator in calculating the percentages shown.

Table G- 4 Risk of injury collisions associated with ophthalmologic conditions



Condition	Number with valid data		Percentage with condition			
	Cases	Controls	Cases	Controls	RR*	95% CI
Glaucoma	234	446	7.7	5.6	1.5	0.8–2.9
Cataracts						
Cataract, pre-surgical	234	446	17.9	17.3	1.0	0.7–1.6
Post-cataract surgery:						
Without lens implant	234	446	1.7	1.3	1.2	0.3–4.6
With lens implant	234	446	4.3	4.3	1.0	0.5–2.3
Any of the above cataract disorders	234	446	23.1	21.5	1.1	0.7–1.6
Retinal disorders						
Retinopathy	234	446	1.3	2.0	0.6	0.1–2.6
Macular degeneration	234	446	3.8	4.0	0.9	0.4–2.0
Any retinal disorder	234	446	5.1	6.0	0.8	0.4–1.6
Corrective lenses						
User, any reason	234	446	91.0	94.6	0.6	0.3–1.1
For far vision	223	438	88.3	90.6	0.8	0.5–1.3
For near vision	223	438	77.1	83.8	0.7	0.4–1.0
New lenses at last optometry exam.	204	410	66.2	62.2	1.2	0.8–1.7
New single vision lens Rx	203	410	9.4	6.6	1.5	0.8–2.8
New multifocal lens Rx	203	410	56.6	55.6	1.0	0.7–1.4
Refractive disorders						
Myopia	204	410	18.1	24.1	0.6	0.4–1.0
Hypermetropia	204	410	63.2	65.1	0.9	0.7–1.4
Presbyopia	204	410	88.7	89.0	1.0	0.6–1.8
Astigmatism	204	410	63.7	66.6	0.9	0.6–1.2
One or more	204	410	95.1	98.5	0.3	0.1–0.8
Other ophthalmologic conditions						
Monocular vision†	204	410	1.0	1.2	0.7	0.1–4.1
Diplopia	204	410	2.0	1.5	1.2	0.4–4.2
Miscellaneous‡	204	410	0.5	2.4	0.1	0.0–1.3
One or more other conditions	204	410	3.4	5.1	0.6	0.2–1.6
Optometry exam present in medical record	234	446	87.2	91.9	0.6	0.4–1.0
DOL certificate in medical record§	234	446	1.3	2.2	0.5	0.1–2.0
Vision trailer present in DOL record¶	235	440	0.9	2.0	0.3	0.1–1.7
Corrective lenses required for licence	235	440	64.7	64.3	1.0	0.7–1.4

* Estimated relative risks (RR) and confidence intervals (CI) were determined using Mantel–Haenszel methodology.

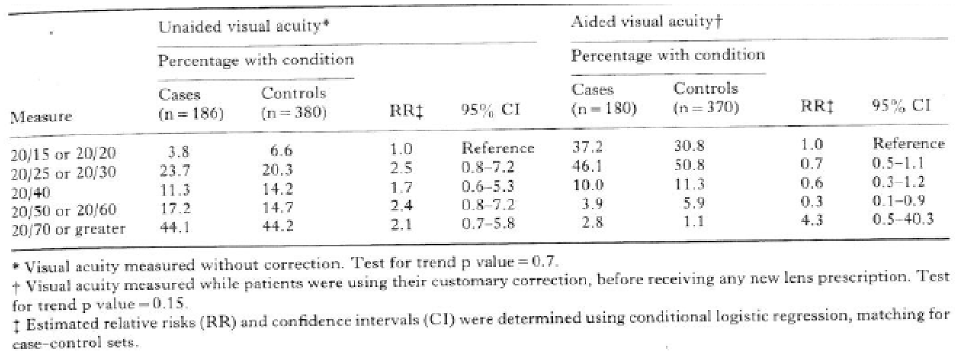
† Unilateral blindness, unilateral intermittent visual loss, and strabismus.

‡ Amblyopia, floaters, Horner's syndrome unilateral aphakia, vitreous detachment, ocular pain, corneal dystrophy, and night vision impairment.

§ The Department of Licensing (DOL) requires periodical examinations for certain medical conditions. If such a mandatory examination has been done at Group Health Cooperative, a copy of the DOL physical examination form should appear in the patient's medical record.

¶ The vision trailer is a portion of the DOL's annual driver summary that records visual acuity measurements as well as providing other details about that driver's visual impairment.

Table G-5 . Risk of injury at various levels of VA



Measure	Unaided visual acuity*				Aided visual acuity†			
	Percentage with condition				Percentage with condition			
	Cases (n = 186)	Controls (n = 380)	RR‡	95% CI	Cases (n = 180)	Controls (n = 370)	RR‡	95% CI
20/15 or 20/20	3.8	6.6	1.0	Reference	37.2	30.8	1.0	Reference
20/25 or 20/30	23.7	20.3	2.5	0.8–7.2	46.1	50.8	0.7	0.5–1.1
20/40	11.3	14.2	1.7	0.6–5.3	10.0	11.3	0.6	0.3–1.2
20/50 or 20/60	17.2	14.7	2.4	0.8–7.2	3.9	5.9	0.3	0.1–0.9
20/70 or greater	44.1	44.2	2.1	0.7–5.8	2.8	1.1	4.3	0.5–40.3

* Visual acuity measured without correction. Test for trend p value = 0.7.

† Visual acuity measured while patients were using their customary correction, before receiving any new lens prescription. Test for trend p value = 0.15.

‡ Estimated relative risks (RR) and confidence intervals (CI) were determined using conditional logistic regression, matching for case-control sets.

<table>
<tr><td colspan="15">McKnight AJ, Shinar D, Hilburn B. The Visual and Driving Performance of Monocular and Binocular Heavy-Duty Truck Drivers. Accid. Anal. & Prev. 1991; Vol 23 No. 4: 225-237</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3">√</td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="14">• To analyze and identify aspects of visual performance that might be affected by monocularity and the particular driving functions of heavy vehicle operators that are likely to be significantly affected the by the reduced visual function
• Identify and formulated specific measures of visual and driving performance
• Conduct a study to compare performance of monocular and binocular heavy vehicle drivers on the mentioned measures</td></tr>
<tr><td>Study Design</td><td colspan="14">Prospective Cohort</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="13">Cases/Controls:
NR</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13">Cases/Controls:
NR</td></tr>
<tr><td>Study population Characteristics</td><td colspan="13"><table>
<tr><th>Measurement</th><th>Monocular</th><th>Binocular</th></tr>
<tr><td>Population (n)</td><td>40</td><td>40</td></tr>
<tr><td>Age (mean)</td><td>46.5</td><td>44.3</td></tr>
<tr><td>Driving exposure</td><td>58,259</td><td>61,633</td></tr>
<tr><td>Years of experience</td><td>21.5</td><td>16.8</td></tr>
</table></td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="13">Relevant</td></tr>
<tr><td>Methods</td><td colspan="14">• Initial search for monocular drivers based on search completed through Maryland Motor Vehicle Administration Driver records
• All Class A drivers restricted to driving with outside mirrors contacted due to limited monocularity history on driving records
• 33 recruited initially; remaining were recruited through notices posted in truck stops, letters sent to 300 ophthalmologists practicing in Maryland, Virginia and Washington D.C; newsletters mailed to truckers in the Northeast area
• Sample obtained--40 binocular drivers matched for age and truck driving experience; included interviews total 1200 binocular drivers without any known visual limitations
• All participants paid for participating in study
• Visual performance measures considered totaled 8—static VA, dynamic VA, acuity under low levels of illumination, glare resistance, glare recovery, VF, depth perception, and contrast sensitivity
• Driving performances included in study were identified by comparing visual deficiencies of monocular drivers with the requirements of heavy vehicle operation; measures included lane keeping, gap judgment, clearance judgment, information interpretation, and mirror checks
• Operation definition of each visual performance measured included in Table G-6.
• Performance measured during the day and at night to prevent deficiencies in acuity under low levels of light, glare resistance, and glare recovery
• Trucks used in the study were the standard tractor-trailer combination, GMC Astro Cabo-over-engine Tractor and a 13.72m enclosed cargo trailer; tractors had a sleeper berth for data recording equipment installation
• Cameras used to record events and drivers' responses just as they occurred with a forward-facing video cameras mounted on a shock absorber pad in the sleeper berth behind the driver's seat, zoomed to the maximum extent for a 90-degre field view
• The 56km route contained a mixture of test batteries including freeway, urban, suburban, and rural street driving requiring subjects to turn
• Time measured using counting video frames; camera facing rear measured distance of vehicles behind, length of gaps, clearance behind following lane changes and/or merging.
• Nighttime measurements captured using super-8 motion picture camera
• Behavior measured unbeknownst to drivers by informing them that test completed at certain point; requiring drivers to return to station with only one potential route; drivers unaware equipment still operating
• Off street test measured using University of Maryland driving range to test for clearance judgment and sign recognition
• Information recognition portion tested on circular track—subjects drover around the circle turning into crossroads
• At the end of crossroads were signs directing drivers to perform an observable act--applicants instructed to respond to each sign as soon as they were able to read it. Assistant test administrator outside the vehicle observed the position of the tractor cab at the moment the subject responded and measured the distance from that point to the sign</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">NR</td></tr>
<tr><td>Quality assessment</td><td>Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
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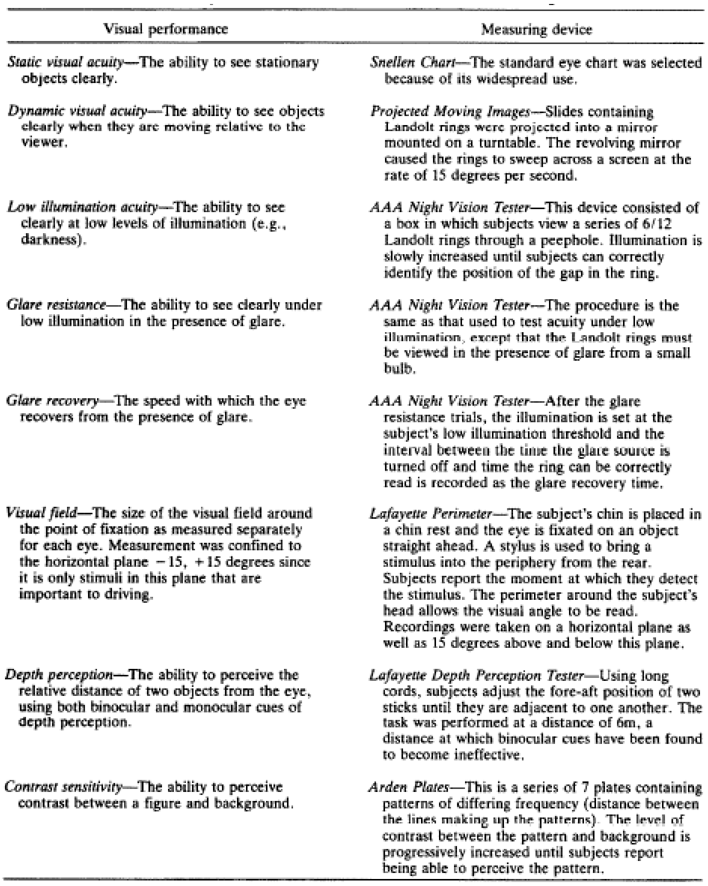
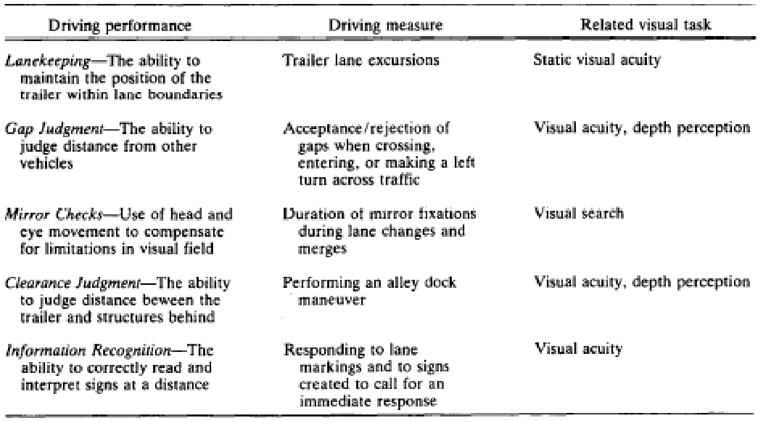
<tr><td rowspan="2">Low</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">• Visual and driving performance (monocular vision, static VA, dynamic VA, contrast sensitivity, depth perception, glare resistance, night vision) measured using a battery of tests
• Driving exposure measured in kilometers driven per year
• Case and controls compared to assess potential risk of crash</td></tr>
<tr><td>Results</td><td colspan="14">• Refer to Table G-7 for driving performance measures in conjunction with visual performance measures
Mean performance levels of monocular and binocular drivers on all the vision test summarized in Table G-8Table G-8; there were no significant differences between groups in static VA, dynamic VA, VF and glare recovery
• Differences between two group no significant for VA in the seeing eye of monocular drivers compared to binocular acuity of binocular drivers
• Groups did not differ in contrast sensitivity, depth perception, minimal illumination for night vision and glare resistance; however in all of these tests, the binocular drivers performance outweighed monocular drivers
• Poorer performance recorded of monocular drivers in night vision and glare resistance; statistical significance of poor performance for monocular drivers in contrast sensitivity
• All 3 measures differences for groups were less than one standard deviation within each group
• Summarized mean performance levels and standard deviations located in Table G-9.
• Off-street test showed significant differences between the two groups both during the day and during the night, with binocular drivers having a reading distance that was on average 13% (5.6m) farther than the monocular drivers during th day and 12% (3.0m) farther at night
• No significant differences found between the two groups of the five measures during day and night maneuvers
No significance differences found in the total number of gaps considered unsafe either for day or nighttime driving
• The only significant correlations for monocular drivers were between depth perception and daytime reading distance (r=0.39, p<.05) and between depth perception and nighttime sign reading distance (r=0.57, p<.05); Visual measures did not correlate significantly for either one of driving measures</td></tr>
<tr><td>Authors' Comments</td><td colspan="14">"…in the present study only one vision test was significantly related to only one driving performance variable. If the present sample of monocular drivers were tested directly on the signs test, simply screening out drivers who had to get closer than 30m in day time to respond to the signs would have raised the mean performance level of the remaining monocular drivers to that of the binocular drivers."</td></tr>
</table>

Table G-6. Visual performance measures and their associated measuring devices



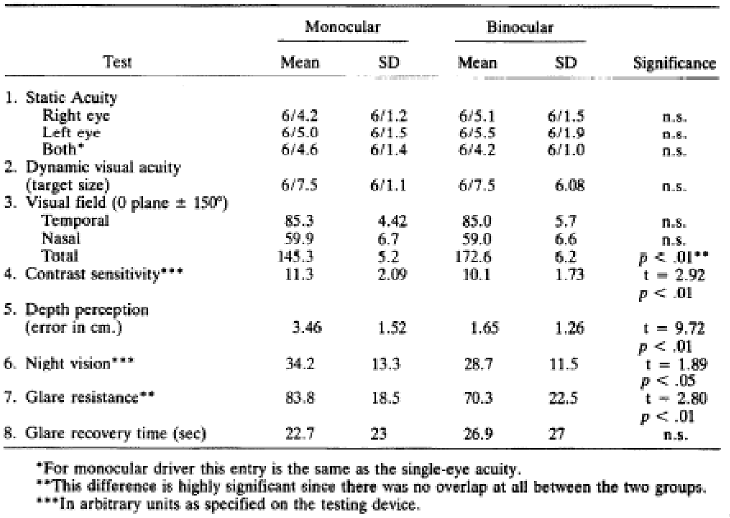
Visual performance	Measuring device
Static visual acuity—The ability to see stationary objects clearly.	*Snellen Chart*—The standard eye chart was selected because of its widespread use.
Dynamic visual acuity—The ability to see objects clearly when they are moving relative to the viewer.	*Projected Moving Images*—Slides containing Landolt rings were projected into a mirror mounted on a turntable. The revolving mirror caused the rings to sweep across a screen at the rate of 15 degrees per second.
Low illumination acuity—The ability to see clearly at low levels of illumination (e.g., darkness).	*AAA Night Vision Tester*—This device consisted of a box in which subjects view a series of 6/12 Landolt rings through a peephole. Illumination is slowly increased until subjects can correctly identify the position of the gap in the ring.
Glare resistance—The ability to see clearly under low illumination in the presence of glare.	*AAA Night Vision Tester*—The procedure is the same as that used to test acuity under low illumination, except that the Landolt rings must be viewed in the presence of glare from a small bulb.
Glare recovery—The speed with which the eye recovers from the presence of glare.	*AAA Night Vision Tester*—After the glare resistance trials, the illumination is set at the subject's low illumination threshold and the interval between the time the glare source is turned off and time the ring can be correctly read is recorded as the glare recovery time.
Visual field—The size of the visual field around the point of fixation as measured separately for each eye. Measurement was confined to the horizontal plane −15, +15 degrees since it is only stimuli in this plane that are important to driving.	*Lafayette Perimeter*—The subject's chin is placed in a chin rest and the eye is fixated on an object straight ahead. A stylus is used to bring a stimulus into the periphery from the rear. Subjects report the moment at which they detect the stimulus. The perimeter around the subject's head allows the visual angle to be read. Recordings were taken on a horizontal plane as well as 15 degrees above and below this plane.
Depth perception—The ability to perceive the relative distance of two objects from the eye, using both binocular and monocular cues of depth perception.	*Lafayette Depth Perception Tester*—Using long cords, subjects adjust the fore-aft position of two sticks until they are adjacent to one another. The task was performed at a distance of 6m, a distance at which binocular cues have been found to become ineffective.
Contrast sensitivity—The ability to perceive contrast between a figure and background.	*Arden Plates*—This is a series of 7 plates containing patterns of differing frequency (distance between the lines making up the patterns). The level of contrast between the pattern and background is progressively increased until subjects report being able to perceive the pattern.

Table G-7. Driving performance measures



Driving performance	Driving measure	Related visual task
Lanekeeping—The ability to maintain the position of the trailer within lane boundaries	Trailer lane excursions	Static visual acuity
Gap Judgment—The ability to judge distance from other vehicles	Acceptance/rejection of gaps when crossing, entering, or making a left turn across traffic	Visual acuity, depth perception
Mirror Checks—Use of head and eye movement to compensate for limitations in visual field	Duration of mirror fixations during lane changes and merges	Visual search
Clearance Judgment—The ability to judge distance beween the trailer and structures behind	Performing an alley dock maneuver	Visual acuity, depth perception
Information Recognition—The ability to correctly read and interpret signs at a distance	Responding to lane markings and to signs created to call for an immediate response	Visual acuity

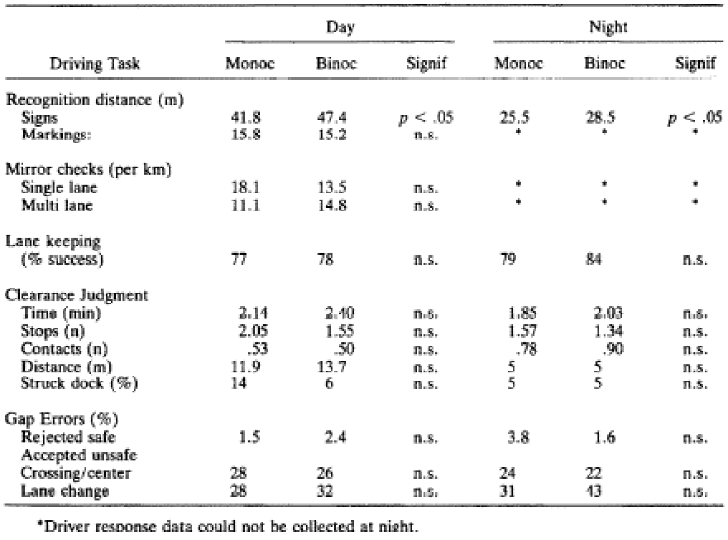
Table G-8. Summary of performance on the driving tasks for the monocular and binocular drivers



Test	Monocular		Binocular		Significance
	Mean	SD	Mean	SD	
1. Static Acuity					
Right eye	6/4.2	6/1.2	6/5.1	6/1.5	n.s.
Left eye	6/5.0	6/1.5	6/5.5	6/1.9	n.s.
Both*	6/4.6	6/1.4	6/4.2	6/1.0	n.s.
2. Dynamic visual acuity (target size)	6/7.5	6/1.1	6/7.5	6.08	n.s.
3. Visual field (0 plane ± 150°)					
Temporal	85.3	4.42	85.0	5.7	n.s.
Nasal	59.9	6.7	59.0	6.6	n.s.
Total	145.3	5.2	172.6	6.2	$p < .01$**
4. Contrast sensitivity***	11.3	2.09	10.1	1.73	$t = 2.92$ $p < .01$
5. Depth perception (error in cm.)	3.46	1.52	1.65	1.26	$t = 9.72$ $p < .01$
6. Night vision***	34.2	13.3	28.7	11.5	$t = 1.89$ $p < .05$
7. Glare resistance**	83.8	18.5	70.3	22.5	$t = 2.80$ $p < .01$
8. Glare recovery time (sec)	22.7	23	26.9	27	n.s.

*For monocular driver this entry is the same as the single-eye acuity.
**This difference is highly significant since there was no overlap at all between the two groups.
***In arbitrary units as specified on the testing device.

Table G-9. Summary of performance on the visual tasks for the monocular and binocular drivers



Driving Task	Day			Night		
	Monoc	Binoc	Signif	Monoc	Binoc	Signif
Recognition distance (m)						
Signs	41.8	47.4	$p < .05$	25.5	28.5	$p < .05$
Markings:	15.8	15.2	n.s.	*	*	*
Mirror checks (per km)						
Single lane	18.1	13.5	n.s.	*	*	*
Multi lane	11.1	14.8	n.s.	*	*	*
Lane keeping (% success)	77	78	n.s.	79	84	n.s.
Clearance Judgment						
Time (min)	2.14	2.40	n.s.	1.85	2.03	n.s.
Stops (n)	2.05	1.55	n.s.	1.57	1.34	n.s.
Contacts (n)	.53	.50	n.s.	.78	.90	n.s.
Distance (m)	11.9	13.7	n.s.	5	5	n.s.
Struck dock (%)	14	6	n.s.	5	5	n.s.
Gap Errors (%)						
Rejected safe	1.5	2.4	n.s.	3.8	1.6	n.s.
Accepted unsafe						
Crossing/center	28	26	n.s.	24	22	n.s.
Lane change	28	32	n.s.	31	43	n.s.

*Driver response data could not be collected at night.

Study Summary Tables for Key Question 2

<table>
<tr><td colspan="2">Atchison D, Pedersen C, Dain S, Wood J. Traffic signal color recognition is a problem for both protan and deutan color-vision deficiencies. Human Factors 2003;45: 495-503.</td></tr>
<tr><td>Key Questions Addressed</td><td><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td></td><td>✓</td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>Research Question</td><td>Assess response times for color deficient individuals when responding to simulated traffic signals</td></tr>
<tr><td>Study Design</td><td>Cohort</td></tr>
<tr><td>Population</td><td><table>
<tr><td>Inclusion Criteria</td><td>Individuals free of systemic and ocular diseases and not taking medication that could affect color vision or driving performance</td></tr>
<tr><td>Exclusion Criteria</td><td></td></tr>
<tr><td>Study population Characteristics</td><td><table><tr><td><u>Variable</u></td><td><u>Value</u></td></tr><tr><td>n</td><td>69</td></tr><tr><td>Ages</td><td>16-35</td></tr><tr><td>Gender M/F</td><td>100% M</td></tr></table></td></tr>
<tr><td>Generalizability to CMV drivers</td><td>Unclear</td></tr>
</table></td></tr>
<tr><td>Methods</td><td>20 control (color-normal) and 49 color-vision deficient individuals (25 deutans and 24 protans) participated in the study. Color deficient subjects were grouped by severity of deficit (Table G-10). All participants had binocular VA of 6/6 or better (11 achieving level with untinted ophthalmic corrections). All study subjects participated in a simulated driving divided attention task. Instructions were to place a 1.5-cm diameter circle viewed on a computer screen inside a 1.5 x 2 cm rectangle (moving in a straight line at varied speeds). Feedback was received upon correct insertion of the circle. In addition, participants were asked to abandon the tracking task to respond to simulated traffic light signals and identify red, green, and yellow lights by pressing an appropriate response button. Failure to respond within 3 seconds was recorded as a failure to detect. No feedback was given for responses. Each color was presented a total of 16 times.</td></tr>
<tr><td>Statistical Methods</td><td>Shapiro-Wilks test, ANOVA, paired sample t tests, Bonferroni adjustment</td></tr>
<tr><td>Quality Assessment</td><td><table>
<tr><td>Internal Validity</td><td rowspan="2">1</td><td rowspan="2">2</td><td rowspan="2">3</td><td rowspan="2">4</td><td rowspan="2">5</td><td rowspan="2">6</td><td rowspan="2">7</td><td rowspan="2">8</td><td rowspan="2">9</td><td rowspan="2">10</td></tr>
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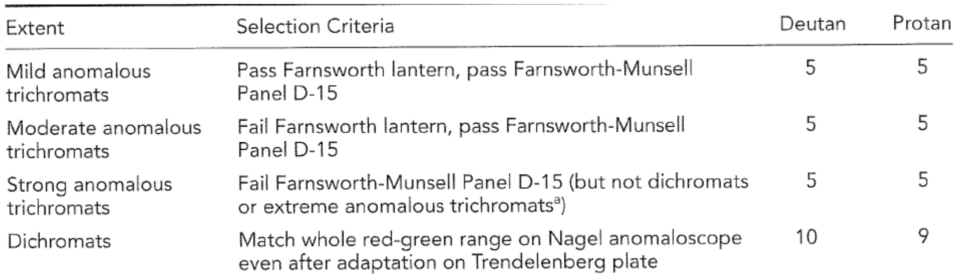
</table></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td>Response time and errors</td></tr>
<tr><td>Results</td><td>Post hoc analysis for red (R) signals shows the color-normal group has significantly shorter <u>response times</u> than all color-deficient groups except for protanomals, and that protanomals have significantly shorter reaction times than do deuteranopes. A similar pattern occurred with yellow (Y) signals except that both deuteranomals and protanomals have significantly shorter response times that do deuteranopes. A clear trend of increasing response time with increasing severity is apparent for the deuteranomalous participants for both R and Y signals (Figure G-4). Response times to green (G) signals were not affected significantly by category of defect. Analysis of effect of illumination demonstrated that color deficient groups overall were quicker to respond to brighter than dimmer lights. Results for mean percentage errors show a similar trend to response times with errors increasing as the severity of the deficiency increased. Deutans overall performed worse than protans of the same severity category with the exception of mild deutans (Figure G-5).</td></tr>
<tr><td>Authors' Comments</td><td>Response times were longer and errors more prevalent in the color deficient group versus color normal in responding to simulated traffic signals.</td></tr>
</table>

Table G-10: Color Vision Deficient Group

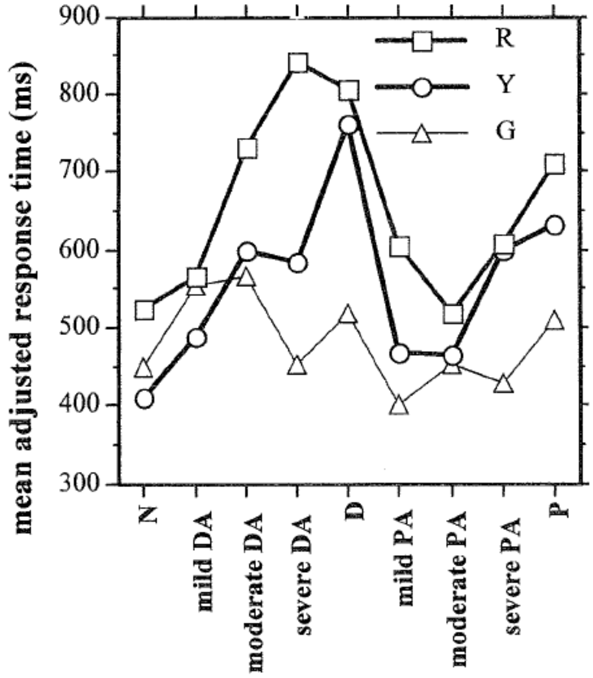


Extent	Selection Criteria	Deutan	Protan
Mild anomalous trichromats	Pass Farnsworth lantern, pass Farnsworth-Munsell Panel D-15	5	5
Moderate anomalous trichromats	Fail Farnsworth lantern, pass Farnsworth-Munsell Panel D-15	5	5
Strong anomalous trichromats	Fail Farnsworth-Munsell Panel D-15 (but not dichromats or extreme anomalous trichromats[a])	5	5
Dichromats	Match whole red-green range on Nagel anomaloscope even after adaptation on Trendelenberg plate	10	9

Note: The Farnsworth lantern contains nine pairs of colored lights. Colors involved are green, red, and white. A pass is 2 or fewer identification errors on two runs. The Farnsworth-Munsell Panel D-15 test involves arranging 15 caps in order of color; color deficients of sufficient severity make particular types of arrangement errors. The Nagel anomaloscope requires participants to match various red-green mixtures with a yellow light.

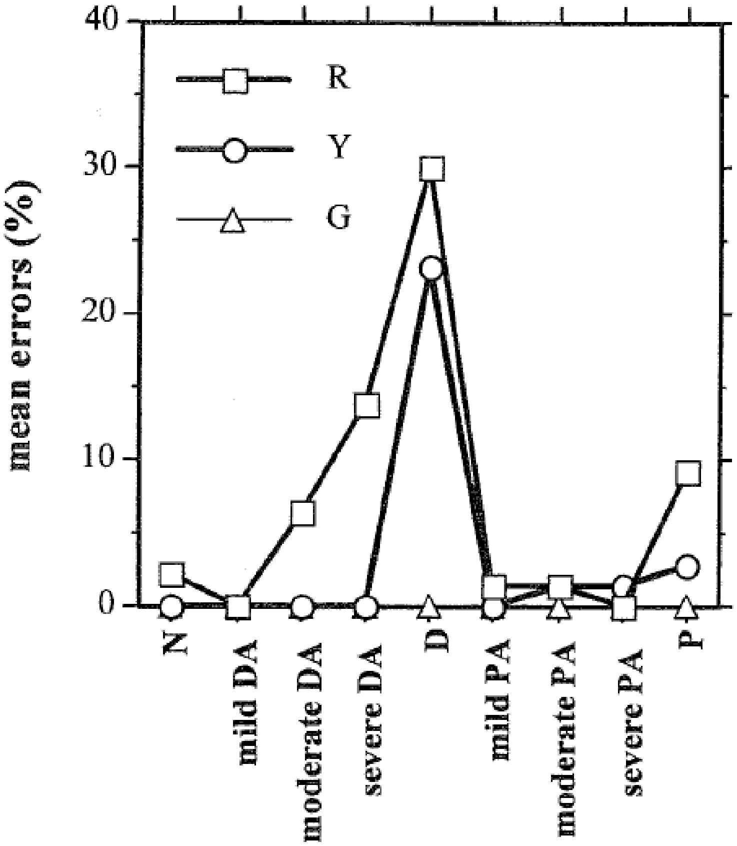
[a] Extreme anomalous trichromats are defined on three criteria. They accept matches at one extreme of the Nagel anomaloscope range, they accept the normal match, and they demonstrate high variability in the apparent extent of their deficiency. This has been described as “tuning” of their range after neutral adaptation (the Trendelenberg plate on most anomaloscopes; Pokorny et al., 1979). They were excluded from this study.

Figure G-4: Mean adjusted response time (ms)



Mean adjusted response times as a function of color-vision deficient subgroups for R, Y, and G signals. N=normals, DA = deuteranomals, D=deuteranopes, PA=protanomals, P=protanopes.

Figure G-5: Mean errors (%)



Mean errors (%) as a function of color-vision deficiency subgroups for R, Y, and G signals. Error bars have been omitted for the sake of clarity. N = normals, DA = deuteranomals, D = deuteranopes, PA = protanomals, P = protanopes

<table>
<tr><td colspan="12">Shirley S, Gauthier R. Recognition of coloured lights by color defective individuals. Canad J Ophthal 1968; 3: 244-253</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td colspan="3">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="2">5</td></tr>
<tr><td colspan="2"></td><td colspan="3">✓</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="11">Response of color blind individuals to light signals</td></tr>
<tr><td>Study Design</td><td colspan="11">Cohort</td></tr>
<tr><td rowspan="6">Population</td><td>Inclusion Criteria</td><td colspan="10">Cases were individuals recruited from an all male technical school in Canada. Controls were female nurses of similar age.</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10">Individuals with yellow-blue deficiencies</td></tr>
<tr><td rowspan="3">Study population Characteristics</td><td colspan="4"></td><td colspan="3">Cases</td><td colspan="3">Control</td></tr>
<tr><td colspan="4">n</td><td colspan="3">52</td><td colspan="3">21</td></tr>
<tr><td colspan="4">Gender M/F</td><td colspan="3">100% M</td><td colspan="3">100% F</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">Subjects were recruited from a group of 800 male students with use of Ishihara color plates. 52 (6%) of individuals had some degree of red/green color blindness. Subjects were classified by degree of color defect using the Hardy-Rand-Rittler test (Table G-11). Cases that were mildly defective but not green/red defective were reported as “unclassified”. Response to standard traffic signals was tested in addition to response to “Symbolite” shaped signals. Canadian Aviation Electronics provided investigators with three traffic signal heads mounted on a trailer. On one side each signal head consisted of 4 color faces making a total of 12 faces available in random order (Figure G-6). All lenses had 12” round surfaces with bulbs of varying watts. Two intensities of light were used to provide equal or varied brightness to color. On the other side of the trailer, everything was the same except for the shape and the size of the lenses (Figure G-7). The red light was square; green light round; and yellow was diamond shape. Surface size varied with red at 132 square inches, green at 100, and yellow at 72. Brightness varied with yellow being brightest and red the least bright. Lights were presented in similar sequence from top to bottom and left to right. Each exposure was 5 seconds. An indoor flashing light test exposed subjects to five different lights four times in random order. Intensities were either standard or reduced. Subjects were tested in a well-lit room and a dark room. The ordinary street traffic light test and Symbolite test were both performed outdoors and presented at standard and reduced intensities.</td></tr>
<tr><td>Statistical Methods</td><td colspan="11"></td></tr>
<tr><td rowspan="3">Quality Assessment</td><td>Internal Validity</td><td rowspan="2">1</td><td rowspan="2">2</td><td rowspan="2">3</td><td rowspan="2">4</td><td rowspan="2">5</td><td rowspan="2">6</td><td rowspan="2">7</td><td rowspan="2">8</td><td rowspan="2">9</td><td rowspan="2">10</td></tr>
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<tr><td>Category: Low</td><td>S</td><td>Y</td><td>N</td><td>Y</td><td>N</td><td>N</td><td>Y</td><td>Y</td><td>NR</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">Risk of crash</td></tr>
<tr><td>Results</td><td colspan="11">Results for flashing signal test are shown in Figure G-8 and Figure G-9. The influence of chromaticity (hue, saturation, intensity on recognition of flashing light) is shown in Figure G-10Figure G-10. Results demonstrate that all colors were more mistaken at a low intensity. Amber is the most mistaken color at either intensity. Blue is the least mistaken. 11% made errors at high intensity, 13% at low. Conditions of daytime and nighttime were also tested. Results demonstrate that all colors are seen better at night with the exception of red (Figure G-11). 21 normal controls made no mistakes. Further analysis indicates that the “mild deutan” could be a safe driver in a flashing lit condition. Results for street traffic signals indicate that both the protan and deutan make fewer mistakes (almost none) on the yellow when its relative brightness is increased. Again, 21 controls made no mistakes. Results for the Symbolite test indicate slightly more than 1% of mistakes being made when deciphering between various symbol traffic lights at low intensity (Figure G-12). No mistakes were made at a higher intensity for either group.</td></tr>
<tr><td>Authors’ Comments</td><td colspan="11">Color blind drivers would have less difficulty differentiating traffic signals with installation of symbol traffic lights and increased brightness of lights.</td></tr>
</table>

Table G-11: Classification of Color Defective Subjects

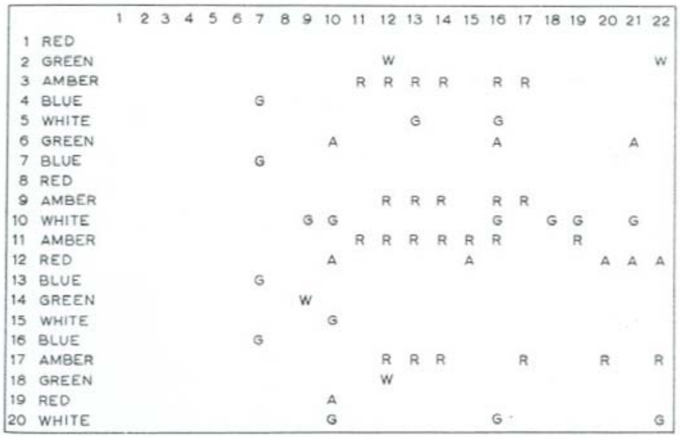
	Mild	Medium	Strong
Protans (red defective)	8	7	2
Deutans (green defective)	4	13	10
Unclassified	8		

Figure G-6: One side of trailer (similar shaped signals)

Fig. 2.—One side of trailer.

Figure G-7: Other side of trailer (different shaped signals)

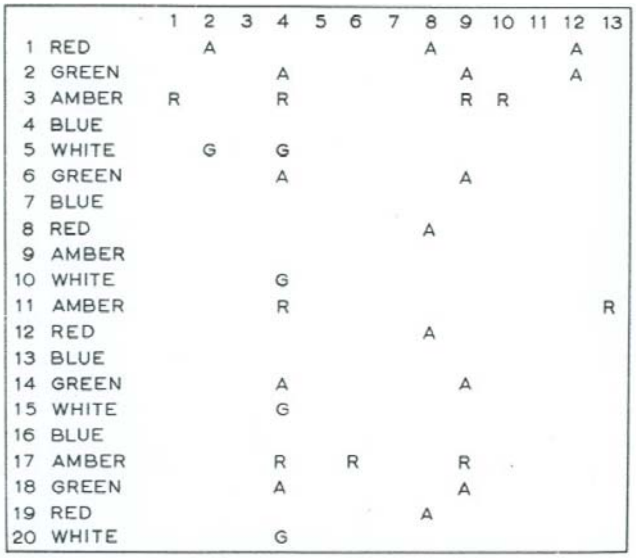
Figure G-8: Flashing Lights Test by Increasing Deuteranomaly



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1 RED																						
2 GREEN												W										W
3 AMBER											R	R	R	R		R	R					
4 BLUE							G															
5 WHITE													G			G						
6 GREEN										A						A					A	
7 BLUE							G															
8 RED																						
9 AMBER												R	R	R		R	R					
10 WHITE									G	G						G		G	G		G	
11 AMBER											R	R	R	R	R	R			R			
12 RED										A					A					A	A	A
13 BLUE							G															
14 GREEN									W													
15 WHITE										G												
16 BLUE							G															
17 AMBER												R	R	R			R			R		R
18 GREEN												W										
19 RED										A												
20 WHITE										G						G						G

Results of flashing lights test by green defective subjects arranged by increasing deuteranomaly. Ordinate represents color presented, the abcissae the wrong color named by the subjects.

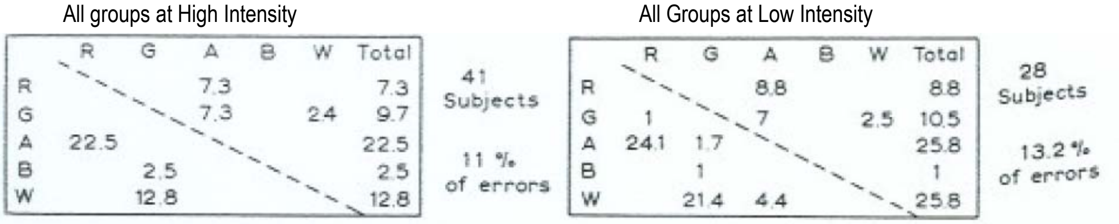
Figure G-9: Flashing Lights Test by Increasing Protanomaly



	1	2	3	4	5	6	7	8	9	10	11	12	13
1 RED		A						A				A	
2 GREEN				A					A			A	
3 AMBER	R			R					R	R			
4 BLUE													
5 WHITE		G		G									
6 GREEN				A					A				
7 BLUE													
8 RED								A					
9 AMBER													
10 WHITE				G									
11 AMBER				R									R
12 RED								A					
13 BLUE													
14 GREEN				A					A				
15 WHITE				G									
16 BLUE													
17 AMBER				R		R			R				
18 GREEN				A					A				
19 RED								A					
20 WHITE				G									

Results of flashing lights test by the red defective subjects arranged by increasing protanomaly. Ordinate represents color presented, the abcissae the wrong color named by the subject.

Figure G-10: Influence of Intensity



All groups at High Intensity

	R	G	A	B	W	Total
R			7.3			7.3
G			7.3		2.4	9.7
A	22.5					22.5
B		2.5				2.5
W		12.8				12.8

41 Subjects

11 % of errors

All Groups at Low Intensity

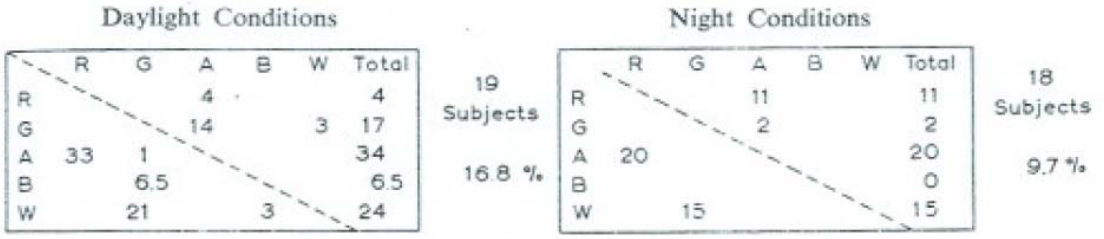
	R	G	A	B	W	Total
R			8.8			8.8
G	1		7		2.5	10.5
A	24.1	1.7				25.8
B		1				1
W		21.4	4.4			25.8

28 Subjects

13.2 % of errors

Influence of intensity on red-green color defectives. The ordinate represents the color presented, and the abcissae the wrong color named by the subjects in percentage of possible errors.

Figure G-11: Influence of Background



Daylight Conditions

	R	G	A	B	W	Total
R			4			4
G			14		3	17
A	33	1				34
B		6.5				6.5
W		21		3		24

19 Subjects

16.8 %

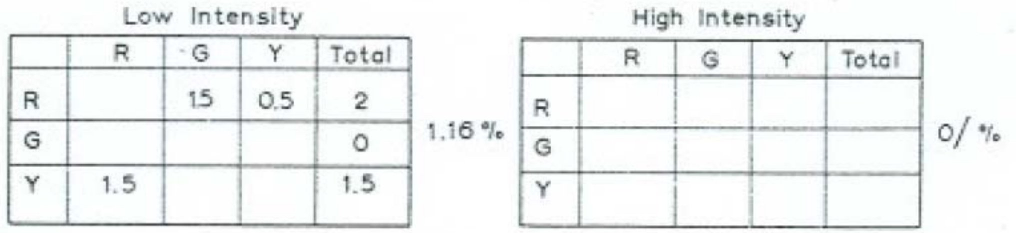
Night Conditions

	R	G	A	B	W	Total
R			11			11
G			2			2
A	20					20
B						0
W		15				15

18 Subjects

9.7 %

Figure G-12: Symbol Street Traffic Lights



Low Intensity

	R	G	Y	Total
R		1.5	0.5	2
G				0
Y	1.5			1.5

1.16 %

High Intensity

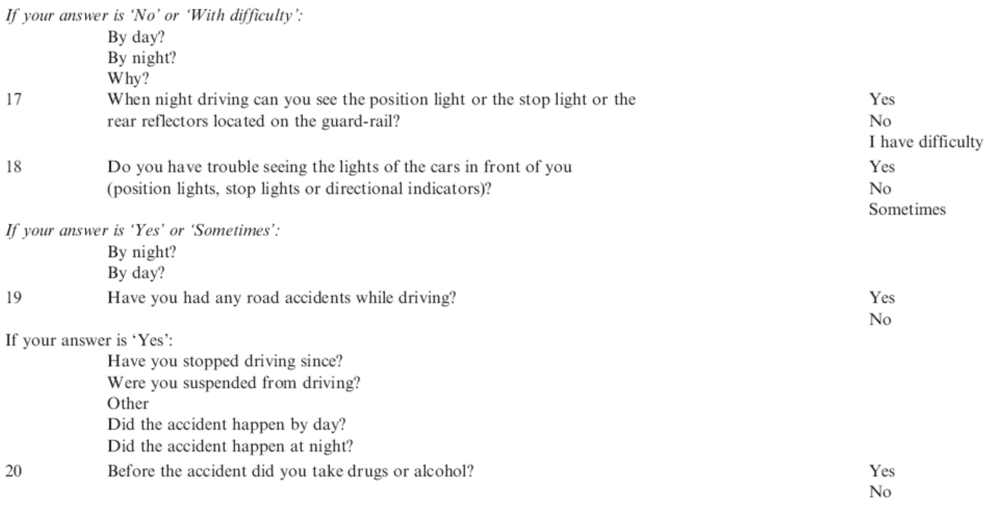
	R	G	Y	Total
R				
G				
Y				

0/ %

<table>
<tr><td colspan="12">Tagarelli A, Piro A, Tagarelli G, Lantieri P, Risso D, Olivieri R. Color blindness in everyday life and car driving. Acta Ophthalmologica Scandinavica 2004; 82: 436-442</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="3">3</td><td colspan="2">4</td><td colspan="2">5</td></tr>
<tr><td colspan="2"></td><td colspan="2">✓</td><td colspan="3"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="11">Driver performance of color blind individuals</td></tr>
<tr><td>Study Design</td><td colspan="11">Cohort</td></tr>
<tr><td rowspan="8">Population</td><td>Inclusion Criteria</td><td colspan="10">Male students screened at age 11-14 years living in the province of Cosenza, in Calabria, southern Italy with color vision or normal vision recruited from 1987-1991. Upon maturity, students must hold a drivers license but for no longer than 3 years.</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10">19 towns with populations including an Albanian ethnic minority</td></tr>
<tr><td rowspan="5">Study population Characteristics</td><td colspan="3"></td><td colspan="2"><u>Total Population</u></td><td colspan="3"><u>Color blind</u></td><td colspan="2"><u>Normal vision</u></td></tr>
<tr><td colspan="3">n</td><td colspan="2"></td><td colspan="3">151</td><td colspan="2">302</td></tr>
<tr><td colspan="3">Age (yrs) mean±SD</td><td colspan="2"></td><td colspan="3">21.4±1.3</td><td colspan="2">21.2±1.3</td></tr>
<tr><td colspan="3">Gender M/F</td><td colspan="2">100% M</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td colspan="3">Driving Experience</td><td colspan="2"></td><td colspan="3">2.7±1.2</td><td colspan="2">2.6±1.2</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">4,194 male students were screened for color defectiveness using the Ishihara test, a standard pseudoisochromatic test for identifying red-green color blindness. This tool is typically not used to grade severity of color deficiency. 268 (6%) of the students had color deficiencies. In 2001, after sufficient time for maturity, investigators tracked down 151 subjects by telephone for interviews. Questionnaire utilized (Table G-12) covered difficulties faced during everyday life including driving a car.</td></tr>
<tr><td>Statistical Methods</td><td colspan="11">Fisher test, chi-square test, Mann-Whitney <i>U</i>-test</td></tr>
<tr><td rowspan="3">Quality Assessment</td><td>Internal Validity</td><td rowspan="2">1</td><td rowspan="2">2</td><td rowspan="2">3</td><td rowspan="2">4</td><td rowspan="2">5</td><td rowspan="2">6</td><td rowspan="2">7</td><td rowspan="2">8</td><td rowspan="2">9</td><td rowspan="2">10</td></tr>
<tr><td>Score:</td></tr>
<tr><td>Category:
Moderate</td><td>S</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>N</td><td>NR</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">Driving performance</td></tr>
<tr><td>Results</td><td colspan="11">Questionnaire results are shown in Table G-13. Results indicated differences in responses in <u>everyday life</u> situations between the color-blind subjects (CS) and orthochromatic subjects (OS). The CS group had more difficulty perceiving natural color (40.4% vs 1.0%, p<0.0001), distinguishing cooking colors (31.7% vs 8.6%, p<0.0001), and clothes colors (23.8% vs1.0%, p<0.0001). Responses for <u>driving performance</u> only demonstrated significance for daytime driving preference for the CS group, (38.4% vs 6.7%, p <0.0001). The CS group stated more difficulty (4.8% vs 2.0, NS) in stopping when the orders of the colors of the traffic-lights are changed and in identifying the reflectors on the road at night (4.0% vs 2.8%, NS). Similar results were found in percent obtaining license (83.4% vs 83.8%, NS), identifying the colors of traffic light signals (98.4% vs 96.8%, NS), and involvement in car crashes (18.3% vs 19.8%, NS).</td></tr>
<tr><td>Authors' Comments</td><td colspan="11">A significant difference between color-blind and orthochromatic subjects was only demonstrated in a daytime driving preference by the color deficient individuals.</td></tr>
</table>

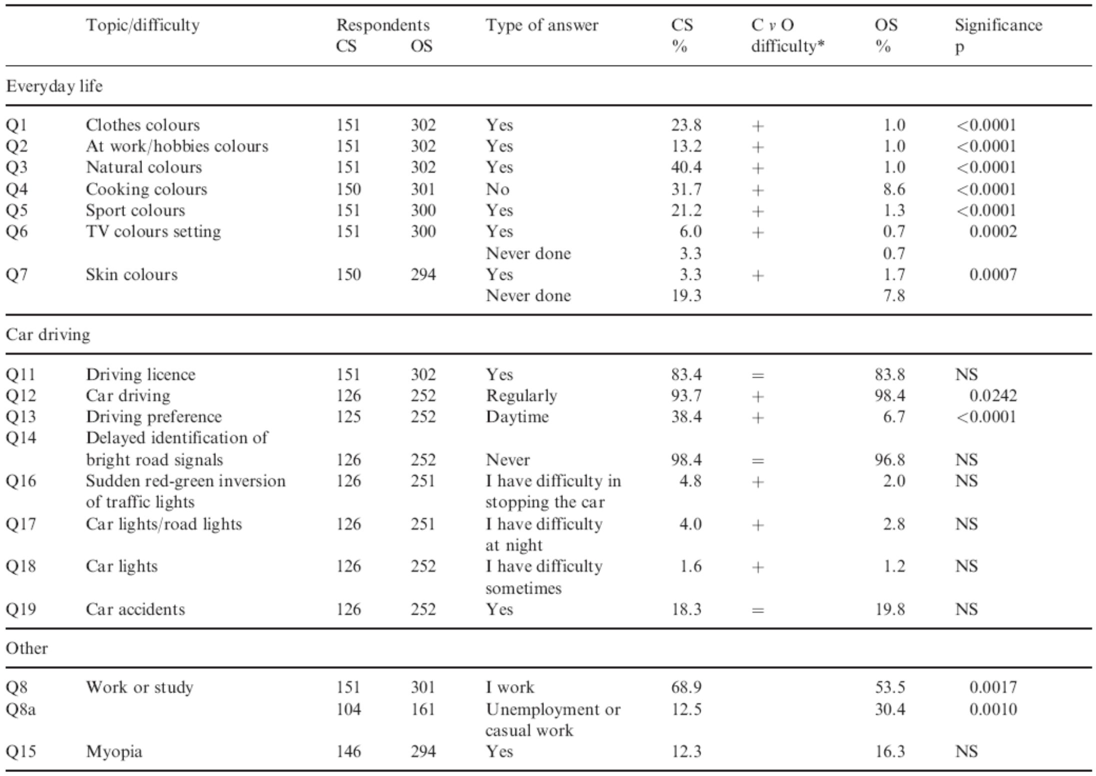
Table G-12: Study Questionnaire

1	Do you have trouble choosing the colour of your clothing or outfits such as ties and shirts?	Yes No
2	In your work and hobbies do you have trouble choosing the colours of materials?	Yes No
3	Do you have trouble choosing the colours of plants, fruits or flowers?	Yes No
4	Can you identify when meat is cooked by its colour?	Yes No
5	Do you have trouble identifying the colours of the shirts of players of any sport? (football, basketball, cycling, etc.)	Yes No
6	Do you have trouble balancing the colours on the TV?	Yes No I've never done it
7	Do you have trouble identifying skin anomalies, for example a birthmark or a rash?	Yes No I've never done it
8	Do you study or work?	I study I work
If you work:		
8a	What kind of work do you do?	Employed work Desultory work
8b	When choosing your work are you influenced by the troubles linked to colour vision?	Yes No
8c	Was some of your work choice influenced by the troubles linked to colour vision?	Yes No
8d	Does colour vision influence your daily work?	Yes No
If you study:		
8e	What is the subject of your study?	
8f	Was your choice of study influenced by trouble linked to colour vision?	Yes No
9	Do you have trouble understanding coloured diagrams?	Yes No
10	How old are you?	
11	Do you have a driving licence?	Yes No
If Yes:		
	When did you obtain the driving license?	Year
12	Do you drive?	Never When I cannot do without Regularly
If your answer is 'When I cannot do without' or 'Never':		
	Why? Don't you like driving the car? Do you prefer walking? Do you feel uncomfortable driving? Other	
13	Do you prefer driving by day or by night?	By day By night Indifferent
14	Do you identify the bright road signals late?	Never Sometimes Always
If your answer is 'Sometimes' or 'Always':		
	When do you have more trouble?	By night By day Within a short reaction time At a long distance At a low intensity
15	Do you wear glasses for short-sightedness?	Yes No
16	If the order of the colours of the traffic-lights are changed, can you stop at the red signal?	Yes No With difficulty



If your answer is 'No' or 'With difficulty':		
	By day?	
	By night?	
	Why?	
17	When night driving can you see the position light or the stop light or the rear reflectors located on the guard-rail?	Yes No I have difficulty
18	Do you have trouble seeing the lights of the cars in front of you (position lights, stop lights or directional indicators)?	Yes No Sometimes
If your answer is 'Yes' or 'Sometimes':		
	By night?	
	By day?	
19	Have you had any road accidents while driving?	Yes No
If your answer is 'Yes':		
	Have you stopped driving since?	
	Were you suspended from driving?	
	Other	
	Did the accident happen by day?	
	Did the accident happen at night?	
20	Before the accident did you take drugs or alcohol?	Yes No

Table G-13: Questionnaire Responses



	Topic/difficulty	Respondents CS	OS	Type of answer	CS %	C *v* O difficulty*	OS %	Significance p
Everyday life								
Q1	Clothes colours	151	302	Yes	23.8	+	1.0	<0.0001
Q2	At work/hobbies colours	151	302	Yes	13.2	+	1.0	<0.0001
Q3	Natural colours	151	302	Yes	40.4	+	1.0	<0.0001
Q4	Cooking colours	150	301	No	31.7	+	8.6	<0.0001
Q5	Sport colours	151	300	Yes	21.2	+	1.3	<0.0001
Q6	TV colours setting	151	300	Yes	6.0	+	0.7	0.0002
				Never done	3.3		0.7	
Q7	Skin colours	150	294	Yes	3.3	+	1.7	0.0007
				Never done	19.3		7.8	
Car driving								
Q11	Driving licence	151	302	Yes	83.4	=	83.8	NS
Q12	Car driving	126	252	Regularly	93.7	+	98.4	0.0242
Q13	Driving preference	125	252	Daytime	38.4	+	6.7	<0.0001
Q14	Delayed identification of bright road signals	126	252	Never	98.4	=	96.8	NS
Q16	Sudden red-green inversion of traffic lights	126	251	I have difficulty in stopping the car	4.8	+	2.0	NS
Q17	Car lights/road lights	126	251	I have difficulty at night	4.0	+	2.8	NS
Q18	Car lights	126	252	I have difficulty sometimes	1.6	+	1.2	NS
Q19	Car accidents	126	252	Yes	18.3	=	19.8	NS
Other								
Q8	Work or study	151	301	I work	68.9		53.5	0.0017
Q8a		104	161	Unemployment or casual work	12.5		30.4	0.0010
Q15	Myopia	146	294	Yes	12.3		16.3	NS

CS=color-blind subjects (n=151); OS=orthochromatic subjects (n=302); C v O = color-blind versus orthochromatic. Statistical significance of differences (chi-square test or Fisher exact test, two-tailed significance level 0.05, NS=not significant). Questions Q8b-f, Q9, Q20 (all answers yes or no) and Q10 (age) are not included in the table.

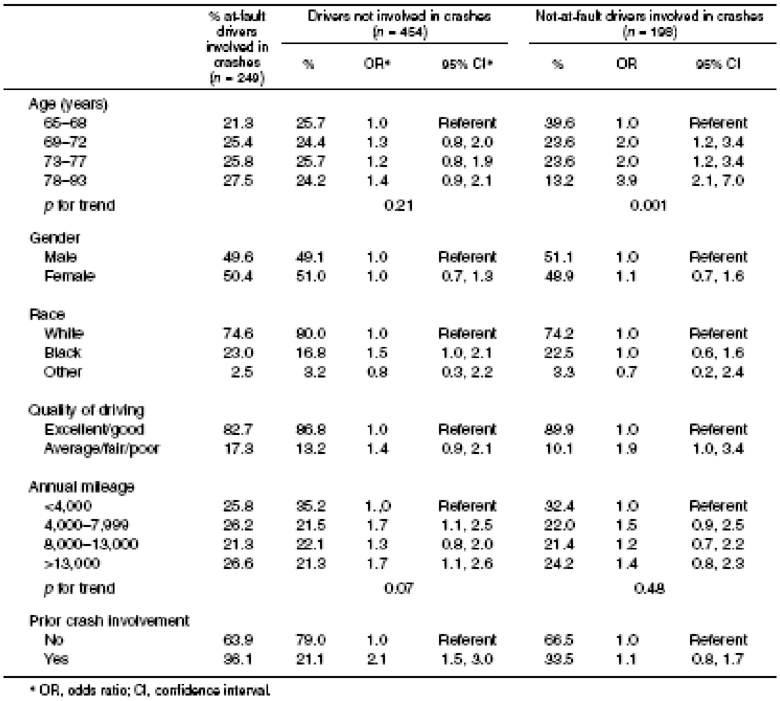
* Percentage with 5% intervals of their values overlapping were considered equals. Sign test: global (12´+´/12, p = 0.0004), everyday life (7´+´/7, p = 0.0016) and car driving (5´+´/5, p = 0.0625).

Study Summary Tables for Key Question 3

<table>
<tr><td colspan="15">McGwin G, Sims R, Pulley L, Roseman J. Relations among Chronic Medical Conditions, Medications, and Automobile Crashes in te Elderly: A Population-based Case-Control Study. American Journal of Epidemiology 2000; Vol 152 No. 5: 424-31.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3">√</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="14">What is the association between at-fault invol vement in crashes for drivers with VF loss?</td></tr>
<tr><td>Study Design</td><td colspan="14">Case-Control (Single blinded)</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="13">Cases:
Involved in at least one automobile crash between January 1 and December 31 1996
Controls:
Population abase included all residents of Mobile County, Alabama aged ≥65, having a driver's license in 1996 according to data tapes from the Alabama Department of Safety (DPS)</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13">Cases:
NR
Controls:
44 excluded because they reported stopped driving prior to 1996</td></tr>
<tr><td>Study population Characteristics</td><td colspan="13">Refer to Table G-14, Table G-15, and Table G-16 for complete details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="13">Unclear</td></tr>
<tr><td>Methods</td><td colspan="14">Participants matched nonparticipants in age or gender; racial differences were not measured
Telephone interviews conducted using the local telephone directories to obtain numbers; a random selection used for individuals who's telephone numbers were not identified using the directories
Trained interviewers used to conduct interview who were blinded to cases
Information pertaining to chronic medical conditions, medications, driving habits, visual and cognitive functioning obtained
Police records for crashes of the participants obtained by Alabama DPS
A random sample of 1,900 potential controls selected from the DPS file; more controls used then cases for future exclusion
During interview, subjects were asked if a healthcare professional told them that they had several medical conditions including but not limited to kidney disease and diabetes
Information on driving habits collected including information pertaining to crash involvement (1991-5) provided by the DPS of Alabama
Visual function assessed using a version of the National Eye Institute Visual Functioning Questionnaire (VFQ); Cognitive status assessed using the Short Portable Mental Status questionnaire</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">Crude odds ratios (OR) and 95% CI were computed
Chronic medical conditions, driving, and demographics for subjects calculated using frequency distributions
Analyses for demographic factors and annual mileage performed
Separate (unconditional) logistic regression models used to compare at-fault drivers involved in crashes with reference groups—not-at-fault drivers involved in crashes and drivers not involved in crashes
Short Portable Mental Status Questionnaire used to used to measure cognitive impairments</td></tr>
<tr><td rowspan="4">Quality assessment</td><td rowspan="2">Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td rowspan="2">Moderate</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td rowspan="2"></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">• Rate of driving exposure measured subjectively
• VF function assessed using the National Eye Institute Visual Functioning Questionnaire (VFQ)</td></tr>
<tr><td>Results</td><td colspan="14">• At-fault drivers were more likely to rate the quality of their driving as average or worse compared with not-at-fault drivers
• For self-reported vision impairment, adjusted odds ratios (OR) for far (OR=1.2, 95% CI: 0.8, 1.7) and peripheral (OR=1.4, 95% CI: 0.8, 3.0) vision impairment were both elevated
• The annual mileage of at-fault drivers was greater than that among not-at-fault drivers and drivers not involved in crashes; all subsequent analyses are mileage adjusted. The at-fault crash rate was 2.1 times (95 percent CI: 1.5, 3.0) higher in drivers who had been involved in a crash in the previous 4 years than in drivers who had not been involved in crashes</td></tr>
</table>

Authors' Comments	Study has several limitations: "All information on independent variables of interest was obtained via self-report. In particular, information on self-reported health status is a concern for a number of reasons. Subjects may be unwilling to divulge this information or simply misunderstand or forget the diagnosis." "It should also be noted that drivers involved in fatal crashes were not excluded from this study." "We were able to obtain telephone numbers for 80 percent of the eligible cases."

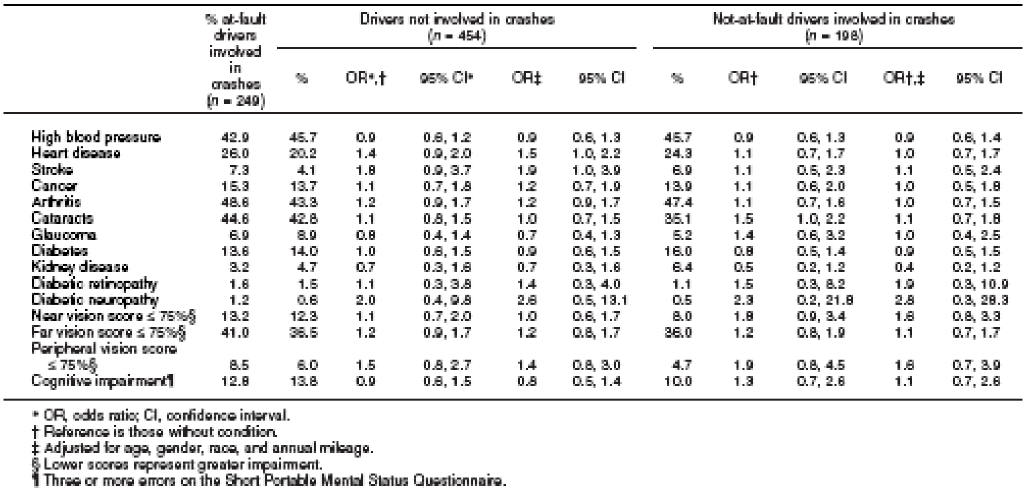
Table G-14. Demographic and driving characteristics of at-fault drivers involved in crashes, not-at-fault drivers involved in crashes, and drivers not involved in crashes, Mobile County, Alabama, Jan. - Dec. 1997



	% at-fault drivers involved in crashes (*n* = 249)	Drivers not involved in crashes (*n* = 454)			Not-at-fault drivers involved in crashes (*n* = 198)		
		%	OR*	95% CI*	%	OR	95% CI
Age (years)							
65–68	21.3	25.7	1.0	Referent	39.6	1.0	Referent
69–72	25.4	24.4	1.3	0.8, 2.0	23.6	2.0	1.2, 3.4
73–77	25.8	25.7	1.2	0.8, 1.9	23.6	2.0	1.2, 3.4
78–93	27.5	24.2	1.4	0.9, 2.1	13.2	3.9	2.1, 7.0
p for trend			0.21			0.001	
Gender							
Male	49.6	49.1	1.0	Referent	51.1	1.0	Referent
Female	50.4	51.0	1.0	0.7, 1.3	48.9	1.1	0.7, 1.6
Race							
White	74.6	80.0	1.0	Referent	74.2	1.0	Referent
Black	23.0	16.8	1.5	1.0, 2.1	22.5	1.0	0.6, 1.6
Other	2.5	3.2	0.8	0.3, 2.2	3.3	0.7	0.2, 2.4
Quality of driving							
Excellent/good	82.7	86.8	1.0	Referent	89.9	1.0	Referent
Average/fair/poor	17.3	13.2	1.4	0.9, 2.1	10.1	1.9	1.0, 3.4
Annual mileage							
<4,000	25.8	35.2	1.,0	Referent	32.4	1.0	Referent
4,000–7,999	26.2	21.5	1.7	1.1, 2.5	22.0	1.5	0.9, 2.5
8,000–13,000	21.3	22.1	1.3	0.8, 2.0	21.4	1.2	0.7, 2.2
>13,000	26.6	21.3	1.7	1.1, 2.6	24.2	1.4	0.8, 2.3
p for trend			0.07			0.48	
Prior crash involvement							
No	63.9	79.0	1.0	Referent	66.5	1.0	Referent
Yes	36.1	21.1	2.1	1.5, 3.0	33.5	1.1	0.8, 1.7

* OR, odds ratio; CI, confidence interval.

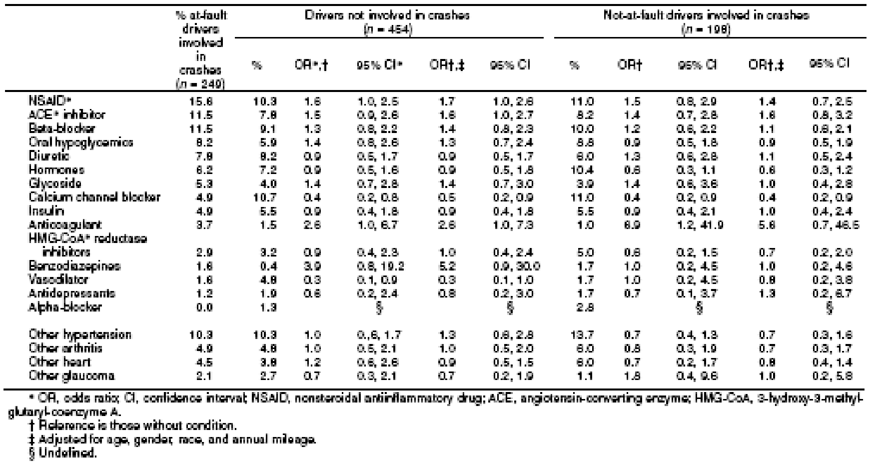
Table G-15. Medical characteristics of at-fault drivers involved in crashes, not-at-fault drivers involved in crashes, and drivers not involved in crashes from Mobile County, Alabama, January to December 1997



	% at-fault drivers involved in crashes (*n* = 249)	Drivers not involved in crashes (*n* = 454)					Not-at-fault drivers involved in crashes (*n* = 198)				
		%	OR*,†	95% CI*	OR‡	95% CI	%	OR†	95% CI	OR†,‡	95% CI
High blood pressure	42.9	45.7	0.9	0.6, 1.2	0.9	0.6, 1.3	45.7	0.9	0.6, 1.3	0.9	0.6, 1.4
Heart disease	26.0	20.2	1.4	0.9, 2.0	1.5	1.0, 2.2	24.3	1.1	0.7, 1.7	1.0	0.7, 1.7
Stroke	7.3	4.1	1.8	0.9, 3.7	1.9	1.0, 3.9	6.9	1.1	0.5, 2.3	1.1	0.5, 2.4
Cancer	15.3	13.7	1.1	0.7, 1.8	1.2	0.7, 1.9	13.9	1.1	0.6, 2.0	1.0	0.5, 1.8
Arthritis	48.6	43.3	1.2	0.9, 1.7	1.2	0.9, 1.7	47.4	1.1	0.7, 1.6	1.0	0.7, 1.5
Cataracts	44.6	42.8	1.1	0.8, 1.5	1.0	0.7, 1.5	35.1	1.5	1.0, 2.2	1.1	0.7, 1.8
Glaucoma	6.9	8.9	0.8	0.4, 1.4	0.7	0.4, 1.3	5.2	1.4	0.6, 3.2	1.0	0.4, 2.5
Diabetes	13.6	14.0	1.0	0.6, 1.5	0.9	0.6, 1.5	16.0	0.8	0.5, 1.4	0.9	0.5, 1.5
Kidney disease	3.2	4.7	0.7	0.3, 1.6	0.7	0.3, 1.6	6.4	0.5	0.2, 1.2	0.4	0.2, 1.2
Diabetic retinopathy	1.6	1.5	1.1	0.3, 3.8	1.4	0.3, 4.0	1.1	1.5	0.3, 8.2	1.9	0.3, 10.9
Diabetic neuropathy	1.2	0.6	2.0	0.4, 9.8	2.6	0.5, 13.1	0.5	2.3	0.2, 21.8	2.8	0.3, 28.3
Near vision score ≤ 75%§	13.2	12.3	1.1	0.7, 2.0	1.0	0.6, 1.7	8.0	1.8	0.9, 3.4	1.6	0.8, 3.3
Far vision score ≤ 75%§	41.0	36.5	1.2	0.9, 1.7	1.2	0.8, 1.7	36.0	1.2	0.8, 1.9	1.1	0.7, 1.7
Peripheral vision score ≤ 75%§	8.5	6.0	1.5	0.8, 2.7	1.4	0.8, 3.0	4.7	1.9	0.8, 4.5	1.6	0.7, 3.9
Cognitive impairment¶	12.8	13.8	0.9	0.6, 1.5	0.8	0.5, 1.4	10.0	1.3	0.7, 2.6	1.1	0.7, 2.6

* OR, odds ratio; CI, confidence interval.
† Reference is those without condition.
‡ Adjusted for age, gender, race, and annual mileage.
§ Lower scores represent greater impairment.
¶ Three or more errors on the Short Portable Mental Status Questionnaire.

Table G-16. Medication use of at-fault drivers involved in crashes, not-at-fault drivers involved in crashes, and drivers not involved in crashes from Mobile County, Alabama, January to December 1997



	% at-fault drivers involved in crashes (*n* = 249)	Drivers not involved in crashes (*n* = 454)					Not-at-fault drivers involved in crashes (*n* = 198)				
		%	OR*,†	95% CI*	OR†,‡	95% CI	%	OR†	95% CI	OR†,‡	95% CI
NSAID*	15.6	10.3	1.6	1.0, 2.5	1.7	1.0, 2.6	11.0	1.5	0.8, 2.9	1.4	0.7, 2.5
ACE* inhibitor	11.5	7.8	1.5	0.9, 2.6	1.6	1.0, 2.7	8.2	1.4	0.7, 2.8	1.6	0.8, 3.2
Beta-blocker	11.5	9.1	1.3	0.8, 2.2	1.4	0.8, 2.3	10.0	1.2	0.6, 2.2	1.1	0.6, 2.1
Oral hypoglycemics	8.2	5.9	1.4	0.8, 2.6	1.3	0.7, 2.4	8.8	0.9	0.5, 1.8	0.9	0.5, 1.9
Diuretic	7.8	8.2	0.9	0.5, 1.7	0.9	0.5, 1.7	6.0	1.3	0.6, 2.8	1.1	0.5, 2.4
Hormones	6.2	7.2	0.9	0.5, 1.6	0.9	0.5, 1.8	10.4	0.6	0.3, 1.1	0.6	0.3, 1.2
Glycoside	5.3	4.0	1.4	0.7, 2.8	1.4	0.7, 3.0	3.9	1.4	0.6, 3.6	1.0	0.4, 2.8
Calcium channel blocker	4.9	10.7	0.4	0.2, 0.8	0.5	0.2, 0.9	11.0	0.4	0.2, 0.9	0.4	0.2, 0.9
Insulin	4.9	5.5	0.9	0.4, 1.8	0.9	0.4, 1.8	5.5	0.9	0.4, 2.1	1.0	0.4, 2.4
Anticoagulant	3.7	1.5	2.6	1.0, 6.7	2.6	1.0, 7.3	1.0	6.9	1.2, 41.9	5.6	0.7, 46.5
HMG-CoA* reductase inhibitors	2.9	3.2	0.9	0.4, 2.3	1.0	0.4, 2.4	5.0	0.6	0.2, 1.5	0.7	0.2, 2.0
Benzodiazepines	1.6	0.4	3.9	0.8, 19.2	5.2	0.9, 30.0	1.7	1.0	0.2, 4.5	1.0	0.2, 4.6
Vasodilator	1.6	4.8	0.3	0.1, 0.9	0.3	0.1, 1.0	1.7	1.0	0.2, 4.5	0.8	0.2, 3.8
Antidepressants	1.2	1.9	0.6	0.2, 2.4	0.8	0.2, 3.0	1.7	0.7	0.1, 3.7	1.3	0.2, 6.7
Alpha-blocker	0.0	1.3		§		§	2.8		§		§
Other hypertension	10.3	10.3	1.0	0.,6, 1.7	1.3	0.6, 2.8	13.7	0.7	0.4, 1.3	0.7	0.3, 1.6
Other arthritis	4.9	4.8	1.0	0.5, 2.1	1.0	0.5, 2.0	6.0	0.8	0.3, 1.9	0.7	0.3, 1.7
Other heart	4.5	3.8	1.2	0.6, 2.6	0.9	0.5, 1.5	6.0	0.7	0.2, 1.7	0.8	0.4, 1.4
Other glaucoma	2.1	2.7	0.7	0.3, 2.1	0.7	0.2, 1.9	1.1	1.8	0.4, 9.6	1.0	0.2, 5.8

* OR, odds ratio; CI, confidence interval; NSAID, nonsteroidal antiinflammatory drug; ACE, angiotensin-converting enzyme; HMG-CoA, 3-hydroxy-3-methyl-glutaryl-coenzyme A.

† Reference is those without condition.

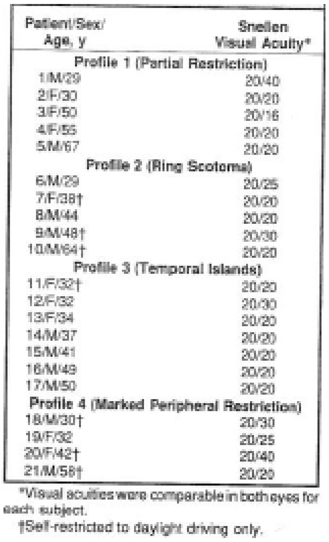
‡ Adjusted for age, gender, race, and annual mileage.

§ Undefined.

<table>
<tr><td colspan="3">Szlyk J. Alexander K, Severing K, Fishman G. Assessment of Driving Performance in Patients with Retinitis Pigmentosa. Arch Ophthalmol 1992; 110: 1709-13.</td></tr>
<tr><td>Key Questions Addressed</td><td colspan="2"><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td></td><td></td><td>√</td><td></td><td></td></tr></table></td></tr>
<tr><td>Research Question</td><td colspan="2">Is there a greater crash risk for individuals with Retinitis Pigmentosa (RP) and VF loss compared to drivers with normal vision?</td></tr>
<tr><td>Study Design</td><td colspan="2">Case-Control</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td>Cases:
Individuals with RP diagnosis with a VA (VA) of 20/40 or better
Absence of astrophic or cystic-appearing forveal lesions
Minimal or no posterior subcapsular cataracts
A minimum of 1000 miles driven per year
Controls:
NR</td></tr>
<tr><td>Exclusion Criteria</td><td>Cases/Controls:
NR</td></tr>
<tr><td>Study population Characteristics</td><td><table><tr><td>Measurement</td><td>Cases</td><td>Controls</td></tr><tr><td>Population (n)</td><td>21</td><td>31</td></tr><tr><td>Gender (m/f)</td><td>12 m/9 f</td><td>15 m/16 f</td></tr><tr><td>Age, years (mean ± SD</td><td>29-67 (42.3±11.8)</td><td>21-64 (39.0±12.4)</td></tr></table></td></tr>
<tr><td>Generalizability to CMV drivers</td><td>Unclear</td></tr>
<tr><td>Methods</td><td colspan="2">Control group had normal vision and held an unrestricted driver's license and drove regularly
Majority of control group were relatives and friends of the subjects with RP; remaining 22% were employees of the university of Illinois in Chicago
RP and control groups did not differ in age, or gender; self reports indicated no differences found in miles driven per year—groups did not differ in either state anxiety as measured with the State-Trait Anxiety Inventory (consulting psychologists press inc.)
Various tests performed including the VF measures, driving assessment system (interactive simulator), simulator performance indexes and crash measure
• VF measures involved binocular VF maps produced by merging monocular fields of each subject with RP. Refer to Figure G-13 for binocular fields; Table G- 17 for characteristics of RP group
Driving simulator analyzed speed along with braking pedal pressure, number of lane crossings and brake response time
The simulator was controlled by a microprocessor which analyzed mean speed, mean braking pedal pressure and number of lane crossings (boundary); subjects able to monitor speed using speedometer, flow fields created by passing landscape and traffic, turning resistance on steering wheel and alterations in engine sound
"Accidents" reported using a self-reported questionnaire and/or state records of accidents
Accidents defined as crashes with moving or stationary objects resulting in property damage; self reported crashed categorized as either peripheral or nonperipheral; daytime or nighttime
All collision with road obstacles on the simulator were recorded as crashes on the microprocessor</td></tr>
<tr><td>Statistical Methods</td><td colspan="2">Kolmogorov-Smirnov two-sample test used to measure demographic comparisons; z scores used
• Self reported crashes and simulators were analyzed separately by a Bayesion method comparing proportions</td></tr>
<tr><td>Quality assessment</td><td colspan="2"><table><tr><td rowspan="2">Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr><tr><td>S</td><td>S</td><td>S</td><td>S</td><td>S</td><td>S</td><td>S</td><td>S</td><td>S</td><td>S</td><td></td><td></td><td></td></tr><tr><td rowspan="2">Moderate</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="2">• Driving performance measured including number of crashes in a 5 year period and response time in regards to driving
• Brake response time recorded using driving simulator
• Crash risk assessed using driving simulator
• Spearman correlations measured differences between VF and number of crashes for RP subjects</td></tr>
<tr><td>Results</td><td colspan="2">• Table G-18 shows crash data for subjects with RP and normal. Self reported crashes had a greater proportion of RP population (.005 probability)(19/23 or 88%) than normal subjects (31%)
• 5 minute test period showed 21 subjects with RP for a total o f4 simulator crashes; 31 of control group had none
• Logistic regression analyses on data from RP subjects completed; Table G 19 displays results
• Correlations between VFs and simulator indexes for the patients with Retinitis Pigmentosa (Table G-20).</td></tr>
</table>

	- Spearman correlations measuring differences for RP group between VF and number of crashes shown in Table G-21; correlations significant for the VF measures used - Binocular VF profiles of subjects with RP measured with Goldmann V-4-e target as shown in Figure G- 13 - Simulator picture shown in Figure G-14; picture illustrates operator's view - Relationship between horizontal field extend (III-4-e) and self reported crashes for RP subjects shown in Figure G-15
Authors' Comments	- "…we were not able to obtain state accident data from all subjects with RP or control subjects, either because a number of our subjects (five subjects with RP and eight controls) did not have Illinois licenses or because they chose not to allow us access to their records (four subjects with RP and four controls) - "There was a statistically significant correlation between the severity of the field loss and number of crashes. Consequently our results demonstrate that VF extent is a primary correlate of automotive accidents in this group of subjects with RP."

Table G- 17 Characteristics of Patients with Retinitis Pigmentosa

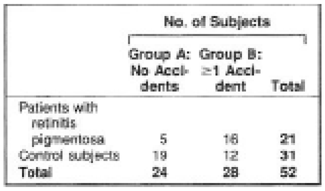


Patient/Sex/ Age, y	Snellen Visual Acuity*
Profile 1 (Partial Restriction)	
1/M/29	20/40
2/F/30	20/20
3/F/50	20/16
4/F/55	20/20
5/M/67	20/20
Profile 2 (Ring Scotoma)	
6/M/29	20/25
7/F/38†	20/20
8/M/44	20/20
9/M/48†	20/30
10/M/64†	20/20
Profile 3 (Temporal Islands)	
11/F/32†	20/20
12/F/32	20/30
13/F/34	20/20
14/M/37	20/20
15/M/41	20/20
16/M/49	20/20
17/M/50	20/20
Profile 4 (Marked Peripheral Restriction)	
18/M/30†	20/30
19/F/32	20/25
20/F/42†	20/40
21/M/58†	20/20

*Visual acuities were comparable in both eyes for each subject.

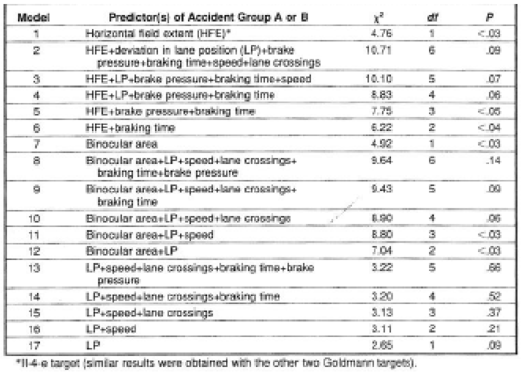
†Self-restricted to daylight driving only.

Table G-18. Self-Reported Accidents



	No. of Subjects		
	Group A: No Accidents	Group B: ≥1 Accident	Total
Patients with retinitis pigmentosa	5	16	21
Control subjects	19	12	31
Total	24	28	52

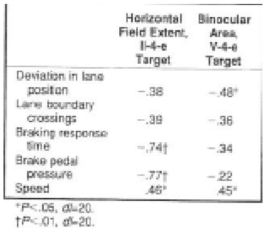
Table G 19. Logistic Regression Analysis for Patients with Retinitis Pigmentosa



Model	Predictor(s) of Accident Group A or B	χ^2	df	P
1	Horizontal field extent (HFE)*	4.76	1	<.03
2	HFE+deviation in lane position (LP)+brake pressure+braking time+speed+lane crossings	10.71	6	.09
3	HFE+LP+brake pressure+braking time+speed	10.10	5	.07
4	HFE+LP+brake pressure+braking time	8.83	4	.06
5	HFE+brake pressure+braking time	7.75	3	<.05
6	HFE+braking time	6.22	2	<.04
7	Binocular area	4.92	1	<.03
8	Binocular area+LP+speed+lane crossings+braking time+brake pressure	9.64	6	.14
9	Binocular area+LP+speed+lane crossings+braking time	9.43	5	.09
10	Binocular area+LP+speed+lane crossings	8.90	4	.06
11	Binocular area+LP+speed	8.80	3	<.03
12	Binocular area+LP	7.04	2	<.03
13	LP+speed+lane crossings+braking time+brake pressure	3.22	5	.66
14	LP+speed+lane crossings+braking time	3.20	4	.52
15	LP+speed+lane crossings	3.13	3	.37
16	LP+speed	3.11	2	.21
17	LP	2.65	1	.09

*II-4-e target (similar results were obtained with the other two Goldmann targets).

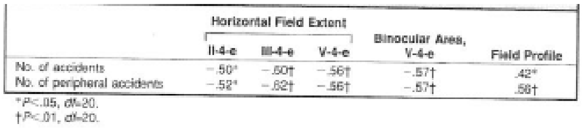
Table G-20. Correlations Between VFs and Simulator indexes for the patients with Retinitis Pigmentosa



	Horizontal Field Extent, II-4-e Target	Binocular Area, V-4-e Target
Deviation in lane position	−.38	−.48*
Lane boundary crossings	−.39	−.36
Braking response time	−.74†	−.34
Brake pedal pressure	−.77†	−.22
Speed	.46*	.45*

*P<.05, df=20.
†P<.01, df=20.

Table G-21. Spearman Correlations Between VF Measures and Self-Reported Accidents for the Patients with Retinitis Pigmentosa



	Horizontal Field Extent			Binocular Area,	
	II-4-e	III-4-e	V-4-e	V-4-e	Field Profile
No. of accidents	−.50*	−.60†	−.56†	−.57†	.42*
No. of peripheral accidents	−.52*	−.62†	−.56†	−.57†	.56†

*P<.05, df=20.
†P<.01, df=20.

Figure G- 13. Representatives binocular VF profiles of the subjects with retinitis pigmentosa measured with a Goldman V-4-e target

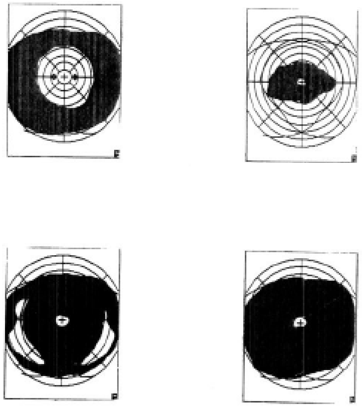


Figure G-14. Left, the configuration of the driving simulator, illustrating the subject's location and the video display

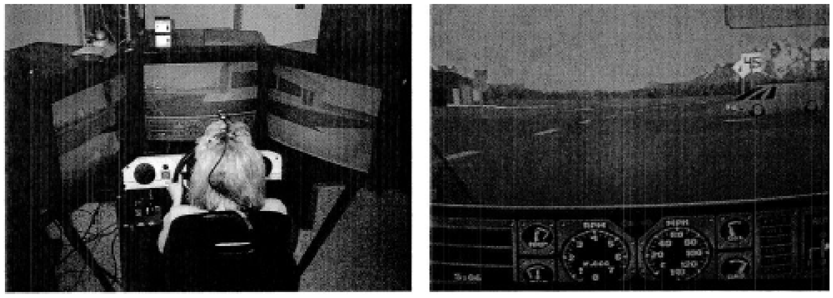
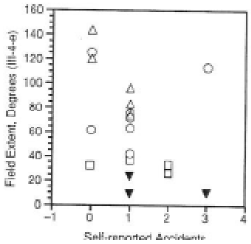


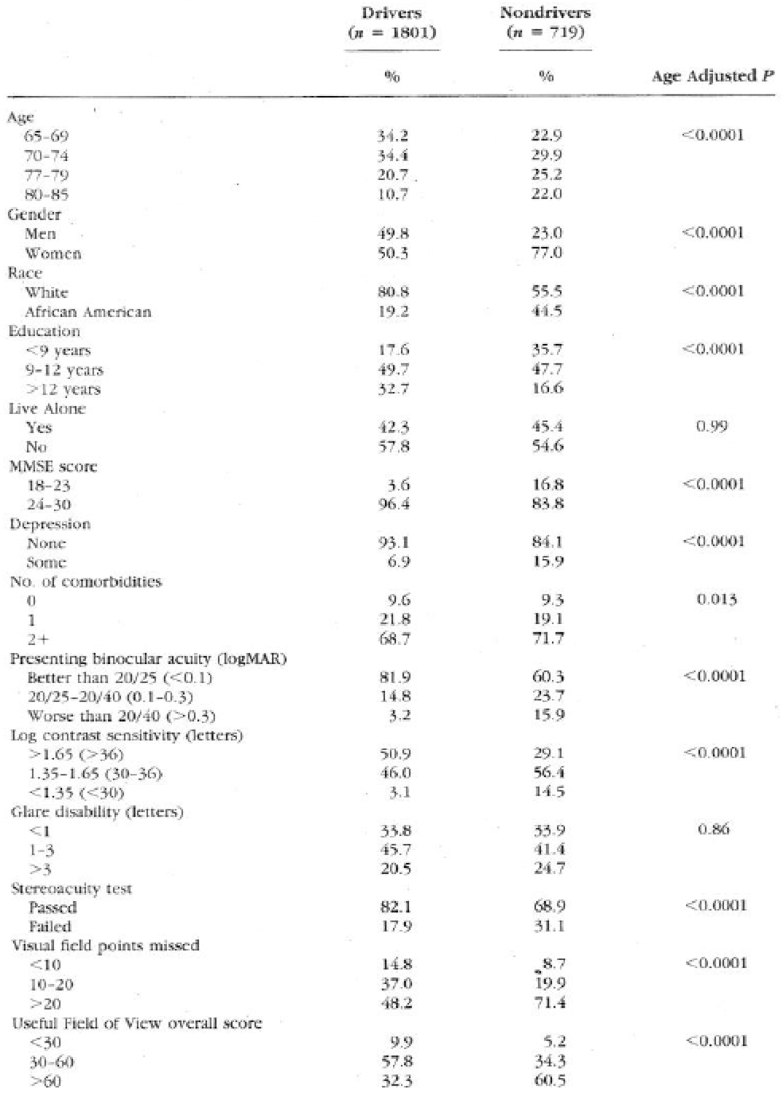
Figure G-15. Horizontal field extent vs number of self-reported accidents for the subjects with retinitis pigmentosa



<table>
<tr><td colspan="7">Rubin G, Ng ESW, Bandeen-Roche K, Keyle PM, Freeman EE, West SK, SEE Project Team. A Prospective, Population-Based Study of the Role of Visual Impairment in Motor Vehicle Crashes among older Drivers: the SEE study. Investigative Ophthalmology and Visual Science 2007; Vol 48 No 4: 1483-91.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="2"></td><td></td><td>✓</td><td></td><td></td></tr>
<tr><td>Research Question</td><td colspan="6">To determine the role of vision and visual attention factor in automobile crash involvement</td></tr>
<tr><td>Study Design</td><td colspan="6">Prospective Cohort</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="5">Participants had to score higher than 17 on the Mini-Mental State Examination (MMSE) and be able to travel to the SEE clinic for examination</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="5">NR</td></tr>
<tr><td>Study population Characteristics</td><td colspan="5"><table>
<tr><th>Characteristics</th><th>Drivers</th><th>Nondrivers</th></tr>
<tr><td>Population (n)</td><td>1,801</td><td>719</td></tr>
<tr><td>Age</td><td>65-65</td><td>65-85</td></tr>
<tr><td>Gender (m/f)</td><td>49.8% m/50.3 f</td><td>23% m/77% f</td></tr>
</table>Refer to Table G-22 for complete details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="5">Unclear</td></tr>
<tr><td>Methods</td><td colspan="6">• Refer to Figure G-16 for characterization of eligible drivers
Sample included 100% of the identified African American residents and an age-stratified random sample of 58% white residents
Informed consent obtained using forms approved by the institutional human experimentation committee, and a 2 hour in-home interview administered followed by a 4-5 hour clinic examination
Almost ½ of eligible subjects who refused to participate in the study agreed to answer a brief subset of the home questionnaire
SEE study participants were invited to return for follow-up examinations at 2, 6 and 8 years after baseline examination; records of participants who did not return for follow-up were examine to determine whether they had died or been admitted to a nursing facility before the end of the crash reporting period, December 31, 1997
Cognitive status assessed with MMSE and number of comorbidities was elicited with a structured medical history questionnaire, both during the home interview; comorbidities included arthritis, broken hip, cardiovascular disease (CVD), hypertension, diabetes, emphysema, asthma, Parkinson’s disease, cancer and stroke
Depression assessed using a General health questionnaire
Several areas of vision tested and measured including:
VA
Contrast sensitivity
Glare sensitivity
Stereoacuity
VFs
Test of attention
VFs were tested separately in each eye by using the 81-point single intensity screening test strategy on the Humphrey Field Analyzer field with a single target intensity of 24 dB
If the fixation losses, false negative, or false positives exceeded 20%, the test was topped and the participant was reinstructed before re-testing
Field tests scored two ways:
Number of points missed counted
VFs for the two eyes were combined according to method described in Turano et al
Binocular field composed of 96 pints that were subdivided into the central region and the upper and lower peripheral regions
Number of miles driven during the year before the interviewed obtained; Individuals reporting fewer than 500 mile driven in prior year excluded from analyses
Follow-up home interview was conducted 2 years later to determine changes to driving status
Crash data obtained from Maryland Automated Accident Reporting System (MAARS) for the years 1991 to 1997 for all subjects licensed to drive in Maryland</td></tr>
<tr><td>Statistical Methods</td><td colspan="6">Survival analysis used to determine relative risk of being involved in crash regarding measured variables including vision
Cox proportional hazard models used to analyze time from baseline examination to first crash
Data censored if subjects stopped driving, died or moved to a nursing facility
Separate models were fit with and without adjustment for four aspects of driving behavior:
Mile driven before baseline examination</td></tr>
</table>

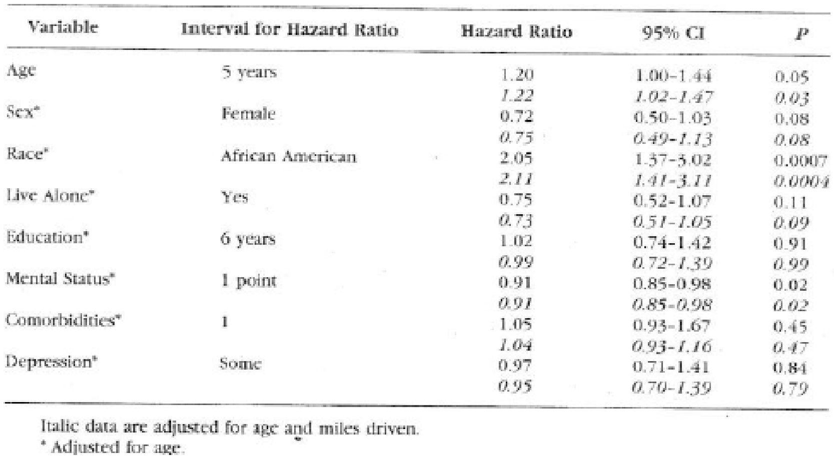
<table>
<tr><td></td><td colspan="14">Reduction fewer than 3000 miles per year at baseline
Cessation of night driving during follow-up among night drivers at baseline
Log-log plots, residual plats and global test were used to check the proportional hazards assumption
Analyses performed with SAS/JMP version 5.1; Cary, NC software</td></tr>
<tr><td rowspan="4">Quality assessment</td><td rowspan="2">Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>S</td><td>S</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Moderate</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">• Visual function assessed including VA, VF, contrast and glare sensitivity
• Crash risk measured according to vision</td></tr>
<tr><td>Results</td><td colspan="14">• Age at baseline was a predictor of crash risk (hazard ration (HR=1.20 per 5 years of age; 95% CI =1.00-1.44, p<0.05). More details in Table G-23
• Nearly 13% of the participants (n=227) failed the stereoacuity screening test at 457 arc sec and categorized as stereodeficient; Figure G-17 show unadjusted crash rates for each quintile of the remaining vision variables and UFOV
• Table G-24 presents the crash risk for each of the vision variables individually and adjusted for demographics and health status variables
• HRs are computed for a 15 letter loss of VA (0.3 logMAR or a doubling of the visual angle), a six-letter worsening of contrast or glare sensitivity (0.3 logCS or doubling of threshold contrast) and a loss of 15 points in VFs; values derived from previous studies showing that these levels of vision loss are associated with an increase in self reported disability or a measurable decline in performance
• Acuity at normal and low luminance, contrast sensitivity and stereoacuity were not significant predictors of crash risk (p> 0.1)
• Glare sensitivity and binocular VFs were associated with crash risk
• <i>The VF data analyzed to determine which part of the field was most critical for crash risk: central and upper peripheral fields no associated with crash risk (p> 0.05); significant reduction in crash risk with lower peripheral field loss < 10 points (HR=0.44, p=0.03) and significant increase in risk with lower field loss ≥10 points (HR= 1.96; p=0.01)</i>
• UFOV data available for 857 eligible drivers; Figure G-17
• Table G-24 shows results adjusted for demographic and health status; UFOV score associated with crash risk (HR=2.12, p=0.002); worse UFOV score associated with increased crash risk</td></tr>
<tr><td>Authors' Comments</td><td colspan="14">• “VFs are known to play an important role in mobility, and we have shown that field loss is associated with a decline in mobility performance and driving cessation in the SEE cohort.”
• “We found that UFOV is a strong predictor of crash involvement.”</td></tr>
</table>

Table G-22. Baseline Characteristics of Drivers and Nondrivers



	Drivers (n = 1801) %	Nondrivers (n = 719) %	Age Adjusted P
Age			
65-69	34.2	22.9	<0.0001
70-74	34.4	29.9	
77-79	20.7	25.2	
80-85	10.7	22.0	
Gender			
Men	49.8	23.0	<0.0001
Women	50.3	77.0	
Race			
White	80.8	55.5	<0.0001
African American	19.2	44.5	
Education			
<9 years	17.6	35.7	<0.0001
9-12 years	49.7	47.7	
>12 years	32.7	16.6	
Live Alone			
Yes	42.3	45.4	0.99
No	57.8	54.6	
MMSE score			
18-23	3.6	16.8	<0.0001
24-30	96.4	83.8	
Depression			
None	93.1	84.1	<0.0001
Some	6.9	15.9	
No. of comorbidities			
0	9.6	9.3	0.013
1	21.8	19.1	
2+	68.7	71.7	
Presenting binocular acuity (logMAR)			
Better than 20/25 (<0.1)	81.9	60.3	<0.0001
20/25-20/40 (0.1-0.3)	14.8	23.7	
Worse than 20/40 (>0.3)	3.2	15.9	
Log contrast sensitivity (letters)			
>1.65 (>36)	50.9	29.1	<0.0001
1.35-1.65 (30-36)	46.0	56.4	
<1.35 (<30)	3.1	14.5	
Glare disability (letters)			
<1	33.8	33.9	0.86
1-3	45.7	41.4	
>3	20.5	24.7	
Stereoacuity test			
Passed	82.1	68.9	<0.0001
Failed	17.9	31.1	
Visual field points missed			
<10	14.8	8.7	<0.0001
10-20	37.0	19.9	
>20	48.2	71.4	
Useful Field of View overall score			
<30	9.9	5.2	<0.0001
30-60	57.8	34.3	
>60	32.3	60.5	

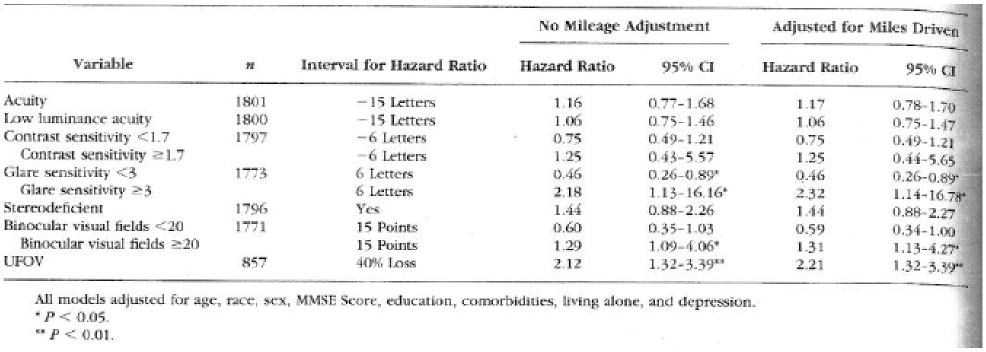
Table G-23. Analysis of Baseline Characteristics



Variable	Interval for Hazard Ratio	Hazard Ratio	95% CI	P
Age	5 years	1.20	1.00-1.44	0.05
		1.22	*1.02-1.47*	*0.03*
Sex*	Female	0.72	0.50-1.03	0.08
		0.75	*0.49-1.13*	*0.08*
Race*	African American	2.05	1.37-3.02	0.0007
		2.11	*1.41-3.11*	*0.0004*
Live Alone*	Yes	0.75	0.52-1.07	0.11
		0.73	*0.51-1.05*	*0.09*
Education*	6 years	1.02	0.74-1.42	0.91
		0.99	*0.72-1.39*	*0.99*
Mental Status*	1 point	0.91	0.85-0.98	0.02
		0.91	*0.85-0.98*	*0.02*
Comorbidities*	1	1.05	0.93-1.67	0.45
		1.04	*0.93-1.16*	*0.47*
Depression*	Some	0.97	0.71-1.41	0.84
		0.95	*0.70-1.39*	*0.79*

Italic data are adjusted for age and miles driven.
* Adjusted for age.

Table G-24. Analysis of Vision Risk Factors



			No Mileage Adjustment		Adjusted for Miles Driven	
Variable	n	Interval for Hazard Ratio	Hazard Ratio	95% CI	Hazard Ratio	95% CI
Acuity	1801	−15 Letters	1.16	0.77-1.68	1.17	0.78-1.70
Low luminance acuity	1800	−15 Letters	1.06	0.75-1.46	1.06	0.75-1.47
Contrast sensitivity <1.7	1797	−6 Letters	0.75	0.49-1.21	0.75	0.49-1.21
Contrast sensitivity ≥1.7		−6 Letters	1.25	0.43-5.57	1.25	0.44-5.65
Glare sensitivity <3	1773	6 Letters	0.46	0.26-0.89*	0.46	0.26-0.89*
Glare sensitivity ≥3		6 Letters	2.18	1.13-16.16*	2.32	1.14-16.78*
Stereodeficient	1796	Yes	1.44	0.88-2.26	1.44	0.88-2.27
Binocular visual fields <20	1771	15 Points	0.60	0.35-1.03	0.59	0.34-1.00
Binocular visual fields ≥20		15 Points	1.29	1.09-4.06*	1.31	1.13-4.27*
UFOV	857	40% Loss	2.12	1.32-3.39**	2.21	1.32-3.39**

All models adjusted for age, race, sex, MMSE Score, education, comorbidities, living alone, and depression.

* $P < 0.05$.

** $P < 0.01$.

Figure G-16. Characterization of the sample of eligible drivers

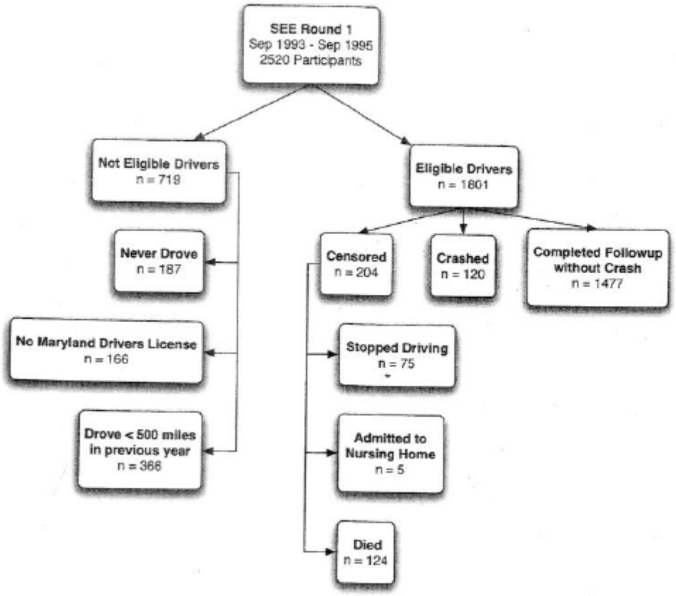
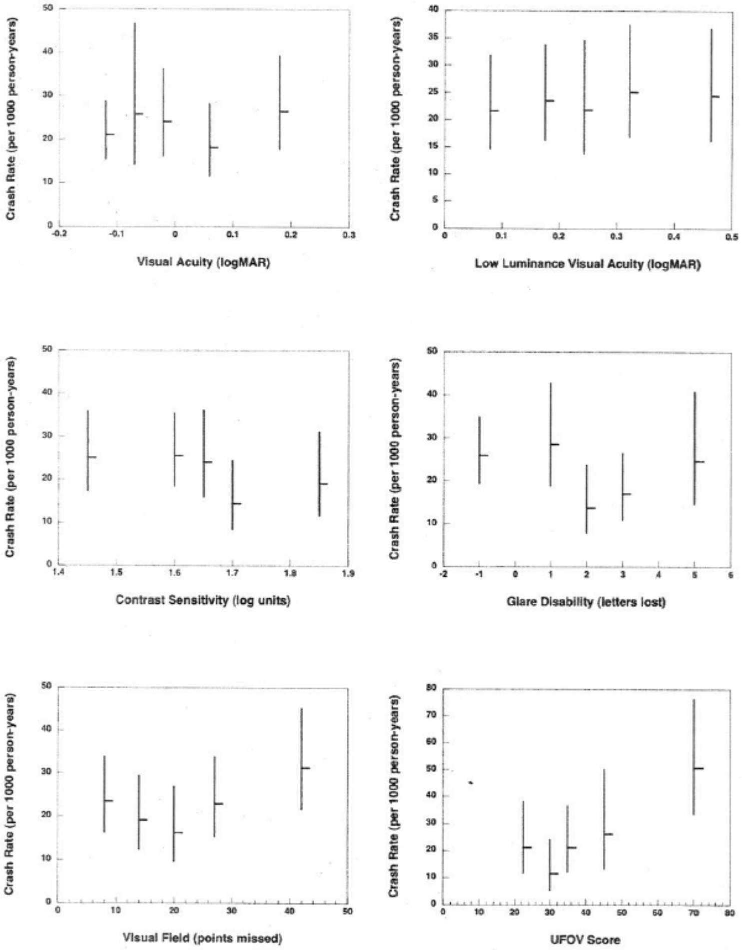


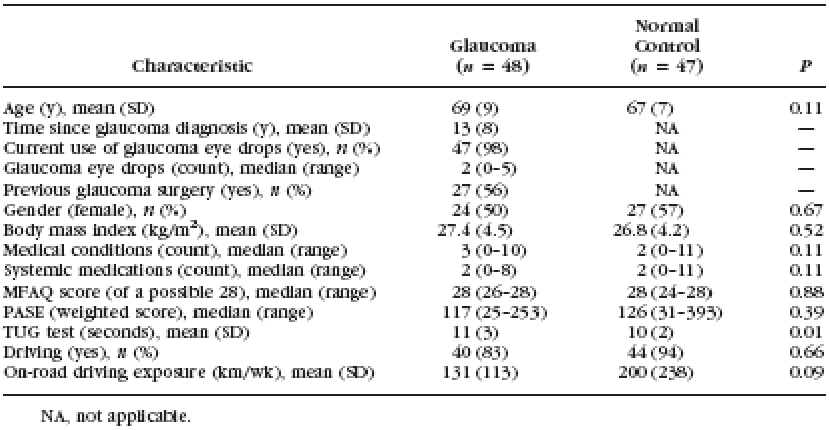
Figure G-17. Plots showing unadjusted crash rates for each of the vision tests and the UFOV test, divided into quintiles



<table>
<tr><td colspan="7">Haymes S, LeBlanc R, Nicolela M, Chiasson L, Chauban B. Risk of Falls and Motor Vehicle Collisions in Glaucoma. Ophthalmology & Visual Science 2007: Volume 48, No. 3: 1149-1155.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="2"></td><td></td><td>√</td><td></td><td></td></tr>
<tr><td>Research Question</td><td colspan="6">To investigate the risk of falls and motor vehicle collisions (MVCs) in subjects with glaucoma</td></tr>
<tr><td>Study Design</td><td colspan="6">Case-Control</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="5">Cases:
Included if a glaucoma specialists diagnosed glaucoma, glaucomatous optic disc damage (e.g., notching or progressing thinning of the neuroretinal rim), and corresponding VF damage detected with standard automated perimetry
Controls:
Normal ocular examination and VA better than 0.30 logMAR (20/40) in each eye
Individuals with glaucoma were recruited from the Glaucoma Clinic of the Eye Care Centre, Queen Elizabeth II Health Sciences Centre (Halifax, Nova Scotia)
All subjects had to be older than 50 years</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="5">Cases/Controls:
Individuals in nursing home residence, use of a mobility device, cognitive impairment (more than two errors on the Short Portable Mental Status Questionnaire), systematic disease or medication known to affect the VF, cataract (worse than grade II using the Lens Opacities Classification System II), and concomitant ocular disease</td></tr>
<tr><td>Study population Characteristics</td><td colspan="5"><table>
<tr><th>Measurement</th><th>Cases</th><th>Controls</th></tr>
<tr><td>Population (n)</td><td>48</td><td>47</td></tr>
<tr><td>Age (years), mean (SD)</td><td>69 (9)</td><td>67 (7)</td></tr>
<tr><td>Gender (female), n (%)</td><td>24 (50)</td><td>27 (57)</td></tr>
<tr><td>Refer to Table G-25 for complete details</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="5">Unclear</td></tr>
<tr><td>Methods</td><td colspan="6">Demographic and medical data collected from subjects by using structured questions and checklists that included age, gender body mass index (BMI), medical conditions and systemic medications
Data on glaucoma duration, eye drops and glaucoma surgery were obtained from clinical records
Protocol included clinical record review, interview to obtain demographic, medical, glaucoma, falls, MVC data—followed by questionnaires; full ocular test for subjects, vision test
Procedure conducted at baseline and repeated at 6 and 12 months
Subjects issued calendar and diary to record falls and MVCs occurring during the study upon informed consent
Functional independence assess with Multidimensional Functional Assessment Questionnaire (MFAQ); Physical activity level was assessed with the Physical Activity Scale for elderly (PASE)
Both questionnaires were administered in person by a trained interviewer
UFOV test was administered and comprised of 3 subtests: central vision and processing speed, divided attention and selective attention
Main outcome measures at baseline were previous self reported MVCs and falls, and police-reported MVCs
Clinical vision measures included VA, contrast sensitivity, standard automated perimetry, useful field view (UFOV), and steropsis
Analysis of falls and MVCs adjusted to account for possible confounding effects of demographic characteristics, medications, and visual impairment
MVC analyses were adjusted for kilometers driven per week
MVCs defined as “any collision with another car, object, or person while driving a motor vehicle, regardless of damage or fault</td></tr>
<tr><td>Statistical Methods</td><td colspan="6">Data analyzed on computer (SPSS ver. 12.0 for Windows; SPSS Inc., Chicago, IL)
Descriptive statistics calculated for demographic, medical, functional, vision, clinical, and riving exposure characteristics
Groups comparisons were made using t-test, Mann Whitney tests, and X^2 test for continuous, ordinal and nominal data
Analysis were two-tailed and P<0.05 considered statistically significant
Agreement between self-reported and province-recorded police-report was analyzed using the k coefficient
Associations between glaucoma an falls and glaucoma and MVCS; visual factors and main outcome measures in glaucoma group were evaluated using logistic regression analysis
Vision measures were dichotomized using criteria considered to be clinically important and adjustments made for possible confounders</td></tr>
</table>

<table>
<tr><td rowspan="4">Quality assessment</td><td rowspan="2">Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>S</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Moderate</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">• Risk of MVCs and falls for individuals diagnosed with glaucoma assessed
• Distant VA was measured monocularly using Early Treatment Diabetic Retinopathy Study (ETDRS); CS measured using the Pelli-Robson CS Chart
• VFs assessed using HFA Swedish Interactive Threshold Algorithm (SITA) 24-2 program, and the binocular Esterman program
• Rate of driving exposure measured using the driving habits questionnaire to estimate the number of kilometers driven weekly</td></tr>
<tr><td>Results</td><td colspan="14">• There were no significant differences between patients with glaucoma and control subjects with respect to number of systemic medical conditions, body mass index, functional independence, and physical activity level (<i>P</i> >0.10).
• At baseline, 40 (83%) patients with glaucoma and 44 (94%) control subjects were driving. Compared with control subjects, patients with glaucoma were over three times more likely to have fallen in the previous year (odds ratio [OR] adjusted = 3.71; 95% CI, 1.14 –12.05)(Figure G-18), over six times more likely to have been involved in one or more MVCs in the previous 5 years (OR adjusted = 6.62; 95% CI, 1.40 –31.23), and more likely to have been at fault (OR adjusted = 12.44; 95% CI, 1.08 – 143.99). Refer to Table G-26 for complete details
• The strongest risk factor for MVCs in patients with glaucoma was impaired UFOV selective attention (OR adjusted = 10.29; 95% CI, 1.10 –96.62; for selective attention >350 ms compared with ≤350 ms).Refer to Table G-27 for complete details
• Reports from province records similar in self-reported results (Figure G-19)
• Agreement between self-reported and police-reported MVCs were high (k= 0.82, <i>P</i> < 0.001); agreement high for individuals MVCs (k=0.74, p<0.001)
• Subjects who had undergone glaucoma surgery were less likely to have been involved in MVCs (OR self-report, all = 0.15; 95% CI, 0.03– 0.87 and OR self-report, at-fault = 0.05; 95% CI, 0.00–0.65).
• Patients with greater VF impairment (worse eye HFA MD ≤-10 dB), were over four times more likely than those with less impairment to have been involved in self-reported at-fault MVCs after adjustment for age, gender, number of systemic medications and on-road driving exposure, although the 95% CI included 1.00 (OR = 4.97; 95% CI, 0.73–33.81)</td></tr>
<tr><td>Authors' Comments</td><td colspan="14">• Self- reported findings appeared stronger than police-reported findings
• Although possible factors involving risk of falls and MVCs in glaucoma, “our sample size was small and visual factors were assessed after the MVCs had occurred”.
• “The findings of this clinical study indicate there is an increased risk of falls and MVCs in patients with glaucoma. On the basis of this, we have commenced a larger prospective study to investigate the underlying factors further. Potentially, the results have implications for patient education, licensing of drivers, and intervention programs.”</td></tr>
</table>

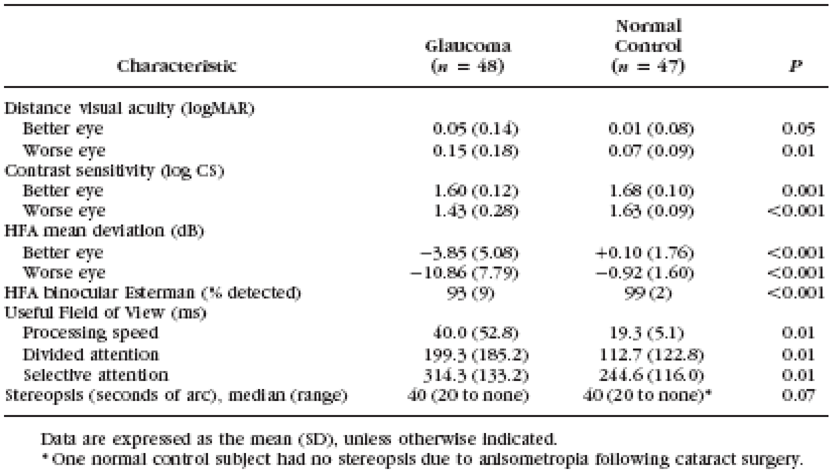
Table G-25. Demographic, Medical and Functional Characteristics of Study Sample



Characteristic	Glaucoma (*n* = 48)	Normal Control (*n* = 47)	*P*
Age (y), mean (SD)	69 (9)	67 (7)	0.11
Time since glaucoma diagnosis (y), mean (SD)	13 (8)	NA	—
Current use of glaucoma eye drops (yes), *n* (%)	47 (98)	NA	—
Glaucoma eye drops (count), median (range)	2 (0–5)	NA	—
Previous glaucoma surgery (yes), *n* (%)	27 (56)	NA	—
Gender (female), *n* (%)	24 (50)	27 (57)	0.67
Body mass index (kg/m^2), mean (SD)	27.4 (4.5)	26.8 (4.2)	0.52
Medical conditions (count), median (range)	3 (0–10)	2 (0–11)	0.11
Systemic medications (count), median (range)	2 (0–8)	2 (0–11)	0.11
MFAQ score (of a possible 28), median (range)	28 (26–28)	28 (24–28)	0.88
PASE (weighted score), median (range)	117 (25–253)	126 (31–393)	0.39
TUG test (seconds), mean (SD)	11 (3)	10 (2)	0.01
Driving (yes), *n* (%)	40 (83)	44 (94)	0.66
On-road driving exposure (km/wk), mean (SD)	131 (113)	200 (238)	0.09

NA, not applicable.

Table G-26. Vision Characteristics of Study Sample

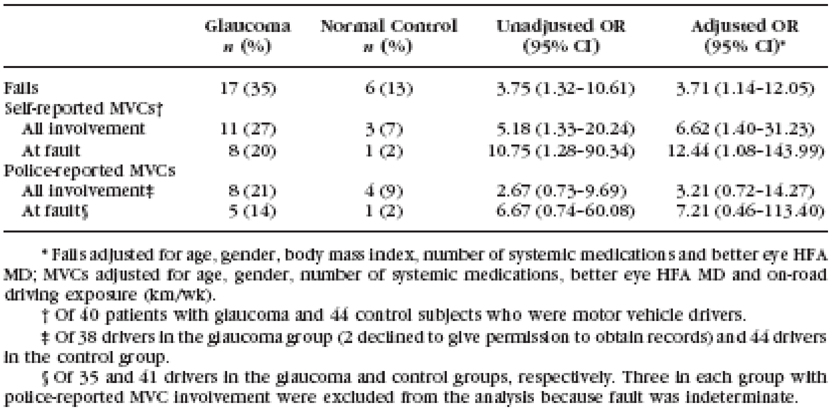


Characteristic	Glaucoma (*n* = 48)	Normal Control (*n* = 47)	*P*
Distance visual acuity (logMAR)			
Better eye	0.05 (0.14)	0.01 (0.08)	0.05
Worse eye	0.15 (0.18)	0.07 (0.09)	0.01
Contrast sensitivity (log CS)			
Better eye	1.60 (0.12)	1.68 (0.10)	0.001
Worse eye	1.43 (0.28)	1.63 (0.09)	<0.001
HFA mean deviation (dB)			
Better eye	−3.85 (5.08)	+0.10 (1.76)	<0.001
Worse eye	−10.86 (7.79)	−0.92 (1.60)	<0.001
HFA binocular Esterman (% detected)	93 (9)	99 (2)	<0.001
Useful Field of View (ms)			
Processing speed	40.0 (52.8)	19.3 (5.1)	0.01
Divided attention	199.3 (185.2)	112.7 (122.8)	0.01
Selective attention	314.3 (133.2)	244.6 (116.0)	0.01
Stereopsis (seconds of arc), median (range)	40 (20 to none)	40 (20 to none)*	0.07

Data are expressed as the mean (SD), unless otherwise indicated.

* One normal control subject had no stereopsis due to anisometropia following cataract surgery.

Table G-27. Odds Ratios for Falls and MVC's in Patients with Glaucoma



	Glaucoma *n* (%)	Normal Control *n* (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)*
Falls	17 (35)	6 (13)	3.75 (1.32–10.61)	3.71 (1.14–12.05)
Self-reported MVCs†				
All involvement	11 (27)	3 (7)	5.18 (1.33–20.24)	6.62 (1.40–31.23)
At fault	8 (20)	1 (2)	10.75 (1.28–90.34)	12.44 (1.08–143.99)
Police-reported MVCs				
All involvement‡	8 (21)	4 (9)	2.67 (0.73–9.69)	3.21 (0.72–14.27)
At fault§	5 (14)	1 (2)	6.67 (0.74–60.08)	7.21 (0.46–113.40)

* Falls adjusted for age, gender, body mass index, number of systemic medications and better eye HFA MD; MVCs adjusted for age, gender, number of systemic medications, better eye HFA MD and on-road driving exposure (km/wk).

† Of 40 patients with glaucoma and 44 control subjects who were motor vehicle drivers.

‡ Of 38 drivers in the glaucoma group (2 declined to give permission to obtain records) and 44 drivers in the control group.

§ Of 35 and 41 drivers in the glaucoma and control groups, respectively. Three in each group with police-reported MVC involvement were excluded from the analysis because fault was indeterminate.

Figure G-18. Proportion of subjects in the glaucoma group (n=48) and the normal control group (n=47) who reported one or more falls in the previous 12 months

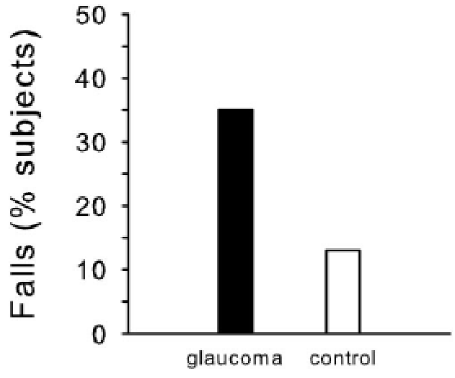
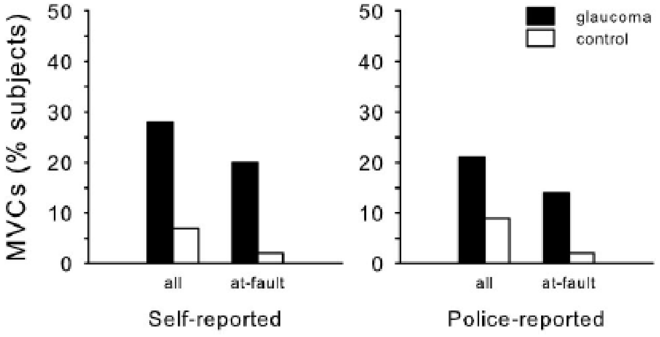


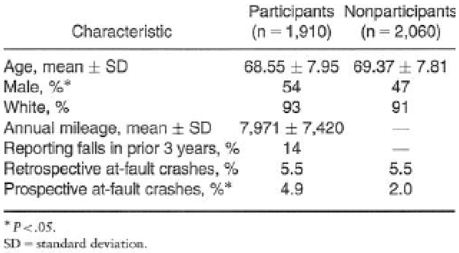
Figure G-19. Proportion of drivers in the glaucoma group and the normal control group who reported one or more motor vehicle collisions in the previous 5 years



<table>
<tr><td colspan="15">Ball K, Roenker D, Wadley V, Edwards J, Roth D, McGwin G, Raleigh R, Joyce J, Cissell G, Dube T. Can High-Risk Older Drivers Be Identified Through Performance-Based Measures in a Department of Motor Vehicles Setting? JAGS 2006; 54: 77-84.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3">√</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="14">To evaluate the relationship between performance-based risk factors and subsequent at-fault motor vehicle collision (MVC) involvement</td></tr>
<tr><td>Study Design</td><td colspan="14">Cohort</td></tr>
<tr><td rowspan="8">Population</td><td>Inclusion Criteria</td><td colspan="13">Subjects:
Older adults who renewed their driving licenses at three MVA field site offices in Maryland (Glen Burnie, Annapolis, Bel Air) between 1998 and 1999
Individuals from community site, Leisure World including individuals referred to Maryland Advisory Board</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13">Cases/Controls:
NR</td></tr>
<tr><td rowspan="5">Study population Characteristics</td><td colspan="5">Measurement</td><td colspan="4">Participants</td><td colspan="4">Non-Participants</td></tr>
<tr><td colspan="5">Population (n)</td><td colspan="4">1,910</td><td colspan="4">2,060</td></tr>
<tr><td colspan="5">Age, mean ± SD</td><td colspan="4">68.55±7.95</td><td colspan="4">69.37±7.81</td></tr>
<tr><td colspan="5">White (%)</td><td colspan="4">54</td><td colspan="4">47</td></tr>
<tr><td colspan="13">Refer to Table G-28 for complete details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="13">Unclear</td></tr>
<tr><td>Methods</td><td colspan="14">An MVA staff member approached participants to request that they assist in evaluating a series of assessment measures
Recruitment began after license renewal completion and subjects were reassured that their participation who had no bearing on their driving privileges
Vision assessments performed although not a part of the study
Individuals who agreed to participate were placed in a room to obtain informed consent
Test batteries divided into two part consisting of GRIMPS along with the UFOV and Mobility Questionnaire
Declaration of Helsinki ethical guidelines followed
The GRIMPS battery included an 11 minute assessment composed of Physical measurements which included, foot tap, arm reach, head/neck rotation, Cognitive measures including cued and delayed recall, symbol scan, motor free visual perception test, Trails A & B
Speed of processing part of the UFOV test—participants are to identify a central target and locate a peripheral target simultaneously
A questionnaire used for self reported mobility which included information about employment, driving exposure, driving avoidance, general mobility, etc.
Tester training held for all volunteer MVA staff which assessed performance in serving battery tests; testers required to perform/practice on elements without error prior to being permitted to administer tests
Primary outcome of interest was MVA because of information availability—as information is readily available for measuring
Crash records obtained during follow-up period from Maryland MVA Administration of Driver Safety Research Office; outcome period ranged from 4.18 to 5.13 years after assessment depending on the initial date of assessment</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">At fault and fault-unknown events included as independent measure
Subjects presented with scale containing mileage in 2,500-mile blocks (0-2,500 miles, 2,501-5,000 miles etc)--participants asked to estimate their annual driving mileage; midpoint of selected interval used as an estimate of annual mileage
t-tests used for MVC comparisons
To evaluate predictors of at-fault MVC occurrences, logistic regression analyses run in SAS using the event/trial syntax
Number of trials determined by calculating interval between participants assessment and follow-up period
Multivariate analysis conducted to examine if cognitive measures found to be significant predictors in univariate analysis
Dichotomous measures used to identify cutpoints to determine crash prediction</td></tr>
<tr><td rowspan="4">Quality assessment</td><td rowspan="2">Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Moderate</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">• VA and VFs assessed
• Driving exposure recorded subjectively using a self assessed questionnaire</td></tr>
</table>

	• General mobility recorded using questionnaire which included information on falls or difficulty walking/climbing stairs • Crash risk assessed at MVA field sites
Results	• In drivers aged 55± with intact vision, age, gender and all tests performed were predictive of future MVC at-fault crash • Participants age 78 and older were 2.11 as more likely to be involved in an at-fault MVC after mileage adjustments; those who made four or more errors on the MVPT were 2.10 times likely to crash • Subjects who took 147 second or longer to complete Trails B were 2.01 times as likely to crash, and those who took 353 ms or longer on subtest 2 of the UFOV were 2.02 times likely to incur an at-fault MVC • Older adults, men and those with history of falls were more likely to be involved in at-fault MVCs • Table G-29 contains mean scores, standard deviation and unadjusted p-values comparing those involved and uninvolved in MVCs • Number of subjects who passed or failed scored elements of the screening battery found in Table G-30. • Subjects who were involved in MVCs performed significantly worse on UFOV (t 1,838) = -2.24, p=.03 and MVPT (t (1,898) = -2.52, p=.01) (Table G-31). • In all three multivariate models, mileage was a predictor of more miles experiencing a greater increase of at-fault crashes per year • MVPT (OR=1.24, P=.03) and UFOV (OR=1.23, p=.04) found to be most useful in predicting at fault crash rates/annually
Authors' Comments	"Preliminary results of the follow-up data reveal that these same measures remain predictive of at-fault crash involvement and that an additional 10% of older drivers fail the assessment 5 years later (unpublished data)."

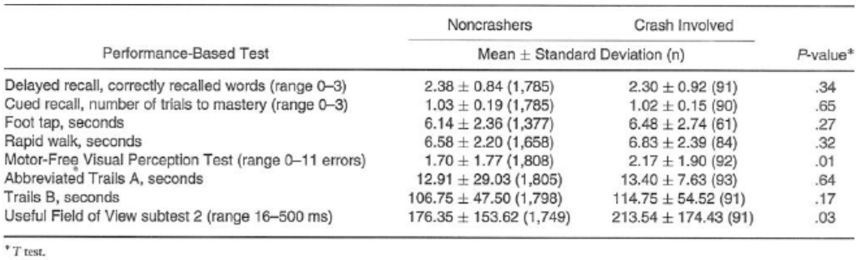
Table G-28. Characteristics of Participants and Nonparticipants



Characteristic	Participants (n = 1,910)	Nonparticipants (n = 2,060)
Age, mean ± SD	68.55 ± 7.95	69.37 ± 7.81
Male, %*	54	47
White, %	93	91
Annual mileage, mean ± SD	7,971 ± 7,420	—
Reporting falls in prior 3 years, %	14	—
Retrospective at-fault crashes, %	5.5	5.5
Prospective at-fault crashes, %*	4.9	2.0

* $P < .05$.
SD = standard deviation.

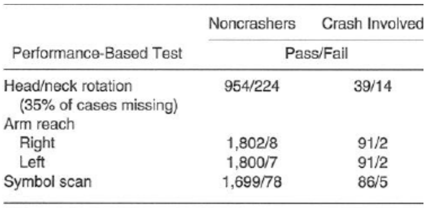
Table G-29. Summary Scores of Performance-Based Physical and Cognitive Measures



Performance-Based Test	Noncrashers	Crash Involved	P-value*
	Mean ± Standard Deviation (n)		
Delayed recall, correctly recalled words (range 0–3)	2.38 ± 0.84 (1,785)	2.30 ± 0.92 (91)	.34
Cued recall, number of trials to mastery (range 0–3)	1.03 ± 0.19 (1,785)	1.02 ± 0.15 (90)	.65
Foot tap, seconds	6.14 ± 2.36 (1,377)	6.48 ± 2.74 (61)	.27
Rapid walk, seconds	6.58 ± 2.20 (1,658)	6.83 ± 2.39 (84)	.32
Motor-Free Visual Perception Test (range 0–11 errors)	1.70 ± 1.77 (1,808)	2.17 ± 1.90 (92)	.01
Abbreviated Trails A, seconds	12.91 ± 29.03 (1,805)	13.40 ± 7.63 (93)	.64
Trails B, seconds	106.75 ± 47.50 (1,798)	114.75 ± 54.52 (91)	.17
Useful Field of View subtest 2 (range 16–500 ms)	176.35 ± 153.62 (1,749)	213.54 ± 174.43 (91)	.03

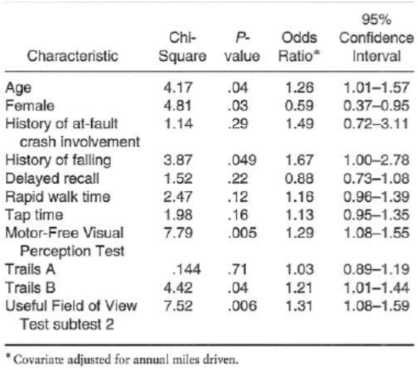
* *T* test.

Table G-30. Number Who Passed or Failed Categorical Physical Screening Measures



Performance-Based Test	Noncrashers	Crash Involved
	Pass/Fail	
Head/neck rotation (35% of cases missing)	954/224	39/14
Arm reach		
Right	1,802/8	91/2
Left	1,800/7	91/2
Symbol scan	1,699/78	86/5

Table G-31. Association Between At-Fault Motor Vehicle Collisions and Demographics and Selected Screening Tests



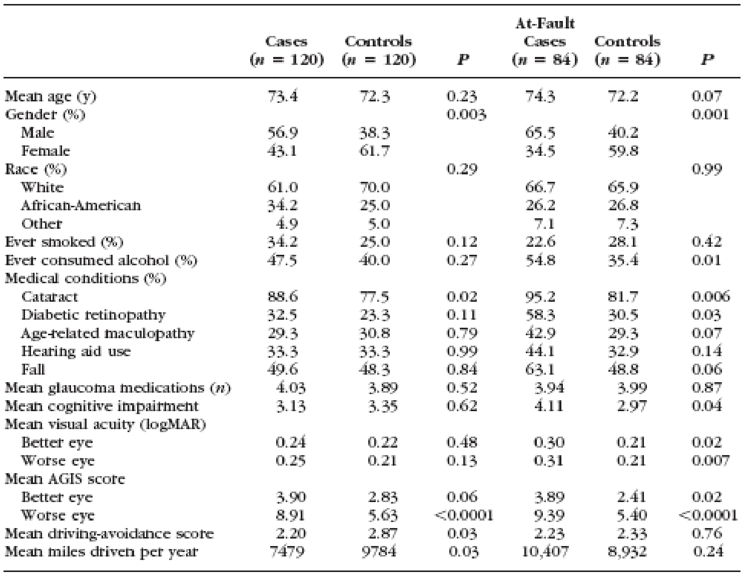
Characteristic	Chi-Square	*P*-value	Odds Ratio*	95% Confidence Interval
Age	4.17	.04	1.26	1.01–1.57
Female	4.81	.03	0.59	0.37–0.95
History of at-fault crash involvement	1.14	.29	1.49	0.72–3.11
History of falling	3.87	.049	1.67	1.00–2.78
Delayed recall	1.52	.22	0.88	0.73–1.08
Rapid walk time	2.47	.12	1.16	0.96–1.39
Tap time	1.98	.16	1.13	0.95–1.35
Motor-Free Visual Perception Test	7.79	.005	1.29	1.08–1.55
Trails A	.144	.71	1.03	0.89–1.19
Trails B	4.42	.04	1.21	1.01–1.44
Useful Field of View Test subtest 2	7.52	.006	1.31	1.08–1.59

* Covariate adjusted for annual miles driven.

<table>
<tr><td colspan="6">McGwin G, Xie A, Mays A, Joiner W, DeCarlo D, Hall T, Owsley C. VF Defects and the risk of Motor Vehicle Collisions among Patients with Glaucoma.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td>√</td><td></td><td></td></tr>
<tr><td>Research Question</td><td colspan="5">To evaluate the association between VF defects in the central 24° field and the risk of motor vehicle collisions (MVCs) among a individuals with glaucoma and their risk of vehicle crashes</td></tr>
<tr><td>Study Design</td><td colspan="5">Nested Case-Control</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="4">Cases:
Individuals involved in a police-reported motor vehicle collision (MVC) between January 1994 and June 2000
Controls:
Individuals who had not experienced an MVC at the time of selection</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="4">Cases/Controls:
Exclusions applied to individuals whose primary cause of visual impairment was ocular disorder other than glaucoma (e.g., macular degeneration, diabetic retinopathy, or clinically significant cataract for which surgery was recommended)</td></tr>
<tr><td>Study population Characteristics</td><td colspan="4"><table>
<tr><th>Measurement</th><th>Cases</th><th>Controls</th></tr>
<tr><td>Mean age (y)</td><td>73.4</td><td>72.3</td></tr>
<tr><td>Gender (%)</td><td></td><td></td></tr>
<tr><td>Male</td><td>56.9</td><td>38.3</td></tr>
<tr><td>Female</td><td>43.1</td><td>61.7</td></tr>
<tr><td>Mean VA (logMAR)</td><td></td><td></td></tr>
<tr><td>Better eye</td><td>0.24</td><td>0.22</td></tr>
<tr><td>Worse eye</td><td>0.25</td><td>0.21</td></tr>
</table>Refer to Table G-32 for complete details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="4">Unclear</td></tr>
<tr><td>Methods</td><td colspan="5">Study subjects were those aged ≥55 who were seen at least once between January 1994 and December 1995 in any of the 3 university-affiliated ophthalmology and optometry practices specializing in the diagnosis and treatment of glaucoma
The International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes 365.1 and 365.2 used to identify potentially eligible subjects with glaucoma seen at each of these locations
Subjects permitted into study if diagnosis of refractive error, dry eye, and early cataract
Licensure status secured by cross-referencing each subject's demographic and residential information obtained from the medical record with Alabama Department of Public Safety (ADPS) database
For each case, a matched control, the collision date for the case was used to identify the VF measurement in closest proximity before the collision; a single subject was randomly selected among eligible control subjects of a case
Incidence-density sample used to select controls for at-fault cases from individuals who had not experienced at-fault MVC at time of event occurrence
Advanced Glaucoma Intervention Study (AGIS) score was calculated on automated VFs collected with the 24-2 or 3-2 programs
Medical records used to obtain information on use of glaucoma medication, best corrected VA in both eyes and VFs in both eyes
All visits between January 1994 through December 1995 abstracted; visual reports used to calculate VF defect score for each eye based on the Advanced Glaucoma Intervention Study (AGIS) scoring system
Telephone survey used to obtain additional demographic, driving, general health, smoking and alcohol use between February and June 2000; demographic information included age, gender and race
The Short Portable mental Status Questionnaire modified for telephone administration used to assess the cognitive status
Respondents asked to respond to a general health questionnaire—driving habits questionnaire (DHQ) used to collect information on driving exposure defined in terms of estimated weekly mileage; items addressed night driving in fog, rain, alone, during rush hour, freeway/highway, with children, in high-density traffic, when passing cars, changing lanes, making left turns in intersection and parallel parking—responses were "always", "often", "sometimes", "rarely", or "never"
"often" were defined as avoiders; "sometimes", "rarely", or "never" defined as non-avoiders
Information regarding all MVCs that occurred between January 1994 and June 2000 was obtained from the Alabama department of Public Safety
The institutional review board for Human use at UAB approved the study protocol</td></tr>
<tr><td>Statistical Methods</td><td colspan="5">Descriptive statistics were generated for demographic, behavioral, driving and clinical characteristics
Variables compared between case and control groups using X² and t-test for categorical and continuous various respectively
Crude and adjusted odds rations (OR) and associated 95% confidence intervals (Cis) for the association between field defects and</td></tr>
</table>

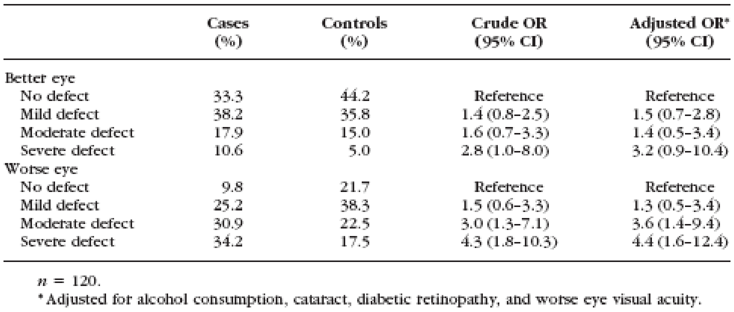
<table>
<tr><td></td><td colspan="14">the risk of MVC involvement were calculated by using generalized estimating equations (GEEs)
GEEs used for dependence among subjects with multiple cases
Determination of variables retained as confounders based on the change-in-estimate criteria using 10% value
To prevent the exclusion of these subjects from the analysis, multiple imputation to create values for missing observations using Markov Chain Monte Carlo (MCMC) method</td></tr>
<tr><td rowspan="4">Quality assessment</td><td rowspan="2">Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td></tr>
<tr><td rowspan="2">Moderate</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">• Risk of crash among driving population diagnosed with visual impairments
• Rate of driving exposure measured subjectively using questionnaire
• VA measured</td></tr>
<tr><td>Results</td><td colspan="14">• Subjects representing cases and at fault cases matched for age, race, ever having smoked and various glaucoma medications
• Cases and control similar in cognitive impairment and VA
• Compared to controls, cases and at-fault cases more likely to be male (p=0.003 and p=0.001, respectively)
• According to better-eye AGIS score, compared with patients with no VF defect, those with severe defects (scores 12–20) had an increased risk of an MVC (odds ratio [OR] 3.2, 95% CI 0.9 –10.4), although the association was not statistically significant.
• Crude and adjusted OR for MVCs according to AGIS categories for the cases and controls shown in Table G-33.
• Moderate (6 –11) or minor field defects (1–5) in the better eye were not associated with the risk of involvement in a crash
• In the worse eye, patients with moderate or severe field defects were at significantly increased risk of an MVC (OR 3.6, 95% CI 1.4 –9.4 and OR 4.4, 95% CI 1.6 –12.4, respectively) compared with those with no defects
• Associations were significant for both moderate and severe defects (OR 4.2, 95% CI 1.2–15.0 and OR 9.0, 95% CI 2.4 –33.2, respectively) after adjustments. Refer to Table G-34.
• Minor field defects in the worse eye did not increase risk of MVC (OR 1.3, 95% CI 0.5–3.4).</td></tr>
<tr><td>Authors' Comments</td><td colspan="14">• Demographic, behavioral, driving, and general health characteristics were not available for 40% of the selected cases and 37% of the selected controls due to incomplete telephone surveys
• Study limitations include:
• Collected information in 2000 acquired via telephone conversations—requiring subjects to “recall” events in 1995
• “the response rate for the telephone survey was not ideal (approximately 61% overall due), yet it did not differ between the cases (60%) and controls (63%)”
• “adjusted analyses were performed excluding patients with imputed data, the overall results were highly consistent with the results based on all patients, suggesting that little bias resulted from the imputation process”</td></tr>
</table>

Table G-32. Demographic, Medical, and Visual Function Characteristics among Glaucoma Patients Involved in an MVC (Cases) Versus Those Not (Controls) and Those at Fault for an MVC Versus Control Subjects



	Cases (*n* = 120)	Controls (*n* = 120)	*P*	At-Fault Cases (*n* = 84)	Controls (*n* = 84)	*P*
Mean age (y)	73.4	72.3	0.23	74.3	72.2	0.07
Gender (%)			0.003			0.001
Male	56.9	38.3		65.5	40.2	
Female	43.1	61.7		34.5	59.8	
Race (%)			0.29			0.99
White	61.0	70.0		66.7	65.9	
African-American	34.2	25.0		26.2	26.8	
Other	4.9	5.0		7.1	7.3	
Ever smoked (%)	34.2	25.0	0.12	22.6	28.1	0.42
Ever consumed alcohol (%)	47.5	40.0	0.27	54.8	35.4	0.01
Medical conditions (%)						
Cataract	88.6	77.5	0.02	95.2	81.7	0.006
Diabetic retinopathy	32.5	23.3	0.11	58.3	30.5	0.03
Age-related maculopathy	29.3	30.8	0.79	42.9	29.3	0.07
Hearing aid use	33.3	33.3	0.99	44.1	32.9	0.14
Fall	49.6	48.3	0.84	63.1	48.8	0.06
Mean glaucoma medications (*n*)	4.03	3.89	0.52	3.94	3.99	0.87
Mean cognitive impairment	3.13	3.35	0.62	4.11	2.97	0.04
Mean visual acuity (logMAR)						
Better eye	0.24	0.22	0.48	0.30	0.21	0.02
Worse eye	0.25	0.21	0.13	0.31	0.21	0.007
Mean AGIS score						
Better eye	3.90	2.83	0.06	3.89	2.41	0.02
Worse eye	8.91	5.63	<0.0001	9.39	5.40	<0.0001
Mean driving-avoidance score	2.20	2.87	0.03	2.23	2.33	0.76
Mean miles driven per year	7479	9784	0.03	10,407	8,932	0.24

Table G-33. Crude and Adjusted OR according to AGIS Score Categories for Cases and Controls

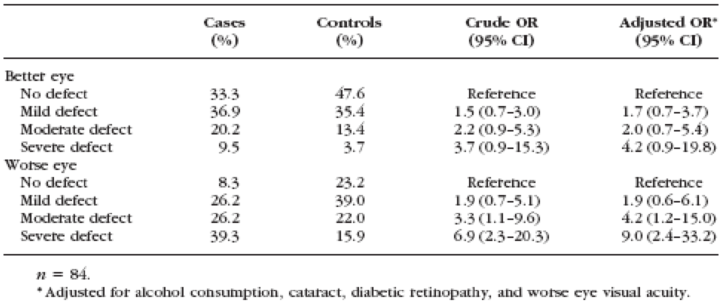


	Cases (%)	Controls (%)	Crude OR (95% CI)	Adjusted OR* (95% CI)
Better eye				
No defect	33.3	44.2	Reference	Reference
Mild defect	38.2	35.8	1.4 (0.8–2.5)	1.5 (0.7–2.8)
Moderate defect	17.9	15.0	1.6 (0.7–3.3)	1.4 (0.5–3.4)
Severe defect	10.6	5.0	2.8 (1.0–8.0)	3.2 (0.9–10.4)
Worse eye				
No defect	9.8	21.7	Reference	Reference
Mild defect	25.2	38.3	1.5 (0.6–3.3)	1.3 (0.5–3.4)
Moderate defect	30.9	22.5	3.0 (1.3–7.1)	3.6 (1.4–9.4)
Severe defect	34.2	17.5	4.3 (1.8–10.3)	4.4 (1.6–12.4)

n = 120.

* Adjusted for alcohol consumption, cataract, diabetic retinopathy, and worse eye visual acuity.

Table G-34. Crude and Adjusted OR by AGIS Score Categories for At-Fault Cases and Controls



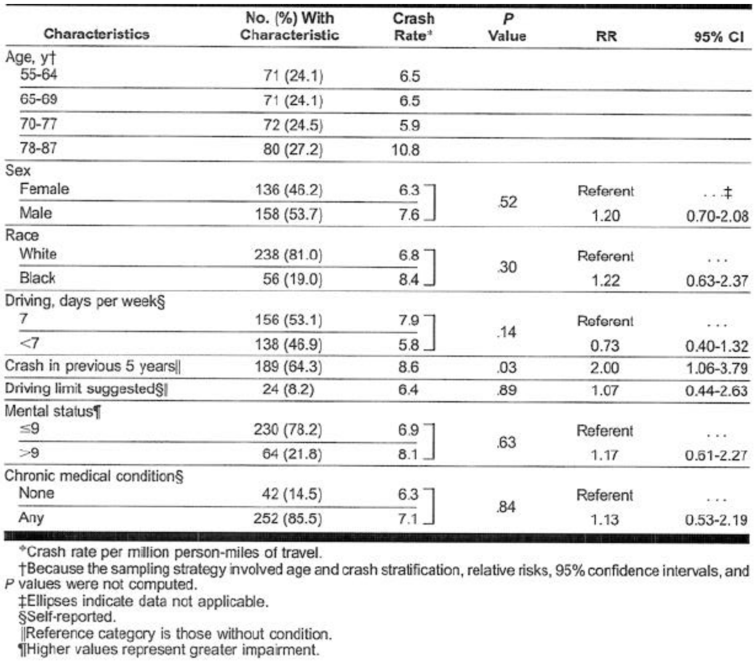
	Cases (%)	Controls (%)	Crude OR (95% CI)	Adjusted OR* (95% CI)
Better eye				
No defect	33.3	47.6	Reference	Reference
Mild defect	36.9	35.4	1.5 (0.7–3.0)	1.7 (0.7–3.7)
Moderate defect	20.2	13.4	2.2 (0.9–5.3)	2.0 (0.7–5.4)
Severe defect	9.5	3.7	3.7 (0.9–15.3)	4.2 (0.9–19.8)
Worse eye				
No defect	8.3	23.2	Reference	Reference
Mild defect	26.2	39.0	1.9 (0.7–5.1)	1.9 (0.6–6.1)
Moderate defect	26.2	22.0	3.3 (1.1–9.6)	4.2 (1.2–15.0)
Severe defect	39.3	15.9	6.9 (2.3–20.3)	9.0 (2.4–33.2)

n = 84.

* Adjusted for alcohol consumption, cataract, diabetic retinopathy, and worse eye visual acuity.

<table>
<tr><td colspan="15">Owsley C, Ball K, McGwin G, Sloane M, Roenker D, White M, Overley T. Visual processing impairment and risk of motor vehicle crash among older adults. JAMA 1998; 279: 1083-1088</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3">✓</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="14">3 year follow-up to determine correlation of visual impairment to crash risk in an older adult population</td></tr>
<tr><td>Study Design</td><td colspan="14">Prospective cohort</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="13">Licensed and current drivers in Jefferson County, Alabama, aged 55+ years in 1990</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13"></td></tr>
<tr><td>Study population Characteristics</td><td colspan="13">N 294
Number of crashes during previous 5 years
0 33%
1-3 49%
4+ 18%
Gender M/F 158/136</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="13">Unclear</td></tr>
<tr><td>Methods</td><td colspan="14">Subjects were identified from a total population of 118, 553 licensed drivers. Drivers were matched for crash frequency during previous 5 years (0, 1-3, and 4+) and age (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+). Enrollment of 302 subjects was achieved by randomly selecting 75 drivers from each possible cell (21). Eight subjects were later excluded; 6 for not currently driving and 2 for not completing the protocol. Testing for VF sensitivity was measured with a Humphrey Field Analyzer 120-point screening program for the central 60° radius field using the quantify defects option. Each eye was tested individually. VF was compared against a preset initialization value of 34dB (central and peripheral) (standard for 50 year old adults with good eye health). Impaired VF sensitivity (central and peripheral) was defined as a loss of sensitivity of more than 1 log unit (10 dB). UFOV testing was performed to assess visual attention and visual processing speed. During testing, subjects were asked to identify the radial direction of a target (car) displayed up to 30° in the periphery while simultaneously identifying 2 targets presenting in their central vision. The VF area that information is acquired is estimated as the eccentricity of the peripheral target changes (10°, 20° and 30°). Performance is scaled from 1 to 30 and expressed as a function of 3 variables: minimum target duration required to perform the central discrimination task (subtest 1); the ability to divide attention between central and peripheral tasks successfully (subtest 2), and the ability to filter out distracting stimuli (subtest 3). An impaired UFOV is defined as a 40% reduction or greater with scoring expressed as percent reduction (0-90%) of a maximum 30° field size. Driving estimates were obtained by self-report. Crash data from June 1990 to August 1993 was obtained from the Alabama Department of Public Safety. To calculate person-miles per year, the number of person-years was multiplied by the annual number of miles driven that was self-reported.</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">Cox proportional hazards modeling, multivariable proportional hazards model, Walk x^2 test, Martingale and deviance residuals</td></tr>
<tr><td rowspan="2">Quality assessment</td><td>Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td></td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">Risk of crash due to VF loss</td></tr>
<tr><td>Results</td><td colspan="14">Crash rate
o In 760.8 person-years of driving and 7,909,240 person-miles of travel, 56 older drivers were involved in at least 1 crash during the 3 year follow-up period; 11 experiencing more than one crash.
o 70% of crashes involved failure to yield right-of-way, failure to stop, and misjudging stopping distance.
o Drivers involved in a crash 5 years prior to study enrollment were significantly associated with an increased risk of crash (RR=2.0; 95% CI, 1.1-3.8) (Table G-35).
UFOV
o Older drivers with a 40% or greater reduction in the UFOV were 2.1 times more likely to be involved in a crash during the follow-up period compared with those with <40% reduction (Table G-36).
o A significant linear trend (P=.03) was observed between crash risk and UFOV reduction when analyzed in the model as a continuous variable. For every 10 points of UFOV reduction, a 16% increase in crash risk was demonstrated by older drivers.
o In a further analyses of UFOV components, impairment in the divided attention task was associated with a 2.3-fold (95% CI, 1.2-4.4; p=.01) increased risk of crash involvement.</td></tr>
<tr><td>Authors' Comments</td><td colspan="14">Older drivers with >40% reduction in the UFOV were twice as likely to incur a crash during the 3 year follow-up period. A 10 point reduction in the UFOV correlated with a 16% increase in crash risk for this study population.</td></tr>
</table>

Table G-35: Crash Rates, Relative Risk and Confidence Intervals for 294 Drivers



Characteristics	No. (%) With Characteristic	Crash Rate*	*P* Value	RR	95% CI
Age, y†					
55-64	71 (24.1)	6.5			
65-69	71 (24.1)	6.5			
70-77	72 (24.5)	5.9			
78-87	80 (27.2)	10.8			
Sex					
Female	136 (46.2)	6.3	.52	Referent	. . .‡
Male	158 (53.7)	7.6		1.20	0.70-2.08
Race					
White	238 (81.0)	6.8	.30	Referent	. . .
Black	56 (19.0)	8.4		1.22	0.63-2.37
Driving, days per week§					
7	156 (53.1)	7.9	.14	Referent	. . .
<7	138 (46.9)	5.8		0.73	0.40-1.32
Crash in previous 5 years‖	189 (64.3)	8.6	.03	2.00	1.06-3.79
Driving limit suggested§‖	24 (8.2)	6.4	.89	1.07	0.44-2.63
Mental status¶					
≤9	230 (78.2)	6.9	.63	Referent	. . .
>9	64 (21.8)	8.1		1.17	0.61-2.27
Chronic medical condition§					
None	42 (14.5)	6.3	.84	Referent	. . .
Any	252 (85.5)	7.1		1.13	0.53-2.19

*Crash rate per million person-miles of travel.

†Because the sampling strategy involved age and crash stratification, relative risks, 95% confidence intervals, and *P* values were not computed.

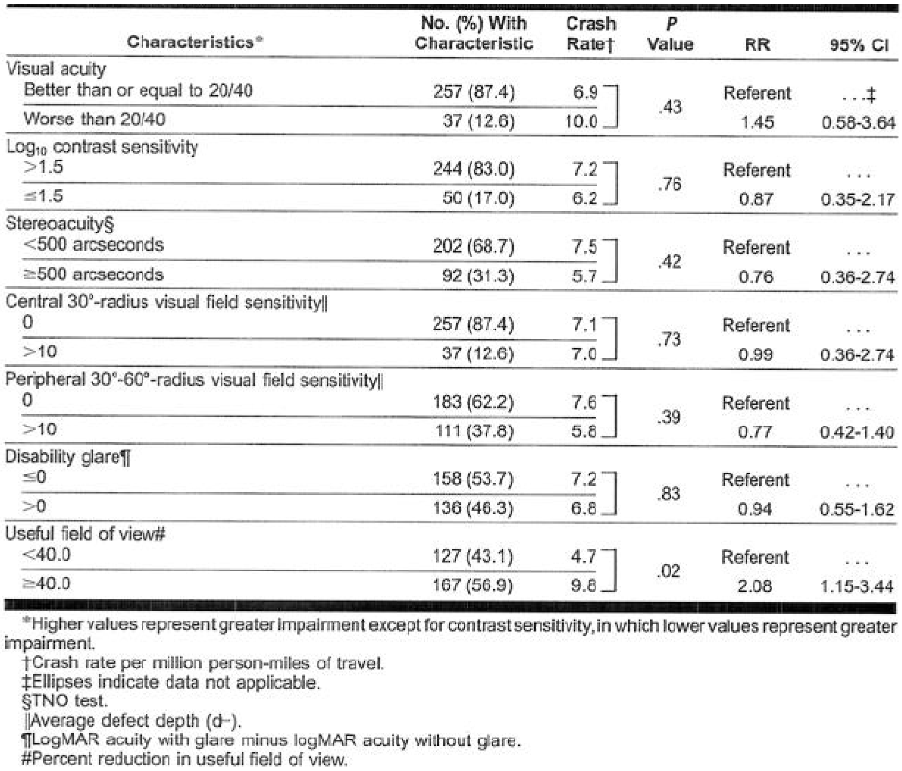
‡Ellipses indicate data not applicable.

§Self-reported.

‖Reference category is those without condition.

¶Higher values represent greater impairment.

Table G-36: Correlation of UFOV and Crash Rates



Characteristics*	No. (%) With Characteristic	Crash Rate†	*P* Value	RR	95% CI
Visual acuity					
Better than or equal to 20/40	257 (87.4)	6.9	.43	Referent	. . .‡
Worse than 20/40	37 (12.6)	10.0		1.45	0.58-3.64
Log_{10} contrast sensitivity					
>1.5	244 (83.0)	7.2	.76	Referent	. . .
≤1.5	50 (17.0)	6.2		0.87	0.35-2.17
Stereoacuity§					
<500 arcseconds	202 (68.7)	7.5	.42	Referent	. . .
≥500 arcseconds	92 (31.3)	5.7		0.76	0.36-2.74
Central 30°-radius visual field sensitivity‖					
0	257 (87.4)	7.1	.73	Referent	. . .
>10	37 (12.6)	7.0		0.99	0.36-2.74
Peripheral 30°-60°-radius visual field sensitivity‖					
0	183 (62.2)	7.6	.39	Referent	. . .
>10	111 (37.8)	5.8		0.77	0.42-1.40
Disability glare¶					
≤0	158 (53.7)	7.2	.83	Referent	. . .
>0	136 (46.3)	6.8		0.94	0.55-1.62
Useful field of view#					
<40.0	127 (43.1)	4.7	.02	Referent	. . .
≥40.0	167 (56.9)	9.8		2.08	1.15-3.44

*Higher values represent greater impairment except for contrast sensitivity, in which lower values represent greater impairment.

†Crash rate per million person-miles of travel.

‡Ellipses indicate data not applicable.

§TNO test.

‖Average defect depth (d–).

¶LogMAR acuity with glare minus logMAR acuity without glare.

#Percent reduction in useful field of view.

Owsley C, Ball K, Sloane M, Roenker D, and Bruni J. Visual/cognitive correlates of vehicle accidents in older drivers. Psychology and Aging 1991; 6: 403-415

Key Questions Addressed	1	2	3	4	5
			✓		

Research Question	Assess correlation of UFOV and risk of crash	
Study Design	Retrospective cohort	
Population	**Inclusion Criteria**	Licensed individuals who drove at least 1,000 mi/year recruited from the Primary Care Clinic of the School of Optometry at the University of Alabama at Birmingham; living independently in the community
	Exclusion Criteria	
	Study population Characteristics	N 53 Age (yrs) mean 70 Age (yrs) range 57-83 Gender M/F 26/27
	Generalizability to CMV drivers	Unclear

Methods	VF sensitivity
	o VF loss was measured separately in each eye with the Humphrey VF Analyzer
	o Measurements included the depth or degree of sensitivity loss at 120 locations in the VF
	UFOV
	o Tests were undertaken to assess mechanisms typically responsible for restricting UFOV – slowing of information processing, impaired ability to divide attention and impaired ability to ignore visual distracters
	  o Subtest 1: subjects performed a central task only (subjects indicated items contained in a 2 lane road were similar or different). Failure for Subtest 1 is defined as an inability to make the same-difference judgment correctly 75% of the time within 250 ms.
	  o Subtest 2: concurrent testing on central (described above) and peripheral tasks (On a 60˚x60˚ screen, spot a target which appears unpredictably at one of 24 different locations and is sometimes embedded in 47 distractor stimuli). Test time for Subtest 2 is compared to test time for Subtest 1. Failure for Subtest 2 and Subtest 3 was defined by the inability to perform the central task and concurrently localize the peripheral target beyond the minimum field size of 5˚ at 250 ms.
	  o Subtest 3: concurrent testing on central and peripheral tasks but with distracters in the field. Test performance was compared with results for Subtest 2.
	o After test completion, individuals were grouped into 2 groups (those failing all 3 subtests vs remaining subjects)
	o UFOV testing has good test-retest reliability (r=.93-.97) in older adults
	Driving Habits Questionnaire
	o Individuals were asked to self-report crash during prior 5-year period prior to UFOV testing
	State agency data
	o Alabama Dept of Public Safety provided information on total number of vehicle crashes for prior 5 years	

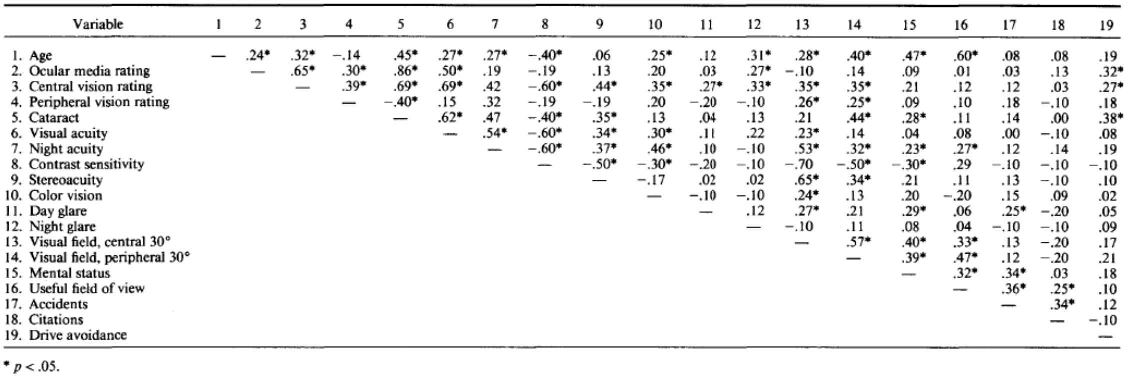
Statistical Methods	Pearson correlation coefficients	

Quality assessment	Study quality	1	2	3	4	5	6	7	8	9	10
		S	S	Y	N	N	Y	Y	Y	Y	Y

Relevant Outcomes Assessed	UFOV testing as a predictor of crash
Results	o Driving data obtained from the Alabama Dept of Public Safety was solely used as self-report data was unreliable upon comparison o Pearson correlation coefficients for all variables are shown in Table G-37. Results demonstrated a significant relationship between UFOV and state-recorded accidents (r=.36, p<.05). o Interrelationships between study variables are shown in Figure G-20. There were significant zero-order correlations between UFOV and crash frequency (r=.36, p<.004). o Analysis was undertaken to compare subjects who passed the UFOV test (n=27) with those who failed (n=26). Subjects who failed UFOV testing experienced 4.2 times more crashes on average than those individuals who passed. o UFOV was a better predictor of intersection crashes than overall crashes (rs=.46). UFOV test failures (n=26) were responsible for all but one of the intersection crashes and experienced 15.6 times more intersection crashes on average than those who passed. Based on UFOV testing, prediction of crash for 11 individuals was accurate. There were however 14 individuals that were predicted to have a crash but did not. These “false alarms” may be attributed to individuals who may restrict their driving thus reducing risk of crash.

Authors' Comments	UFOV was the best predictor of crash in this study model. Subjects who failed UFOV testing were 3-4 times more likely to incur a crash and 15 times more likely to be involved in intersection crashes.

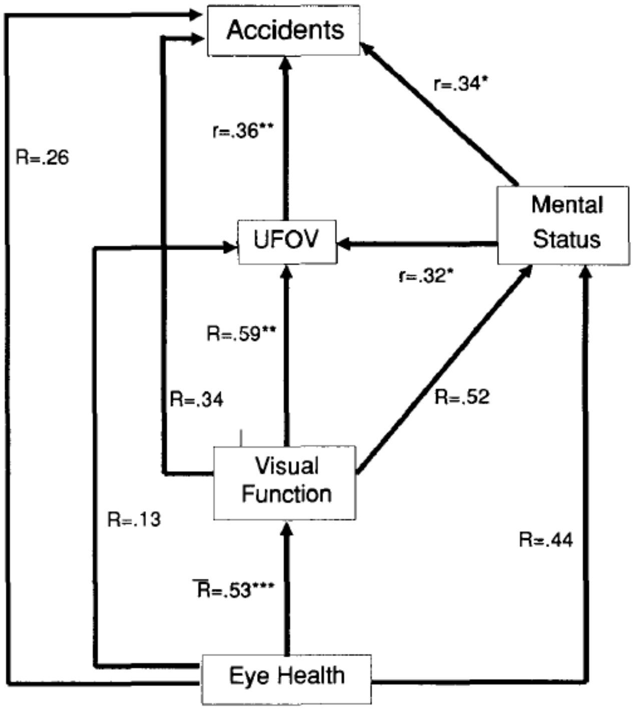
Table G-37: Pearson Correlation Coefficients for VF and UFOV



Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Age	—	.24*	.32*	−.14	.45*	.27*	.27*	−.40*	.06	.25*	.12	.31*	.28*	.40*	.47*	.60*	.08	.08	.19
2. Ocular media rating		—	.65*	.30*	.86*	.50*	.19	−.19	.13	.20	.03	.27*	−.10	.14	.09	.01	.03	.13	.32*
3. Central vision rating			—	.39*	.69*	.69*	.42	−.60*	.44*	.35*	.27*	.33*	.35*	.35*	.21	.12	.12	.03	.27*
4. Peripheral vision rating				—	−.40*	.15	.32	−.19	−.19	.20	−.20	−.10	.26*	.25*	.09	.10	.18	−.10	.18
5. Cataract					—	.62*	.47	−.40*	.35*	.13	.04	.13	.21	.44*	.28*	.11	.14	.00	.38*
6. Visual acuity						—	.54*	−.60*	.34*	.30*	.11	.22	.23*	.14	.04	.08	.00	−.10	.08
7. Night acuity							—	−.60*	.37*	.46*	.10	−.10	.53*	.32*	.23*	.27*	.12	.14	.19
8. Contrast sensitivity								—	−.50*	−.30*	−.20	−.10	−.70	−.50*	−.30*	.29	−.10	−.10	−.10
9. Stereoacuity									—	−.17	.02	.02	.65*	.34*	.21	.11	.13	−.10	.10
10. Color vision										—	−.10	−.10	.24*	.13	.20	−.20	.15	.09	.02
11. Day glare											—	.12	.27*	.21	.29*	.06	.25*	−.20	.05
12. Night glare												—	−.10	.11	.08	.04	−.10	−.10	.09
13. Visual field, central 30°													—	.57*	.40*	.33*	.13	−.20	.17
14. Visual field, peripheral 30°														—	.39*	.47*	.12	−.20	.21
15. Mental status															—	.32*	.34*	.03	.18
16. Useful field of view																—	.36*	.25*	.10
17. Accidents																	—	.34*	.12
18. Citations																		—	−.10
19. Drive avoidance																			—

* $p < .05$.

Figure G-20: Relationship between UFOV and Crash

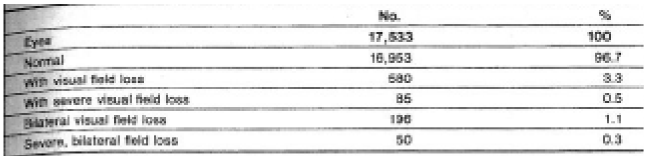


Interrelationship among variables at different levels of analysis.
(*p<.05, **p<.01, ***p<.001. UFOV

<table>
<tr><td colspan="15">Johnson C, Keltner J. Incidence of VF Loss in 20,000 Eyes and Its Relationship to Driving Performance. Arch Ophthalmol 1983; Vol 101: 371-5.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3">√</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="14">To examine the relationship between the status of peripheral vision and driving performance by comparing the vision test results with crash and conviction record for three year prior.</td></tr>
<tr><td>Study Design</td><td colspan="14">Case-Control</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="13">Cases:
Subjects were volunteers from driver’s license applicants at the Department of Motor Vehicles (DMV) in El Cerrito and Redwood City, California
Controls:
NR</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13">Cases/Controls:
NR</td></tr>
<tr><td>Study population Characteristics</td><td colspan="13">Refer to Figure G-23 for further details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="13">Unclear</td></tr>
<tr><td>Methods</td><td colspan="14">• Total of 10K persons participated in study; subjects asked to complete visual screening (Figure G-21) and asked to complete a answer questionnaire including the following:
Name, address, city and state, telephone number, driver’s license number, age, yearly miles driven, genders, years since last eye exam, contact lens or glass prescription, glaucoma history, family history, VA, asked if problems discovered would subject prefer to be notified
Answers to questions entered into video terminal and transferred to cassette tape storage unit
Average testing time was 54 seconds per eye with an additional average of 1 min 57 seconds for additional time needed to enter responses to questions
Data transferred to floppy disk and analyzed by computer; software separated VF algorithms
Judgments of normal or abnormal VFs were based on previously developed criteria for defining VF defects
Additional analysis performed to determine whether VF loss was severe for abnormal readings</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">NR</td></tr>
<tr><td rowspan="4">Quality assessment</td><td rowspan="2">Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Moderate</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">Rate of driving exposure reported by subjects
VA measured for each subject entered into study</td></tr>
<tr><td>• Results</td><td colspan="14">• Results analyzed for 17,534 of 20,000 eyes undergoing the VF screening test
• Table G-38 presents frequency of VF loss for the entire population tested
• Effects of age on the frequency of abnormal fields shown in Figure G-22
• Differences between two DMV testing sites were less than 0.3% for each value
• Approximately 13% of all persons over 65 years exhibited visual defects; age distributions for the population presented in Figure G-23
• The relationship between categories presented in Table G-39 and VF loss is shown in Table G-40; almost 35% of persons reporting that they had glaucoma had VF defects
• VF loss was greater than the general population incidence for the categories of family history of glaucoma (5.6%), eye problems (18.5%), and decreased VA (31.2%)
• For comparison, accident and conviction records obtained for age and gender matched control groups of persons with normal VFs in both eyes Figure G-24
• Comparison of crash and conviction rates for persons with VF loss in one eye (v) their age and gender-matched control groups indicates that there are only minor differences; Results of x^2 tests of the frequencies of accidents and conviction for the two groups were not statistically significant (X^2=1.193, df=1, p>.2 for crashes; X^2=1.244, df=1, p>.2 for convictions)
• Statistical differences found in crash versus conviction rates (X^2=8.25, df=1, p<.005 for crashes; X^2=15.25 df=1, p<.001 for convictions</td></tr>
<tr><td>Authors’</td><td colspan="14">“Our results indicate that subjects with VF loss in both eyes exhibited a traffic accident and conviction rate that was more than twice</td></tr>
</table>

Comments	as high as that of age and sex matched control subjects with normal VFs.”

Table G-38. Frequency of VF Loss



	No.	%
Eyes	17,533	100
Normal	16,953	96.7
With visual field loss	580	3.3
With severe visual field loss	85	0.5
Bilateral visual field loss	196	1.1
Severe, bilateral field loss	50	0.3

Table G-39. Frequency of Eye Problems

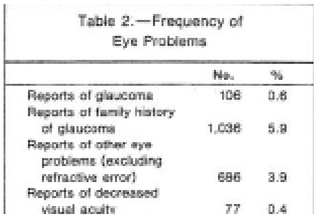


Table 2.—Frequency of Eye Problems

	No.	%
Reports of glaucoma	106	0.6
Reports of family history of glaucoma	1,036	5.9
Reports of other eye problems (excluding refractive error)	686	3.9
Reports of decreased visual acuity	77	0.4

Table G-40. Incidence of VF Loss for Subject Populations

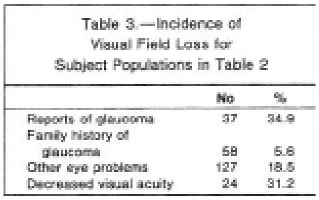


Table 3.—Incidence of Visual Field Loss for Subject Populations in Table 2

	No	%
Reports of glaucoma	37	34.9
Family history of glaucoma	58	5.6
Other eye problems	127	18.5
Decreased visual acuity	24	31.2

Figure G-21. Distribution of 78 target locations used to perform mass VF screening

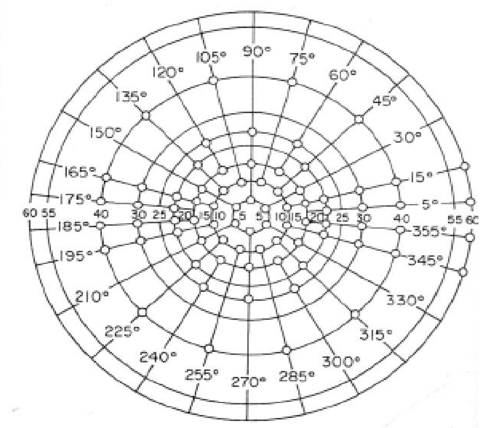


Figure G-22. Frequency distribution of incidence of abnormal/severely abnormal VFs as function of age

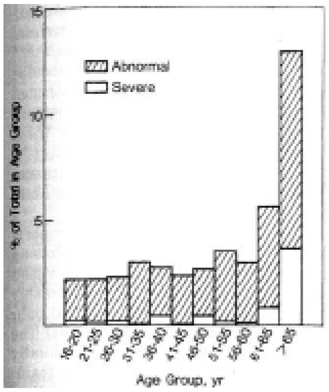


Figure G-23. Distribution of ages of participants

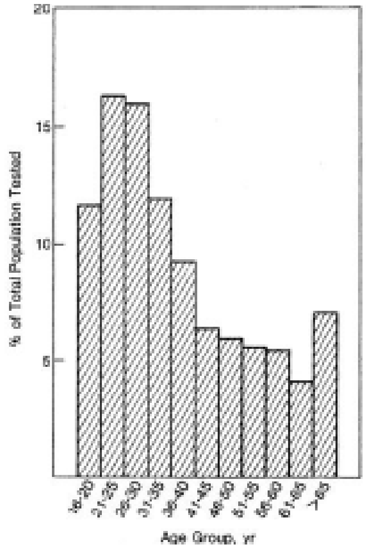
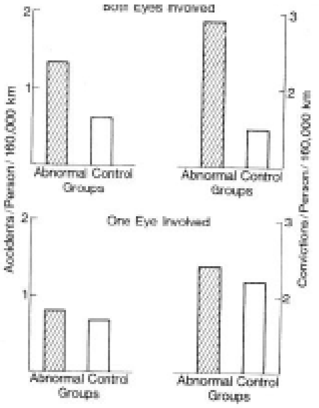
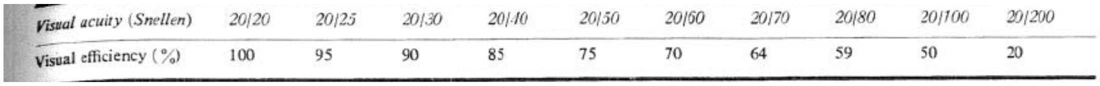


Figure G-24. Average traffic accident and conviction rates (per 160,000) during three-year period prior to VF screening for persons with binocular (top) and monocular (bottom), VF loss, as well as their age-and sex matched control groups



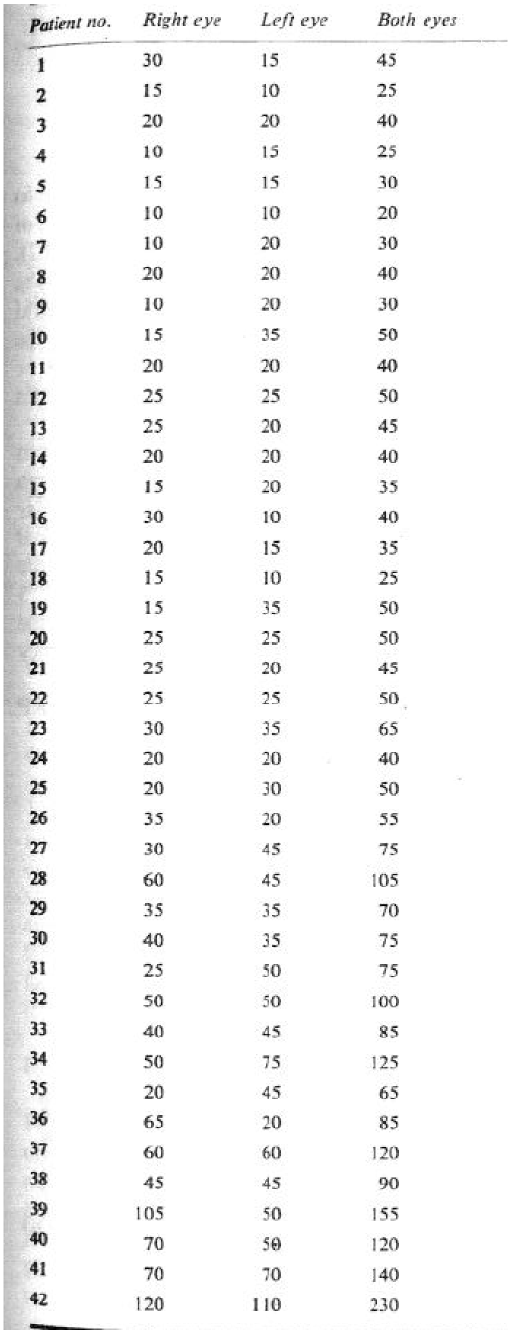
<table>
<tr><td colspan="12">Fishman G, Anderson R, Stinson L, Haque A. Driving performance of retinitis pigmentosa patients. Br J Ophthalmol 1981; 65: 122-126</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td><td colspan="2">✓</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="11">Assess frequency of crash between patients with retinitis pigmentosa (RP) versus controls without ocular disease</td></tr>
<tr><td>Study Design</td><td colspan="11">Case control</td></tr>
<tr><td rowspan="9">Population</td><td>Inclusion Criteria</td><td colspan="10">Individuals from a clinic population with characteristic RP disease including abnormal rod and cone function by electroretinography, peripheral field loss, bone spicule pigmentation, attenuated retinal vessels and some degree of night blindness. Controls had no ophthalmic or general defects and were either family members of RP patients, family members with patients with other ocular disease seen by study investigators, relatives of patients being seen in the general eye clinic, or clerical staff of the ophthalmology department.</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10">Individuals with a VA of less than 20/100 in the best corrected eye and those who were aphakic</td></tr>
<tr><td rowspan="6">Study population Characteristics</td><td colspan="4"><u>Variable</u></td><td colspan="2"><u>Cases</u></td><td colspan="4"><u>Controls</u></td></tr>
<tr><td colspan="4">n</td><td colspan="2">42</td><td colspan="4">87</td></tr>
<tr><td colspan="4">Age: (yrs.) mean ±SD</td><td colspan="2">38</td><td colspan="4">37</td></tr>
<tr><td colspan="4">Gender M/F (%)</td><td colspan="2">52% M</td><td colspan="4">44% M</td></tr>
<tr><td colspan="4">Mean years driving experience</td><td colspan="2">17.4</td><td colspan="4">17.2</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">Visual assessments of best corrected VA and peripheral field exam with a Goldmann perimeter were undertaken by all study participants. VA exams were converted into central visual efficiency by use of the Lebensohn near-vision chart and data for central field efficiency (Table G-41). Conversions of peripheral field exams into field efficiency were also completed. Total horizontal meridian field diameters for 42 RP patients are shown in Table G-42. Driving histories obtained included driving hours/week and crash involvement over past 5 years. 31 RP patients stated they had restricted themselves to daytime driving.</td></tr>
<tr><td>Statistical Methods</td><td colspan="11">Mantel-Haenszel statistic</td></tr>
<tr><td rowspan="2">Quality assessment</td><td>Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td></td><td>S</td><td>S</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">Frequency of crash</td></tr>
<tr><td>Results</td><td colspan="11">Crash rate for RP patients during a 5 year period demonstrated no involvement by 50% of RP patients and 71% of controls Table G-43). After controlling for hours per week spent driving, driving years, and gender, a significant difference between the 2 groups existed for females and for those driving the least number of years (p<0.05) (Table G-44). In the control group, males caused a significantly greater number of crash (42% vs 18%, p=0.02), however in the RP group, 55% of females had one or more crashes. Comparison of peripheral and central VF efficiency and crash showed no relationship (Figure G-25) (Figure G-26). Additional analysis comparing RP patients and controls with the Mantel-Haenszel statistic is shown in (Table G-45). A statistically significant difference in number of crashes only existed comparing females driving 1-10 hours/week and from 5 – 10 years. RP females were involved in more crashes than the control female subjects.</td></tr>
<tr><td>Authors' Comments</td><td colspan="11">RP patients demonstrated an increased rate of crash versus controls however this difference was mostly attributable to a population of females with driving histories of 5-10 years.</td></tr>
</table>

Table G-41: Conversion of VA to Visual Efficiency



Visual acuity (Snellen)	*20/20*	*20/25*	*20/30*	*20/40*	*20/50*	*20/60*	*20/70*	*20/80*	*20/100*	*20/200*
Visual efficiency (%)	100	95	90	85	75	70	64	59	50	20

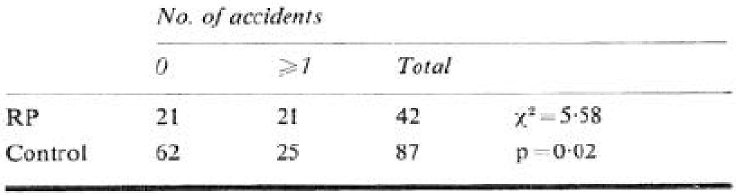
Table G-42: Total Horizontal Meridian Degrees for Peripheral VF



Patient no.	*Right eye*	*Left eye*	*Both eyes*
1	30	15	45
2	15	10	25
3	20	20	40
4	10	15	25
5	15	15	30
6	10	10	20
7	10	20	30
8	20	20	40
9	10	20	30
10	15	35	50
11	20	20	40
12	25	25	50
13	25	20	45
14	20	20	40
15	15	20	35
16	30	10	40
17	20	15	35
18	15	10	25
19	15	35	50
20	25	25	50
21	25	20	45
22	25	25	50
23	30	35	65
24	20	20	40
25	20	30	50
26	35	20	55
27	30	45	75
28	60	45	105
29	35	35	70
30	40	35	75
31	25	50	75
32	50	50	100
33	40	45	85
34	50	75	125
35	20	45	65
36	65	20	85
37	60	60	120
38	45	45	90
39	105	50	155
40	70	50	120
41	70	70	140
42	120	110	230

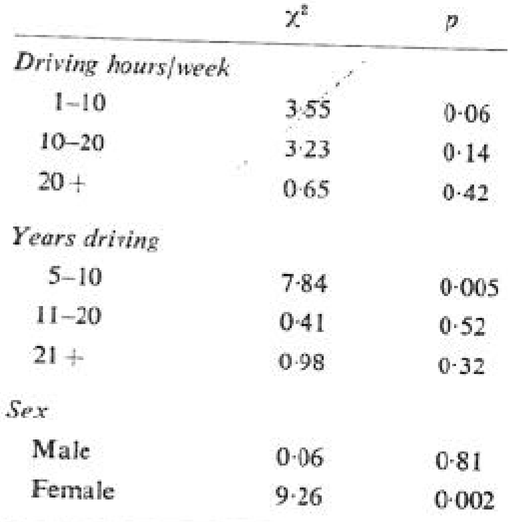
Data for 42 patients with retinitis pigmentosa

Table G-43: Accident Records of RP Patients versus Controls (5 year period)



	No. of accidents			
	0	*≥1*	*Total*	
RP	21	21	42	$\chi^2 = 5{\cdot}58$
Control	62	25	87	$p = 0{\cdot}02$

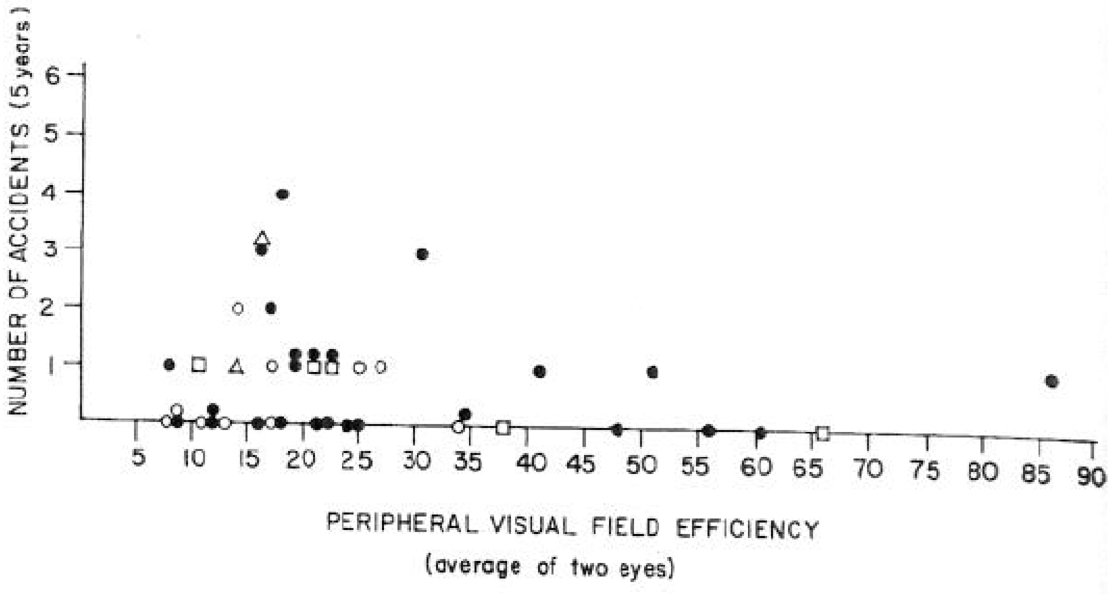
Table G-44: Statistical Differences in Number of Crashes (RP vs Controls)



	χ^2	p
Driving hours/week		
1–10	3·55	0·06
10–20	3·23	0·14
20 +	0·65	0·42
Years driving		
5–10	7·84	0·005
11–20	0·41	0·52
21 +	0·98	0·32
Sex		
Male	0·06	0·81
Female	9·26	0·002

* Comparisons are made for each category of driving hours/week, years driving, and gender

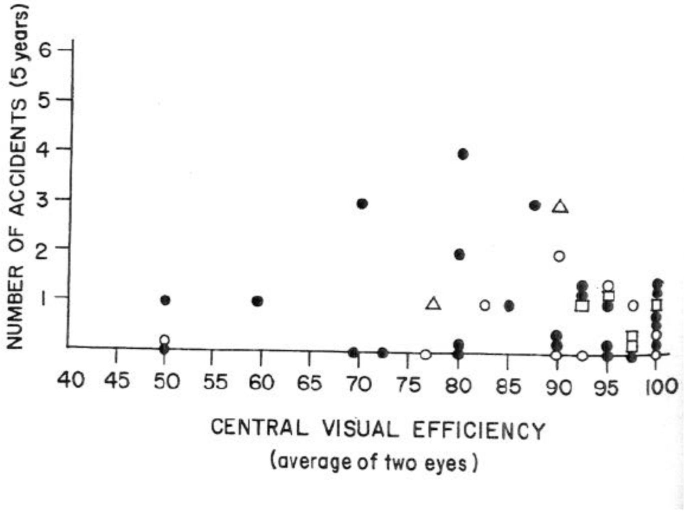
Figure G-25: Correlation of Driving Records with Peripheral VF Efficiency (RP patients)



Driving records are correlated with peripheral VF efficiency (average of 2 eyes) in 42 patients with retinitis pigmentosa.

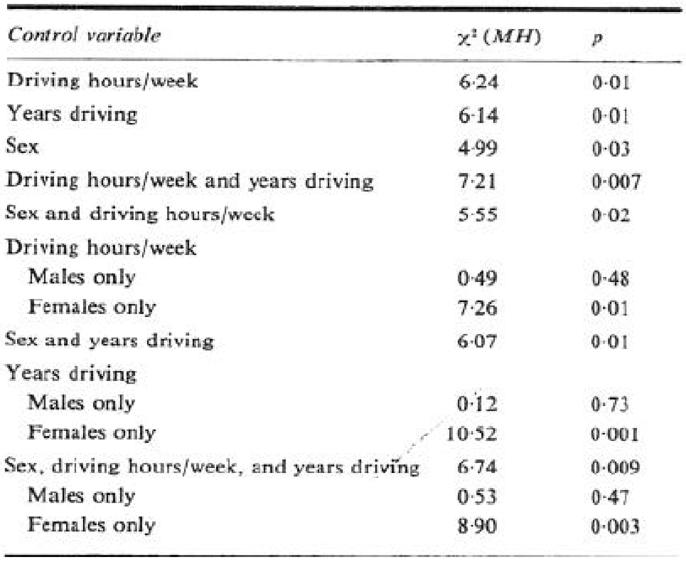
Black circles (●) indicate 1 to 10 driving hours per week; open circles (○) 10 to 15 hours per week; triangles (∆) 15 to 20 hours per week; and squares (□) more than 20 hours per week.

Figure G-26: Correlation of Driving Records with Central Visual Efficiency



Driving records are correlated with central visual efficiency (average of 2 eyes) In 42 patients with Retinitis pigmentosa. Black circles (●) indicate 1 to 10 driving hours per week; open circles (○) 10 to 15 hours per week; triangles (∆)15 to 20 hours per week; and squares (□) more than 20 hours per week.

Table G-45: Mantel-Haenszel statistics comparing Number of Crash

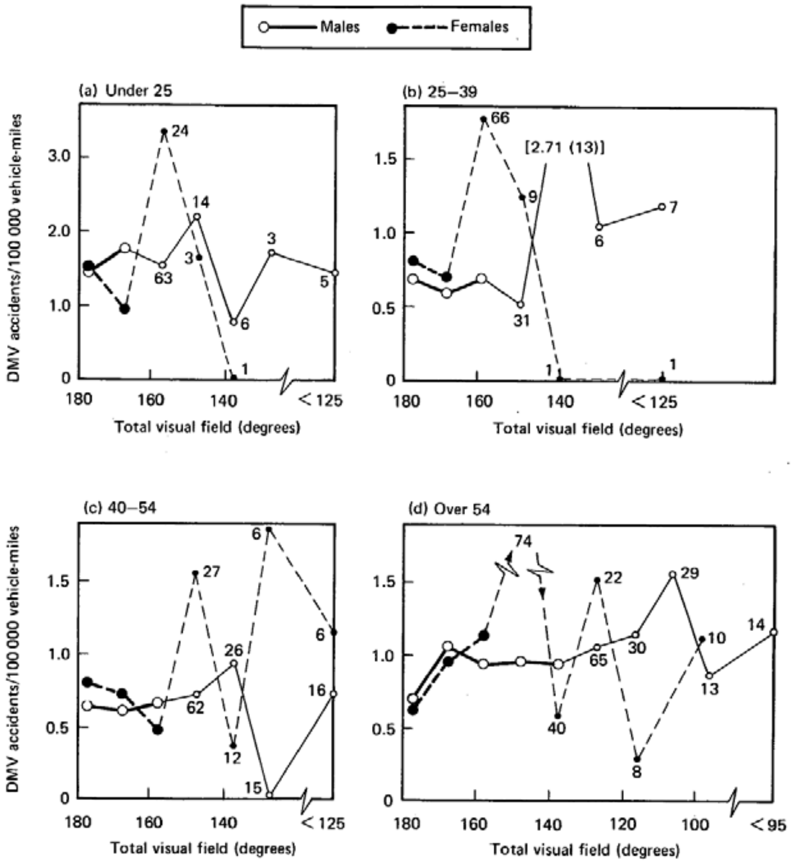


Control variable	χ^2 *(MH)*	*p*
Driving hours/week	6·24	0·01
Years driving	6·14	0·01
Sex	4·99	0·03
Driving hours/week and years driving	7·21	0·007
Sex and driving hours/week	5·55	0·02
Driving hours/week		
Males only	0·49	0·48
Females only	7·26	0·01
Sex and years driving	6·07	0·01
Years driving		
Males only	0·12	0·73
Females only	10·52	0·001
Sex, driving hours/week, and years driving	6·74	0·009
Males only	0·53	0·47
Females only	8·90	0·003

* Data were analyzed by the Mantel-Haenszel statistic, X^2 (MH), which tests for the existence of an association between 2 variables (case/control status and number of crashes) while controlling for the effects of 1 or more confounding variables (i.e., years driving, gender, gender by years driving).

<table>
<tr><td colspan="12">Hills B, Burg A. A reanalysis of California driver vision data: general findings. Transport and Road Research Laboratory Report 1977; 768: 1-19</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="3">5</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2">✓</td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td>Research Question</td><td colspan="11">Correlation of visual variables as predictors of crash</td></tr>
<tr><td>Study Design</td><td colspan="11">Prospective cohort</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="10">Drivers with valid mileage estimates, valid three year driving records, age and gender data</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10">Drivers with average annual mileage of 999 miles or less</td></tr>
<tr><td>Study population Characteristics</td><td colspan="10">N 14,283
Age (years/mean) 41.5
Annual average mileage (mean) 13,865
Gender M/F 63%/37%
Total VF (mean) 170.7˚
All Crashes/100,000 Vehicle Miles (VM) 1.09
DMV Crashes/100,000 VM 0.89</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">Age categories administered were (1) under 25, (2) 25-39, (3) 40-54, and (4) over 54. DMV Crash Rate was selected to demonstrate study results as it was the one crash criterion which complete data was available for all drivers tested.</td></tr>
<tr><td>Statistical Methods</td><td colspan="11">Pearson Product-Moment coefficients, t-test</td></tr>
<tr><td rowspan="2">Quality assessment</td><td>Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td></td><td>S</td><td>S</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">VF as a predictor for crash</td></tr>
<tr><td>Results</td><td colspan="11"><u>Under 25, 25-39 and 40-54 Age Group</u>
o No significant relationship between crash rate and total VF was demonstrated (Table G-46).
<u>Over 54 Age Group</u>
o No evidence of a trend for progressive increase in crash with reduction in total VF.
o Significant correlation coefficients may be due to drivers with total VF of 175˚ or better having rather lower crash rates than the remaining age groups (Table G-47).
o Mean crash rate with very good VFs were no higher than those of the 40-54 age group.
o No evidence was found for recommending a vision field standard of 140˚.
o 14 male drivers (0.5% of age group) with total VFs less than 95˚ had average All Crash and Of-Interest Crash Rates that were approximately twice the rest of the group. Differences between groups were not statistically significant using a t-test.
o Significant t-statistics were obtained for both genders for a pass score of 170˚. Holding this pass score as a vision standard however would place 80% of the age group in the “fail” category. At lower “pass scores”, the Relative Accident Rates are close and the t-statistics become non-significant.</td></tr>
<tr><td>Authors’ Comments</td><td colspan="11">VF is a weak predictor for crash in this study of 14,000 drivers at any age group.</td></tr>
</table>

Table G-46: DMV Crash Rate as a Function of Total VF



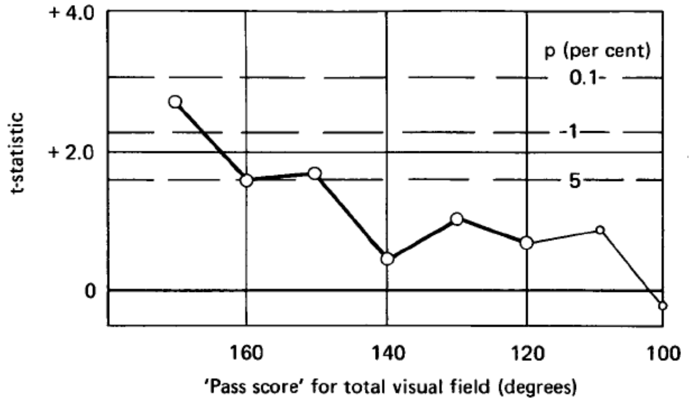
	N_B	r_B	N_M	r_M	N_F	r_F
Under 25	2256	0.010	1445	0.020	811	–0.010
25–39	4520	0.014	2860	0.014	1660	0.025
40–54	4480	–0.009	2705	–0.011	1775	–0.002
Over 54	2885	0.044*	1922	0.040	963	0.059

(i) N_B (ii) N_M (iii) N_F: Age group sample sizes for Both Sexes Combined, Males Only and Females Only respectively.

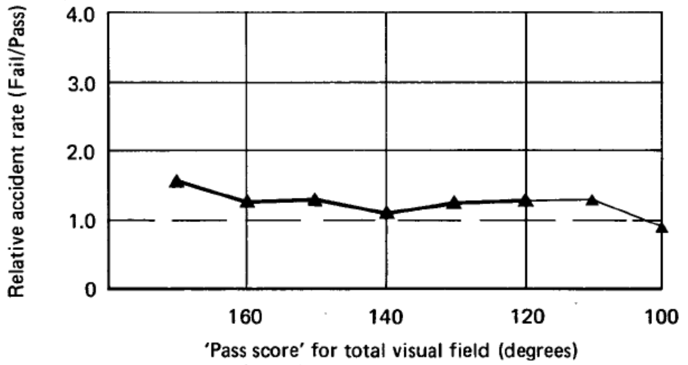
(i) r_B (ii) r_M (iii) r_F: corresponding Pearson Product-Moment correlation coefficients between visual performance score and accident rate.

* Statistically significant at 5% level.

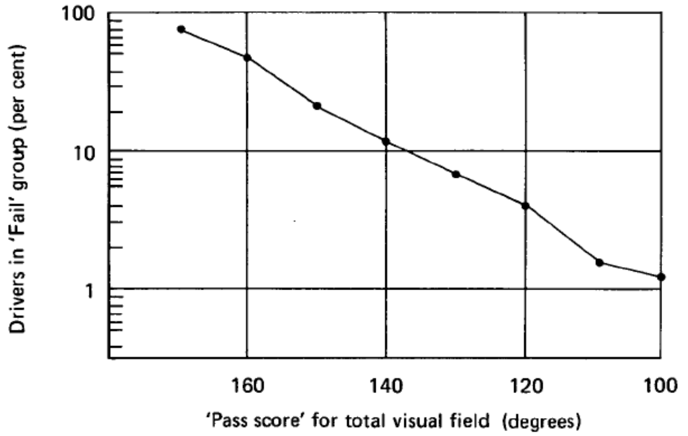
Table G-47: Total VF: Effects of Varying the "Pass Score" for 54+ Age Group



(i) The statistical significance of the differences between DMV accident rates of the 'Pass' and 'Fail' groups



(ii) The ratio of the mean DMV accident rates ('Fail'/'Pass')



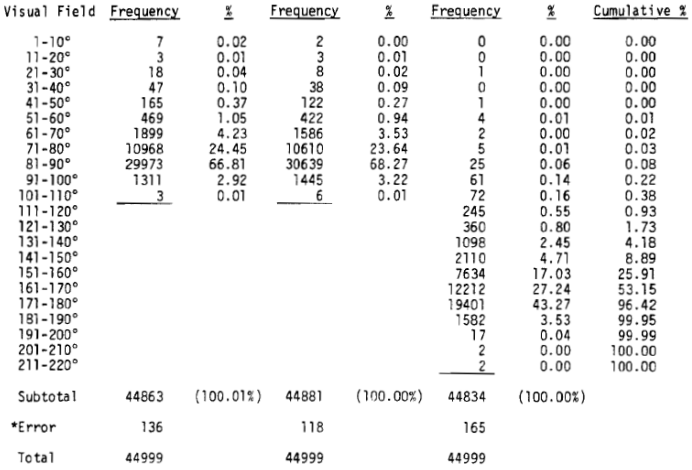
(iii) The percentage of drivers in the 'Fail' group

Pass- vision test scores better than or equal to a "pass" score

Fail – test scores less than the "pass" score

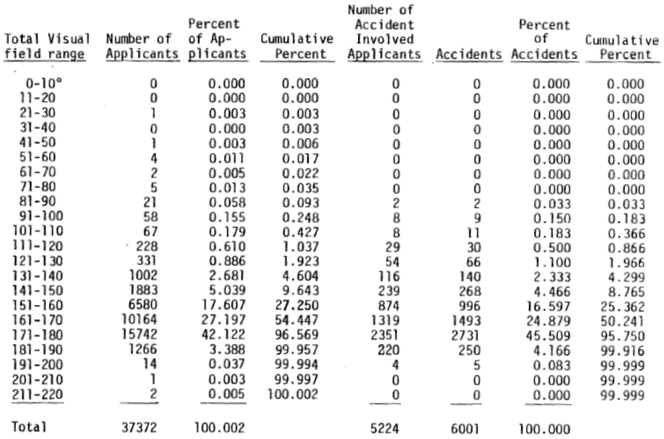
<table>
<tr><td colspan="12">Council F, Allen J. A study of the VFs of North Carolina drivers and their relationship to accidents. Highway Safety Research Center, University of North Carolina 1974; i-17</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="3">5</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2">✓</td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td>Research Question</td><td colspan="11">Assess relationship of VF and crash risk</td></tr>
<tr><td>Study Design</td><td colspan="11">Retrospective cohort</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="10">North Carolina residents recruited at driver licensing stations during December 1972.</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10"></td></tr>
<tr><td>Study population Characteristics</td><td colspan="10">N 44,999 (UFOV testing)
N 37,372 (crash data)</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">Driver license examiners performed 52, 397 tests of applicants. Individuals were instructed to fixate on a target that moved horizontally along a circular path and indicate at what point the target could still be viewed at his/her side. Eyes were tested individually and a total VF was derived from test scores. VFs for subjects were grouped by 10° ranges.
Crash data was obtained for the period Jan 1, 1971-Dec 31, 1972 from the North Carolina Crash File.</td></tr>
<tr><td>Statistical Methods</td><td colspan="11">Kolomogorov-Smirnov test</td></tr>
<tr><td rowspan="2">Quality assessment</td><td>Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td></td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">Total VF and crash rate</td></tr>
<tr><td>Results</td><td colspan="11">Total VF
o Only 2 of 44,834 (.0044%) subjects have severely limited VF (≤50°); .0848% of subjects has total VFs ≤90° and 0.928% had VFs ≤120° (Table G-48).
o <5% had VFs ≤140° standard criterion and 75% of subjects had fields >160°
Crash Involvement
o Crash data is shown in Table G-49.
o The Kolomogorov-Smirnov test was conducted to compare the difference between VFs of crash and crash-free subjects. Analysis showed that the two groups were different (p<.001) but surprisingly demonstrated that the crash-involved drivers had slightly larger fields than drivers who had not incurred crashes. There is no indication however those drivers with limited VFs incurred more crash.
o Additional analysis utilizing the Kolomogorov-Smirnov test was completed for VFs and crash by age group (Table G-50, Table G-51, Table G-52, Table G-53, and Table G-54). Only age group demonstrating significance at the <.01 level involved the 41-60 yr old drivers, Table G-52. Again, crash-free drivers demonstrated more limited VFs than crash-involved drivers.
o Analysis of mean number of crash/driver by VF is shown in Table G-55.
o Significance was found for ≤25 age group, with the mean number of crash/driver for drivers with VF <120° is significantly less than the mean crash/driver for the normal group (p<.01). No significant findings were demonstrated for any other “limited” fields of vision for this age group.
o For the oldest age group, ≥71 yrs, the number of crash/driver is > for drivers with fields of vision ≤140° than for the normal group (p<.10). No significant findings were again demonstrated for any other “limited” fields of vision for this age group.</td></tr>
<tr><td>Authors’ Comments</td><td colspan="11">No strong relationship was demonstrated between VF and crash for 35,000+ subjects for any age group.</td></tr>
</table>

Table G-48: Total VF for 44,834 Subjects



Visual Field	Frequency	%	Frequency	%	Frequency	%	Cumulative %
1-10°	7	0.02	2	0.00	0	0.00	0.00
11-20°	3	0.01	3	0.01	0	0.00	0.00
21-30°	18	0.04	8	0.02	1	0.00	0.00
31-40°	47	0.10	38	0.09	0	0.00	0.00
41-50°	165	0.37	122	0.27	1	0.00	0.00
51-60°	469	1.05	422	0.94	4	0.01	0.01
61-70°	1899	4.23	1586	3.53	2	0.00	0.02
71-80°	10968	24.45	10610	23.64	5	0.01	0.03
81-90°	29973	66.81	30639	68.27	25	0.06	0.08
91-100°	1311	2.92	1445	3.22	61	0.14	0.22
101-110°	3	0.01	6	0.01	72	0.16	0.38
111-120°					245	0.55	0.93
121-130°					360	0.80	1.73
131-140°					1098	2.45	4.18
141-150°					2110	4.71	8.89
151-160°					7634	17.03	25.91
161-170°					12212	27.24	53.15
171-180°					19401	43.27	96.42
181-190°					1582	3.53	99.95
191-200°					17	0.04	99.99
201-210°					2	0.00	100.00
211-220°					2	0.00	100.00
Subtotal	44863	(100.01%)	44881	(100.00%)	44834	(100.00%)	
*Error	136		118		165		
Total	44999		44999		44999		

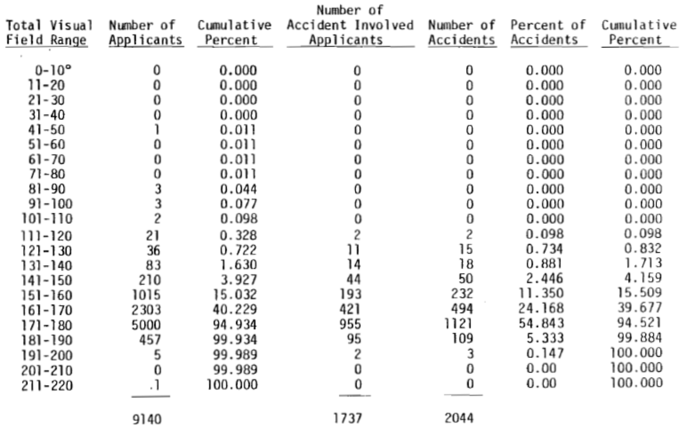
Table G-49: Crash Involvement by 10 Degree Total VF Range



Total Visual field range	Number of Applicants	Percent of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0.000	0	0	0.000	0.000
11-20	0	0.000	0.000	0	0	0.000	0.000
21-30	1	0.003	0.003	0	0	0.000	0.000
31-40	0	0.000	0.003	0	0	0.000	0.000
41-50	1	0.003	0.006	0	0	0.000	0.000
51-60	4	0.011	0.017	0	0	0.000	0.000
61-70	2	0.005	0.022	0	0	0.000	0.000
71-80	5	0.013	0.035	0	0	0.000	0.000
81-90	21	0.058	0.093	2	2	0.033	0.033
91-100	58	0.155	0.248	8	9	0.150	0.183
101-110	67	0.179	0.427	8	11	0.183	0.366
111-120	228	0.610	1.037	29	30	0.500	0.866
121-130	331	0.886	1.923	54	66	1.100	1.966
131-140	1002	2.681	4.604	116	140	2.333	4.299
141-150	1883	5.039	9.643	239	268	4.466	8.765
151-160	6580	17.607	27.250	874	996	16.597	25.362
161-170	10164	27.197	54.447	1319	1493	24.879	50.241
171-180	15742	42.122	96.569	2351	2731	45.509	95.750
181-190	1266	3.388	99.957	220	250	4.166	99.916
191-200	14	0.037	99.994	4	5	0.083	99.999
201-210	1	0.003	99.997	0	0	0.000	99.999
211-220	2	0.005	100.002	0	0	0.000	99.999
Total	37372	100.002		5224	6001	100.000	

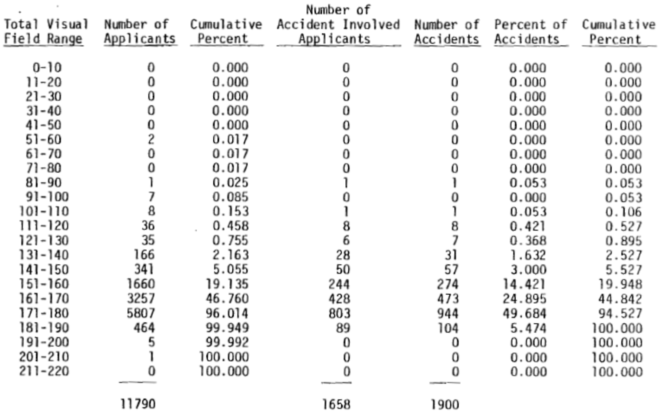
Accident-free subjects can be established by subtracting the frequencies of crash-involved subjects (column 4) from the total number of subjects (column 1).

Table G-50: Crash and Total VF Range <26 Yrs of Age



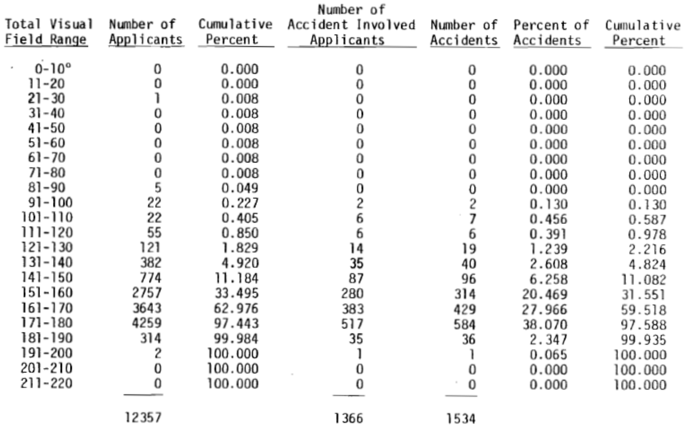
Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	0	0.000	0	0	0.000	0.000
31-40	0	0.000	0	0	0.000	0.000
41-50	1	0.011	0	0	0.000	0.000
51-60	0	0.011	0	0	0.000	0.000
61-70	0	0.011	0	0	0.000	0.000
71-80	0	0.011	0	0	0.000	0.000
81-90	3	0.044	0	0	0.000	0.000
91-100	3	0.077	0	0	0.000	0.000
101-110	2	0.098	0	0	0.000	0.000
111-120	21	0.328	2	2	0.098	0.098
121-130	36	0.722	11	15	0.734	0.832
131-140	83	1.630	14	18	0.881	1.713
141-150	210	3.927	44	50	2.446	4.159
151-160	1015	15.032	193	232	11.350	15.509
161-170	2303	40.229	421	494	24.168	39.677
171-180	5000	94.934	955	1121	54.843	94.521
181-190	457	99.934	95	109	5.333	99.884
191-200	5	99.989	2	3	0.147	100.000
201-210	0	99.989	0	0	0.00	100.000
211-220	.1	100.000	0	0	0.00	100.000
	9140		1737	2044		

Table G-51: Crash and Total VF Range 26-40 Yrs of Age



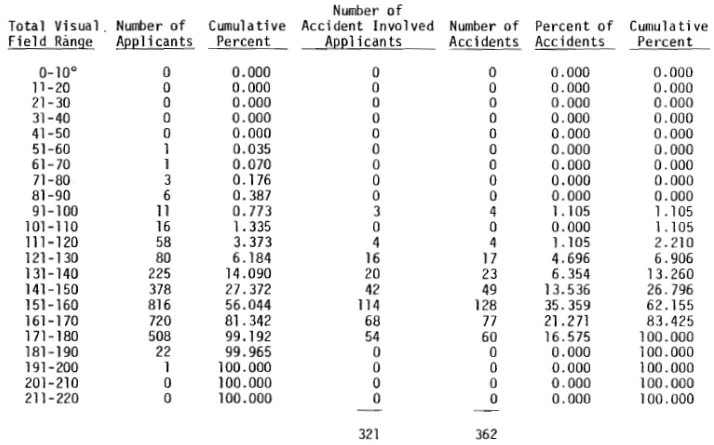
Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	0	0.000	0	0	0.000	0.000
31-40	0	0.000	0	0	0.000	0.000
41-50	0	0.000	0	0	0.000	0.000
51-60	2	0.017	0	0	0.000	0.000
61-70	0	0.017	0	0	0.000	0.000
71-80	0	0.017	0	0	0.000	0.000
81-90	1	0.025	1	1	0.053	0.053
91-100	7	0.085	0	0	0.000	0.053
101-110	8	0.153	1	1	0.053	0.106
111-120	36	0.458	8	8	0.421	0.527
121-130	35	0.755	6	7	0.368	0.895
131-140	166	2.163	28	31	1.632	2.527
141-150	341	5.055	50	57	3.000	5.527
151-160	1660	19.135	244	274	14.421	19.948
161-170	3257	46.760	428	473	24.895	44.842
171-180	5807	96.014	803	944	49.684	94.527
181-190	464	99.949	89	104	5.474	100.000
191-200	5	99.992	0	0	0.000	100.000
201-210	1	100.000	0	0	0.000	100.000
211-220	0	100.000	0	0	0.000	100.000
	11790		1658	1900		

Table G-52: Crash and Total VF Range 41-60 Yrs of Age



Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	1	0.008	0	0	0.000	0.000
31-40	0	0.008	0	0	0.000	0.000
41-50	0	0.008	0	0	0.000	0.000
51-60	0	0.008	0	0	0.000	0.000
61-70	0	0.008	0	0	0.000	0.000
71-80	0	0.008	0	0	0.000	0.000
81-90	5	0.049	0	0	0.000	0.000
91-100	22	0.227	2	2	0.130	0.130
101-110	22	0.405	6	7	0.456	0.587
111-120	55	0.850	6	6	0.391	0.978
121-130	121	1.829	14	19	1.239	2.216
131-140	382	4.920	35	40	2.608	4.824
141-150	774	11.184	87	96	6.258	11.082
151-160	2757	33.495	280	314	20.469	31.551
161-170	3643	62.976	383	429	27.966	59.518
171-180	4259	97.443	517	584	38.070	97.588
181-190	314	99.984	35	36	2.347	99.935
191-200	2	100.000	1	1	0.065	100.000
201-210	0	100.000	0	0	0.000	100.000
211-220	0	100.000	0	0	0.000	100.000
	12357		1366	1534		

Table G-53: Crash and Total VF Range for 61-70 Yrs of Age



Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	0	0.000	0	0	0.000	0.000
31-40	0	0.000	0	0	0.000	0.000
41-50	0	0.000	0	0	0.000	0.000
51-60	1	0.035	0	0	0.000	0.000
61-70	1	0.070	0	0	0.000	0.000
71-80	3	0.176	0	0	0.000	0.000
81-90	6	0.387	0	0	0.000	0.000
91-100	11	0.773	3	4	1.105	1.105
101-110	16	1.335	0	0	0.000	1.105
111-120	58	3.373	4	4	1.105	2.210
121-130	80	6.184	16	17	4.696	6.906
131-140	225	14.090	20	23	6.354	13.260
141-150	378	27.372	42	49	13.536	26.796
151-160	816	56.044	114	128	35.359	62.155
161-170	720	81.342	68	77	21.271	83.425
171-180	508	99.192	54	60	16.575	100.000
181-190	22	99.965	0	0	0.000	100.000
191-200	1	100.000	0	0	0.000	100.000
201-210	0	100.000	0	0	0.000	100.000
211-220	0	100.000	0	0	0.000	100.000
			321	362		

Table G-54: Crash and Total VF Range 70+ Yrs of Age

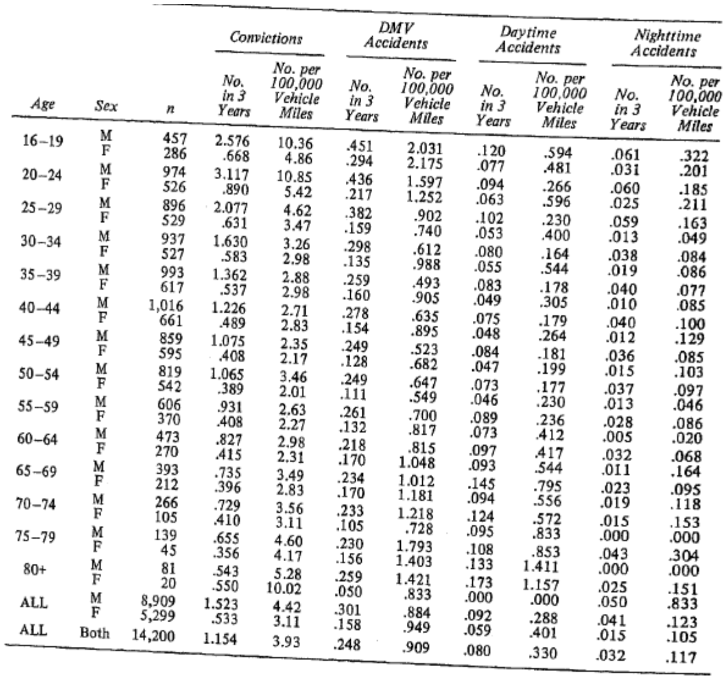
Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	0	0.000	0	0	0.000	0.000
31-40	0	0.000	0	0	0.000	0.000
41-50	0	0.000	0	0	0.000	0.000
51-60	1	0.081	0	0	0.000	0.000
61-70	1	0.161	0	0	0.000	0.000
71-80	2	0.323	0	0	0.000	0.000
81-90	6	0.807	1	1	0.621	0.621
91-100	15	2.018	3	3	1.863	2.484
101-110	19	3.551	1	3	1.863	4.348
111-120	58	8.232	9	10	6.211	10.559
121-130	59	12.994	7	8	4.969	15.528
131-140	146	24.778	19	28	17.391	32.919
141-150	180	39.306	16	16	9.938	42.857
151-160	332	66.102	43	48	29.814	72.671
161-170	241	85.553	19	20	12.422	85.093
171-180	168	99.112	22	22	13.665	98.758
181-190	9	99.839	1	1	0.621	99.379
191-200	1	99.919	1	1	0.621	100.000
201-210	0	99.919	0	0	0.000	100.000
211-220	1	100.000	0	0	0.000	100.000
	1239		142	161		

Table G-55: Frequency of Crash and Mean and Variance of Crash/Driver by Visual vs Normal Field of Vision

		Accidents								
Age	Total Visual Field	0	1	2	3	4	5	$\bar{x}$	s^2	z
≤25	≤ 90°	4	0	0	0	0	0	0	0	
	≤100°	7	0	0	0	0	0	0	0	
	≤110°	9	0	0	0	0	0	0	0	
	≤120°	28	2	0	0	0	0	.066667	.064368	-3.337 (p<.01)
	≤130°	53	9	4	0	0	0	.257576	.317249	0.506 (NS)
	≤140°	122	20	6	1	0	0	.234899	.302558	0.276 (NS)
	≥160°	6293	1251	194	25	2	1	.222380	.247901	
26-40	≤ 90°	2	1	0	0	0	0	.333333	.333333	.521 (NS)
	≤100°	9	1	0	0	0	0	.100000	.100000	-.595 (NS)
	≤110°	16	2	0	0	0	0	.111111	.104575	-.634 (NS)
	≤120°	44	10	0	0	0	0	.185185	.153739	.479 (NS)
	≤130°	73	15	1	0	0	0	.191011	.179009	.699 (NS)
	≤140°	211	41	2	1	0	0	.188235	.192774	1.031 (NS)
	≥160°	8214	1146	152	17	5	0	.159534	.182980	
41-60	≤ 90°	6	0	0	0	0	0	0	0	
	≤100°	26	2	0	0	0	0	.0714286	.068783	1.133 (NS)
	≤110°	42	7	1	0	0	0	.180000	.191429	.842 (NS)
	≤120°	91	13	1	0	0	0	.142857	.142857	.407 (NS)
	≤130°	198	22	6	0	0	0	.150442	.181711	.791 (NS)
	≤140°	545	52	11	0	0	0	.121711	.143317	.381 (NS)
	≥160°	7282	831	97	7	1	0	.127768	.141638	
61-70	≤ 90°	11	0	0	0	0	0	0	0	
	≤100°	19	2	1	0	0	0	.181818	.251082	.674 (NS)
	≤110°	35	2	1	0	0	0	.105263	.150782	-.0667(NS)
	≤120°	89	6	1	0	0	0	.083333	.098246	-.781 (NS)
	≤130°	153	21	2	0	0	0	.142045	.145422	1.0684(NS)
	≤140°	358	39	3	1	0	0	.119701	.135636	.486 (NS)
	≥160°	1129	110	9	3	0	0	.109512	.126397	
≥71	≤ 90°	9	1	0	0	0	0	.100000	.100000	.0471(NS)
	≤100°	21	4	0	0	0	0	.160000	.140000	.723 (NS)
	≤110°	39	4	0	0	0	0	.159091	.276427	.673 (NS)
	≤120°	88	12	1	0	0	0	.138614	.140594	.839 (NS)
	≤130°	140	18	2	0	0	0	.137500	.144497	.920 (NS)
	≤140°	267	33	4	2	0	1	.169381	.271870	+1.930 (p<.10)
	≥160°	377	42	1	0	0	0	.104762	.098784	

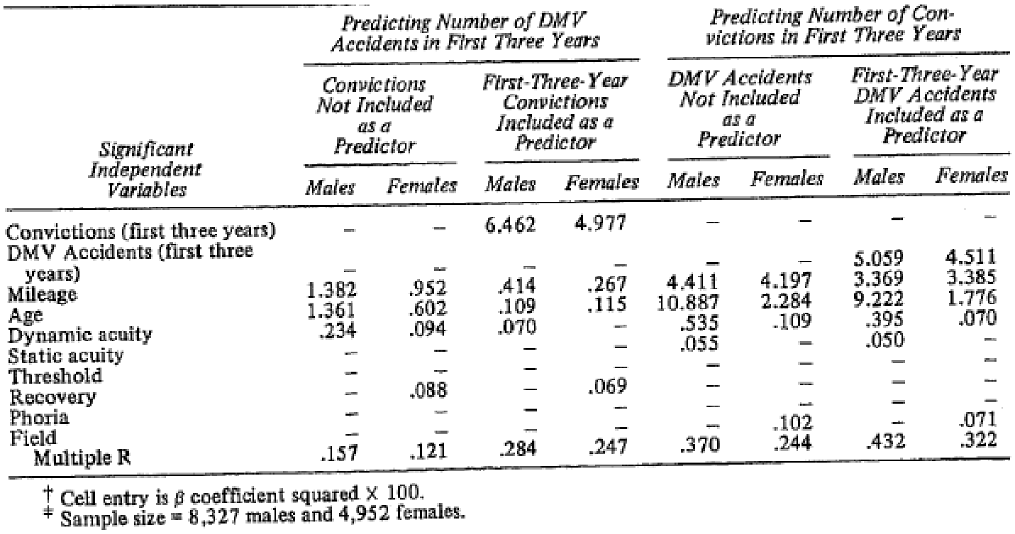
<table>
<tr><td colspan="12">Burg A. Vision and driving: a report on research. Human Factors 1971; 13 (1): 79-87</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="3">5</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2">✓</td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td>Research Question</td><td colspan="11">Strength of visual variables to predict risk of crash over a 3 year and 6 year period</td></tr>
<tr><td>Study Design</td><td colspan="11">Prospective cohort</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="10">Volunteers recruited from 46 DMV field offices in California</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10"></td></tr>
<tr><td>Study population Characteristics</td><td colspan="10">November 1962-April 1966 (3 year study)
Cases
N 14,000 drivers
Age range 16-92 years
Gender M/F 62.7%/37.3%
November 1962-March 1968 (6 year study)
N 7,841</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">Information on crashes incurred and convictions for traffic citations were obtained for a 36-month period from the DMV for both cases and controls. Lateral VF (extent of an individual's side vision when looking straight ahead) was measured by an American Optical Company Screening Perimeter. Age, gender and average annual mileage were controlled for.</td></tr>
<tr><td>Statistical Methods</td><td colspan="11">Multiple regression analysis and extensive product-moment correlational analyses</td></tr>
<tr><td rowspan="2">Quality assessment</td><td>Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td></td><td>S</td><td>S</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">Contribution of VF as a predictor for crash</td></tr>
<tr><td>Results</td><td colspan="11">3 year record data
o Driving record data is listed in Table G-56.
o Results for multiple regression analyses by gender are shown in Table G-57. Results allow assessment of each significant independent variable to predict the dependent variable. As shown, total lateral VF is a limited contributor to prediction with binocular dynamic acuity and binocular static acuity being the strongest contributors.
6 year record data
o Total VF was a significant contributor to predicting crash (Table G-58) especially for males.</td></tr>
<tr><td>Authors' Comments</td><td colspan="11">VF was a stronger contributor to predicting crash for males in an analysis of 6 year data but showed limited contribution in predicting crash for a 3 year period.</td></tr>
</table>

Table G-56: 3 Year Driving Data by Age and Gender



			Convictions		DMV Accidents		Daytime Accidents		Nighttime Accidents	
Age	Sex	n	No. in 3 Years	No. per 100,000 Vehicle Miles	No. in 3 Years	No. per 100,000 Vehicle Miles	No. in 3 Years	No. per 100,000 Vehicle Miles	No. in 3 Years	No. per 100,000 Vehicle Miles
16–19	M	457	2.576	10.36	.451	2.031	.120	.594	.061	.322
	F	286	.668	4.86	.294	2.175	.077	.481	.031	.201
20–24	M	974	3.117	10.85	.436	1.597	.094	.266	.060	.185
	F	526	.890	5.42	.217	1.252	.063	.596	.025	.211
25–29	M	896	2.077	4.62	.382	.902	.102	.230	.059	.163
	F	529	.631	3.47	.159	.740	.053	.400	.013	.049
30–34	M	937	1.630	3.26	.298	.612	.080	.164	.038	.084
	F	527	.583	2.98	.135	.988	.055	.544	.019	.086
35–39	M	993	1.362	2.88	.259	.493	.083	.178	.040	.077
	F	617	.537	2.98	.160	.905	.049	.305	.010	.085
40–44	M	1,016	1.226	2.71	.278	.635	.075	.179	.040	.100
	F	661	.489	2.83	.154	.895	.048	.264	.012	.129
45–49	M	859	1.075	2.35	.249	.523	.084	.181	.036	.085
	F	595	.408	2.17	.128	.682	.047	.199	.015	.103
50–54	M	819	1.065	3.46	.249	.647	.073	.177	.037	.097
	F	542	.389	2.01	.111	.549	.046	.230	.013	.046
55–59	M	606	.931	2.63	.261	.700	.089	.236	.028	.086
	F	370	.408	2.27	.132	.817	.073	.412	.005	.020
60–64	M	473	.827	2.98	.218	.815	.097	.417	.032	.068
	F	270	.415	2.31	.170	1.048	.093	.544	.011	.164
65–69	M	393	.735	3.49	.234	1.012	.145	.795	.023	.095
	F	212	.396	2.83	.170	1.181	.094	.556	.019	.118
70–74	M	266	.729	3.56	.233	1.218	.124	.572	.015	.153
	F	105	.410	3.11	.105	.728	.095	.833	.000	.000
75–79	M	139	.655	4.60	.230	1.793	.108	.853	.043	.304
	F	45	.356	4.17	.156	1.403	.133	1.411	.000	.000
80+	M	81	.543	5.28	.259	1.421	.173	1.157	.025	.151
	F	20	.550	10.02	.050	.833	.000	.000	.050	.833
ALL	M	8,909	1.523	4.42	.301	.884	.092	.288	.041	.123
	F	5,299	.533	3.11	.158	.949	.059	.401	.015	.105
ALL	Both	14,200	1.154	3.93	.248	.909	.080	.330	.032	.117

Table G-57: Multiple Regression Analyses



	Predicting Number of DMV Accidents in First Three Years				Predicting Number of Convictions in First Three Years			
	Convictions Not Included as a Predictor		First-Three-Year Convictions Included as a Predictor		DMV Accidents Not Included as a Predictor		First-Three-Year DMV Accidents Included as a Predictor	
Significant Independent Variables	Males	Females	Males	Females	Males	Females	Males	Females
Convictions (first three years)	–	–	6.462	4.977	–	–	–	–
DMV Accidents (first three years)	–	–	–	–	–	–	5.059	4.511
Mileage	1.382	.952	.414	.267	4.411	4.197	3.369	3.385
Age	1.361	.602	.109	.115	10.887	2.284	9.222	1.776
Dynamic acuity	.234	.094	.070	–	.535	.109	.395	.070
Static acuity	–	–	–	–	.055	–	.050	–
Threshold	–	–	–	–	–	–	–	–
Recovery	–	.088	–	.069	–	–	–	–
Phoria	–	–	–	–	–	–	–	–
Field	–	–	–	–	–	.102	–	.071
Multiple R	.157	.121	.284	.247	.370	.244	.432	.322

† Cell entry is β coefficient squared × 100.
‡ Sample size = 8,327 males and 4,952 females.

Table G-58: Correlation of Independent Variables to Predict Crash

Significant Independent Variable	Predicting Number of DMV Accidents in First Three Years				Predicting Number of DMV Accidents in Second Three Years								Predicting Number of DMV Accidents in Six Years			
	Convictions Not Included as a Predictor		First-Three-Year Convictions Included as a Predictor		Neither-DMV Accidents nor Convictions Included as Predictors		First-Three-Year DMV Accidents Included as a Predictor		First-Three-Year Convictions Included as a Predictor		Both DMV Accidents and Convictions Included as Predictors		Six-Year Convictions Not Included as a Predictor		Six-Year Convictions Included as a Predictor	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Convictions (six years)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8.829	9.219
Convictions (first three years)	–	–	6.960	5.524	–	–	–	–	.628	2.280	.301	2.280	–	–	–	–
DMV Accidents (first three years)	–	–	–	–	–	–	1.103	.410	–	–	.854	–	–	–	–	–
Mileage	1.648	1.272	.417	.391	.495	.815	.323	.690	.262	.351	.204	.351	1.759	1.925	.474	.382
Age	1.469	.902	.137	.331	1.687	.638	1.359	.561	1.087	.355	1.008	.355	2.934	1.706	.347	.331
Dynamic acuity	.262	.231	.108	.209	.377	–	.317	–	.314	–	.283	–	.546	.264	.236	–
Static acuity	–	–	–	–	–	.251	–	.231	–	.224	–	.224	–	.131	–	.213
Threshold	–	–	–	.100	–	–	–	–	–	–	–	–	–	–	–	–
Recovery	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Phoria	–	.119	–	.132	–	–	–	–	–	–	–	–	–	–	–	.089
Field	–	–	–	–	.118	–	.108	–	.112	–	.105	–	.107	–	.102	–
Multiple R.	.168	.143	.295	.270	.124	.122	.161	.137	.144	.190	.169	.190	.192	.178	.332	.340

† Cell entry is β coefficient squared × 100.
‡ Sample size = 4,580 males and 2,759 females.

<table>
<tr><td colspan="7">McGwin G, Owsley C, Ball K. Identifying crash involvement among older drivers: agreement between self-report and state records. Accid. Anal. Ad Prev., 1998; Vol 30 No 6: 781-91.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td>1</td><td>2</td><td>3</td><td>4</td><td colspan="2">5</td></tr>
<tr><td></td><td></td><td>✓</td><td></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="6">To estimate the level of agreement between self-reported and state-recorded crashes among sample population
To evaluate whether the prevalence of visual and cognitive impairment differs across three groups of older crash-involved drivers
To assess if risk factors for crash involvement differed when crash-involved drivers were identified by either self-report or state records</td></tr>
<tr><td>Study Design</td><td colspan="6">Cohort</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="5">Cases:
All licensed drivers in Jefferson county, Alabama age 55 years and older</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="5">NR</td></tr>
<tr><td>Study population Characteristics</td><td colspan="5">Refer to Table G-59 for complete details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="5">Unclear</td></tr>
<tr><td>Methods</td><td colspan="6">75 drivers randomly selected from each cell after Jefferson county drivers sorted into 21 cells to represent 3 crash categories
Enrollment ended when 302 subjects were successfully recruited; 16 additional subjects who did not provide information on self-reported crashes excluded; final sample consisted of 278 older drivers
33% of the overall sample had 0 crashes on record, 49% had 1-3 crashes and 18% had more than 4 over a 5 year period; subjects were classified as having 0 or 1 or more state-recorded crashes
Written informed consent obtained after process explained; protocol completed in single visit to clinic in 1990 which consisted of:
Visual sensory function assessments
Visual attention/processing speed
Eye health
Questionnaire about driving exposure
Cognitive function
Review of demographics and health information
All vision tests performed under photopic conditions (100 cd/m²)
Letter acuity measured using ETDRS chart and expressed as log minimum angle resolvable (logMAR)
Impaired acuity defined as worse than 20/40 acuity—the legal limit for most states
Contrast sensitivity measured using Pelli-Robson chart—impaired contrast sensitivity defined as score of 1.5 or worse
Stereoacuity was measured using the TNO test and expressed as arcseconds—impaired stereoacuity defined as 500 arcseconds or worse
Disability glare measured with MCT-8000 (VisTech) and defined as the difference in letter acuity (logMAR)
VF sensitivity measured with Humphrey Field Analyzer's 120-point screening program for the central 60° radius field using the quantify defects option
All test administered binocularly except VF tests in which each eye was tested separately
The UFOV defined as the VF area over which one can use rapidly presented visual information
All subjects received comprehensive eye exams by an ophthalmologist and mental status was evaluated by the Mattis Organic Mental Syndrome Screening Examination (MOMSSE) designed to assess cognitive functioning
Questionnaires completed by subjects to estimate driving or "on the road" exposure
• Refer to Figure G-27 for Self report and state recorded crash involvement
Two comparisons made to determine prevalence of visual and cognitive impairment across three groups:
Compared drivers with crashes that were self-reported but not state-recorded to drivers with both self-reported and state recorded crashes
Compared those drivers with crashes that were not self-reported but state recorded to drivers with both self-reported and state-recorded crashes</td></tr>
<tr><td>Statistical Methods</td><td colspan="6">Kappa coefficient calculated for agreements between both groups
t-tests used to measure differences in visual and cognitive groups for continuous variables
Fisher's exact test used when expected cell counts of contingency table were less than 5
Logistic regression used to calculate odds ratios (OR) and 95% confidence intervals (Cis) for the association between self-reported crashes and state recorded crashes and measures of visual and cognitive impairment</td></tr>
</table>

Quality assessment	**Study quality**	1	2	3	4	5	6	7	8	9	10	11	12	13
		N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y

	Moderate	14	15	16	17	18	19	20	21	22	23	24	25	
Relevant Outcomes Assessed	• Crash risk measured for vision impairment • VF assessed • Driving exposure calculated													
Results	• Table G-59, Table G-60, and Table G-61 compare the demographic, driving, health, visual and cognitive characteristics for study participants according to self-reported and state recorded crash involvement. • Proportion of subjects driving <10,000 miles per year was significantly greater among those with self-report only 85.7% and with state-recorded (76.2%) than those with both (57.7%) • Drivers involved in state-recorded crashes were significantly more likely to have impaired contrast sensitivity (25%) compared to self-reported and state-recorded (11.7%). See Table G-60. • To determine whether differences in the prevalence of visual and cognitive impairment had an impact on measures of association, ORs and 95% CIs calculated for association between prevalence and visual and cognitive impairment and self-reported and state-recorded crash involvement • OR for UFOV was larger than that obtained using self-report (13.7 vs. 3.4). See Table G-62.													
Authors' Comments	"While validation of these findings is required, research designed to identify risk factors for crash involvement among older drivers should carefully consider the issue of case definition, particularly if self-report is used to identify crash-involved older drivers."													

Table G-59. Demographic, driving and health characteristics of drivers by self-reported/state-recorded crash

Characteristics	(Self+/State−)[†] N=14	(Self−/State+)[†] N=64	(Self+/State+)[†] N=111
Age (years)			
Mean (SD)	67.4 (7.9)	72.8* (9.0)	70.3 (9.4)
Race (%)			
White	92.9	73.4	76.6
Black	7.1*	26.6	23.4
Sex (%)			
Female	57.1	51.6	40.5
Male	42.9	48.4	59.5
Annual miles driven (%)			
10,000+	14.3	23.8	42.4
⩽9,999	85.7*	76.2*	57.7
Days per week driven (%)			
7	42.9	46.0	59.5
<7	57.1	54.0*	40.5
Chronic diseases[‡] (%)			
0	28.6	12.5	18.0
⩾1	71.4	87.5	82.0
Cognitive score[‡,§] (%)			
⩽9	85.7	76.6	75.7
>9	14.3	23.4	24.3

[*] $p < 0.10$ compared to Self+/State+.
[†] Self-report only crashes=Self+/State−; state record only crashes=Self−/State+; self-report and state-record crashes=Self+/State+.
[‡] Higher values represent greater impairment except for contrast sensitivity, where lower values represent greater impairment.
[§] Score on Mattis Organic Mental Status Syndrome Examination (range: 0–28).

Table G-60. Prevalence of visual processing impairment of drivers by self-reported/state-recorded crash

Visual characteristics	(Self+/State−)[†] (%) N=14	(Self−/State+)[†] (%) N=64	(Self+/State+)[†] (%) N=111
Letter acuity			
20/40 or better	100.0	82.8	87.4
Worse than 20/40	0.0*	17.2	12.6
Log$_{10}$ contrast sensitivity[‡]			
>1.5	92.9	75.0	88.3
⩽1.5	7.1	25.0*	11.7
Stereoacuity[‡]			
<500 Arcseconds	78.6	60.3	73.9
⩾500 Arcseconds	21.4	39.7	26.1
Disability glare[‡,§]			
⩽0	50.0	43.7	59.5
>0	50.0	56.3	40.5
Central 30° visual field sensitivity[‡,‖]			
0 to 10	92.9	82.8	89.2
>10	7.1	17.2	10.8
Peripheral 30–60° visual field sensitivity[‡,‖]			
0 to 10	85.7	51.6	64.9
>10	14.3*	48.4*	35.1
Useful field of view[‡,¶]			
<40.0	78.6	26.6	27.9
⩾40.0	21.4*	73.4	72.1

[*] $p < 0.10$ compared to Self+/State+.
[†] Self-report only crashes=Self+/State−; state record only crashes=Self−/State+; self-report and state-record crashes=Self+/State+.
[‡] Higher values represent greater impairment except for contrast sensitivity, where lower values represent greater impairment.
[§] LogMAR acuity with glare minus LogMAR acuity without glare.
[‖] Average defect depth (dB)
[¶] Percentage reduction in useful field of view.

Table G-61. Prevalence of visual processing impairment of drivers by self-reported/state-recorded crash

Eye conditions	(Self+/State−)[†] (%) $N = 14$	(Self−/State+)[†] (%) $N = 64$	(Self+/State+)[†] (%) $N = 111$
Glaucoma	7.1	12.5	9.0
Cataract	42.9	56.3	46.0
Macular degeneration	7.1	9.4	7.2

[†] Self-report only crashes = Self+/State−; state record only crashes = Self−/State+; self-report and state-record crashes = Self+/State+.

Table G-62. Prevalence of eye conditions of drivers by self-reported and state-recorded crash involvement

	State-recorded crash involvement		Self-reported crash involvement		All crashes	
Variables	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Useful field of view[†,‡]						
< 40.0	1.0	(Referent)	1.0	(Referent)	1.0	(Referent)
$\geqslant 40.0$	13.7	(6.7, 28.3)	3.4	(1.9, 6.0)	10.6	(5.2–21.9)
Glaucoma[§]	3.0	(0.8, 11.0)	—		3.5	(0.9–14.5)

[†] Higher values represent greater impairment.

[‡] Percentage reduction score in useful field of view.

[§] Referent group is those without glaucoma.

Figure G-27. Drivers cross-classified by self-reported and state-recorded crash involvement

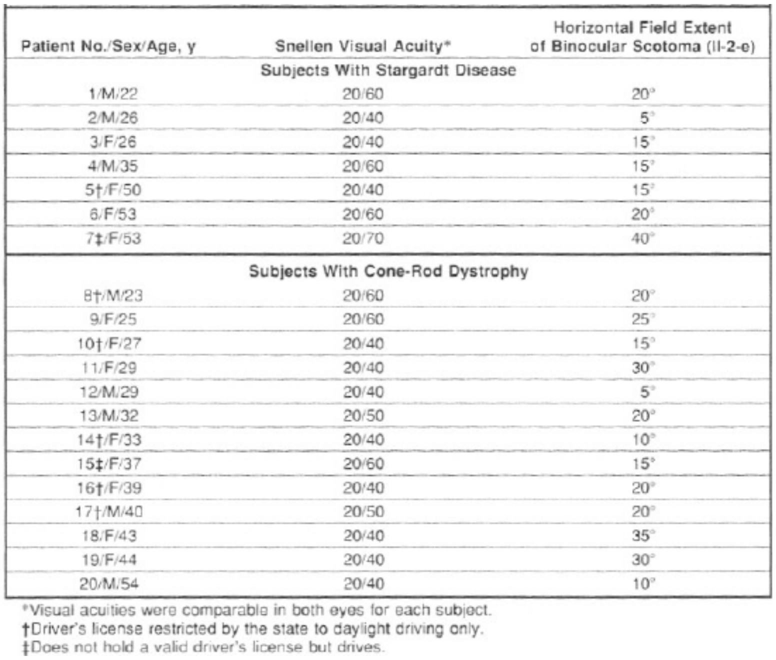
	State Recorded Crash Involvement		
Self report	No	Yes	**TOTAL**
No	Self - / State - N=89	Self - / State + N=64	153
Yes	Self + / State - N=14	Self + / State + N=111	125
TOTAL	103	175	278

<table>
<tr><td colspan="14">**Szlyk J, Fishman G, Severing K, Alexander K, Viana M. Evaluation of Driving Performance in Patients with Juvenile MFacular Dystrophies. Arch Ophthalmol 1993; Vol 111: 207-12.**</td></tr>
<tr><td rowspan="2">**Key Questions Addressed**</td><td colspan="2">**1**</td><td colspan="3">**2**</td><td colspan="3">**3**</td><td colspan="3">**4**</td><td colspan="2">**5**</td></tr>
<tr><td colspan="2"></td><td colspan="3"></td><td colspan="3">✓</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>**Research Question**</td><td colspan="13">To measure driving performance of subjects with losses of central vision due to hereditary macular dystrophy of juvenile onset and compare the driving performance of group of patients with central vision loss with that of previously studied group of patients with RP to investigate the relative roles of central vs. peripheral vision loss in driving</td></tr>
<tr><td>**Study Design**</td><td colspan="13">Case-Control</td></tr>
<tr><td rowspan="4">**Population**</td><td>**Inclusion Criteria**</td><td colspan="12">Cases:
Individuals with the clinical diagnosis of Stargart disease or cone-rod dystrophy
Subjects who regularly drove a minimum of 1600km/y for the period that data analyzed and who had a best corrected Snellen VA of 20/40 to 20/70 in at least one eye
Controls:
Individuals with normal VA ranging from 20/10 to 20/20 and no eye disease or VF loss</td></tr>
<tr><td>**Exclusion Criteria**</td><td colspan="12">Cases:
Individuals with glaucoma or greater than mild cataract
Controls:
NR</td></tr>
<tr><td>**Study population Characteristics**</td><td colspan="12">Refer to Table G-63 for complete details</td></tr>
<tr><td>**Generalizability to CMV drivers**</td><td colspan="12">Unclear</td></tr>
<tr><td>**Methods**</td><td colspan="13">Both groups held unrestricted driver's licenses at the time of testing
Findings of subjects with central vision loss and control subjects obtained in the present study were compared with the data on driving performance of 21 subjects with RP from previous study
Monocular VFs measured with Goldmann perimeter; binocular field maps were produced by merging the monocular fields of each patient by the method described by Arditi
• See Figure G-28 for illustration of binocular fields for Stargardt subjects and cone-rod dystrophy; area of binocular scotoma calculated and each field measured twice, and the values were averaged
• All subjects underwent testing on an interactive driving simulator that has been previously described; See Figure G-29 for picture of simulator
Testing performed with room lights off and subjects instructed to operate the simulator as they would normally drive a car
15 minutes permitted for course practice; data collected for subject's responses during a 5 minute session of drive the test course
Simulator indexed analyzed were:
Mean speed
Deviation in lane position
Number of lane boundary crossing
Brake pedal pressure
Braking response time to stop sign
Braking response time to traffic
Subjects able to monitor speed using:
Speedometer on central monitor
Flow fields created by passing landscapes
Turning resistance on the steering wheel
Alterations in engine sound with changing speeds
Collisions recorded on the simulator as crashes; there were 6 staged challenges on the simulator course requiring visuocognitive/motor skills to avoid a crash
• All subjects asked to respond to "true" or "false" questions used to assess risk taking perception (Table G-64)
Information about crashed within the past 5 years analyzed from state records and subjective questionnaire
Self-reported crashes categorized as daytime or nighttime based on information provided; descriptions included date and time of day and weather and road conditions</td></tr>
<tr><td>**Statistical Methods**</td><td colspan="13">Bayesian methods for comparing binomial probabilities used to test proportions of hypothesis
Spearman correlation used to measure correlations
Logistic regression analysis was performed to develop predictive model of crash involving simulator</td></tr>
<tr><td>**Quality assessment**</td><td>**Study quality**</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
</table>

		S	S	Y	N	N	N	Y	Y	Y	Y			
	Moderate	14	15	16	17	18	19	20	21	22	23	24	25	

Relevant Outcomes Assessed	• Crash risk assessed using subjective questionnaire and state records • Brake response time assessed • Vision assess to determine crash risk • Driving exposure included
Results	• Refer to Table G-65 and Table G-66 for the proportion of subjects in each of the crash groups with regard to self-reported crashes for both central vision loss group (Spearman's r [8]=.67, p<.05) and the control group (Spearman's r[17]=.52, p<.05) • Visual function measures and simulator indexes did not predict crash involvement for the central visual loss group, although these subjects showed longer braking response times and a greater number of lane boundary crossings than the control group • A Bayesian analysis of the PPs does not provide evidence to support or reject the hypothesis that there is a difference in the proportions (PP=.57) • Refer to Table G-67 for information pertaining to analyzed day and night crashes • Only one subject with central vision loss and no controls had a simulator crash during the 5 minute test period • VA was not correlated significantly with crash involvement (spearman's r[19]=-/35; p, not significant); neither was horizontal extent of central scotoma (Spearman's r[19]=.10; p, not significant; nor binocular area of central scotoma (spearman's r[19]=-.22) • The portion of individuals who had at least one lane boundary crossing was significantly greater for both the central vision loss group (40%) and the RP group than for the control group (21%) • Refer to Table G-68 for brake response times to stop signs and traffic lights--Planned comparisons show central vision loss group (mean ± SD, 6.67±1.04 seconds) and the RP group 6.82±1.04 seconds) were not significantly different on this index (p=.76) and RP (p<.02) groups had significantly longer breaking response times than the control group (5.93±1.19 seconds) • Significant main effect for diagnostic group (central vision loss, RP, or control) (F[2,66]= 8.96, P<.001) in an analysis of variance using subjective risk analysis scores as the dependent variable; see Table G-69 for further details
Authors' Comments	"The accident data from the state records were somewhat limited for two reasons. First, we were not able to obtain data from all subjects, either because a number of our subjects did not have Illinois licenses (seven subjects with central vision loss, eight controls, and five subjects with RP) or because they chose not to allow us access to their record (three subjects with central vision loss, three controls, and four subjects with RP). Second, the state reports did not include all accident involvement but only those accidents in which the police were called to the scene and a report was filed."

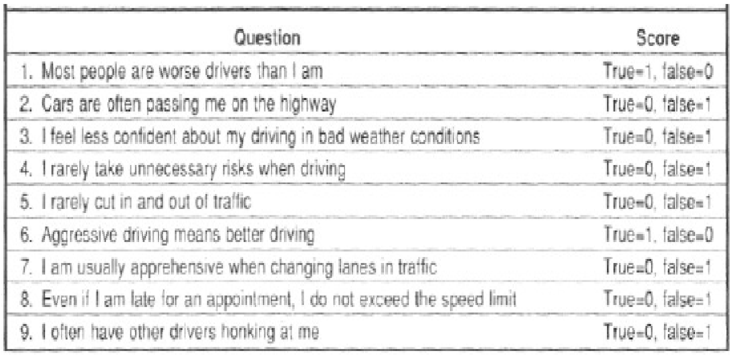
Table G-63. Characteristics of Patients With Central Vision Loss



Patient No./Sex/Age, y	Snellen Visual Acuity*	Horizontal Field Extent of Binocular Scotoma (II-2-e)
	Subjects With Stargardt Disease	
1/M/22	20/60	20°
2/M/26	20/40	5°
3/F/26	20/40	15°
4/M/35	20/60	15°
5†/F/50	20/40	15°
6/F/53	20/60	20°
7‡/F/53	20/70	40°
	Subjects With Cone-Rod Dystrophy	
8†/M/23	20/60	20°
9/F/25	20/60	25°
10†/F/27	20/40	15°
11/F/29	20/40	30°
12/M/29	20/40	5°
13/M/32	20/50	20°
14†/F/33	20/40	10°
15‡/F/37	20/60	15°
16†/F/39	20/40	20°
17†/M/40	20/50	20°
18/F/43	20/40	35°
19/F/44	20/40	30°
20/M/54	20/40	10°

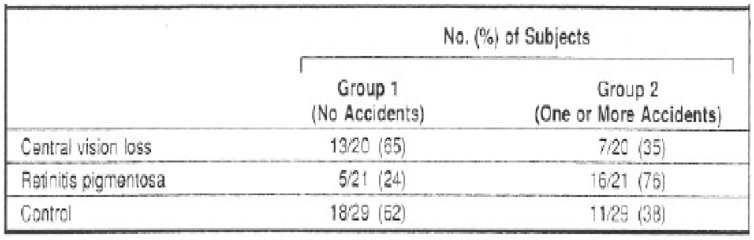
*Visual acuities were comparable in both eyes for each subject.
†Driver's license restricted by the state to daylight driving only.
‡Does not hold a valid driver's license but drives.

Table G-64. Risk-Taking Questionnaire



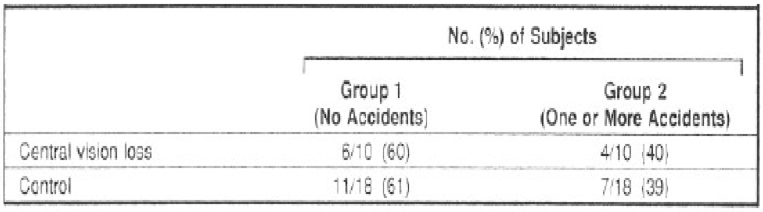
Question	Score
1. Most people are worse drivers than I am	True=1, false=0
2. Cars are often passing me on the highway	True=0, false=1
3. I feel less confident about my driving in bad weather conditions	True=0, false=1
4. I rarely take unnecessary risks when driving	True=0, false=1
5. I rarely cut in and out of traffic	True=0, false=1
6. Aggressive driving means better driving	True=1, false=0
7. I am usually apprehensive when changing lanes in traffic	True=0, false=1
8. Even if I am late for an appointment, I do not exceed the speed limit	True=0, false=1
9. I often have other drivers honking at me	True=0, false=1

Table G-65. Self Reported Accidents



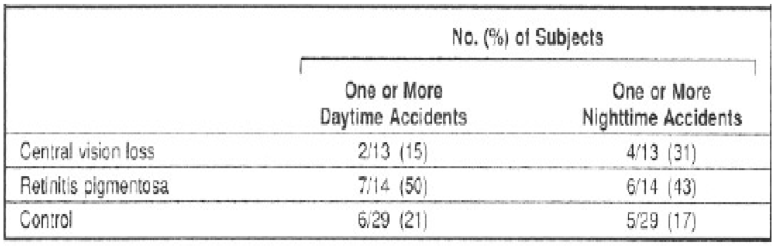
	No. (%) of Subjects	
	Group 1 (No Accidents)	Group 2 (One or More Accidents)
Central vision loss	13/20 (65)	7/20 (35)
Retinitis pigmentosa	5/21 (24)	16/21 (76)
Control	18/29 (62)	11/29 (38)

Table G-66. State-Recorded Accidents



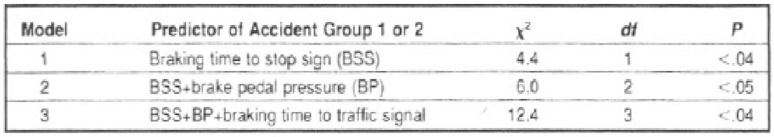
	No. (%) of Subjects	
	Group 1 (No Accidents)	Group 2 (One or More Accidents)
Central vision loss	6/10 (60)	4/10 (40)
Control	11/18 (61)	7/18 (39)

Table G-67. Daytime vs. Nighttime Accidents



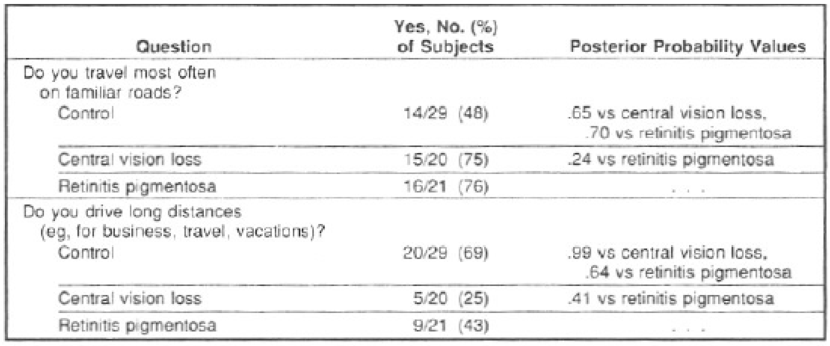
	No. (%) of Subjects	
	One or More Daytime Accidents	One or More Nighttime Accidents
Central vision loss	2/13 (15)	4/13 (31)
Retinitis pigmentosa	7/14 (50)	6/14 (43)
Control	6/29 (21)	5/29 (17)

Table G-68. Logistic Regression Analyses



Model	Predictor of Accident Group 1 or 2	χ^2	*df*	*P*
1	Braking time to stop sign (BSS)	4.4	1	<.04
2	BSS+brake pedal pressure (BP)	6.0	2	<.05
3	BSS+BP+braking time to traffic signal	12.4	3	<.04

Table G-69. Analyses of Responses to Questionnaire on Driving Habits



Question	Yes, No. (%) of Subjects	Posterior Probability Values
Do you travel most often on familiar roads?		
Control	14/29 (48)	.65 vs central vision loss, .70 vs retinitis pigmentosa
Central vision loss	15/20 (75)	.24 vs retinitis pigmentosa
Retinitis pigmentosa	16/21 (76)	. . .
Do you drive long distances (eg, for business, travel, vacations)?		
Control	20/29 (69)	.99 vs central vision loss, .64 vs retinitis pigmentosa
Central vision loss	5/20 (25)	.41 vs retinitis pigmentosa
Retinitis pigmentosa	9/21 (43)	. . .

Figure G-28. Representative binocular VF profiles of two subjects with central VF loss due of Stargardt disease (left) and cone-rod dystrophy (right), measured with a Goldmann II-2-e target

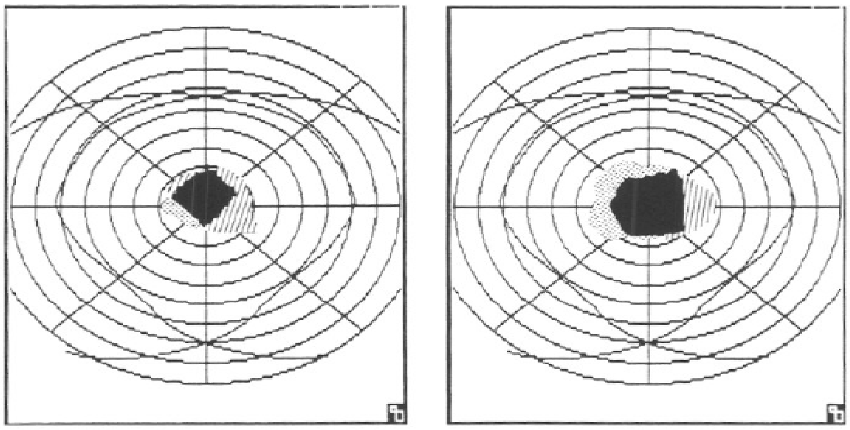
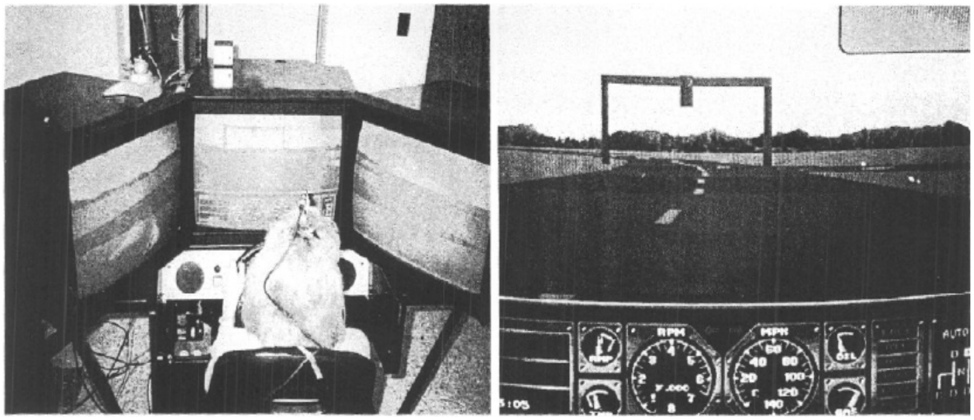


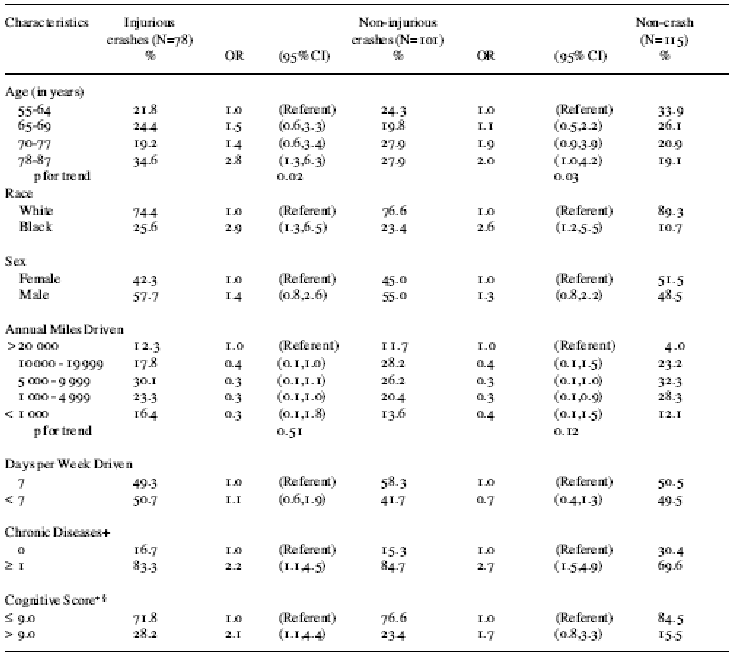
Figure G-29. Left, The configuration of the driving simulator, illustrating the subject's location and the video display. Right. A representative scene on the simulator's central monitor, showing a traffic light regulating cars merging onto the roadway from the right and lane boundary markers.



<table>
<tr><td colspan="15">Owsley C, McGwin G, Ball K. Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. Ophthalmic Epidemiology 1998; Vol 5 No 2: 101-113.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3">✓</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="14">To identify visual risk factors for vehicle crashes by elderly drivers which result in injury</td></tr>
<tr><td>Study Design</td><td colspan="14">Case-Control (Single-blinded)</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="13">Cases/ Controls:
Subjects identified through Alabama Department of Public Safety (ADPS) files and living in Jefferson County, Alabama</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13">NR</td></tr>
<tr><td>Study population Characteristics</td><td colspan="13">Refer to Table G- 70 for complete details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="13">Unclear</td></tr>
<tr><td>Methods</td><td colspan="14">75 drivers randomly selected from each cell after Jefferson county drivers sorted into 21 cells to represent 3 crash categories
Enrollment ended when 302 subjects were successfully recruited; 16 additional subjects who did not provide information on self-reported crashes excluded; final sample consisted of 294 older drivers
• Cases were defined as those drivers who had incurred at least one vehicle crash between 1985 and 1990 resulting in an injury to anyone in the involved vehicles according to the accident report.
• Controls defined as older drivers not involved in crashes during the same five-year period.
• Subjects underwent a battery of visual processing tests and a comprehensive eye examination
Written informed consent obtained after process explained; protocol completed in single visit to clinic in 1990 which consisted of:
Visual sensory function assessments
Visual attention/processing speed
Eye health
Questionnaire about driving exposure
Cognitive function
All vision tests performed under photopic conditions (100 cd/m²)
Letter acuity measured using ETDRS chart and expressed as log minimum angle resolvable (logMAR)
Impaired acuity defined as worse than 20/40 acuity
Contrast sensitivity measured using Pelli-Robson chart—impaired contrast sensitivity defined as score of 1.5 or worse
Stereoacuity was measured using the TNO test and expressed as arcseconds—impaired stereoacuity defined as 500 arcseconds or worse
Disability glare measured with MCT-8000 (VisTech) and defined as the difference in letter acuity (logMAR)
VF sensitivity measured with Humphrey Field Analyzer's 120-point screening program for the central 60° radius field using the quantify defects option
• Impaired VF sensitivity (for both the central and peripheral VFs) was defined as a loss of sensitivity of more than 1 log unit (10dB)
The UFOV defined as the VF area over which one can use rapidly presented visual information
All subjects received comprehensive eye exams by an ophthalmologist and mental status was evaluated by the Mattis Organic Mental Syndrome Screening Examination (MOMSSE) designed to assess cognitive functioning in the elderly
Examiners and interviewers were not aware of the crash histories of all subjects</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">• Estimated odds ratios (ORs) and 95% confidence intervals (CIs) for associations between injurious and noninjurious motor vehicle crash involvement and visual impairment using logistic regression
• ORs and 95% CIs calculated separately for each case group as compared to the single group of controls.
• All variables that had significant associations (¤ = 0.10) at the univariate level were included in a multivariable logistic regression model
• Variables individually removed from the model, and likelihood ratio tests (LRTs) performed to determine which variables had significant independent associations with crash involvement
• Linear trend test performed by entering a continuous variable into the logistic regression models and assessing the significance of the term using the Wald chi-square test.
• SAS software used to conduct statistical analyses
• All significance tests were conducted at the ¤=0.05 level (two-tailed).</td></tr>
<tr><td>Quality assessment</td><td>Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
</table>

		N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y
	Moderate	14	15	16	17	18	19	20	21	22	23	24	25	
Relevant Outcomes Assessed	Visual impairment including VF assessed to measure crash risk													
Results	• For injurious crashes, the odds ratio for having one or more chronic diseases was 2.2 (95% CI 1.1-4.5); OR was similarly elevated for the noninjurious crash group (OR=2.7; 95% CI 1.5-4.9) • Table G-71 shows the univariate results for visual processing variables • For the injurious crash case group, the OR for impaired stereoacuity (≥ 500 arcseconds) was 2.2 (95% CI 1.0-3.3). Impairment in central VF sensitivity (defect depth > 10 dB) was associated with 2.6-times (95% CI 1.1-6.3) the risk of injurious crash involvement; noninjurious Cases had an elevated, non-significant association was observed for impaired central VF sensitivity (OR=1.8; 95% CI 0.8-2.2). • Injurious and non-injurious crash cases were 2.4-times (95% CI 1.3- 4.5) and 1.8-times (95% CI 1.0-3.1) more likely to have defect depths greater than 10 dB as compared to controls, respectively; injurious crash cases, ORs for reductions in the UFOV of 23-40%, 41-60% and >60% were 5.3 (95% CI, 1.9-14.0), 16.3 (95% CI, 5.8-46.0), and 22.0 (95% CI, 7.0-69.0), respectively, compared to reductions of less than 23% (p for trend <0.001). • Table G-72 displays univariate analyses for common eye conditions in elderly • UFOV reductions of 22.5-40%, 41-60% and >60% associated with 5.2-, 16.5-, and 21.5-fold increased risk of injurious crash, respectively (p for trend <0.01), compared to those with reductions of <22.5%; Subjects involved in non-injurious crashes were 2.3-, 4.6-, and 7.1-times more likely to have UFOV impairments of 22.5-40%, 41.0-60.0%, and >60.0%, respectively, compared to controls (p for trend <0.001). (see Table G-73)													
Authors' Comments	"In addition to the incorporation of visual processing tests with high face validity to the driving task, another strength of this study is its reliance on accident reports provided by the state for defining the outcome of interest, injurious crash involvement."													

Table G- 70 Demographic, driving, and health characteristics of drivers

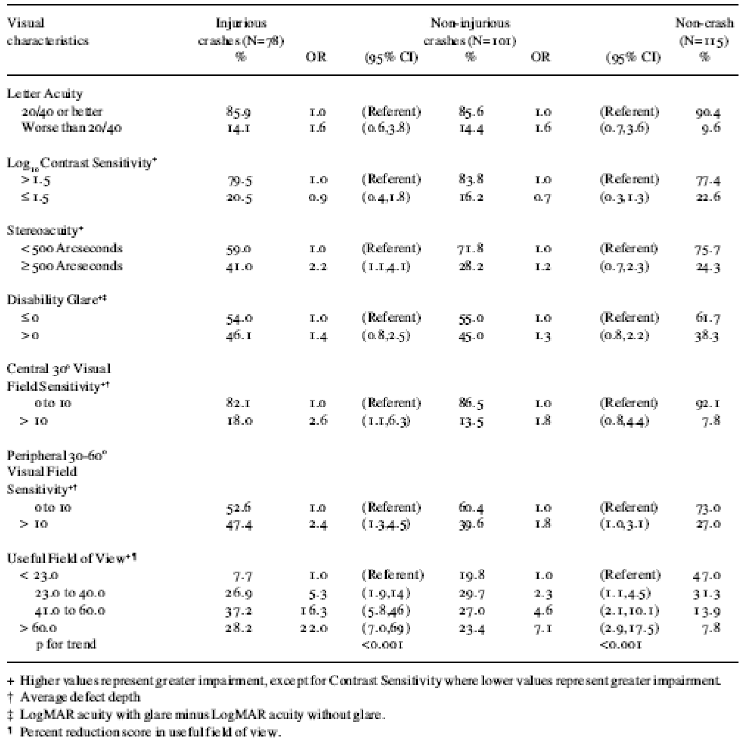


Characteristics	Injurious crashes (N=78) %	OR	(95%CI)	Non-injurious crashes (N=101) %	OR	(95% CI)	Non-crash (N=115) %
Age (in years)							
55-64	21.8	1.0	(Referent)	24.3	1.0	(Referent)	33.9
65-69	24.4	1.5	(0.6,3.3)	19.8	1.1	(0.5,2.2)	26.1
70-77	19.2	1.4	(0.6,3.4)	27.9	1.9	(0.9,3.9)	20.9
78-87	34.6	2.8	(1.3,6.3)	27.9	2.0	(1.0,4.2)	19.1
p for trend			0.02			0.03	
Race							
White	74.4	1.0	(Referent)	76.6	1.0	(Referent)	89.3
Black	25.6	2.9	(1.3,6.5)	23.4	2.6	(1.2,5.5)	10.7
Sex							
Female	42.3	1.0	(Referent)	45.0	1.0	(Referent)	51.5
Male	57.7	1.4	(0.8,2.6)	55.0	1.3	(0.8,2.2)	48.5
Annual Miles Driven							
>20 000	12.3	1.0	(Referent)	11.7	1.0	(Referent)	4.0
10000 - 19999	17.8	0.4	(0.1,1.0)	28.2	0.4	(0.1,1.5)	23.2
5 000 - 9 999	30.1	0.3	(0.1,1.1)	26.2	0.3	(0.1,1.0)	32.3
1 000 - 4 999	23.3	0.3	(0.1,1.0)	20.4	0.3	(0.1,0.9)	28.3
< 1 000	16.4	0.3	(0.1,1.8)	13.6	0.4	(0.1,1.5)	12.1
p for trend			0.51			0.12	
Days per Week Driven							
7	49.3	1.0	(Referent)	58.3	1.0	(Referent)	50.5
< 7	50.7	1.1	(0.6,1.9)	41.7	0.7	(0.4,1.3)	49.5
Chronic Diseases+							
0	16.7	1.0	(Referent)	15.3	1.0	(Referent)	30.4
≥ 1	83.3	2.2	(1.1,4.5)	84.7	2.7	(1.5,4.9)	69.6
Cognitive Score+ §							
≤ 9.0	71.8	1.0	(Referent)	76.6	1.0	(Referent)	84.5
> 9.0	28.2	2.1	(1.1,4.4)	23.4	1.7	(0.8,3.3)	15.5

+ Higher values represent greater impairment except for Contrast Sensitivity where lower values represent greater impairment.

§ Score on Mattis Organic Mental Status Syndrome Examination (range: 0-28)

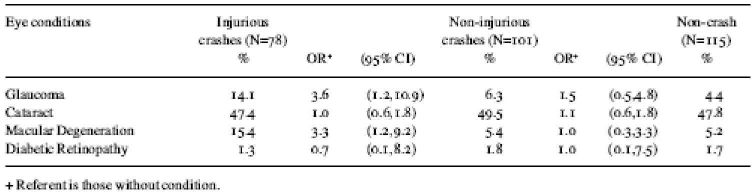
Table G-71. Visual characteristics of drivers



Visual characteristics	Injurious crashes (N=78) %	OR	(95% CI)	Non-injurious crashes (N=101) %	OR	(95% CI)	Non-crash (N=115) %
Letter Acuity							
20/40 or better	85.9	1.0	(Referent)	85.6	1.0	(Referent)	90.4
Worse than 20/40	14.1	1.6	(0.6,3.8)	14.4	1.6	(0.7,3.6)	9.6
Log_{10} Contrast Sensitivity[+]							
> 1.5	79.5	1.0	(Referent)	83.8	1.0	(Referent)	77.4
≤ 1.5	20.5	0.9	(0.4,1.8)	16.2	0.7	(0.3,1.3)	22.6
Stereoacuity[+]							
< 500 Arcseconds	59.0	1.0	(Referent)	71.8	1.0	(Referent)	75.7
≥ 500 Arcseconds	41.0	2.2	(1.1,4.1)	28.2	1.2	(0.7,2.3)	24.3
Disability Glare[+‡]							
≤ 0	54.0	1.0	(Referent)	55.0	1.0	(Referent)	61.7
> 0	46.1	1.4	(0.8,2.5)	45.0	1.3	(0.8,2.2)	38.3
Central 30° Visual Field Sensitivity[+†]							
0 to 10	82.1	1.0	(Referent)	86.5	1.0	(Referent)	92.1
> 10	18.0	2.6	(1.1,6.3)	13.5	1.8	(0.8,4.4)	7.8
Peripheral 30-60° Visual Field Sensitivity[+†]							
0 to 10	52.6	1.0	(Referent)	60.4	1.0	(Referent)	73.0
> 10	47.4	2.4	(1.3,4.5)	39.6	1.8	(1.0,3.1)	27.0
Useful Field of View[+¶]							
< 23.0	7.7	1.0	(Referent)	19.8	1.0	(Referent)	47.0
23.0 to 40.0	26.9	5.3	(1.9,14)	29.7	2.3	(1.1,4.5)	31.3
41.0 to 60.0	37.2	16.3	(5.8,46)	27.0	4.6	(2.1,10.1)	13.9
> 60.0	28.2	22.0	(7.0,69)	23.4	7.1	(2.9,17.5)	7.8
p for trend			<0.001			<0.001	

+ Higher values represent greater impairment, except for Contrast Sensitivity where lower values represent greater impairment.
† Average defect depth
‡ LogMAR acuity with glare minus LogMAR acuity without glare.
¶ Percent reduction score in useful field of view.

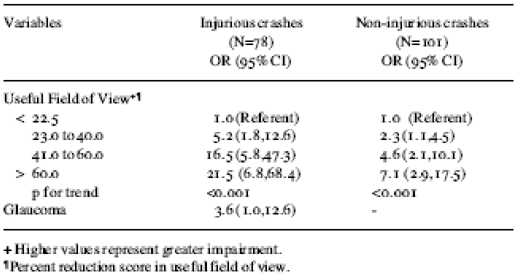
Table G-72. Eye conditions of drivers involved in injurious crashes, noninjurious crashes and no crashes.



Eye conditions	Injurious crashes (N=78) %	OR[+]	(95% CI)	Non-injurious crashes (N=101) %	OR[+]	(95% CI)	Non-crash (N=115) %
Glaucoma	14.1	3.6	(1.2,10.9)	6.3	1.5	(0.5,4.8)	4.4
Cataract	47.4	1.0	(0.6,1.8)	49.5	1.1	(0.6,1.8)	47.8
Macular Degeneration	15.4	3.3	(1.2,9.2)	5.4	1.0	(0.3,3.3)	5.2
Diabetic Retinopathy	1.3	0.7	(0.1,8.2)	1.8	1.0	(0.1,7.5)	1.7

+ Referent is those without condition.

Table G-73. Odds ratios and 95% confidence intervals for significant variables from multiple logistic regression models for injurious crashes and non-injurious crashes.



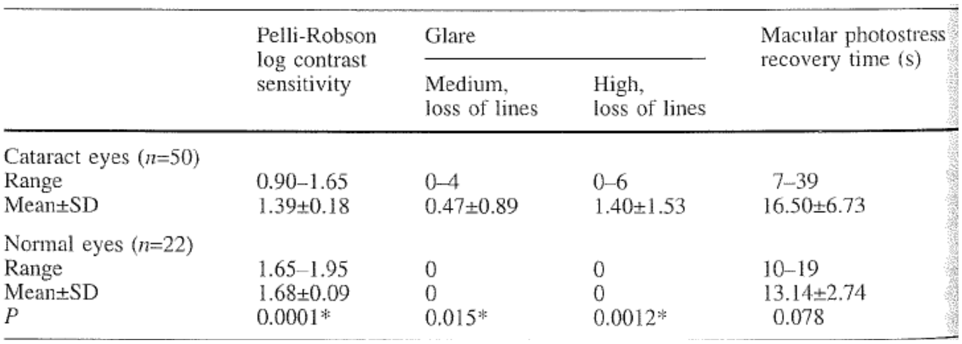
Variables	Injurious crashes (N=78) OR (95% CI)	Non-injurious crashes (N=101) OR (95% CI)
Useful Field of View[+¶]		
< 22.5	1.0 (Referent)	1.0 (Referent)
23.0 to 40.0	5.2 (1.8,12.6)	2.3 (1.1,4.5)
41.0 to 60.0	16.5 (5.8,47.3)	4.6 (2.1,10.1)
> 60.0	21.5 (6.8,68.4)	7.1 (2.9,17.5)
p for trend	<0.001	<0.001
Glaucoma	3.6 (1.0,12.6)	-

+ Higher values represent greater impairment.
¶ Percent reduction score in useful field of view.

Study Summary Tables for Key Question 4

<table>
<tr><td colspan="12">Mantyjarvi M, Tuppurainen K. Cataract in traffic. Graefe's Arch Clin Exp Ophthalmol 1999; 237: 278-282</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td>1</td><td colspan="2">2</td><td colspan="3">3</td><td colspan="2">4</td><td colspan="3">5</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td><td colspan="2">✓</td><td colspan="3"></td></tr>
<tr><td>Research Question</td><td colspan="11">Examine contrast sensitivity and VA under glare in cataract patients compared with individuals without cataract who are eligible for a drivers license</td></tr>
<tr><td>Study Design</td><td colspan="11">Prospective Cohort-Controlled</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="10">Cases presented for an eye exam at the Eye Clinic of the University Hospital in Kuopio with one or more cataracts.</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10"></td></tr>
<tr><td>Study population Characteristics</td><td colspan="10">Variable Cases Controls
N 35 13
Age (yrs)mean±SD 70.1 ±6.1 (range 60 – 87) 67.3±4.6
Gender M/F 13/22
VA ≥0.5 (50/70 of the eyes) (range 0.5-0.9) 1.0 or better (22/26 eyes)</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">Patients were tested monocularly for all tests; central and peripheral VFs with the automatic Peristat 433 equipment. Contrast sensitivity testing utilized a Pelli-Robson chart with eight lines of letters with varied contrast across and down the lines. Exam was performed at 3 m, corresponding to a spatial frequency of approximately 3 cycles/degree. Brightness acuity and macular photostress test were performed with the Brightness Acuity Tester. Normal recovery time in a glare test is 0 to 30 s.</td></tr>
<tr><td>Statistical Methods</td><td colspan="11">Unpaired t-test, Mann-Whitney U-test, linear regression</td></tr>
<tr><td rowspan="2">Quality Assessment</td><td rowspan="2">Revised Newcastle-Ottawa Quality Scale
Cohort Studies Score:
Moderate</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>S</td><td>No</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">Contrast sensitivity disability glare testing</td></tr>
<tr><td>Results</td><td colspan="11">Results for the Pelli-Robson contrast sensitivity test were significantly worse in the cataract eyes (1.39±0.18) than in the control eyes (1.68±0.09) (Table G-74). During glare testing, a significant difference was demonstrated as controls made no errors while loss of lines for cataract eyes varied from 0-6 and 0-4 with high and medium glare respectively. No significance was found for macular photostress recovery time although the cataract eyes did take longer (16.50±6.73) than normal eyes (13.14±2.74). Investigators also compared responses from different types of cataract with normal eyes. Results demonstrated significant differences in all types of cataract eyes (nuclear, posterior subcapsular, cortical, and mixed) in contrast sensitivity and in the number of lines lost in glare. Only the eyes with nuclear cataract had a significant difference in the macular photostress recovery time (7-39 s versus 10-19 s) (Table G-75).</td></tr>
<tr><td>Authors' Comments</td><td colspan="11">Cataract eyes performed significantly worse on contrast sensitivity and glare testing and had longer recovery time in the macular photostress test. While this study did not demonstrate risk of increased crash when measuring visual functions separately, investigators stress that other studies have demonstrated that the combination of these visual deficiencies have shown a significant correlation with increased crash risk in drivers aged 66 years and older.</td></tr>
</table>

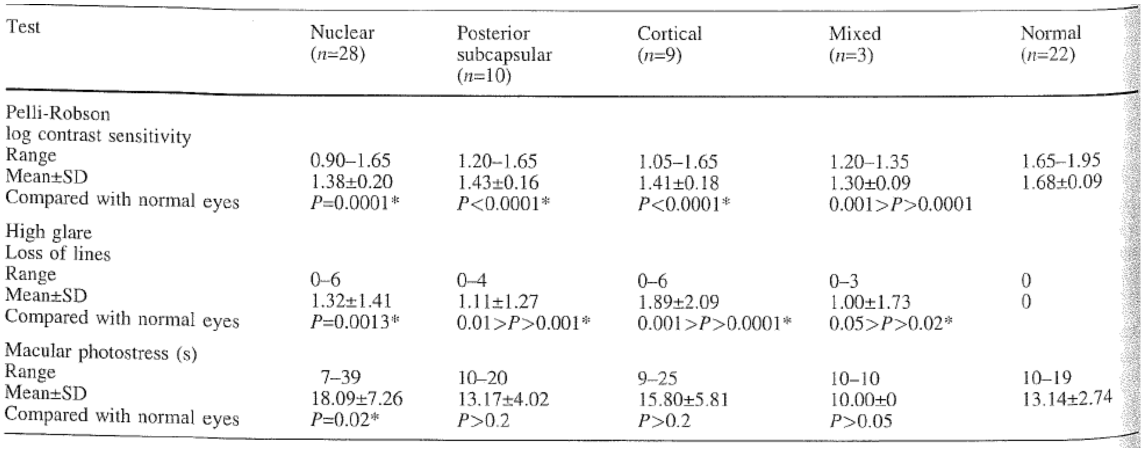
Table G-74: Contrast Sensitivity and Glare Test Results



	Pelli-Robson log contrast sensitivity	Glare		Macular photostress recovery time (s)
		Medium, loss of lines	High, loss of lines	
Cataract eyes (n=50)				
Range	0.90–1.65	0–4	0–6	7–39
Mean±SD	1.39±0.18	0.47±0.89	1.40±1.53	16.50±6.73
Normal eyes (n=22)				
Range	1.65–1.95	0	0	10–19
Mean±SD	1.68±0.09	0	0	13.14±2.74
P	0.0001*	0.015*	0.0012*	0.078

*Significant difference, unpaired *t*-test

Table G-75: Comparison of eyes with different types of cataract with normal eyes in contrast sensitivity and glare tests

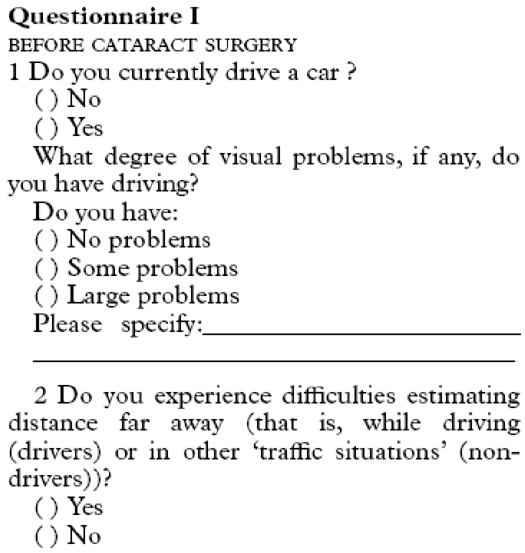


Test	Nuclear (n=28)	Posterior subcapsular (n=10)	Cortical (n=9)	Mixed (n=3)	Normal (n=22)
Pelli-Robson log contrast sensitivity					
Range	0.90–1.65	1.20–1.65	1.05–1.65	1.20–1.35	1.65–1.95
Mean±SD	1.38±0.20	1.43±0.16	1.41±0.18	1.30±0.09	1.68±0.09
Compared with normal eyes	$P=0.0001$*	$P<0.0001$*	$P<0.0001$*	$0.001>P>0.0001$	
High glare Loss of lines					
Range	0–6	0–4	0–6	0–3	0
Mean±SD	1.32±1.41	1.11±1.27	1.89±2.09	1.00±1.73	0
Compared with normal eyes	$P=0.0013$*	$0.01>P>0.001$*	$0.001>P>0.0001$*	$0.05>P>0.02$*	
Macular photostress (s)					
Range	7–39	10–20	9–25	10–10	10–19
Mean±SD	18.09±7.26	13.17±4.02	15.80±5.81	10.00±0	13.14±2.74
Compared with normal eyes	$P=0.02$*	$P>0.2$	$P>0.2$	$P>0.05$	

* Significant difference, unpaired *t*-test in nuclear, Mann-Whitney U-test in other groups

<table>
<tr><th colspan="16">Monestam E, Wachtmeister L. Impact of cataract surgery on car driving: a population based study in Sweden. Br J Ophthalmol 1997; 81: 16-22</th></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="3">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3">✓</td><td colspan="3"></td></tr>
<tr><td>Research Question</td><td colspan="15">Subjective difficulty driving of an adult population post cataract surgery</td></tr>
<tr><td>Study Design</td><td colspan="15">Pre-post</td></tr>
<tr><td rowspan="11">Population</td><td>Inclusion Criteria</td><td colspan="14">Individuals consecutively recruited between April 1, 1992 and March 31, 1993 who underwent cataract surgery at Norrlands University Hospital in Umea, Sweden</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="14">Patients who underwent cataract surgery for reasons other than restoring vision or had traumatic, juvenile, or congenital cataracts; patients with limited mental status who could not understand a study questionnaire; patients preoperatively scheduled for cataract surgery without an intra-ocular lens (IOL) implantation; patients with combined cataract and corneal or trabeculectomy surgery</td></tr>
<tr><td rowspan="8">Study population Characteristics</td><td colspan="2">Variable</td><td colspan="4">All</td><td colspan="4">Drivers</td><td colspan="4">Unlicensed</td></tr>
<tr><td colspan="2">N</td><td colspan="4">453</td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td colspan="2">Surgeries</td><td colspan="4">459
(6 pts had surgery on both eyes)</td><td colspan="4">211</td><td colspan="4">248</td></tr>
<tr><td colspan="2">Gender M/F
(based on surgeries)</td><td colspan="4">155/304</td><td colspan="4">125/86</td><td colspan="4">13%M/87%F</td></tr>
<tr><td colspan="2">Age (yrs) median</td><td colspan="4"></td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td colspan="2">Male</td><td colspan="4">75</td><td colspan="4">74</td><td colspan="4">79.5</td></tr>
<tr><td colspan="2">Female</td><td colspan="4">77</td><td colspan="4">71</td><td colspan="4">78.5</td></tr>
<tr><td colspan="2">Age (yrs) range</td><td colspan="4">38 - 95</td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="14">Unclear</td></tr>
<tr><td>Methods</td><td colspan="15">Patients responded to 2 self-administered questionnaires regarding visual function before and after surgery (Figure G-30) (Figure G-31). Medical records confirmed stabilized vision post-surgery. Up to 2 months after the patients had received their new prescription glasses, the 2nd questionnaire was forwarded. Mean lapse time from date of surgery to receipt of questionnaire was 5.3±1.8 months to allow participants to adjust to new prescription. Confirmation of license information was obtained by the Swedish National Register of Driving Licenses; 208 patients (211 cases) had licenses and 245 patients (248 cases) had not. The distribution of men and women by age group are shown in Figure G-32.</td></tr>
<tr><td>Statistical Methods</td><td colspan="15">Paired two sample, two tailed *t* tests, one way analysis of variance Yates corrected X^2 test, Fisher's exact test</td></tr>
<tr><td rowspan="2">Quality Assessment</td><td rowspan="2">ECRI Institute Quality Scale for Pre-Post Studies:
Low
*Vision test are objective, driving difficulty outcome</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td>No</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y
N*</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="15">Subjective visual function and distance estimation for driving, difficulty driving</td></tr>
<tr><td>Results</td><td colspan="15">In adults over 65, 23% of women drove while 78% of men were licensed. In the subgroup of adults aged below 55 years of age, number of licensed drivers was comparable by gender. Responses to Questionnaire #1 presented before surgery are shown in Table G-76. Only 56% of 211 drivers were driving before surgery with 82% claiming visual function problems. Difficulty when driving in darkness and twilight were the most common complaints and reported by 71% drivers. Problems with distance estimation were reported by 37%. Significant improvements in mean VA (MVA) were demonstrated in all groups with driving licenses (Table G-77). VA did not improve for only 1.9% of cases. Results for distance estimation demonstrated 46% of cases with driving licenses had difficulties but after surgery only 14% (29/211) had problems (p<0.0001). Mean VA in this subgroup of 29 individuals showed a significantly lower MVA in their operated eyes (logMAR=0.28, p<0.01) and their fellow eyes (logMAR=0.54, p<0.001) and significantly more cases with a VA of logMAR>0.3 (<20/40) in one eye (62%, 18/29).</td></tr>
<tr><td>Authors' Comments</td><td colspan="15">Subjective visual function and distance estimation while driving improved after cataract surgery. In order to achieve optimal distance estimation, investigators recommend undergoing surgery in both eyes.</td></tr>
</table>

Figure G-30: Before Surgery Questionnaire



Questionnaire I

BEFORE CATARACT SURGERY

1 Do you currently drive a car ?
( ) No
( ) Yes

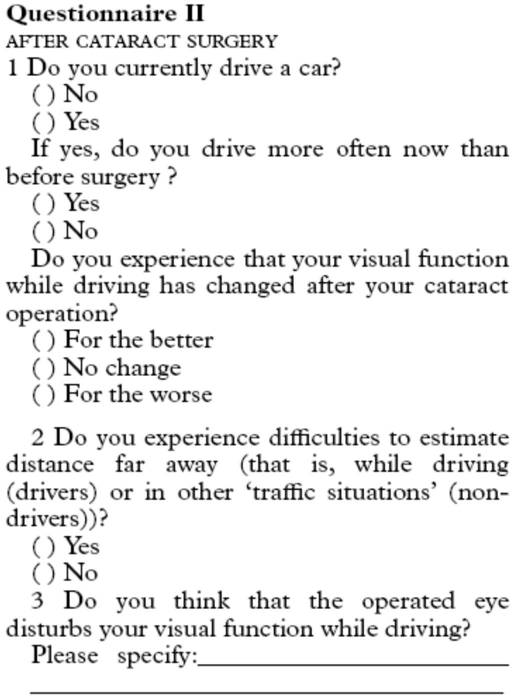
What degree of visual problems, if any, do you have driving?

Do you have:
( ) No problems
( ) Some problems
( ) Large problems

Please specify:________________________
____

2 Do you experience difficulties estimating distance far away (that is, while driving (drivers) or in other 'traffic situations' (non-drivers))?
( ) Yes
( ) No

Figure G-31: Post-surgery Questionnaire



Questionnaire II

AFTER CATARACT SURGERY

1 Do you currently drive a car?
( ) No
( ) Yes

If yes, do you drive more often now than before surgery ?
( ) Yes
( ) No

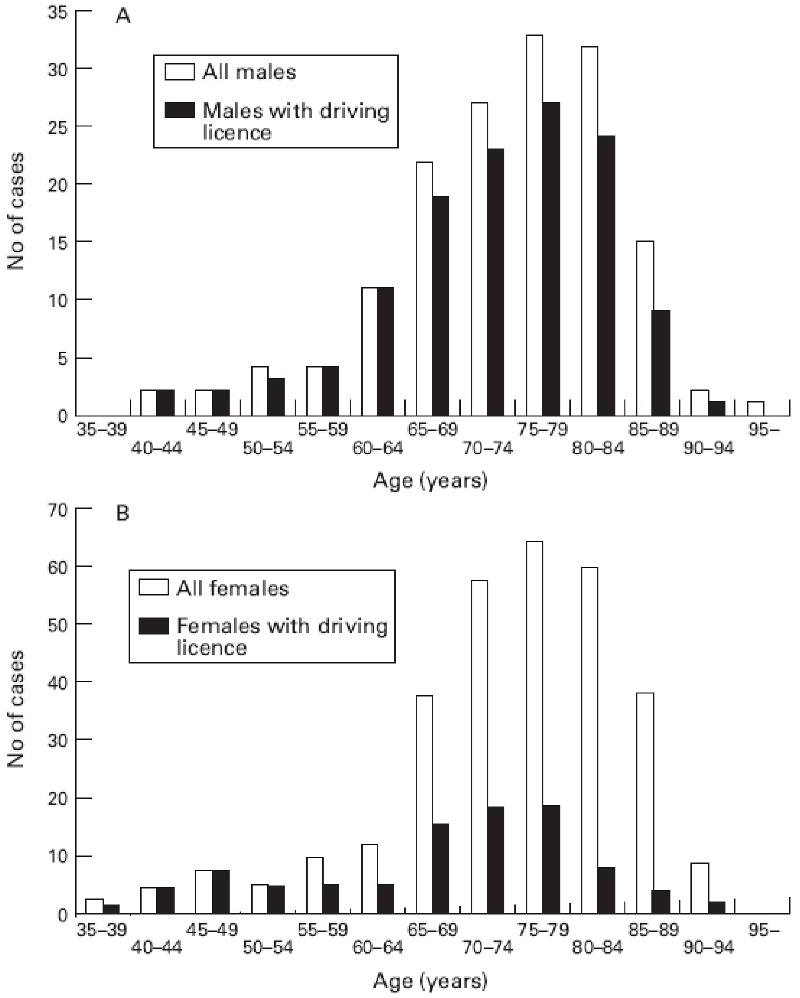
Do you experience that your visual function while driving has changed after your cataract operation?
( ) For the better
( ) No change
( ) For the worse

2 Do you experience difficulties to estimate distance far away (that is, while driving (drivers) or in other 'traffic situations' (non-drivers))?
( ) Yes
( ) No

3 Do you think that the operated eye disturbs your visual function while driving?

Please specify:________________________
____

Figure G-32: Distribution of Driving Licenses by Age Groups



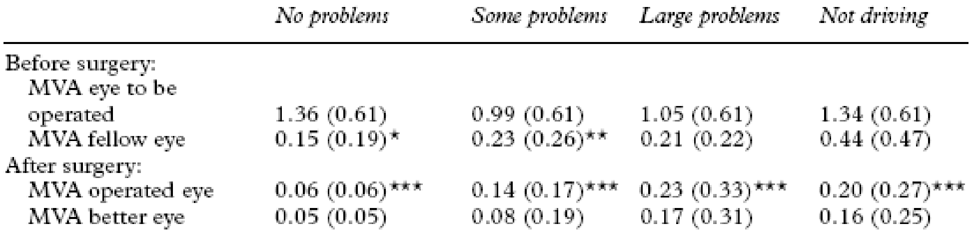
Distribution of driving licenses in men (A) and women (B) of different ages.

Table G-76: Self Reported Visual Difficulties while Driving

	All	*No problems*	*Some problems*	*Large problems*	*Not driving*
No of cases*	211	21	78	9	92
Mean age (years)	70.8	74.5	67.7	61.3	73.2
Age range (years)	38–91	65–91	40–83	46–86	38–90
Males (%)	59	71	63	67	51
First eye (%)	78	76	80	89	75
Right eye (%)	51	48	58	44	50

*11 cases did not report their degree of visual problems while driving.

Table G-77: Visual Functional Problems before Surgery versus Mean VA Before/after Surgery



	No problems	*Some problems*	*Large problems*	*Not driving*
Before surgery:				
MVA eye to be operated	1.36 (0.61)	0.99 (0.61)	1.05 (0.61)	1.34 (0.61)
MVA fellow eye	0.15 (0.19)*	0.23 (0.26)**	0.21 (0.22)	0.44 (0.47)
After surgery:				
MVA operated eye	0.06 (0.06)***	0.14 (0.17)***	0.23 (0.33)***	0.20 (0.27)***
MVA better eye	0.05 (0.05)	0.08 (0.19)	0.17 (0.31)	0.16 (0.25)

***Significant improvement of MVA after surgery in the operated eye at a level of p<0.0001.

**Significantly less improvement in MVA of the fellow eye before surgery for non-drivers compared with the various groups of drivers at a level of p<0.001 and *p<0.01.

<table>
<tr><td colspan="3">Monestam E, Lundquist B, Wachtmeister L. Visual function and car driving: longitudinal results 5 years after cataract surgery in a population. Br J Ophthalmol 2005; 89: 459-463.</td></tr>
<tr><td>Key Questions Addressed</td><td colspan="2"><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td></td><td></td><td></td><td>✓</td><td></td></tr></table></td></tr>
<tr><td>Research Question</td><td colspan="2">5 year follow-up of visual function for cataract patients and self-reported difficulty driving after cataract surgery</td></tr>
<tr><td>Study Design</td><td colspan="2">Prospective Pre-Post</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td>Active drivers who had cataract surgery between June 1, 1997 – May 31, 1998 at Norrlands University Hospital in Umea, Sweden</td></tr>
<tr><td>Exclusion Criteria</td><td>Patients who underwent cataract surgery for reasons other than restoring vision or had cataract surgery combined with other types of ocular surgery; patients with dementia</td></tr>
<tr><td>Study population Characteristics</td><td><table>
<tr><td><u>Variable</u></td><td><u>Value</u></td></tr>
<tr><td>n</td><td>189</td></tr>
<tr><td>Gender</td><td>62%M</td></tr>
<tr><td>Age (yrs) mean±SD</td><td>70.3±11</td></tr>
<tr><td>One eye operated for cataract</td><td>33% (62/189)</td></tr>
<tr><td>Both eyes had surgery</td><td>67% (127/189)</td></tr>
<tr><td>Presenting VA less than 20/40 of the better eye</td><td>5% (9/174)</td></tr>
<tr><td>Best corrected VA less than 20/40 of the better eye</td><td>3% (5/174)</td></tr>
<tr><td>Visual difficulties, daytime driving</td><td>5% (9/188)</td></tr>
<tr><td>Visual difficulties, night-time</td><td>32% (61/188)</td></tr>
<tr><td>Do not drive in darkness</td><td>12% (22/188)</td></tr>
</table></td></tr>
<tr><td>Generalizability to CMV drivers</td><td>Unclear</td></tr>
<tr><td>Methods</td><td colspan="2">Participants had eye exams and answered questionnaires before and 5 years after surgery. Records from the Swedish Population Register identified five year survivors. 590 surviving patients were asked to respond to a questionnaire and have an eye exam. 530 (90%) patients completed the questionnaire; 467% patients had an eye exam; 189% patients stated they were currently driving. Vision assessments were completed and pts responded to a questionnaire on three occasions; 1-2 weeks before surgery, 1 month after receiving new glasses and five years post-surgery. Questions presented are shown in Table G-78.</td></tr>
<tr><td>Statistical Methods</td><td colspan="2">Two sample t tests, Yates corrected x^2 tests, Fisher's exact tests</td></tr>
<tr><td>Quality Assessment</td><td colspan="2"><table>
<tr><td rowspan="2">ECRI Institute Quality Scale for Pre-Post Studies:
Low
*Visual function objective, self-reported</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td>No</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y
N*</td><td>No</td><td>No</td><td>No</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
</table></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="2">Visual function, VA and self-reported difficulty driving 5 years post-cataract surgery</td></tr>
<tr><td>Results</td><td colspan="2">
Driving status before and after surgery for pts operated on from 1997-1998 is shown in Figure G-33.
Prior to surgery, 407 (50%) patients had a license; 50 (6%) had a license earlier, and 353 (46%) had never had a license
Pts without licenses had significantly worse VA of the eye to be operated and the better eye, both before and after surgery
Before surgery, 32% of patients did not fulfill visual requirements for driving while only 5% did not fulfill visual requirements post-surgery
Fulfillment of VA requirements for driving
Prior to surgery, 55% of patients were active drivers; 16% of these drivers did not fulfill the visual requirements for driving.
After surgery, 285 patients drove; only 2 patients driving without fulfilling visual requirements

5 years post-surgery, 189 patients were active drivers (63% of eligible drivers); 9 of 174 respondents not fulfilling the legal VA requirements; worst VA of 20/83. 5 additional patients were able to drive with improvement in eyeglasses. Six of nine respondents (67%) who did not fulfill the legal requirements had a diagnosis of Age-related maculopathy (ARM) before surgery, versus 11% of those who had sufficient VA (p<0.0005). Five years post-surgery, 8 of 9 patients (89%) with too low VA had ARM.
Results for driving status after surgery and 5 years later demonstrated 37% of pt population beginning to drive after surgery</td></tr>
</table>

	for the first time. All of the 67 patients had sufficient VA to drive legally. Five years post-surgery, 82% (40/50) who responded were still active drivers. • Results for non-drivers 5 years post-surgery demonstrated 132 patients not driving who either drove earlier in life or were eligible to drive chose not to drive. Reasons stated for not driving are listed in Table G-79. • Visual difficulties with daytime driving were reported by 50% of patients prior to surgery with only 6% reporting problems post-surgically (Table G-80). Visual difficulties with nighttime driving were reported by 69% pre-surgery and 24% post-surgically. Five years post-surgically, 95% of patients reported no visual difficulties with daytime driving while 56% of patients reported no visual difficulties with nighttime driving. 12% of patients still had such visual difficulty driving they never drove during the nighttime. A statistically significant result was found with a larger percentage of patients with self-reported visual difficulty driving at night ($p<0.05$) 5 years after surgery compared with a few months post-surgery.
Authors' Comments	While most patients fulfilled VA requirements for driving 5 years post-surgery, a large percentage of patients had greater difficulty with nighttime driving 5 years after surgery versus only a few months post-surgery.

Table G-78: Patient Questionnaire

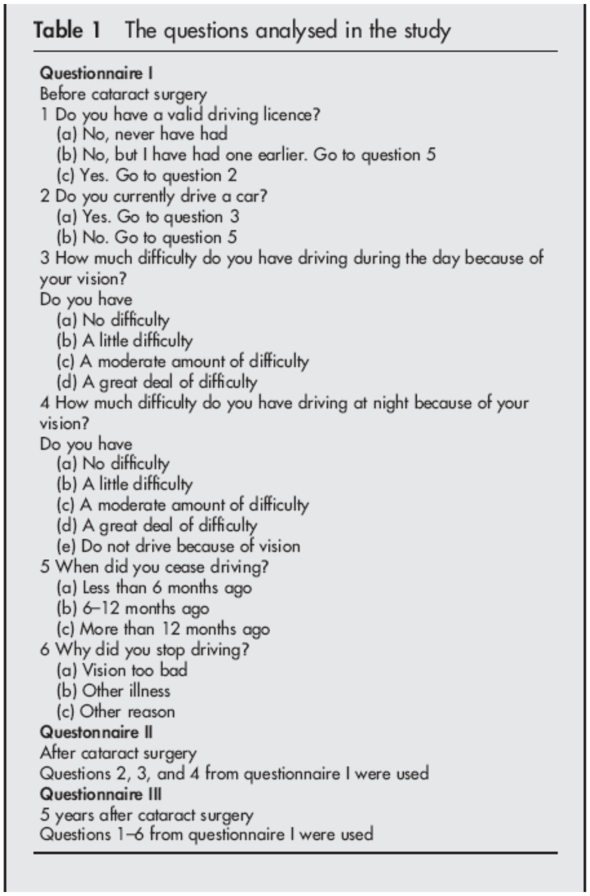


Table 1 The questions analysed in the study

Questionnaire I
Before cataract surgery
1 Do you have a valid driving licence?
  (a) No, never have had
  (b) No, but I have had one earlier. Go to question 5
  (c) Yes. Go to question 2
2 Do you currently drive a car?
  (a) Yes. Go to question 3
  (b) No. Go to question 5
3 How much difficulty do you have driving during the day because of your vision?
Do you have
  (a) No difficulty
  (b) A little difficulty
  (c) A moderate amount of difficulty
  (d) A great deal of difficulty
4 How much difficulty do you have driving at night because of your vision?
Do you have
  (a) No difficulty
  (b) A little difficulty
  (c) A moderate amount of difficulty
  (d) A great deal of difficulty
  (e) Do not drive because of vision
5 When did you cease driving?
  (a) Less than 6 months ago
  (b) 6–12 months ago
  (c) More than 12 months ago
6 Why did you stop driving?
  (a) Vision too bad
  (b) Other illness
  (c) Other reason
Questonnaire II
After cataract surgery
Questions 2, 3, and 4 from questionnaire I were used
Questionnaire III
5 years after cataract surgery
Questions 1–6 from questionnaire I were used

Figure G-33: Driving Status Pre-Post Surgery

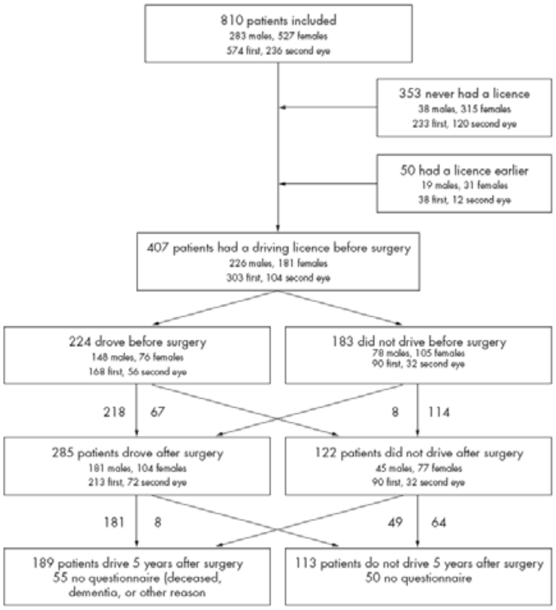
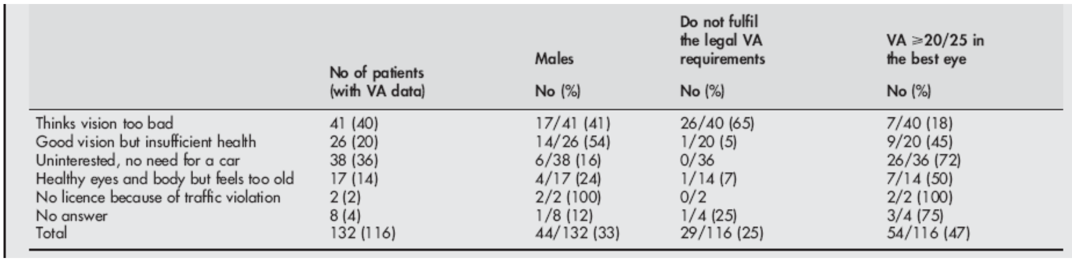
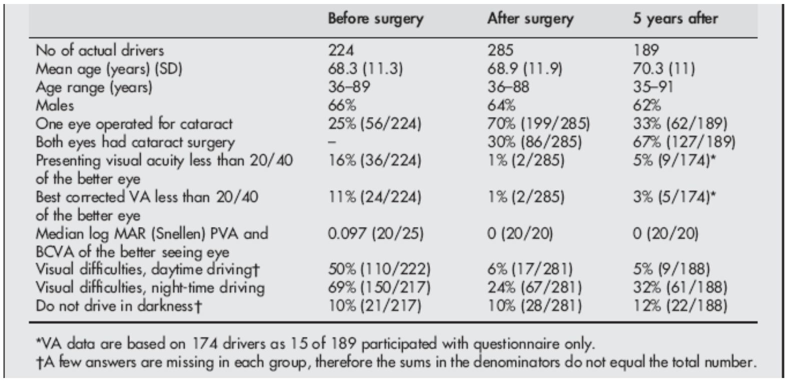


Table G-79: Reasons Stated for Not Driving



	No of patients (with VA data)	Males	Do not fulfil the legal VA requirements	VA ≥20/25 in the best eye
		No (%)	No (%)	No (%)
Thinks vision too bad	41 (40)	17/41 (41)	26/40 (65)	7/40 (18)
Good vision but insufficient health	26 (20)	14/26 (54)	1/20 (5)	9/20 (45)
Uninterested, no need for a car	38 (36)	6/38 (16)	0/36	26/36 (72)
Healthy eyes and body but feels too old	17 (14)	4/17 (24)	1/14 (7)	7/14 (50)
No licence because of traffic violation	2 (2)	2/2 (100)	0/2	2/2 (100)
No answer	8 (4)	1/8 (12)	1/4 (25)	3/4 (75)
Total	132 (116)	44/132 (33)	29/116 (25)	54/116 (47)

Table G-80: Visual function of drivers



	Before surgery	After surgery	5 years after
No of actual drivers	224	285	189
Mean age (years) (SD)	68.3 (11.3)	68.9 (11.9)	70.3 (11)
Age range (years)	36–89	36–88	35–91
Males	66%	64%	62%
One eye operated for cataract	25% (56/224)	70% (199/285)	33% (62/189)
Both eyes had cataract surgery	–	30% (86/285)	67% (127/189)
Presenting visual acuity less than 20/40 of the better eye	16% (36/224)	1% (2/285)	5% (9/174)*
Best corrected VA less than 20/40 of the better eye	11% (24/224)	1% (2/285)	3% (5/174)*
Median log MAR (Snellen) PVA and BCVA of the better seeing eye	0.097 (20/25)	0 (20/20)	0 (20/20)
Visual difficulties, daytime driving†	50% (110/222)	6% (17/281)	5% (9/188)
Visual difficulties, night-time driving	69% (150/217)	24% (67/281)	32% (61/188)
Do not drive in darkness†	10% (21/217)	10% (28/281)	12% (22/188)

*VA data are based on 174 drivers as 15 of 189 participated with questionnaire only.
†A few answers are missing in each group, therefore the sums in the denominators do not equal the total number.

Visual function of drivers before and after surgery and 5 years after surgery

<table>
<tr><td colspan="3">Monestam E, Lundqvist B. Long-time results and associations between subjective visual difficulties with car driving and objective visual function 5 years after cataract surgery. J Cataract Refract Surg 2006; 32: 50-55</td></tr>
<tr><td>Key Questions Addressed</td><td colspan="2"><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td></td><td></td><td></td><td>✓</td><td></td></tr></table></td></tr>
<tr><td>Research Question</td><td colspan="2">Subjective and objective visual function while driving for post-surgery cataract patients</td></tr>
<tr><td>Study Design</td><td colspan="2">Pre-Post</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td>Individuals who had cataract surgery between June 1, 1997 – May 31, 1998 at Norrlands University Hospital in Umea, Sweden; active drivers</td></tr>
<tr><td>Exclusion Criteria</td><td></td></tr>
<tr><td>Study population Characteristics</td><td><table><tr><td><u>Variable</u></td><td><u>Value</u></td></tr><tr><td>n</td><td>189</td></tr><tr><td>Gender M/F</td><td>117/72</td></tr><tr><td>Age (yrs) mean±SD</td><td>71.2±11.7 (male)
68.9±9.7 (female)</td></tr><tr><td>Eye surgery 1997-1998</td><td>145/189 in first eye
44/189 in second eye</td></tr><tr><td>Eye surgery 5 years later</td><td>127/189 surgery in both eyes
One third remained with 1 eye without surgery</td></tr></table></td></tr>
<tr><td>Generalizability to CMV drivers</td><td>Unclear</td></tr>
<tr><td>Methods</td><td colspan="2">Participants had eye exams and answered questionnaires before and up to 5 years after surgery. Records from the Swedish Population Register identified five year survivors. 590 surviving patients were asked to respond to a questionnaire and have an eye exam. 530 (90%) patients completed the questionnaire; 467% patients had an eye exam; 189% patients stated they were currently driving. Vision assessments were done by VA testing (total# of letters read correctly), low-contrast VA (LCVA) (using a Sloan letter logarithmic translucent contrast chart), and by questionnaire. Participants responded to the questionnaire on three occasions; 1-2 weeks before surgery, 1 month and five years post-surgery. Questions presented are shown in Table G-81.</td></tr>
<tr><td>Statistical Methods</td><td colspan="2">Non-parametric Mann-Whitney U tests, chi-square test, Fisher exact tests, logistic regression analyses, adjusted odds ratios</td></tr>
<tr><td>Quality Assessment</td><td colspan="2"><table><tr><td rowspan="2">ECRI Institute Quality Scale for Pre-Post Studies:
Low
*No for difficulty driving, yes for VA</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr><tr><td>No</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y
N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr></table></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="2">Difficulty driving, VA, subjective difficulty driving</td></tr>
<tr><td>Results</td><td colspan="2">Results for objective visual assessments demonstrated greater visual improvements for acuity and LCVA for men than women. VA results for 20/20 or better “best corrected better eye” were (58 vs 26) and “low-contrast better eye” (5 vs 1) (Table G-82). Although results were not significant, there was a statistically significant correlation between BCVA and LCVA (r = 0.80; P<.01). Results for the subjective visual questionnaire show a significantly greater number of drivers had difficulties with driving in darkness after surgery and 5 years later than with daytime driving (Table G-83). Patients demonstrated difficulty driving in darkness whether they had cataract surgery on 1 or 2 eyes (48% vs 41%, p=.36). In response to questions regarding distance estimation, although 10 patients stated difficulty 4 months post-surgery, no patients reported problems 5 years after surgery.</td></tr>
<tr><td>Authors’ Comments</td><td colspan="2">5 years post cataract surgery, over 40% of drivers continued to have difficulty driving in darkness while no difficulty remained in VA function, daytime driving, and distance estimation.</td></tr>
</table>

Table G-81: Vision Questionnaire

Questionnaire I and II (before and after cataract surgery)

1. Do you experience difficulties estimating distance while driving?
   - () Yes
   - () No
2. How much difficulty do you have driving during daytime because of your vision?

   Do you have
   - () No difficulty
   - () A little difficulty
   - () A moderate amount of difficulty
   - () A great deal of difficulty
3. How much difficulty do you have driving at night because of your vision?

   Do you have
   - () No difficulty
   - () A little difficulty
   - () A moderate amount of difficulty
   - () A great deal of difficulty
   - () Do not drive at nighttime because of vision
4. Do you experience difficulties reading traffic signs?

   () Yes () No

   If yes, do you have
   - () A little difficulty
   - () A moderate amount of difficulty
   - () A great deal of difficulty
   - () Impossible to see signs

Questionnaire III (5 years after cataract surgery)

Questions 1 to 4 from questionnaire I were used in addition to questions 5 and 6.

5. When driving in darkness, please estimate the degree of visual difficulty you experience from glare of other cars' headlights.
   - () No difficulty
   - () A little difficulty
   - () A moderate amount of difficulty
   - () A great deal of difficulty
   - () Do not drive at nighttime because of vision
6. When driving in darkness, please estimate the degree of visual difficulty you experience in seeing pedestrians or other moving objects.
   - () No difficulty
   - () A little difficulty
   - () A moderate amount of difficulty
   - () A great deal of difficulty
   - () Do not drive at nighttime because of vision

Table G-82: Distribution of VA and LCVA

	BCVA Better Eye, n (%)				LCVA Better Eye, n (%)			
Visual Acuity	Men (n = 104)	Women (n = 70)	1 Eye (n = 54)	2 Eyes (n = 120)	Men (n = 104)	Women (n = 70)	1 Eye (n = 54)	2 Eyes (n = 120)
20/20 or better	58 (55)	26 (37)	33 (61)	51 (42)	5 (5)	1 (1)	1 (2)	5 (4)
20/25 to 20/20	28 (27)	27 (38)	9 (17)	45 (38)	4 (4)	3 (4)	0	7 (6)
20/30 to 20/25	5 (5)	12 (17)	5 (9)	12 (10)	21 (20)	16 (23)	15 (28)	22 (18)
20/40 to 20/30	9 (9)	5 (7)	5 (9)	9 (8)	31 (30)	20 (29)	17 (31)	34 (29)
< 20/40	4 (4)	1 (1)	2 (4)	3 (2)	43 (41)	30 (43)	21 (39)	52 (43)
P value*	.12		.37		.80		.85	

BCVA=best corrected VA; LCVA = low-contrast VA

*Mann-Whitney U tests; men versus women and 1 eye versus 2 eyes

Table G-83: Self-reported Visual Difficulties while Driving

	Number (%)				
Parameter	No Difficulty	Little Difficulty	Moderate Difficulty	Great Difficulty/ Impossible/Do Not Drive	Missing/Do Not Know
Daytime driving					
Before surgery	73 (39)	66 (35)	18 (9)	31 (16)	1 (1)
After surgery	165 (87)	11 (6)	1 (1)	10 (5)	2 (1)
5 years later	180 (95)	9 (5)	0	0	0
P value*	.0093†				
Nighttime driving					
Before surgery	35 (18)	64 (34)	37 (20)	51 (27)	2 (1)
After surgery	114 (60)	44 (23)	3 (2)	21 (11)	7 (4)
5 years later	107 (57)	55 (29)	6 (3)	21 (11)	0
P value*	.51				
Reading traffic signs					
Before surgery	127 (67)	29 (15)	16 (9)	13 (7)	4 (2)
After surgery	171 (90)	10 (5)	3 (2)	0	5 (3)
5 years later	180 (95)	7 (3)	1 (1)	0	1 (1)
P value*	.19				
Degree of specific problems while driving in darkness 5 years after cataract surgery					
Glare from lights from other cars	85 (45)	75 (40)	16 (8)	12 (7)	1 (1)
Seeing pedestrians or other moving objects	125 (66)	42 (22)	5 (3)	16 (8)	1 (1)

*P values refer to the change in subjective visual difficulties 4 months and 5 years after surgery and were calculated by chi square for trend.

† Statistically significant

Pfoff D, Werner J. Effect of cataract surgery on contrast sensitivity and glare in patients with 20/50 or better Snellen acuity. J Cataract Refract Surg 1994; 20: 620-625

Key Questions Addressed	1	2	3	4	5
				✓	

Research Question

Effectiveness of cataract surgery (measured by MCT 8000) in improving functional contrast sensitivity for patients with 20/50 or better Snellen acuity

Study Design

Pre-post, prospective cohort-controlled

Population

Inclusion Criteria	Consecutive patients with significant cataracts, a Snellen acuity of 20/50 or better, nighttime glare and contrast sensitivity below normal range (20/70 "equivalent acuity") or worse at 6 cycles per degree on the calibrated Vistech MCT 8000 unit and selected from the practice of study author, David S. Pfoff. Controls had no observable cataracts.
Exclusion Criteria	Patients with significant clouding of the lens capsule, advanced glaucoma with field loss, or age-related macular degeneration.
Study population Characteristics	See below
Generalizability to CMV drivers	Unclear

Study population Characteristics

Variable	Case	Control
N	103	24
Mean age	73.8	64.2
Gender M/F	43/60	11/13

Methods

Contrast sensitivity and nighttime glare testing were performed within 8 months of cataract surgery utilizing the MCT 8000

- To simulate night driving conditions, scotopic target luminance was used (1-foot lambert).
- An example of the patients view through the instrument is shown in Figure G-34.
- Each grating diameter subtends 1.4 degrees of visual angle; the centrally located glare source is positioned 1.7 degrees from each grating. Moving in a clockwise direction, the gratings successfully diminish in contrast, with orientations in a vertical, tilted right and tilted left position.
- Contrast sensitivities were measured at spatial frequencies of 1.5, 3, 6, 12, 18 cycles per degree
- A score of 1 was assigned when a pt was unable to identify any gratings at a given spatial frequency

Pts responded to questionnaires inquiring changes in visual performance after cataract removal.

- Additional questions included benefits to surgery and night-driving status pre and post-surgery

Statistical Methods

ANOVA

Quality Assessment

Revised Newcastle-Ottawa Quality Scale Cohort Studies Score: **Moderate**	1	2	3	4	5	6	7	8	9	10
	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

ECRI Institute Quality Scale for Pre-Post Studies: **Moderate**	1	2	3	4	5	6	7	8	9	10	11	12	13	14
*Yes for objective visual function tests, no for subjective self-reported	No	Y	Y	Y	Y	Y	Y N	Y	Y	N	Y	Y	Y	Y

Relevant Outcomes Assessed

Contrast sensitivity

Results

Pre-operative results for testing the effect of cataracts on glare-related contrast sensitivity demonstrated:

- a significant difference in the cataract group with significantly lower contrast sensitivity under glare conditions than controls
- significant effects for spatial frequency (P<.0001)
- Contrast sensitivity means for preoperative patient group and controls are shown in Figure G-35. Controls demonstrated higher mean sensitivity at each spatial frequency with differences narrowing at the highest spatial frequency. Post hoc analyses found differences to be significant at each spatial frequency (p<.0001). In a comparison of normative data, (enclosed region in Figure G-35 for 5th and 95th percentiles), the means for cataract pts preoperatively is below the normal region at the 3 lowest spatial frequencies.

Postoperative results

- Effect of cataract surgery with contrast sensitivity scores significantly higher postoperatively (P<.001).
- Significant effects demonstrated between spatial frequency and testing session (P<.0001). Post hoc analysis differences to be significant at each spatial frequency (P<.0001). While means for preoperative testing fell below

	normal, postoperative testing fell within upper and lower boundaries. Post-operative vs controls: demonstrated o Controls had higher contrast sensitivity under glare conditions than postoperative eyes. o A significant effect was also shown for spatial frequency (P<.0001). o post-hoc comparisons resulted in significant differences at each spatial frequency Although significant differences were demonstrated at all levels of testing, only a relatively small difference was demonstrated between control and cataract patients post-operatively. Snellen Vision Data o Average mean in dim light improved from 20/28 to 20/19 postoperatively. Acuity for controls was 20/20 (Table G-84). Questionnaire Data o Responses indicated a statistically significant improvement in problem glare (74% vs 48% postoperatively) (x^2=12.935, 1 df, P=.0003). o Cataract pts reported a significant improvement in ability to drive (41% vs 80% postoperatively) (x^2=31.43, 1 df, P=.0001).
Authors' Comments	Six months postoperatively, cataract patients demonstrated statistically significant improvement in contrast sensitivity and glare than postoperative cataracts and non-cataract controls on contrast sensitivity were statistically significant but not great.

Figure G-34: Internal Display of MCT 8000 calibrated contrast sensitivity device

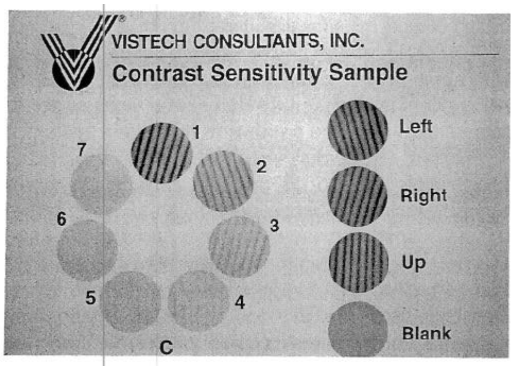


Figure G-35: Mean Contrast Sensitivity of Cataract Patients Pre and Postoperative and Control data, using Nighttime Glare Simulation

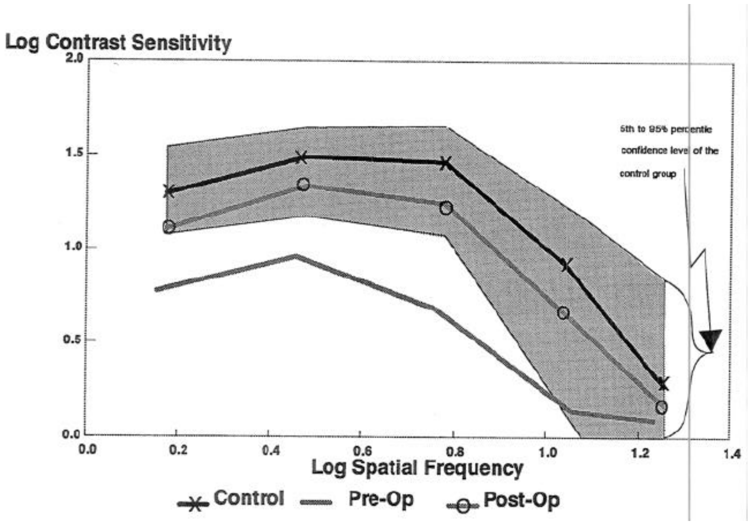
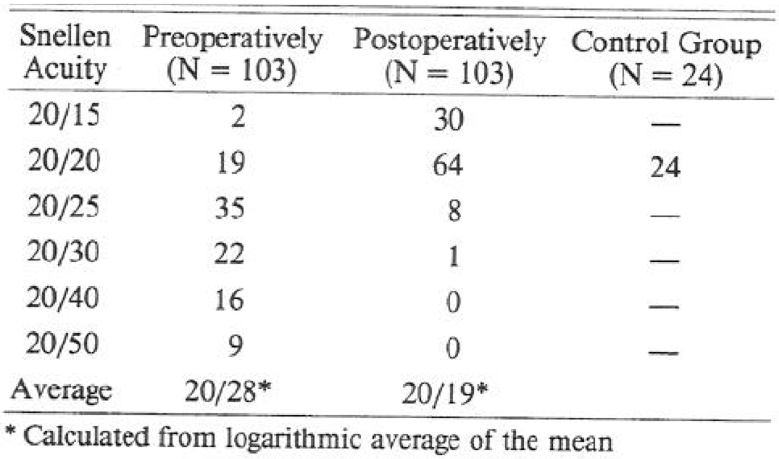


Table G-84: Dim Light Snellen Acuity



Snellen Acuity	Preoperatively (N = 103)	Postoperatively (N = 103)	Control Group (N = 24)
20/15	2	30	—
20/20	19	64	24
20/25	35	8	—
20/30	22	1	—
20/40	16	0	—
20/50	9	0	—
Average	20/28*	20/19*	

* Calculated from logarithmic average of the mean

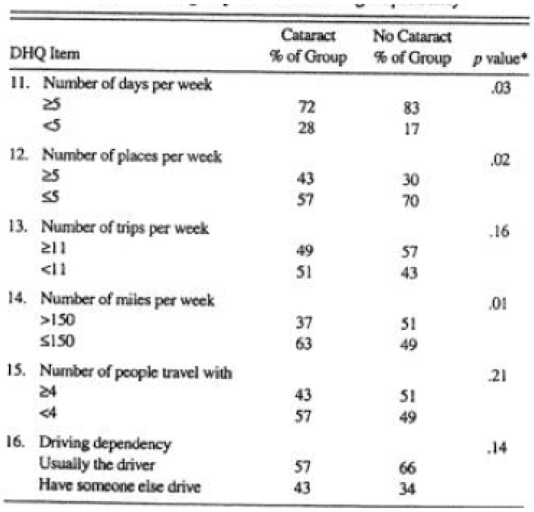
<table>
<tr><td colspan="3">Owsley C, Stalvey B, Wells J, Sloane M. Older drivers and cataract: driving habits and crash risk. J Gerontol 1999; 54: M203-211</td></tr>
<tr><td>Key Questions Addressed</td><td colspan="2"><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td></td><td></td><td></td><td>✓</td><td></td></tr></table></td></tr>
<tr><td>Research Question</td><td colspan="2">What is the role of cataract among older drivers?</td></tr>
<tr><td>Study Design</td><td colspan="2">Retrospective Cohort Control (Crash), Prospective Cohort-Controlled (difficulty driving, vision tests)</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td>Cases aged 55-85 years living independently in the community and legally licensed to drive; diagnosis of cataract in one or both eyes; acuity in one eye of 20/40 or worse (best-corrected distance) and no previous cataract surgery in either eye; primary cause of vision impairment in both eyes had to be cataract according to medical records.
Controls had to be free of a diagnosis of clinically significant cataract in either eye; acuity in each eye of 20/25 or better (best-corrected distance); no previous cataract surgery; and free of identifiable eye disease according to medical records.</td></tr>
<tr><td>Exclusion Criteria</td><td>Amblyopia, use of a wheelchair for mobility, and the presence of dementia, Parkinson’s disease, psychosis, or any illness that precluded annual clinic visits for 3 years</td></tr>
<tr><td>Study population Characteristics</td><td><table><tr><td>Variable</td><td>Case</td><td>Control</td></tr><tr><td>n</td><td>279</td><td>105</td></tr><tr><td>Age (yrs) mean±SD</td><td>71±6</td><td>67±6</td></tr><tr><td>Gender M/F</td><td>53%M,47%F</td><td>48%M,52%F</td></tr><tr><td>Race</td><td>White 86%</td><td>White 84%</td></tr><tr><td></td><td>African American 14%</td><td>African American 16%</td></tr></table></td></tr>
<tr><td>Generalizability to CMV drivers</td><td>Unclear</td></tr>
<tr><td>Methods</td><td colspan="2">All participants were recruited from 12 ophthalmology practices/clinics in Birmingham, Alabama through medical records of previous 12 months. Study phases included an interview and visual function assessment. Participant’s responses to the Driving Habits Questionnaire informed investigators of prior year’s driving status, exposure, dependence on other drivers, driving difficulties, driving space, and crashes and citations. The Alabama Department of Public Safety (DPS) supplied reliable crash data on all study participants for 5 years prior to enrollment. Three independent individuals rated each accident report to determine at-fault involvement. Raters were not aware of participant’s health status. Visual function was assessed for each eye with interest in acuity (measured by ETDRS letter chart), contrast sensitivity (measured by Pelli-Robson Contrast Sensitivity Chart) and VF sensitivity (measured by Humphrey Field Analyzer 81 point screening program for central 60 degrees). As is commonly allowed, older adults were permitted to view targets through plus lenses to correct for the near test distance.</td></tr>
<tr><td>Statistical Methods</td><td colspan="2">Descriptive statistics, chi-square tests, <i>T</i> tests, analysis of covariance, Mann-Whitney U tests, logistic regression, relative risk estimates</td></tr>
<tr><td>Quality Assessment</td><td colspan="2"><table><tr><td rowspan="2">Revised Newcastle-Ottawa Quality Scale Cohort Studies Score: Moderate</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr><tr><td>N</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr></table></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="2">Crash risk, self-reported driving difficulty, vision tests: acuity, contrast sensitivity, VF sensitivity</td></tr>
<tr><td>Results</td><td colspan="2">Responses to the Driving Habits Questionnaire are shown in Table G-85, Table G-86, Table G-87, and Table G-88. Results included an association of cataract with a preference to having someone else drive, RR =2.37 (95% CI, 1.04-5.41, adjusted for age), and driving slower than the general traffic flow, RR=1.79 (95% CI, 1.01-3.16, adjusted for impaired health). Results for driving exposure demonstrated that cataract was associated with reduced days of driving, RR=1.89 (95% CI, 1.06-3.34) and reduced destinations, RR=1.75 (95%CI, 1.08-2.82), but unrelated to reduced miles/week, RR=1.51 (95% CI, 0.95-2.42, adjusted for age). Results for driving difficulty showed a significant correlation to cataract group, RR=4.07 (95% CI, 2.39-6.94, adjusted for depression). Self-reports of crash are noted in Table G-89. Alabama DPS reported a total of 46 at-fault crashes for the participants during the prior 5 years (Table G-90). Nine percent were involved in one at-fault crash while two percent incurred two or more at-fault crashes. Self-reported crash data was similar to DPS records with only 2 crashes not being reported. Analysis showed a significant association between cataract and at-fault crash involvement, which remained significant after adjusting for driving exposure, RR=2.48 (95% CI, 1.00-6.14). Adjustments were also made for impaired health (only other variable related to crash involvement), and the significant association remained, RR=2.46 (95% CI, 1.00-6.16).</td></tr>
<tr><td>Authors’ Comments</td><td colspan="2">Older drivers with cataract have a higher risk of crash involvement than drivers without the condition.</td></tr>
</table>

Table G-85: Current Driving

DHQ Item	Cataract % of Group	No Cataract % of Group	*p* value*
1. Currently drive			.01
Yes	96	100	
No	4	0	
4. Wear glasses when driving			.19
Yes	75	81	
No	25	19	
5. Wear seatbelt when driving			.01
Yes	96	100	
No	4	0	
6. Way you prefer to get around			.05
Drive self	85	92	
Someone else drive	15	8	
7. How fast you drive			.01
Same or faster	70	82	
Slower	30	18	
8. Suggested you limit/stop driving			.01
Yes	9	2	
No	91	98	
9. Rate quality of driving			.13
Above average	79	86	
Average	21	14	
10. Not want to drive			.23
Ask friend or relative	79	71	
Call taxi or take bus	3	3	
Drive regardless of feelings	8	14	
Postpone plans	10	11	

*Chi-square test

Table G-86: Driving Exposure and Driving Dependency



DHQ Item	Cataract % of Group	No Cataract % of Group	*p* value*
11. Number of days per week			.03
≥5	72	83	
<5	28	17	
12. Number of places per week			.02
≥5	43	30	
≤5	57	70	
13. Number of trips per week			.16
≥11	49	57	
<11	51	43	
14. Number of miles per week			.01
>150	37	51	
≤150	63	49	
15. Number of people travel with			.21
≥4	43	51	
<4	57	49	
16. Driving dependency			.14
Usually the driver	57	66	
Have someone else drive	43	34	

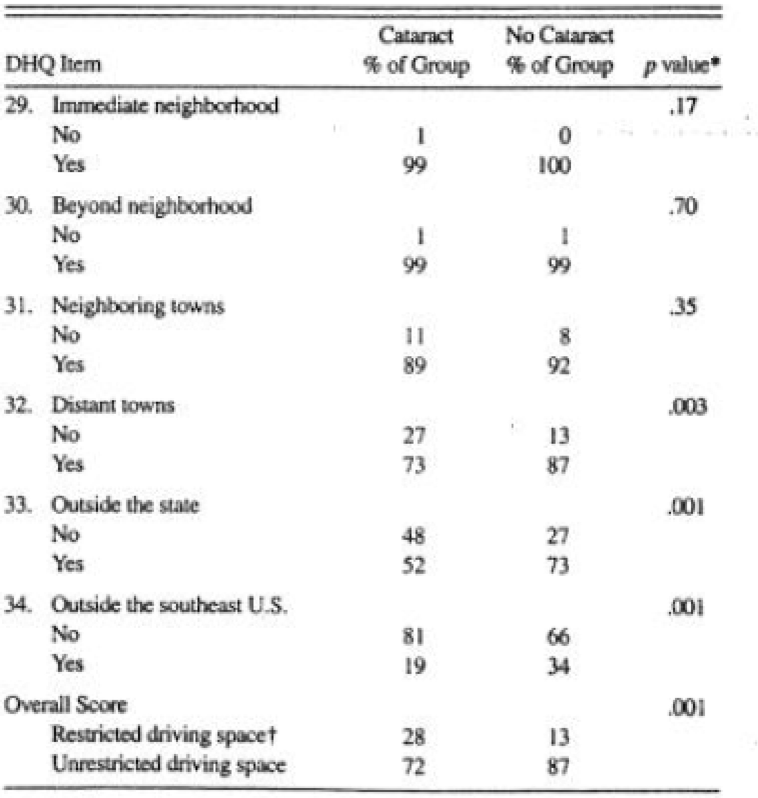
*Chi-square test

Table G-87: Driving Difficulty

DHQ Item	Cataract % of Group	No Cataract % of Group	p value*
17. Driving in the rain			.001
Difficulty	67	44	
No difficulty	33	56	
18. Driving alone			.001
Difficulty	24	5	
No difficulty	76	95	
19. Parallel parking			.50
Difficulty	30	26	
No difficulty	70	74	
20. Left turns in traffic			.001
Difficulty	21	3	
No difficulty	79	97	
21. Driving on interstates			.001
Difficulty	26	10	
No difficulty	74	90	
22. Driving in high traffic			.001
Difficulty	36	19	
No difficulty	64	81	
23. Driving in rush hour			.001
Difficulty	45	24	
No difficulty	55	76	
24. Driving at night			.001
Difficulty	77	41	
No difficulty	23	59	

*Chi-square test

Table G-88: Driving Space

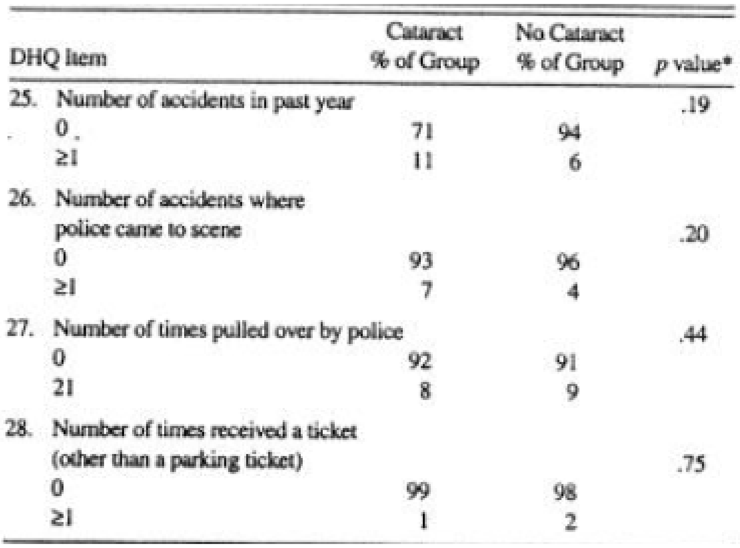


DHQ Item	Cataract % of Group	No Cataract % of Group	p value*
29. Immediate neighborhood			.17
No	1	0	
Yes	99	100	
30. Beyond neighborhood			.70
No	1	1	
Yes	99	99	
31. Neighboring towns			.35
No	11	8	
Yes	89	92	
32. Distant towns			.003
No	27	13	
Yes	73	87	
33. Outside the state			.001
No	48	27	
Yes	52	73	
34. Outside the southeast U.S.			.001
No	81	66	
Yes	19	34	
Overall Score			.001
Restricted driving space†	28	13	
Unrestricted driving space	72	87	

*Chi-square test

† Does not drive beyond neighboring town.

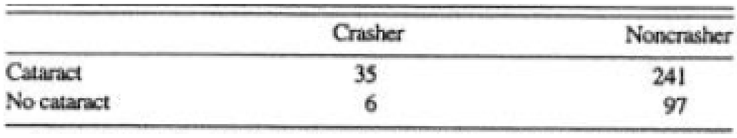
Table G-89: Self-reported Crash and Citations



DHQ Item	Cataract % of Group	No Cataract % of Group	*p* value*
25. Number of accidents in past year			.19
0	71	94	
≥1	11	6	
26. Number of accidents where police came to scene			.20
0	93	96	
≥1	7	4	
27. Number of times pulled over by police			.44
0	92	91	
21	8	9	
28. Number of times received a ticket (other than a parking ticket)			.75
0	99	98	
≥1	1	2	

*Chi-square test

Table G-90: At-Fault State-Recorded Crash Involvement



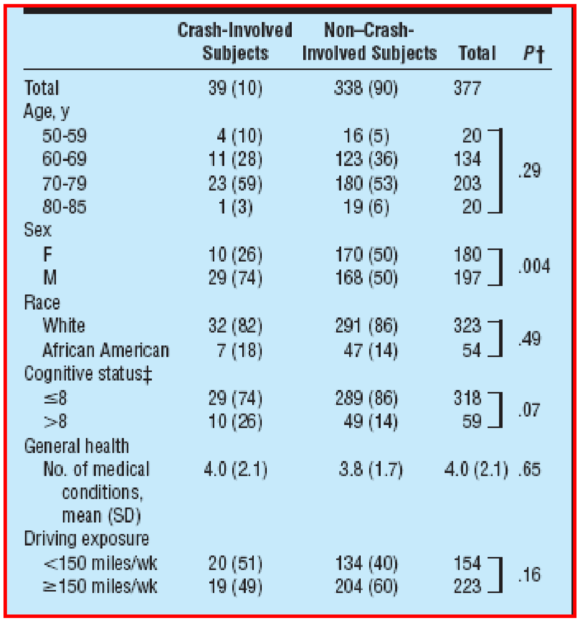
	Crasher	Noncrasher
Cataract	35	241
No cataract	6	97

Notes: Crude RR=2.3 (95% CI, 1.00-5.76); RR=2.48 (95% CI, 1.00-6.14) adjusted for driving exposure (days driven/week; miles/week).

*Five subjects are not included because they had out-of-state licenses; thus, crash data was unavailable through the Alabama DPS

<table>
<tr><td colspan="7">Owsley C, Stalvey B, Wells J, Sloane M, McGwin G. Visual risk factors for crash involvement in older drivers with cataract. Arch Ophthalmol 2001; 119: 881-887</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="2"></td><td></td><td></td><td>✓</td><td></td></tr>
<tr><td>Research Question</td><td colspan="6">Assess visual risk factors for crash in older drivers with cataract</td></tr>
<tr><td>Study Design</td><td colspan="6">Prospective Cohort-Controlled (vision), retrospective cohort-controlled (crash)</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="5">Individuals recruited at 12 eye care clinics in Birmingham, Alabama involved in the Impact of Cataracts on Mobility project; cataract in 1 or both eyes with best-corrected VA of 20/40 or worse in 1 or both eyes verified by medical record; no previous cataract surgery in either eye; a primary diagnostic of cataract in the medical record; living independently in the community; legally licensed to drive and having been driving 5 years prior to enrollment. Controls had similar inclusion criteria with the following exceptions: not having cataracts in either eye and best VA of 20/25 in each eye verified by medical record</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="5">NR</td></tr>
<tr><td>Study population Characteristics</td><td colspan="5"><table>
<tr><th>Variable</th><th>Case</th><th>Control</th></tr>
<tr><td>n</td><td>274</td><td>103</td></tr>
<tr><td>Age (yrs) mean±SD</td><td>71±6 years</td><td>67±6 years</td></tr>
<tr><td>Gender M/F</td><td>54%M,46%F</td><td>48%M,52%F</td></tr>
<tr><td>Nationality</td><td>86% white, non-Hispanic/</td><td>84% white</td></tr>
<tr><td></td><td>14% African American</td><td>16% African American</td></tr>
</table></td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="5">Unclear</td></tr>
<tr><td>Methods</td><td colspan="6">Bilateral cataracts were present in 97% of cases; 75% with no additional eye condition with the exception of refraction error. Acuity, contrast sensitivity and disability glare were assessed. Each eye was evaluated separately.
The Early Treatment Diabetic Retinopathy Study letter chart was used to assess distance acuity. Measurements were grouped into 4 categories: 20/25 or better, 20/25 to 20/30, 20/35 to 20/50, and worse than 20/50. A Pelli-Robson Contrast Sensitivity Chart measured contrast sensitivity with cut points: better than 1.50, 1.50-1.34, 1.24-1.35, and 1.25 or worse. Disability glare was evaluated with the Brightness Acuity Tester (BAT) while the subject viewed the Pelle-Robson Chart. Definition of disability glare equals Pelli-Robson score without the BAT minus the Pelli-Robson Score with the BAT.
Crash data was obtained from the Alabama Department of Public Safety. At-fault crash involvement was defined as participation in at least 1 crash in the previous 5 years in which the subject was reported at least partially at fault. 3 independent judges determined crash responsibility after evaluating each independent crash record. Subjects filled out the Driving Habits questionnaire and were classified into one of two categories; drove more or less than 150 miles/week.</td></tr>
<tr><td>Statistical Methods</td><td colspan="6">Descriptive statistics, X^2, <i>t</i> tests, unadjusted odds ratios, 95% confidence intervals, inferential analyses, logistic regression</td></tr>
<tr><td>Quality Assessment</td><td colspan="6"><table>
<tr><td rowspan="2">Revised Newcastle-Ottawa Quality Scale Cohort Studies Score: Moderate</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>N</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
</table></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="6">Crash, vision: VA, contrast sensitivity, disability glare</td></tr>
<tr><td>Results</td><td colspan="6">A total of 46 at-fault crashes were reported during the 5 years prior to enrollment. Association between at-fault crash involvement and demographic variables, cognitive status, general health and driving exposure are shown in Table G-91. Significance was only noted in gender and crash with males being more likely to be involved in crash (p=.004). Results for VA and contrast sensitivity demonstrated a correlation for better and worse eyes (Pearson r=-0.62 and -0.72, respectively) (Table G-92). Crash involved drivers were approximately 2 ½ times more likely to have cataract than were crash-free drivers (OR=2.46; 95% CI, 1.00-6.16). Additional analysis was done to distinguish specific visual function related to increased crash risk. In the better eye (Table G-93) , contrast sensitivity of 1.25 or less was the only variable associated with crash involvement (OR=2.65; 95% CI, 1.06-6.61) with the relationship becoming stronger (OR=4.97; 95% CI, 1.69-14.63) after adjusting for cognitive function, general health, demographics and driving exposure. After these adjustments were made VA in the range of 20/35 to 20/50 also was associated with crash involvement (OR=3.17; 95% CI, 1.15-8.69). Results for the worse eye (Table G-94) again show a crude association of contrast sensitivity of 1.25 or less with crash (OR=3.38; 95% CI, 1.21-9.47) which became stronger after adjustments noted prior (OR=7.06; 95% CI, 1.88-26.52). A comparison of better eye and worse eye (Table G-95) demonstrated the only independent predictor of crash involvement (when adjusted for other aspects of visual function) was a contrast sensitivity score of 1.25 or less. Results for the worse eye were 2 times stronger (OR=7.86; 95% CI, 1.55-39.79) than for the better eye (OR=3.78; 95% CI, 1.15-12.48). Further analysis of strength of relationship of 1 eye or both eyes with crash demonstrated a strong association of contrast sensitivity impairment in both eyes with crash (OR=5.78; 95% CI, 1.87-17.86) although a significant relationship was also found for 1 eye (OR=2.70; 95% CI, 1.16-6.51) (Table G-96).</td></tr>
<tr><td>Authors' Comments</td><td colspan="6">Cataract is a risk factor for at-fault crash involvement (OR=2.46; 95% CI, 1.00-6.16) with the visual function of contrast sensitivity being primarily responsible for this increased risk.</td></tr>
</table>

Table G-91: Associations between At-fault Crash Involvement and Driving Exposure



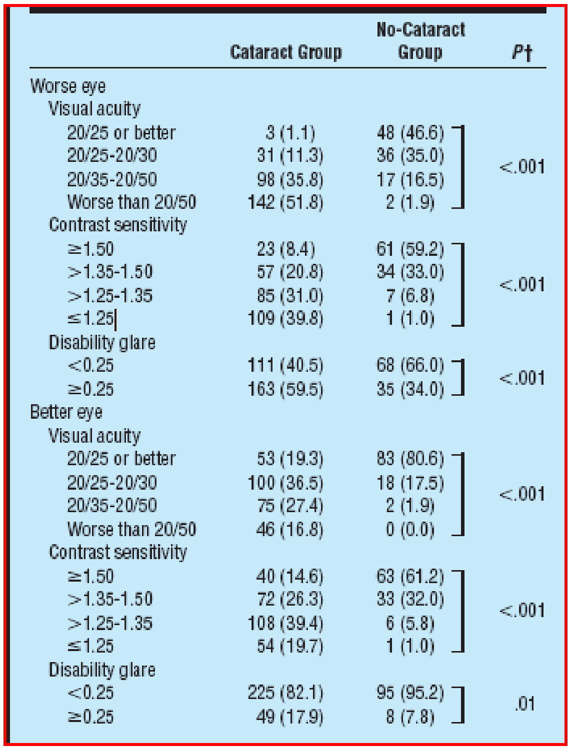
	Crash-Involved Subjects	Non–Crash-Involved Subjects	Total	P†
Total	39 (10)	338 (90)	377	
Age, y				
50-59	4 (10)	16 (5)	20	.29
60-69	11 (28)	123 (36)	134	
70-79	23 (59)	180 (53)	203	
80-85	1 (3)	19 (6)	20	
Sex				
F	10 (26)	170 (50)	180	.004
M	29 (74)	168 (50)	197	
Race				
White	32 (82)	291 (86)	323	.49
African American	7 (18)	47 (14)	54	
Cognitive status‡				
≤8	29 (74)	289 (86)	318	.07
>8	10 (26)	49 (14)	59	
General health				
No. of medical conditions, mean (SD)	4.0 (2.1)	3.8 (1.7)	4.0 (2.1)	.65
Driving exposure				
<150 miles/wk	20 (51)	134 (40)	154	.16
≥150 miles/wk	19 (49)	204 (60)	223	

*Data are presented as number (percentage) unless otherwise indicated.

† P values were determined using the X^2 test, except for the general health variable, for which an independent, 2-sample t test was used.

‡ Cognitive scores based on the Mattis Organic Mental Syndrome Screening Examination.

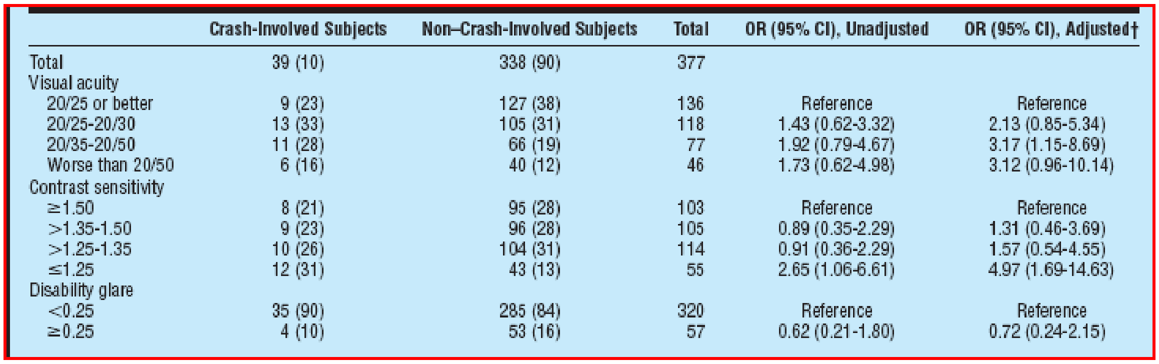
Table G-92: VA, Contrast Sensitivity and Disability Glare



	Cataract Group	No-Cataract Group	P†
Worse eye			
Visual acuity			
20/25 or better	3 (1.1)	48 (46.6)	<.001
20/25-20/30	31 (11.3)	36 (35.0)	
20/35-20/50	98 (35.8)	17 (16.5)	
Worse than 20/50	142 (51.8)	2 (1.9)	
Contrast sensitivity			
≥1.50	23 (8.4)	61 (59.2)	<.001
>1.35-1.50	57 (20.8)	34 (33.0)	
>1.25-1.35	85 (31.0)	7 (6.8)	
≤1.25	109 (39.8)	1 (1.0)	
Disability glare			
<0.25	111 (40.5)	68 (66.0)	<.001
≥0.25	163 (59.5)	35 (34.0)	
Better eye			
Visual acuity			
20/25 or better	53 (19.3)	83 (80.6)	<.001
20/25-20/30	100 (36.5)	18 (17.5)	
20/35-20/50	75 (27.4)	2 (1.9)	
Worse than 20/50	46 (16.8)	0 (0.0)	
Contrast sensitivity			
≥1.50	40 (14.6)	63 (61.2)	<.001
>1.35-1.50	72 (26.3)	33 (32.0)	
>1.25-1.35	108 (39.4)	6 (5.8)	
≤1.25	54 (19.7)	1 (1.0)	
Disability glare			
<0.25	225 (82.1)	95 (95.2)	.01
≥0.25	49 (17.9)	8 (7.8)	

*Data are presented as number (percentage). P values were determined using the X^2 test.

Table G-93: Relationship between Visual Function in the Better Eye and At-Fault Crash Involvement

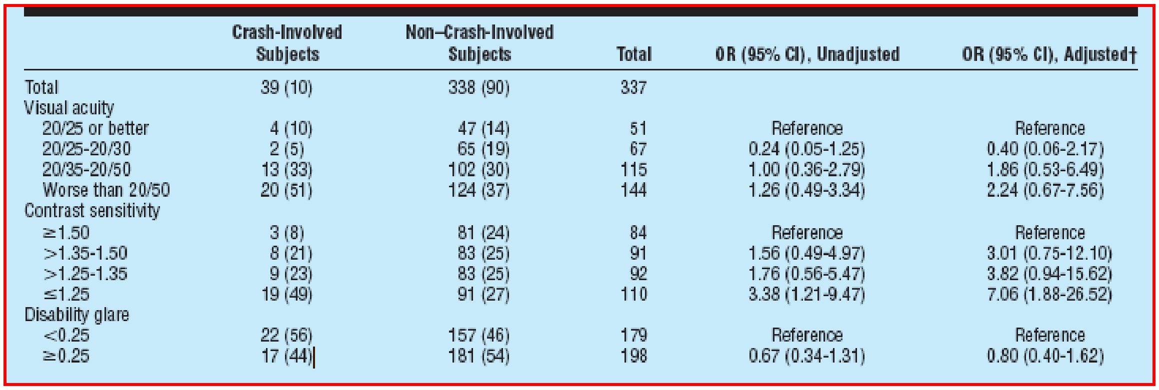


	Crash-Involved Subjects	Non–Crash-Involved Subjects	Total	OR (95% CI), Unadjusted	OR (95% CI), Adjusted†
Total	39 (10)	338 (90)	377		
Visual acuity					
20/25 or better	9 (23)	127 (38)	136	Reference	Reference
20/25-20/30	13 (33)	105 (31)	118	1.43 (0.62-3.32)	2.13 (0.85-5.34)
20/35-20/50	11 (28)	66 (19)	77	1.92 (0.79-4.67)	3.17 (1.15-8.69)
Worse than 20/50	6 (16)	40 (12)	46	1.73 (0.62-4.98)	3.12 (0.96-10.14)
Contrast sensitivity					
≥1.50	8 (21)	95 (28)	103	Reference	Reference
>1.35-1.50	9 (23)	96 (28)	105	0.89 (0.35-2.29)	1.31 (0.46-3.69)
>1.25-1.35	10 (26)	104 (31)	114	0.91 (0.36-2.29)	1.57 (0.54-4.55)
≤1.25	12 (31)	43 (13)	55	2.65 (1.06-6.61)	4.97 (1.69-14.63)
Disability glare					
<0.25	35 (90)	285 (84)	320	Reference	Reference
≥0.25	4 (10)	53 (16)	57	0.62 (0.21-1.80)	0.72 (0.24-2.15)

*Data are presented as number (percentage). OR indicates odds ratio; CI, confidence interval.

† Adjusted for age, sex, race, cognitive status, general health, and driving exposure.

Table G-94: Relationship between Visual Function in the Worse Eye and At-Fault Crash Involvement

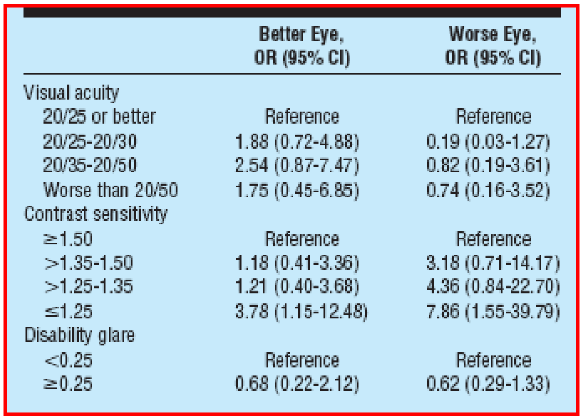


	Crash-Involved Subjects	Non–Crash-Involved Subjects	Total	OR (95% CI), Unadjusted	OR (95% CI), Adjusted†
Total	39 (10)	338 (90)	337		
Visual acuity					
20/25 or better	4 (10)	47 (14)	51	Reference	Reference
20/25-20/30	2 (5)	65 (19)	67	0.24 (0.05-1.25)	0.40 (0.06-2.17)
20/35-20/50	13 (33)	102 (30)	115	1.00 (0.36-2.79)	1.86 (0.53-6.49)
Worse than 20/50	20 (51)	124 (37)	144	1.26 (0.49-3.34)	2.24 (0.67-7.56)
Contrast sensitivity					
≥1.50	3 (8)	81 (24)	84	Reference	Reference
>1.35-1.50	8 (21)	83 (25)	91	1.56 (0.49-4.97)	3.01 (0.75-12.10)
>1.25-1.35	9 (23)	83 (25)	92	1.76 (0.56-5.47)	3.82 (0.94-15.62)
≤1.25	19 (49)	91 (27)	110	3.38 (1.21-9.47)	7.06 (1.88-26.52)
Disability glare					
<0.25	22 (56)	157 (46)	179	Reference	Reference
≥0.25	17 (44)	181 (54)	198	0.67 (0.34-1.31)	0.80 (0.40-1.62)

*Data are presented as number (percentage). OR indicates odds ratio; CI, confidence interval.

† Adjusted for age, sex, race, cognitive status, general health, and driving exposure.

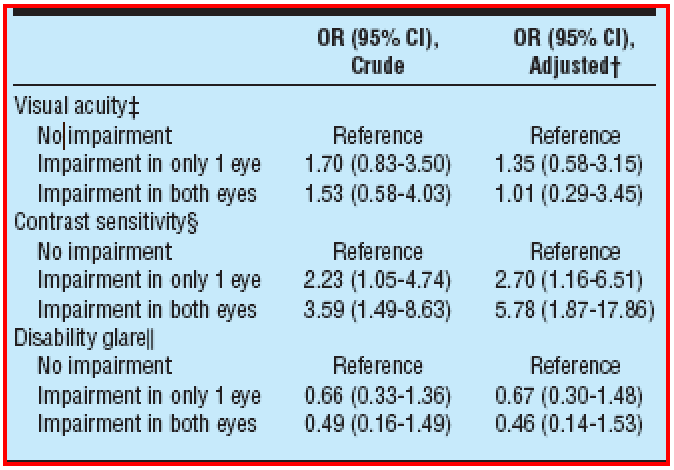
Table G-95: Multiple Visual Function Model for Better Eye and Worse Eye, Examining Relationship Between Vision and At-Fault Crash



	Better Eye, OR (95% CI)	Worse Eye, OR (95% CI)
Visual acuity		
20/25 or better	Reference	Reference
20/25-20/30	1.88 (0.72-4.88)	0.19 (0.03-1.27)
20/35-20/50	2.54 (0.87-7.47)	0.82 (0.19-3.61)
Worse than 20/50	1.75 (0.45-6.85)	0.74 (0.16-3.52)
Contrast sensitivity		
≥1.50	Reference	Reference
>1.35-1.50	1.18 (0.41-3.36)	3.18 (0.71-14.17)
>1.25-1.35	1.21 (0.40-3.68)	4.36 (0.84-22.70)
≤1.25	3.78 (1.15-12.48)	7.86 (1.55-39.79)
Disability glare		
<0.25	Reference	Reference
≥0.25	0.68 (0.22-2.12)	0.62 (0.29-1.33)

*Odds ratios are adjusted for age, sex, race, cognitive status, general health, driving exposure, and the 2 other visual functions not being evaluated.
OR indicates odds ratio; CI, confidence interval.

Table G-96: Association between At-Fault Crash Involvement and Impairment in Only 1 Eye and Both Eyes



	OR (95% CI), Crude	OR (95% CI), Adjusted†
Visual acuity‡		
No impairment	Reference	Reference
Impairment in only 1 eye	1.70 (0.83-3.50)	1.35 (0.58-3.15)
Impairment in both eyes	1.53 (0.58-4.03)	1.01 (0.29-3.45)
Contrast sensitivity§		
No impairment	Reference	Reference
Impairment in only 1 eye	2.23 (1.05-4.74)	2.70 (1.16-6.51)
Impairment in both eyes	3.59 (1.49-8.63)	5.78 (1.87-17.86)
Disability glare‖		
No impairment	Reference	Reference
Impairment in only 1 eye	0.66 (0.33-1.36)	0.67 (0.30-1.48)
Impairment in both eyes	0.49 (0.16-1.49)	0.46 (0.14-1.53)

*OR indicates odds ratios; CI, confidence interval.

† Adjusted for age, sex, race, cognitive status, general health, driving exposure, and the 2 other visual functions not being evaluated.

‡ Acuity impairment defined as worse than 20/50.

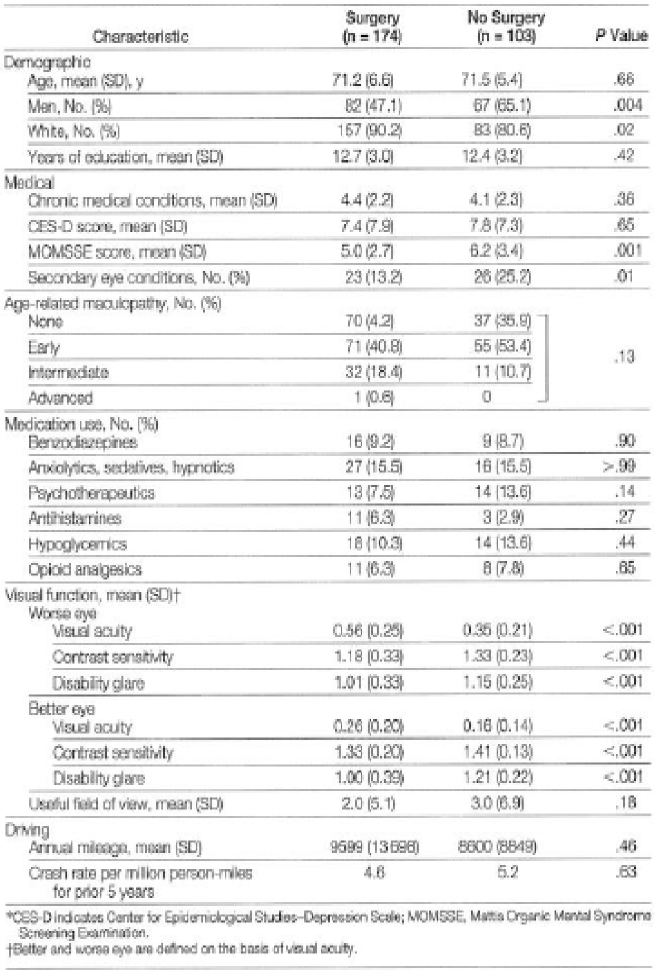
§ Contrast sensitivity impairment defined as score ≤ 1.25.

|| Glare impairment defined as glare score ≥ 0.25.

<table>
<tr><td colspan="6">Owsley C, McGwin G, Sloane M, Wells J, Stalvery B, Gauthreaux S. Impact of Cataract Surgery on Motor Vehicle Crash Involvement by Older Adults. JAMA 2002; Vol 288 No. 7; 841-9.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td>✓</td><td></td></tr>
<tr><td>Research Question</td><td colspan="5">To determine the impact of cataract surgery on the crash risk for older adults in years following surgery compared to older adults with cataract elected not to have surgery.
Self-reported driving difficulty and visual function assessed</td></tr>
<tr><td>Study Design</td><td colspan="5">Prospective Cohort</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="4">Individuals who:
Had cataract in one or both eyes with acuity of 20/40 or worse (best corrected, distance) as indicated by the medical record
Had no previous cataract surgery in either eye
Had cataract surgery in at least one eye had been previously recommended by an ophthalmologist as a treatment for the subject’s visual problems with elected surgery
Were living independently with the community
Were licensed to drive in the state of Alabama; able to drive</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="4">Individuals who:
Had amblyopia (lazy eye)
Used wheelchairs for mobility
Were diagnosed with dementia
Had Parkinson’s disease
Illnesses that would preclude annual clinic visits for the follow-up period</td></tr>
<tr><td>Study population Characteristics</td><td colspan="4"><table><tr><th>Characteristic</th><th>Surgery</th><th>No surgery</th></tr><tr><td>Population (n)</td><td>174</td><td>103</td></tr><tr><td>Age, mean (SD) y</td><td>71.2 (6.6)</td><td>71.5 (5.4)</td></tr><tr><td>Men, No. (%)</td><td>82 (47.1)</td><td>67 (65.1)</td></tr></table>Refer to Table G-97 for complete details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="4">Unclear</td></tr>
<tr><td>Methods</td><td colspan="5">Institutional Review board for Human Use at University of Alabama approved study
Baseline protocol explained to all who enrolled and elected for surgery; test examiners “masked” to crash histories for all subjects
Candidates contracted for enrollment via letter describing study; followed by phone call from study coordinator
Participants who agreed to study were scheduled for appointments at the Clinical Research Unit in the Department of Ophthalmology, University of Alabama at Birmingham
Target enrollment of 130 per group based on sample size calculation from previous cross sectional studies
Information on key variables obtained by phone from declined ICOM project participants
Three types of visual function assessed:
Acuity
Contrast sensitivity
Disability glare
Individuals with cataract recruited from 12 eye clinics in Alabama from October 1994 through March 1996 with 4-6 years of follow-up (to March 1999)
For subjects who elected for surgery, initial visit (baseline) before surgery completed
Cognitive status, visual processing speed/attentional ability, depression, and general health were assessed due to association with crash involvement of older adjust—creating potential confounders
• Cognitive function evaluated by Mattis Organic Syndrome Screening Examination (MOMSSE); Depression symptoms assed by the Center for Epidemiological Studies Depression Scale (CES-D)
• The Alabama Department of Public Safety, the stage agency in charge of compiling crash records, provided information on collision for study subjects during 5 year pre-enrollment; information combined with results of Driving Habits Questionnaire to calculate crash rates
Driving exposure estimated at baseline
Each subject’s person-miles of travel was calculated by summing the estimated miles driven per week from the time of enrollment until date of driving cessation, date of death, or March 1, 1999—whichever came first</td></tr>
<tr><td>Statistical Methods</td><td colspan="5">Poisson regression used to calculate crude and adjusted rate ration (RR) and 95% confidence interval (CI) for the association</td></tr>
</table>

<table>
<tr><td></td><td>between crash rate and cataract surgery
Potential confounding variables adjusted for analyses before selection
Descriptive statistics generated for demographic, medical, visual function and crash rate compared between cataract subjects who did and did not undergo cataract surgery using t and X^2
Dependent variables to test the primary hypothesis of study was crash rate per person-miles of travel
Cutpoints for questioned variables constructed separately for each variable
P values of ≤.05 considered statistically significant; data analyses conducted using SAS v8.0 (SAS Institute Inc, Cary, NC)</td></tr>
<tr><td>Quality Assessment</td><td>
<table>
<tr><td rowspan="2">Revised Newcastle-Ottawa Quality Scale
Cohort Studies Score:
Moderate</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>S</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
</table>
<table>
<tr><td rowspan="2">ECRI Institute Quality Scale for Pre-Post Studies:
Moderate
*No for driving test, yes for visual test</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td>No</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
</table>
</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td>• Risk of crash for individuals with cataract
• Rate of driving exposure measured
• Difficulty of driving measured using self- assessed questionnaire
• Vision assessed utilizing:
• Distance acuity--measured using the Early Treatment Diabetic Retinopathy study (ETDRS) letter chart and standard protocol
• Contrast sensitivity—measured using the Pelli-Robson Contrast Sensitivity chart and its standard protocol
• Disability Glare
• Contrast Sensitivity</td></tr>
<tr><td>Results</td><td>• The rate ratio for crash involvement was 0.47 (95% CI, 0.23-0.94) for cataract surgery cataract group compared to group who did not have surgery; these results were adjusted for race and VA and contrast sensitivity at baseline
• The absolute rate reduction associated with cataract surgery was 4.74 crashes per million miles traveled
• Surgery group average a 2-line (10 letters, 0.2 log 10 minimum angle resolvable (logMAR) acuity improvement on the ETDRS chart by second visit for both right and left eyes (SD, 0.3 logMAR)
• For the no surgery group at visit 2 acuity declined on average by 2 letters in the right eye and 1 letter in the left eye (SD, 0.13 log MAR for both right and left eyes)
• Refer to Table G-98 for LOCS III grades for the surgery and non-surgery groups for the worse and better eyes (defined by VA)
• Table G-99 presents the crash rates for the surgery and non surgery groups—post baseline
• The unadjusted RR comparing the surgery with no surgery group was 0.64 (95% CI 0.37-1.13)
• The no surgery group showed an insignificant increase in crash rate 72% (95% CI, 1.00-3.10); surgery group nonsignificant increase, 27% (95% CI, 0.80-2.10)
• Visual Function and Driving Characteristics Among Surgery/No Surgery Groups shown in Figure G-36</td></tr>
<tr><td>Authors' Comments</td><td>“Employing a randomized design to address the relationship between cataract surgery and crash involvement was not possible because cataract surgery is an accepted standard of care.”</td></tr>
</table>

Table G-97. Baseline Demographic, Medical, and Visual Function Characteristics Among Impact of Cataract on Mobility Project Subjects, According to Surgery Status

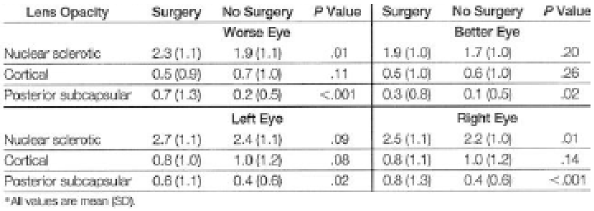


Characteristic	Surgery (n = 174)	No Surgery (n = 103)	P Value
Demographic			
Age, mean (SD), y	71.2 (6.6)	71.5 (5.4)	.66
Men, No. (%)	82 (47.1)	67 (65.1)	.004
White, No. (%)	157 (90.2)	83 (80.6)	.02
Years of education, mean (SD)	12.7 (3.0)	12.4 (3.2)	.42
Medical			
Chronic medical conditions, mean (SD)	4.4 (2.2)	4.1 (2.3)	.36
CES-D score, mean (SD)	7.4 (7.9)	7.8 (7.3)	.65
MOMSSE score, mean (SD)	5.0 (2.7)	6.2 (3.4)	.001
Secondary eye conditions, No. (%)	23 (13.2)	26 (25.2)	.01
Age-related maculopathy, No. (%)			
None	70 (4.2)	37 (35.9)	.13
Early	71 (40.8)	55 (53.4)	
Intermediate	32 (18.4)	11 (10.7)	
Advanced	1 (0.6)	0	
Medication use, No. (%)			
Benzodiazepines	16 (9.2)	9 (8.7)	.90
Anxiolytics, sedatives, hypnotics	27 (15.5)	16 (15.5)	>.99
Psychotherapeutics	13 (7.5)	14 (13.6)	.14
Antihistamines	11 (6.3)	3 (2.9)	.27
Hypoglycemics	18 (10.3)	14 (13.6)	.44
Opioid analgesics	11 (6.3)	8 (7.8)	.65
Visual function, mean (SD)†			
Worse eye			
Visual acuity	0.56 (0.25)	0.35 (0.21)	<.001
Contrast sensitivity	1.18 (0.33)	1.33 (0.23)	<.001
Disability glare	1.01 (0.33)	1.15 (0.25)	<.001
Better eye			
Visual acuity	0.26 (0.20)	0.16 (0.14)	<.001
Contrast sensitivity	1.33 (0.20)	1.41 (0.13)	<.001
Disability glare	1.00 (0.39)	1.21 (0.22)	<.001
Useful field of view, mean (SD)	2.0 (5.1)	3.0 (6.9)	.18
Driving			
Annual mileage, mean (SD)	9599 (13 698)	8600 (8849)	.46
Crash rate per million person-miles for prior 5 years	4.6	5.2	.63

*CES-D indicates Center for Epidemiological Studies–Depression Scale; MOMSSE, Mattis Organic Mental Syndrome Screening Examination.

†Better and worse eye are defined on the basis of visual acuity.

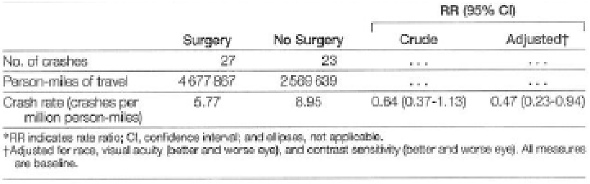
Table G-98. Lens Opacity Classification Systems (LOCS) III Grades for the Surgery and No Surgery Groups



Lens Opacity	Surgery	No Surgery	P Value	Surgery	No Surgery	P Value
		Worse Eye			Better Eye	
Nuclear sclerotic	2.3 (1.1)	1.9 (1.1)	.01	1.9 (1.0)	1.7 (1.0)	.20
Cortical	0.5 (0.9)	0.7 (1.0)	.11	0.5 (1.0)	0.6 (1.0)	.26
Posterior subcapsular	0.7 (1.3)	0.2 (0.5)	<.001	0.3 (0.8)	0.1 (0.5)	.02
		Left Eye			Right Eye	
Nuclear sclerotic	2.7 (1.1)	2.4 (1.1)	.09	2.5 (1.1)	2.2 (1.0)	.01
Cortical	0.8 (1.0)	1.0 (1.2)	.08	0.8 (1.1)	1.0 (1.2)	.14
Posterior subcapsular	0.6 (1.1)	0.4 (0.6)	.02	0.8 (1.3)	0.4 (0.6)	<.001

*All values are mean (SD).

Table G-99. Crash Rates During Follow-up

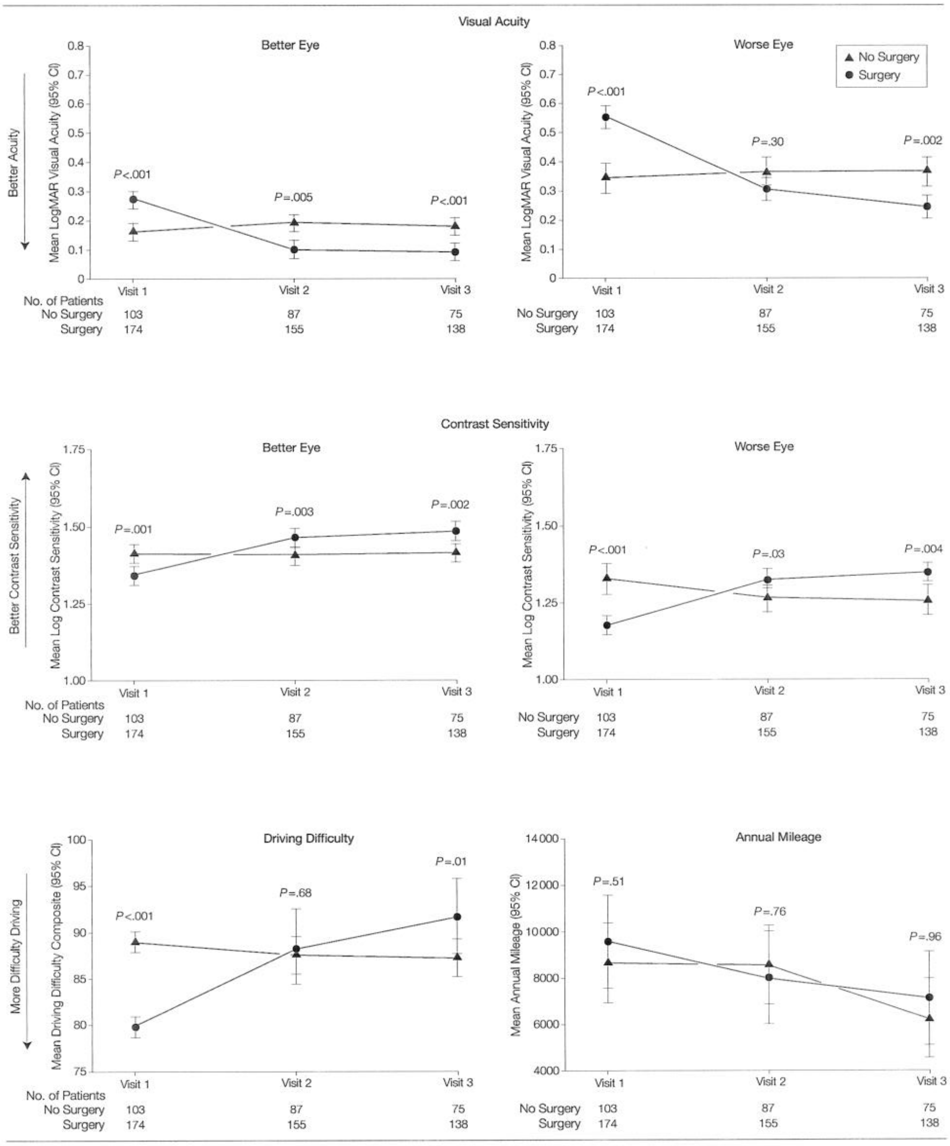


			RR (95% CI)	
	Surgery	No Surgery	Crude	Adjusted†
No. of crashes	27	23	...	...
Person-miles of travel	4 677 867	2 569 639	...	...
Crash rate (crashes per million person-miles)	5.77	8.95	0.64 (0.37-1.13)	0.47 (0.23-0.94)

*RR indicates rate ratio; CI, confidence interval; and ellipses, not applicable.

†Adjusted for race, visual acuity (better and worse eye), and contrast sensitivity (better and worse eye). All measures are baseline.

Figure G-36. Visual Function and Driving Characteristics Over Study Visits Among the Surgery and No Surgery Groups



P values in each figure refer to between-group comparisons for the corresponding visit. LogMAR indicates $\log_{10}$ minimum angle resolvable.

<table>
<tr><td colspan="16">Superstein R, Boyaner D, Overbury O, Collin C. Glare disability and contrast sensitivity before and after cataract surgery. J Cataract Refract Surg 1997 Mar;23(2):248-53.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="3">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3">✓</td><td colspan="3"></td></tr>
<tr><td>Research Question</td><td colspan="15">To compare preoperative and postoperative glare disability and contrast sensitivity in people with cataracts</td></tr>
<tr><td>Study Design</td><td colspan="15">Pre-post</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="14">Best corrected Snellen VA score of 20/70 or better scheduled for cataract surgery and free of other ocular pathology</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="14">None reported</td></tr>
<tr><td>Study population Characteristics</td><td colspan="14">N 20
Mean age 69.15 (SD 10.3) years
Men 50%</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="14">Unclear</td></tr>
<tr><td>Methods</td><td colspan="15">o All patients tested preoperatively, and 1 and 3 months postoperatively.
o VA tested with Optec 3000 (Stero Optical Co, Inc) with internal 3500 lux light using Snellen-type letter chart, with minimum angle of resolution (MAR) recorded for each line for which more than half the letters were identified.
o Spatial contrast sensitivity measured using Functional Acuity Contrast Tester (Stero Optical Co, Inc).
o Verbal questioning of subjective complaints, including poor night driving and changes in vision in brightness.</td></tr>
<tr><td>Statistical Methods</td><td colspan="15">2x2 repeated measures analysis of variance (ANOVA)</td></tr>
<tr><td rowspan="2">Quality Assessment</td><td rowspan="2">ECRI Institute Quality Scale for Pre-Post Studies Score: Moderate</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td>No</td><td>Yes</td><td>No</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="15">VA, contrast sensitivity, subjective difficulty driving</td></tr>
<tr><td>Results</td><td colspan="15">o Improvement in VA was statistically significant under glare and no glare conditions at 1 and 3 months postoperative (P<0.01)
o Spatial contrast sensitivity returned to normal range at 1 and 3 months postoperative (Figure G- 37 and Figure G- 38).
o Subjective visual function improved from all patients reporting difficulty with contrast and glare-related tasks (including driving) before surgery to no patients reporting difficulty afterward.</td></tr>
<tr><td>Authors' Comments</td><td colspan="15">"The results of this study show that brightness-induced glare did not affect VA but did decrease spatial contrast sensitivity in preoperative cataract patients."</td></tr>
</table>

Figure G- 37 Log contrast sensitivity as a function of spatial frequencies under glare and no-glare conditions

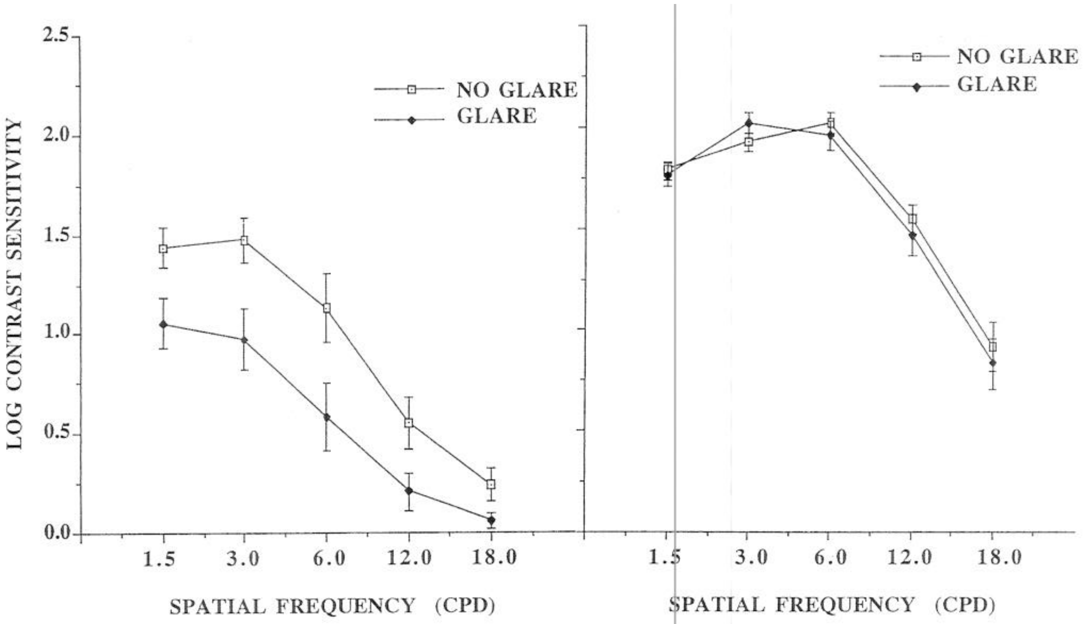


Figure 3. (Superstein) Log contrast sensitivity as a function of spatial frequencies under glare and no-glare conditions. *Left*: Preoperatively. *Right*: 1 month postoperatively (cpd = cycles per degree).

Figure G- 38 Three month postoperative log contrast sensitivity as a function of spatial frequencies for glare and no glare conditions

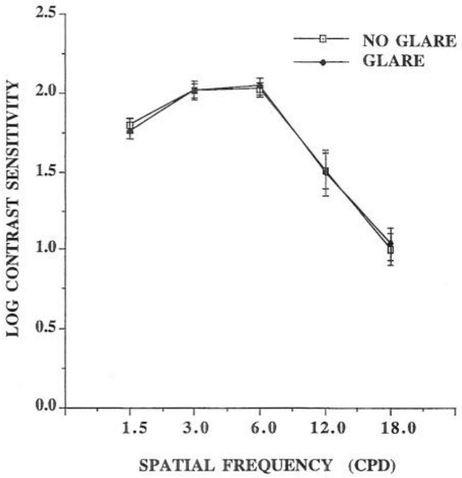
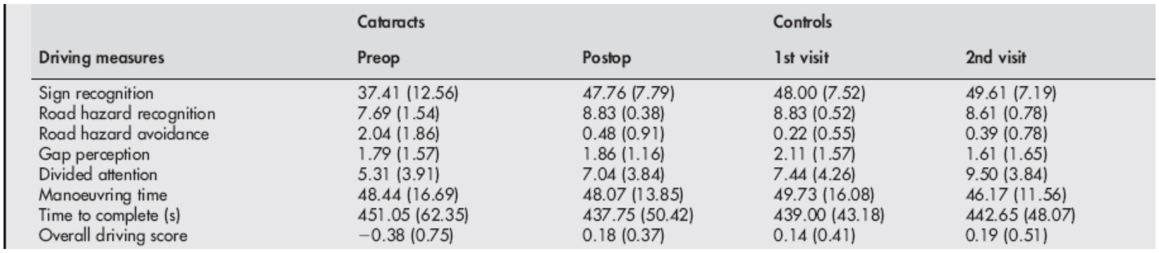


Figure 4. (Superstein) Three month postoperative log contrast sensitivity as a function of spatial frequencies for glare and no-glare conditions (cpd = cycles per degree).

<table>
<tr><th colspan="3">Wood J, Carberry T. Bilateral cataract surgery and driving performance. Br J Ophthalmol 2006; 90: 1277-1280</th></tr>
<tr><td>Key Questions Addressed</td><td colspan="2"><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td></td><td></td><td></td><td>✓</td><td></td></tr></table></td></tr>
<tr><td>Research Question</td><td colspan="2">Change in vision and driving performance post-cataract surgery</td></tr>
<tr><td>Study Design</td><td colspan="2">Pre-Post, Cohort-Control</td></tr>
<tr><td>Population</td><td>Inclusion Criteria</td><td>Cases recruited from scheduled cataract surgeries with no ocular disease present except cataracts. Controls had normal VA (better than 20/25 or 6/7.5) and were free of eye condition. All participants were regular drivers and in good general health.</td></tr>
<tr><td></td><td>Exclusion Criteria</td><td>NR</td></tr>
<tr><td></td><td>Study population Characteristics</td><td><table><tr><td><u>Variable</u></td><td><u>Case</u></td><td><u>Control</u></td></tr><tr><td>n</td><td>29</td><td>18</td></tr><tr><td>Age (yrs) mean±SD</td><td>73±8 (range 50-89)</td><td>68±7 (range 53-78)</td></tr></table></td></tr>
<tr><td></td><td>Generalizability to CMV drivers</td><td>Unclear</td></tr>
<tr><td>Methods</td><td colspan="2">A series of vision and driving test sessions were attended by all participants. Cataract group had testing one month pre/post surgery (mean length of time since the last cataract surgery was 80 days). Testing was similar for controls. Driving performance was evaluated on a closed-road circuit in daytime on a 5.1 km track. Participants were allowed one practice run performed in the opposite direction of the recorded run. Outcome measures included sign recognition, road hazard recognition, correct gap judgments, divided attention, maneuvering time and time to complete the course. A high-contrast Bailey Lovie chart at 3 m and a Pelli-Robson chart were used to assess VA and contrast sensitivity respectively. The Berkeley Glare Test (BGT) and Brightness Acuity Tester (BAT) were used to assess disability glare sensitivity. Disability glare was defined as the Pelli-Robson score without the BAT minus that with the BAT. Kinetic fields were measured using a large low-contrast target (size IV4B) moving at a speed of 4°/s along 12 meridians of the VF.</td></tr>
<tr><td>Statistical Methods</td><td colspan="2">Independent t tests, repeated measures regression models, one-way analyses of variance, bivariate Pearson's correlation</td></tr>
<tr><td>Quality Assessment</td><td>Revised Newcastle-Ottawa Quality Scale
Cohort Studies Score:
Moderate</td><td><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr><tr><td>S</td><td>No</td><td>S</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr></table></td></tr>
<tr><td></td><td>ECRI Institute Quality Scale for Pre-Post Studies:
Moderate
No for driving test, yes for visual test</td><td><table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr><tr><td>No</td><td>Y</td><td>NR</td><td>Y</td><td>Y</td><td>Y</td><td>No
Y</td><td>Y</td><td>Y</td><td>No</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr></table></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="2">Change in driving performance and vision, in terms of acuity, contrast sensitivity, glare sensitivity, and kinetic VFs</td></tr>
<tr><td>Results</td><td colspan="2">Initial driving performance data is shown in Table G- 100. Results for first visit demonstrated significantly worse driving performance for cataract group vs controls for road sign recognition ($t_{(45)}$ = -3.23; p=0.002), road hazard recognition ($t_{(45)}$ = -3.04; p=0.004) and avoidance ($t_{(45)}$ = 4.01; p<0.001), as well as for an index of overall performance (minus maneuvering task)($t_{(45)}$ = -2.68; p=0.01). Post-surgery results showed significant improvements in driving performance by the cataract group for overall driving score ($F_{1,28}$ =14.88; p=0.001), road sign recognition ($F_{1,28}$ = 20.51; p<0.001), road hazards recognized ($F_{1,28}$ = 17.28; p<0.001). Although a significant improvement was found in divided attention task (number of reaction lights seen), further analysis showed improvements resulted only from repeated testing. Vision performance scores are shown in Table G- 101. During the first visit, the cataract group demonstrated significantly worse performance on all visual measurements with the exception of "VA in the second operated eye". BGT measures were excluded from analysis as the measurements may have biased the overall analysis of vision and driving post-surgery. On the second post-surgery visit, vision performance improved significantly for binocular VA, VA in the first operated eye, binocular contrast sensitivity, and contrast sensitivity in the first and second operated eye, and BAT in the first operated eye. Pearson's r values for the bivariate correlations between changes in visual performance and overall driving score after cataract surgery are shown in Table G- 102. Results show that change in driving performance was significantly predicted by VA in the first operated eye (-0.471, p=0.01) and contrast sensitivity binocularly (0.399, p=0.03) and in each eye individually; contrast sensitivity 1st operated eye (0.536, p=0.003), contrast sensitivity 2nd operated eye (0.537, p=0.003). Further analysis demonstrated contrast sensitivity was the single best predictor of the change in driving performance after cataract surgery.</td></tr>
<tr><td>Authors' Comments</td><td colspan="2">Driving performance was impaired by cataract condition and showed marked improvement post-surgically to emulate performance by normal age-matched controls. Improvement in contrast sensitivity in the better eye was the single best predictor for driving performance.</td></tr>
</table>

Table G- 100: Driving Performance Scores for First and Second Visits

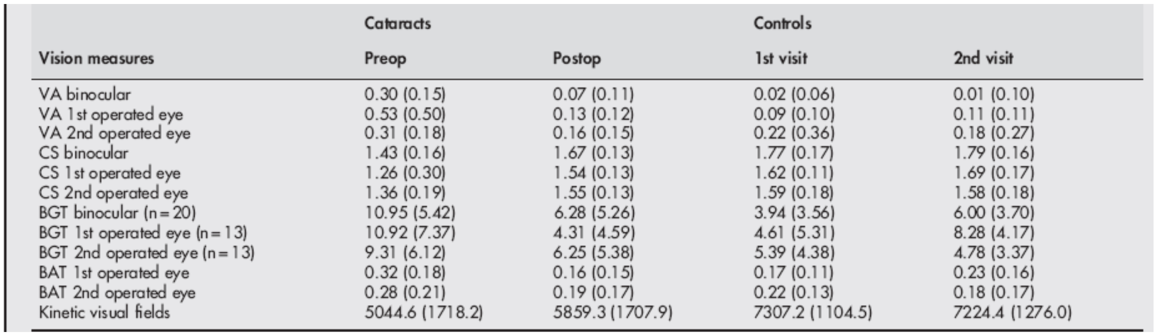


	Cataracts		Controls	
Driving measures	Preop	Postop	1st visit	2nd visit
Sign recognition	37.41 (12.56)	47.76 (7.79)	48.00 (7.52)	49.61 (7.19)
Road hazard recognition	7.69 (1.54)	8.83 (0.38)	8.83 (0.52)	8.61 (0.78)
Road hazard avoidance	2.04 (1.86)	0.48 (0.91)	0.22 (0.55)	0.39 (0.78)
Gap perception	1.79 (1.57)	1.86 (1.16)	2.11 (1.57)	1.61 (1.65)
Divided attention	5.31 (3.91)	7.04 (3.84)	7.44 (4.26)	9.50 (3.84)
Manoeuvring time	48.44 (16.69)	48.07 (13.85)	49.73 (16.08)	46.17 (11.56)
Time to complete (s)	451.05 (62.35)	437.75 (50.42)	439.00 (43.18)	442.65 (48.07)
Overall driving score	−0.38 (0.75)	0.18 (0.37)	0.14 (0.41)	0.19 (0.51)

Group mean driving performance scores (SD) for both participant groups at the first and second visits.

Postop, postoperative; preop, preoperative

Table G- 101: Vision Performance Scores for First and Second Visits

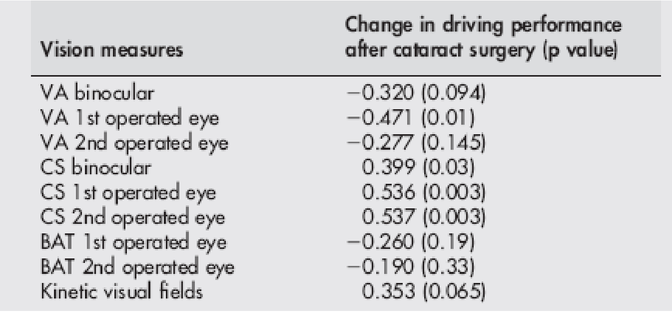


	Cataracts		Controls	
Vision measures	Preop	Postop	1st visit	2nd visit
VA binocular	0.30 (0.15)	0.07 (0.11)	0.02 (0.06)	0.01 (0.10)
VA 1st operated eye	0.53 (0.50)	0.13 (0.12)	0.09 (0.10)	0.11 (0.11)
VA 2nd operated eye	0.31 (0.18)	0.16 (0.15)	0.22 (0.36)	0.18 (0.27)
CS binocular	1.43 (0.16)	1.67 (0.13)	1.77 (0.17)	1.79 (0.16)
CS 1st operated eye	1.26 (0.30)	1.54 (0.13)	1.62 (0.11)	1.69 (0.17)
CS 2nd operated eye	1.36 (0.19)	1.55 (0.13)	1.59 (0.18)	1.58 (0.18)
BGT binocular (n = 20)	10.95 (5.42)	6.28 (5.26)	3.94 (3.56)	6.00 (3.70)
BGT 1st operated eye (n = 13)	10.92 (7.37)	4.31 (4.59)	4.61 (5.31)	8.28 (4.17)
BGT 2nd operated eye (n = 13)	9.31 (6.12)	6.25 (5.38)	5.39 (4.38)	4.78 (3.37)
BAT 1st operated eye	0.32 (0.18)	0.16 (0.15)	0.17 (0.11)	0.23 (0.16)
BAT 2nd operated eye	0.28 (0.21)	0.19 (0.17)	0.22 (0.13)	0.18 (0.17)
Kinetic visual fields	5044.6 (1718.2)	5859.3 (1707.9)	7307.2 (1104.5)	7224.4 (1276.0)

Group mean vision performance scores (SD) for both participant groups at the first and second visits.

BAT, Brightness Acuity Tester; BGT, Berkeley Glare Test; CS, contrast sensitivity; postop, after operation; preop, before operation; VA, VA

Table G- 102: Pearson Moment Correlation Coefficients (r)



Vision measures	Change in driving performance after cataract surgery (p value)
VA binocular	−0.320 (0.094)
VA 1st operated eye	−0.471 (0.01)
VA 2nd operated eye	−0.277 (0.145)
CS binocular	0.399 (0.03)
CS 1st operated eye	0.536 (0.003)
CS 2nd operated eye	0.537 (0.003)
BAT 1st operated eye	−0.260 (0.19)
BAT 2nd operated eye	−0.190 (0.33)
Kinetic visual fields	0.353 (0.065)

Pearson moment correlation coefficients (r) between the change in overall driving performance and change in vision performance scores after bilateral cataract surgery.

BAT, Brightness Acuity Tester; CS, contrast sensitivity; VA, VA

McGwin Jr. G, Sims R, Pulley L, and Roseman J. 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

Key Questions Addressed	1	2	3	4	5
				✓	

Research Question	Odds of crash in elderly drivers with and without chronic medical conditions, including cataract
Study Design	Retrospective case control

Population		
	Inclusion Criteria	Licensed drivers of Mobile County, Alabama aged 65+years involved in at least one automobile crash between January 1 and December 31, 1996
	Exclusion Criteria	Individuals who possessed licenses for identification purposes only
	Study population Characteristics	(see below)
	Generalizability to CMV drivers	Unclear

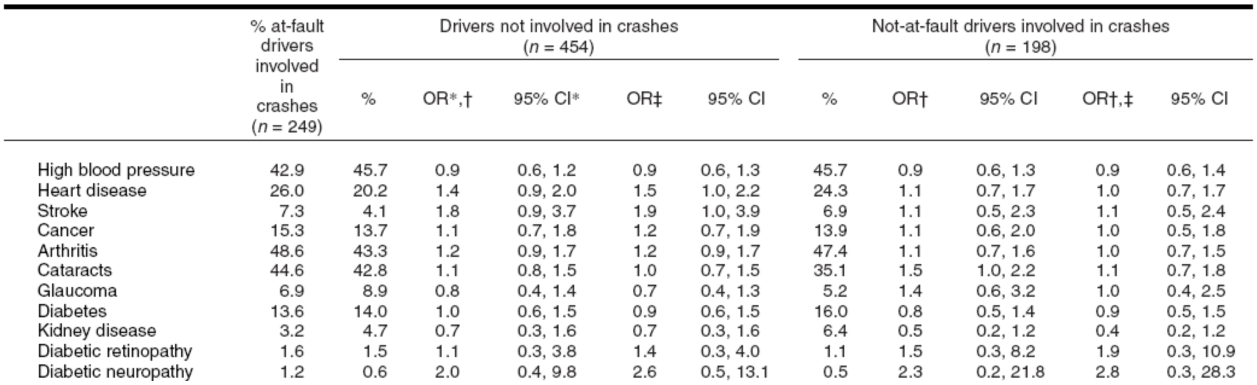
	At-fault drivers involved in crashes	Drivers not involved in crashes	Not-at-fault drivers involved in crashes
n	249	454	198
Age (yr)	%	%	%
65-68	21.3	25.7	39.6
69-72	25.4	24.4	23.6
73-77	25.8	25.7	23.6
78-93	27.5	24.2	13.2
Gender	%	%	%
Male	49.6	49.1	51.1
Female	50.4	51.0	48.9
Prior crash involvement			
No	63.9	79.0	66.5
Yes	36.1	21.1	33.5

Methods	Drivers aged 65 years and older were selected from Alabama Department of Public Safety driving records. Of the 39,687 eligible individuals, 1,906 had been involved in at least one automobile crash during 1996. 560 individuals were contacted by phone and asked to participate in the study. In addition to the 447 who agreed to participate, a random sample of 1,900 possible controls was selected from similar driving records. Phone interviews took place between June – December 1997 by interviewers blind to case status. Information collected included demographics, chronic medical conditions, medications, and driving habits. A focal reference date of January 1, 1996 was used. Subjects were asked if they had been diagnosed with cataract. Crash involvement from 1991 – 1995 was researched via Alabama DPS records.
Statistical Methods	Frequency distributions, odds ratios, 95% CI, logistic regression

Quality Assessment	Study Quality Assessment for Case-Control Studies: Moderate	1	2	3	4	5	6	7	8	9	10	11	12	13
		Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

Relevant Outcomes Assessed	Crash among drivers with and without cataract
Results	Percent of at-fault drivers involved in crash and diagnosed with cataract was 44.6% (Table G-103). Percent of drivers with cataract not involved in crashes was 42.8%. Compared with drivers without cataract, OR of at-fault crash 1.1 (95% CI 0.8-1.5), OR not at fault risk 1.5 (95% CI 1.0-2.2)
Authors' Comments	Drivers diagnosed with cataract did not have an increased risk of crash involvement.

Table G-103. Medical characteristics of at-fault and not-at fault drivers involved in crashes vs drivers not involved in crashes in Mobile County, Alabama, Jan - Dec 1997



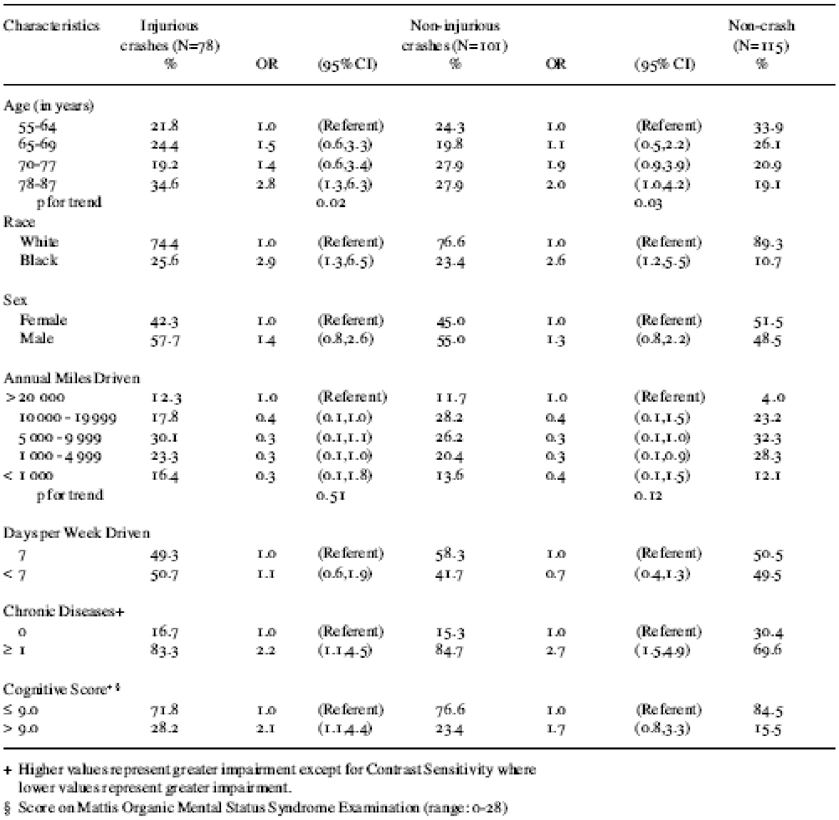
	% at-fault drivers involved in crashes (*n* = 249)	Drivers not involved in crashes (*n* = 454)					Not-at-fault drivers involved in crashes (*n* = 198)				
		%	OR*,†	95% CI*	OR‡	95% CI	%	OR†	95% CI	OR†,‡	95% CI
High blood pressure	42.9	45.7	0.9	0.6, 1.2	0.9	0.6, 1.3	45.7	0.9	0.6, 1.3	0.9	0.6, 1.4
Heart disease	26.0	20.2	1.4	0.9, 2.0	1.5	1.0, 2.2	24.3	1.1	0.7, 1.7	1.0	0.7, 1.7
Stroke	7.3	4.1	1.8	0.9, 3.7	1.9	1.0, 3.9	6.9	1.1	0.5, 2.3	1.1	0.5, 2.4
Cancer	15.3	13.7	1.1	0.7, 1.8	1.2	0.7, 1.9	13.9	1.1	0.6, 2.0	1.0	0.5, 1.8
Arthritis	48.6	43.3	1.2	0.9, 1.7	1.2	0.9, 1.7	47.4	1.1	0.7, 1.6	1.0	0.7, 1.5
Cataracts	44.6	42.8	1.1	0.8, 1.5	1.0	0.7, 1.5	35.1	1.5	1.0, 2.2	1.1	0.7, 1.8
Glaucoma	6.9	8.9	0.8	0.4, 1.4	0.7	0.4, 1.3	5.2	1.4	0.6, 3.2	1.0	0.4, 2.5
Diabetes	13.6	14.0	1.0	0.6, 1.5	0.9	0.6, 1.5	16.0	0.8	0.5, 1.4	0.9	0.5, 1.5
Kidney disease	3.2	4.7	0.7	0.3, 1.6	0.7	0.3, 1.6	6.4	0.5	0.2, 1.2	0.4	0.2, 1.2
Diabetic retinopathy	1.6	1.5	1.1	0.3, 3.8	1.4	0.3, 4.0	1.1	1.5	0.3, 8.2	1.9	0.3, 10.9
Diabetic neuropathy	1.2	0.6	2.0	0.4, 9.8	2.6	0.5, 13.1	0.5	2.3	0.2, 21.8	2.8	0.3, 28.3

*OR, odds ratio; CI, confidence interval; †, reference is those without condition; ‡, adjusted for age, gender, ethnicity and annual mileage

<table>
<tr><td colspan="15">Owsley C, McGwin G, Ball K. Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. Ophthalmic Epidemiology 1998; Vol 5 No 2: 101-113.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3">✓</td><td colspan="3">✓</td><td colspan="2"></td></tr>
<tr><td>Research Question</td><td colspan="14">To identify visual risk factors for vehicle crashes among elderly drivers that result in injury</td></tr>
<tr><td>Study Design</td><td colspan="14">Case-Control (Single-blinded)</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="13">Subjects identified through Alabama Department of Public Safety (ADPS) files and living in Jefferson County, Alabama</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13">NR</td></tr>
<tr><td>Study population Characteristics</td><td colspan="13">Refer to Table G-104 for details</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="13">Unclear</td></tr>
<tr><td>Methods</td><td colspan="14">75 drivers randomly selected from each cell after Jefferson county drivers sorted into 21 cells to represent 3 crash categories
Enrollment ended when 302 subjects were successfully recruited; 16 additional subjects who did not provide information on self-reported crashes excluded; final sample consisted of 294 older drivers
• Cases were defined as those drivers who had incurred at least one vehicle crash between 1985 and 1990 resulting in an injury to anyone in the involved vehicles according to the accident report.
• Controls defined as older drivers not involved in crashes during the same five-year period.
• Subjects underwent a battery of visual processing tests and a comprehensive eye examination
Written informed consent obtained after process explained; protocol completed in single visit to clinic in 1990 which consisted of:
Visual sensory function assessments
Visual attention/processing speed
Eye health
Questionnaire about driving exposure
Cognitive function
All vision tests performed under photopic conditions (100 cd/m²)
Letter acuity measured using ETDRS chart and expressed as log minimum angle resolvable (logMAR)
Impaired acuity defined as worse than 20/40 acuity
Contrast sensitivity measured using Pelli-Robson chart—impaired contrast sensitivity defined as score of 1.5 or worse
Stereoacuity was measured using the TNO test and expressed as arcseconds—impaired stereoacuity defined as 500 arcseconds or worse
Disability glare measured with MCT-8000 (VisTech) and defined as the difference in letter acuity (logMAR)
VF sensitivity measured with Humphrey Field Analyzer's 120-point screening program for the central 60° radius field using the quantify defects option
• Impaired VF sensitivity (for both the central and peripheral VFs) was defined as a loss of sensitivity of more than 1 log unit (10dB)
The UFOV defined as the VF area over which one can use rapidly presented visual information
All subjects received comprehensive eye exams by an ophthalmologist and mental status was evaluated by the Mattis Organic Mental Syndrome Screening Examination (MOMSSE) designed to assess cognitive functioning in the elderly
Examiners and interviewers were not aware of the crash histories of all subjects</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">• Estimated odds ratios (ORs) and 95% confidence intervals (CIs) for associations between injurious and noninjurious motor vehicle crash involvement and visual impairment using logistic regression
• ORs and 95% CIs calculated separately for each case group as compared to the single group of controls.
• All variables that had significant associations (¤ = 0.10) at the univariate level were included in a multivariable logistic regression model
• Variables individually removed from the model, and likelihood ratio tests (LRTs) performed to determine which variables had significant independent associations with crash involvement
• Linear trend test performed by entering a continuous variable into the logistic regression models and assessing the significance of the term using the Wald chi-square test.
• SAS software used to conduct statistical analyses
• All significance tests were conducted at the ¤=0.05 level (two-tailed).</td></tr>
<tr><td>Quality assessment</td><td>Study quality assessment, Case-</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
</table>

	Control Scale: Moderate	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NR	Yes	Yes	Yes
Relevant Outcomes Assessed	Visual impairment including cataract, and relationship with crash risk													
Results	• For cataract, the odds of an injurious crash were 1.0 (95% CI 0.6-1.8) and for non-injurious crash 1.1 (95% CI 0.6-1.8) • For injurious crashes, the odds ratio for having one or more chronic diseases was 2.2 (95% CI 1.1-4.5); OR was similarly elevated for the non-injurious crash group (OR=2.7; 95% CI 1.5-4.9) • Table G-105 shows the Univariate results for visual processing variables • Table G-106 displays Univariate analyses for common eye conditions in the elderly • UFOV reductions of 22.5-40%, 41-60% and >60% associated with 5.2-, 16.5-, and 21.5-fold increased risk of injurious crash, respectively (p for trend <0.01), compared to those with reductions of <22.5%; Subjects involved in non-injurious crashes were 2.3-, 4.6-, and 7.1-times more likely to have UFOV impairments of 22.5-40%, 41.0-60.0%, and >60.0%, respectively, compared to controls (p for trend <0.001). See Table G-107.													
Authors' Comments	"In addition to the incorporation of visual processing tests with high face validity to the driving task, another strength of this study is its reliance on accident reports provided by the state for defining the outcome of interest, injurious crash involvement."													

Table G-104. Demographic, driving, and health characteristics of drivers involved in injurious crashes, noninjurious crashes, and no crashes.

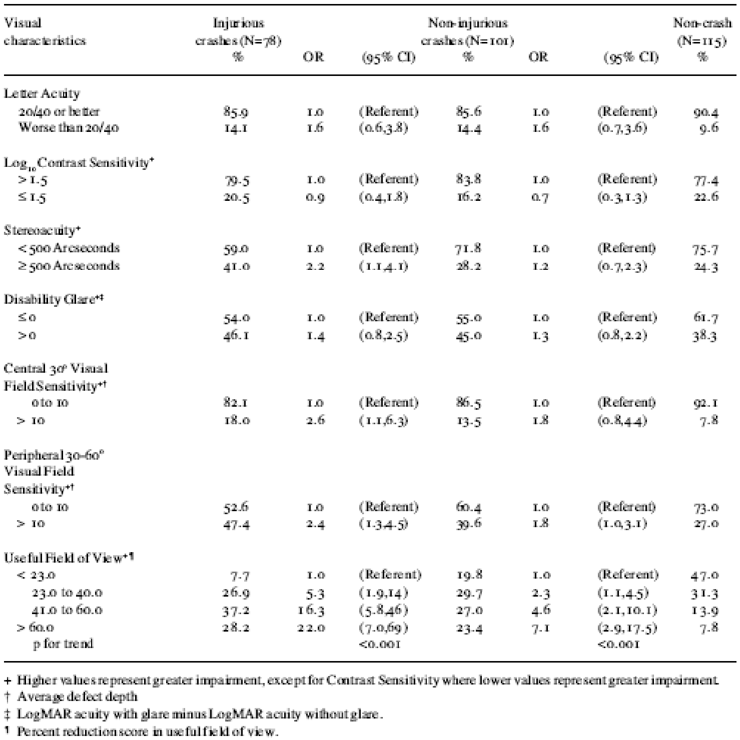


Characteristics	Injurious crashes (N=78) %	OR	(95%CI)	Non-injurious crashes (N=101) %	OR	(95% CI)	Non-crash (N=115) %
Age (in years)							
55-64	21.8	1.0	(Referent)	24.3	1.0	(Referent)	33.9
65-69	24.4	1.5	(0.6,3.3)	19.8	1.1	(0.5,2.2)	26.1
70-77	19.2	1.4	(0.6,3.4)	27.9	1.9	(0.9,3.9)	20.9
78-87	34.6	2.8	(1.3,6.3)	27.9	2.0	(1.0,4.2)	19.1
p for trend			0.02			0.03	
Race							
White	74.4	1.0	(Referent)	76.6	1.0	(Referent)	89.3
Black	25.6	2.9	(1.3,6.5)	23.4	2.6	(1.2,5.5)	10.7
Sex							
Female	42.3	1.0	(Referent)	45.0	1.0	(Referent)	51.5
Male	57.7	1.4	(0.8,2.6)	55.0	1.3	(0.8,2.2)	48.5
Annual Miles Driven							
> 20 000	12.3	1.0	(Referent)	11.7	1.0	(Referent)	4.0
10000 - 19999	17.8	0.4	(0.1,1.0)	28.2	0.4	(0.1,1.5)	23.2
5 000 - 9 999	30.1	0.3	(0.1,1.1)	26.2	0.3	(0.1,1.0)	32.3
1 000 - 4 999	23.3	0.3	(0.1,1.0)	20.4	0.3	(0.1,0.9)	28.3
< 1 000	16.4	0.3	(0.1,1.8)	13.6	0.4	(0.1,1.5)	12.1
p for trend			0.51			0.12	
Days per Week Driven							
7	49.3	1.0	(Referent)	58.3	1.0	(Referent)	50.5
< 7	50.7	1.1	(0.6,1.9)	41.7	0.7	(0.4,1.3)	49.5
Chronic Diseases+							
0	16.7	1.0	(Referent)	15.3	1.0	(Referent)	30.4
≥ 1	83.3	2.2	(1.1,4.5)	84.7	2.7	(1.5,4.9)	69.6
Cognitive Score+ §							
≤ 9.0	71.8	1.0	(Referent)	76.6	1.0	(Referent)	84.5
> 9.0	28.2	2.1	(1.1,4.4)	23.4	1.7	(0.8,3.3)	15.5

+ Higher values represent greater impairment except for Contrast Sensitivity where lower values represent greater impairment.

§ Score on Mattis Organic Mental Status Syndrome Examination (range: 0-28)

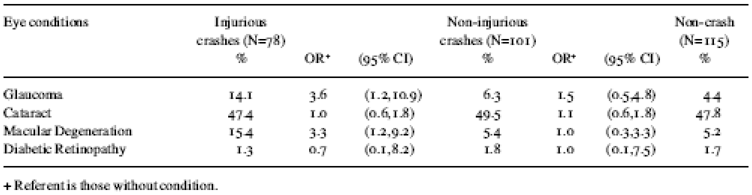
Table G-105. Visual characteristics of drivers involved in injurious crashes, non-injurious crashes and no crashes.



Visual characteristics	Injurious crashes (N=78) %	OR	(95% CI)	Non-injurious crashes (N=101) %	OR	(95% CI)	Non-crash (N=115) %
Letter Acuity							
20/40 or better	85.9	1.0	(Referent)	85.6	1.0	(Referent)	90.4
Worse than 20/40	14.1	1.6	(0.6,3.8)	14.4	1.6	(0.7,3.6)	9.6
Log$_{10}$ Contrast Sensitivity+							
> 1.5	79.5	1.0	(Referent)	83.8	1.0	(Referent)	77.4
≤ 1.5	20.5	0.9	(0.4,1.8)	16.2	0.7	(0.3,1.3)	22.6
Stereoacuity+							
< 500 Arcseconds	59.0	1.0	(Referent)	71.8	1.0	(Referent)	75.7
≥ 500 Arcseconds	41.0	2.2	(1.1,4.1)	28.2	1.2	(0.7,2.3)	24.3
Disability Glare+‡							
≤ 0	54.0	1.0	(Referent)	55.0	1.0	(Referent)	61.7
> 0	46.1	1.4	(0.8,2.5)	45.0	1.3	(0.8,2.2)	38.3
Central 30° Visual Field Sensitivity+†							
0 to 10	82.1	1.0	(Referent)	86.5	1.0	(Referent)	92.1
> 10	18.0	2.6	(1.1,6.3)	13.5	1.8	(0.8,4.4)	7.8
Peripheral 30-60° Visual Field Sensitivity+†							
0 to 10	52.6	1.0	(Referent)	60.4	1.0	(Referent)	73.0
> 10	47.4	2.4	(1.3,4.5)	39.6	1.8	(1.0,3.1)	27.0
Useful Field of View+¶							
< 23.0	7.7	1.0	(Referent)	19.8	1.0	(Referent)	47.0
23.0 to 40.0	26.9	5.3	(1.9,14)	29.7	2.3	(1.1,4.5)	31.3
41.0 to 60.0	37.2	16.3	(5.8,46)	27.0	4.6	(2.1,10.1)	13.9
> 60.0	28.2	22.0	(7.0,69)	23.4	7.1	(2.9,17.5)	7.8
p for trend			<0.001			<0.001	

+ Higher values represent greater impairment, except for Contrast Sensitivity where lower values represent greater impairment.
† Average defect depth
‡ LogMAR acuity with glare minus LogMAR acuity without glare.
¶ Percent reduction score in useful field of view.

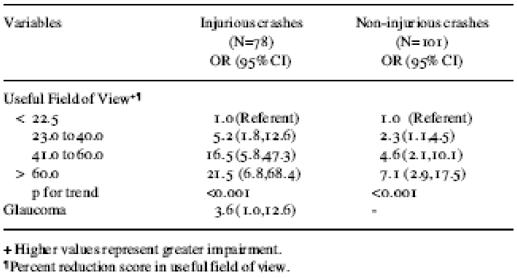
Table G-106. Eye conditions of drivers involved in injurious crashes, noninjurious crashes and no crashes.



Eye conditions	Injurious crashes (N=78) %	OR+	(95% CI)	Non-injurious crashes (N=101) %	OR+	(95% CI)	Non-crash (N=115) %
Glaucoma	14.1	3.6	(1.2,10.9)	6.3	1.5	(0.5,4.8)	4.4
Cataract	47.4	1.0	(0.6,1.8)	49.5	1.1	(0.6,1.8)	47.8
Macular Degeneration	15.4	3.3	(1.2,9.2)	5.4	1.0	(0.3,3.3)	5.2
Diabetic Retinopathy	1.3	0.7	(0.1,8.2)	1.8	1.0	(0.1,7.5)	1.7

+ Referent is those without condition.

Table G-107. Odds ratios and 95% confidence intervals for significant variables from multiple logistic regression models for injurious crashes and non-injurious crashes.



Variables	Injurious crashes (N=78) OR (95% CI)	Non-injurious crashes (N=101) OR (95% CI)
Useful Field of View+¶		
< 22.5	1.0 (Referent)	1.0 (Referent)
23.0 to 40.0	5.2 (1.8,12.6)	2.3 (1.1,4.5)
41.0 to 60.0	16.5 (5.8,47.3)	4.6 (2.1,10.1)
> 60.0	21.5 (6.8,68.4)	7.1 (2.9,17.5)
p for trend	<0.001	<0.001
Glaucoma	3.6 (1.0,12.6)	-

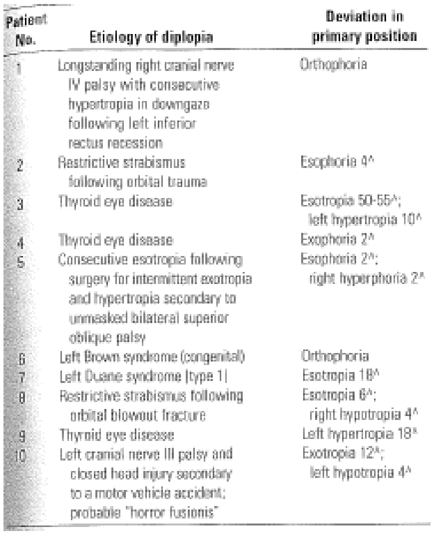
+ Higher values represent greater impairment.
¶ Percent reduction score in useful field of view.

Study Summary Tables for Key Question 5

<table>
<tr><td colspan="15">White JE, Marshall SC, Diedrich-Closson KL, Burton AL. Evaluation of Motor Vehicle Driving Performance in Patients with Chronic Diplopia. J AAPOS 2001; 5: 184-8;</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="2">5</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="2">√</td></tr>
<tr><td>Research Question</td><td colspan="14">To investigate the impact of stable, chronic diplopia on simulated driving ability to predict whether subjects with diplopia can safely operate motor vehicles</td></tr>
<tr><td>Study Design</td><td colspan="14">Cohort (Single blinded)</td></tr>
<tr><td rowspan="8">Population</td><td>Inclusion Criteria</td><td colspan="13">Individuals were to have stable diplopia of at least 6 months duration, possession of a Saskatchewan driver's license and an absence of other complications for driving a motor vehicle for either ocular, neurologic or systemic</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13">Cases/Controls:
NR</td></tr>
<tr><td rowspan="5">Study population Characteristics</td><td colspan="9">Measurement</td><td colspan="2">Cases</td><td colspan="2">Controls</td></tr>
<tr><td colspan="9">Population (n)</td><td colspan="2">10</td><td colspan="2">10</td></tr>
<tr><td colspan="9">Age (years)</td><td colspan="2">39.2 ± 17.5</td><td colspan="2">39.6±16.5</td></tr>
<tr><td colspan="9">Gender (m/f)</td><td colspan="2">6/4</td><td colspan="2">6/4</td></tr>
<tr><td colspan="13">Etiologies for subjects outlined in Table G-108.</td></tr>
<tr><td>Generalizability to CMV drivers</td><td colspan="13">Unclear</td></tr>
<tr><td>Methods</td><td colspan="14">Medical histories taken and recorded on form for subjects
VA expressed as log minimum angle resolvable (logMAR); assessed for cases and controls for each eye using corrective contact lenses
Field binocular vision obtained for all subjects with diplopia; subjects did not have a dilated funduscopic examination because it had been done during another nonstudy visit
Some subjects with diplopia assessed shortly after receiving corrective strabismus surgery by one of the authors
Following vision testing subjects wore tinted lenses or sunglasses for masking purpose; subjects then taken to driving simulator to be assessed by examiner for diagnosis
Subjects were seated in bucket seats and asked to keep their heads straight during testing; subjects to respond to cues during allotted time frames
Responses to braking, steering and accelerating were recorded and monitored by computer; computer recorded non-responses as a missed or an error (examiners noted the type of response error)
Action cues used to measure immediate reaction by the subject—braking, steering to avoid a crash
Distances obtained compared with group averages or preselected norms; for this study subjects with diplopia were compared with age-matched control group</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">Independent samples t test for continuous data and X^2 statistic for nominal data used to compared cases and controls
Analysis of variance used when more than two groups compared
Multiple linear regression used to identify independent variables contributing to missed responses and reaction times
Statistical analysis completed using SPSS for Window version 6.1 software (Chicago, IL)</td></tr>
<tr><td rowspan="4">Quality assessment</td><td rowspan="2">Study quality</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>S</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>NR</td><td>Y</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Low</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">• VFs tested using confrontation method with both eyes open and tested together
• Alignment recorded in all positions of gaze at distance as well as primary position of gaze at nearby certified optometrist
• Braking, steering and acceleration assessed
• Crash risk measured using driving simulator</td></tr>
<tr><td>Results</td><td colspan="14">• Field of BSV scores located in Table G-109.
• No significant differences in missed responses for subjects and controls during driving simulator protocol including number of missed responses across all protocols. See Table G-110.
• No significant differences discovered between group reaction times and averaged reaction times across protocols when compared; refer to Table G-111.
• Age was a significant predictor value for total numbers of missed for all driver simulators (p<.001)</td></tr>
</table>

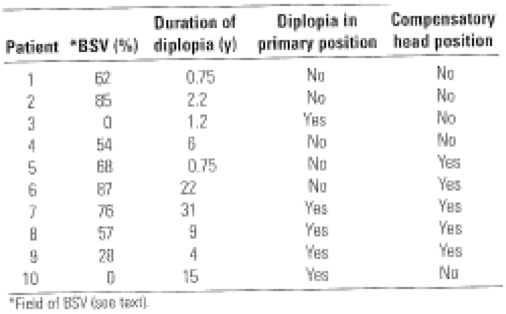
	• For the total combined reaction times across all driver simulator protocols, age was the most significant predictive value (p=.019); BSV showed significance (p=.026) • Figure G-39 and Figure G-40 present figures of the driving simulator and frames from the Threat Recognition films, respectively.
Authors' Comments	

Table G-108. Etiology of Diplopia



Patient No.	Etiology of diplopia	Deviation in primary position
1	Longstanding right cranial nerve IV palsy with consecutive hypertropia in downgaze following left inferior rectus recession	Orthophoria
2	Restrictive strabismus following orbital trauma	Esophoria 4^
3	Thyroid eye disease	Esotropia 50-55^; left hypertropia 10^
4	Thyroid eye disease	Exophoria 2^
5	Consecutive esotropia following surgery for intermittent exotropia and hypertropia secondary to unmasked bilateral superior oblique palsy	Esophoria 2^; right hyperphoria 2^
6	Left Brown syndrome (congenital)	Orthophoria
7	Left Duane syndrome (type 1)	Esotropia 18^
8	Restrictive strabismus following orbital blowout fracture	Esotropia 6^; right hypotropia 4^
9	Thyroid eye disease	Left hypertropia 18^
10	Left cranial nerve III palsy and closed head injury secondary to a motor vehicle accident; probable "horror fusionis"	Exotropia 12^; left hypotropia 4^

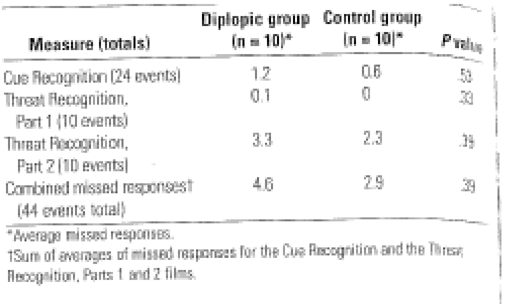
Table G-109. Features of subjects with diplopia



Patient	*BSV (%)	Duration of diplopia (y)	Diplopia in primary position	Compensatory head position
1	62	0.75	No	No
2	85	2.2	No	No
3	0	1.2	Yes	No
4	54	6	No	No
5	68	0.75	No	Yes
6	87	22	No	Yes
7	76	31	Yes	Yes
8	57	9	Yes	Yes
9	28	4	Yes	Yes
10	0	15	Yes	No

*Field of BSV (see text).

Table G-110. Total missed responses

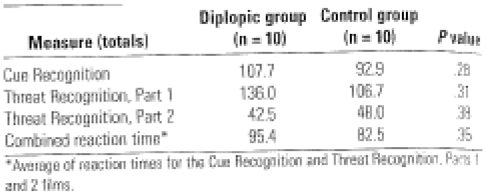


Measure (totals)	Diplopic group (n = 10)*	Control group (n = 10)*	P value
Cue Recognition (24 events)	1.2	0.6	.53
Threat Recognition, Part 1 (10 events)	0.1	0	.33
Threat Recognition, Part 2 (10 events)	3.3	2.3	.39
Combined missed responses† (44 events total)	4.6	2.9	.39

*Average missed responses.

†Sum of averages of missed responses for the Cue Recognition and the Threat Recognition, Parts 1 and 2 films.

Table G-111. Average reaction times



Measure (totals)	Diplopic group (n = 10)	Control group (n = 10)	*P* value
Cue Recognition	107.7	92.9	.28
Threat Recognition, Part 1	136.0	106.7	.31
Threat Recognition, Part 2	42.5	48.0	.38
Combined reaction time*	95.4	82.5	.35

*Average of reaction times for the Cue Recognition and Threat Recognition, Parts 1 and 2 films.

Figure G-39. Subject seated at the console of the driving simulator

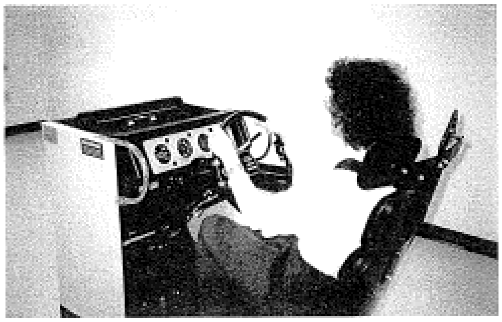


Figure G-40. Representative frame from the Threat Recognition film, Part II