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Association Between Vision Impairment and Driving Exposure in Older Adults Aged 70 Years and Over: A Population-Based Examination

Daniel Sandlin¹, Gerald McGwin Jr.^{1,2,3}, and Cynthia Owsley¹

¹Department of Ophthalmology, School of Medicine, University of Alabama at Birmingham

²Department of Epidemiology, School of Public Health, University of Alabama at Birmingham

³Department of Surgery, School of Medicine, University of Alabama at Birmingham

Abstract

Purpose—To examine the relationship between vision impairment and driving exposure (amount of driving one does) in a population-based sample of older drivers, and to examine to what extent cognitive status impacts this relationship.

Methods—Enrollees consisted of a population-based sample of older adults from Alabama who were 70 years old, held a current driver's license, and had driven within the last 3 months. Three aspects of visual function were measured under binocular conditions – habitual distance visual acuity, contrast sensitivity, and visual processing speed. General cognitive status was assessed with the Mini-mental status examination. Driving exposure was estimated by the Driving Habits Questionnaire that asked about the number of miles, places, trips and days driven per week.

Results—Drivers with impaired contrast sensitivity exhibited reduced annual mileage, and a decreased number of places and trips driven per week compared to those with normal contrast sensitivity, even after adjustment for other factors. Slowed visual processing speed was associated with reduced number of days driven per week after adjustment. Visual acuity deficit was not associated with changes in driving exposure. Cognitive status did not impact any of the associations between vision impairment and driving exposure.

Conclusion—Older drivers with contrast sensitivity impairment exhibit reduced driving exposure in terms of number of trips and places they drive per week, as well as decreased annual mileage. These apparent self-regulatory practices should be viewed as adaptive since contrast sensitivity impairment elevates motor vehicle collision (MVC) risk and reduction in driving exposure can reduce MVC risk.

Keywords

driving; aging; vision impairment; visual acuity; contrast sensitivity; visual processing speed

Corresponding author: Dr. Cynthia Owsley, Department of Ophthalmology, University of Alabama at Birmingham, 700 S. 18th Street, Suite 609, Birmingham AL 35294-0009, phone (205) 325-8635, fax (205) 325-8692, owsley@uab.edu.

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Motor vehicle collision (MVC) involvement rates in the United States increase appreciably starting at age 70, with projections indicating an estimated 178% increase by 2030 (Lyman et al. 2002). Previous research has demonstrated that certain types of vision impairment in older adults hamper driver safety, i.e. elevates their risk of MVC involvement (Owsley & McGwin 2010). Contrast sensitivity impairment in older adults with cataract is associated with an increased rate of crash involvement and driving performance problems (Owsley et al. 2001; Wood & Carberry 2006). Slowed visual processing speed (e.g., time needed to make a visual discrimination under divided attention conditions) increases older adults MVC risk (Ball et al. 2006; Owsley et al. 1998; Rubin et al. 2007), as does moderate or worse visual field loss (Johnson & Keltner 1983; McGwin et al. 2005; Haymes et al. 2007; Tanabe et al. 2011). Interestingly, visual acuity shows no significant relationship, or at best a weak one, with older driver safety. Previous research indicates that those older drivers with visual impairment tend to exhibit decreased driving exposure, i.e. they reduce the number of miles they drive per year; they also are more likely to drive in more familiar locales and to avoid challenging driving situations (Stutts 1998; Ball et al. 1998; McGwin et al. 2000; Freeman et al. 2006; Keay et al. 2009; Lyman et al. 2001; Kaleem et al. 2012). These types of self-regulatory behaviors can be viewed as adaptive in that they reduce visually impaired drivers' on-road exposure and thus the risk of incurring a collision (Eberhard 1996; Gebers 2003; Charlton et al. 2003).

Here we report the results of a population-based study on the association of vision and driving exposure among drivers who are age 70 and over. Because cognitive impairment is relatively common in the older adult population, we also examined whether this association was differential for those with excellent mental status versus reduced cognitive status. We reasoned that older drivers with reduced cognitive status may have less insight into their impaired visual capabilities, and thus would be less likely to engage in self-regulatory practices such as reducing their driving exposure.

Materials and Methods

The study was approved by the Institutional Review Board of the University of Alabama at Birmingham and was consistent with the Declaration of Helsinki. This study involved a population-based sample of older drivers (N = 2,000) who are part of an ongoing study on older driver safety in the Department of Ophthalmology at the University of Alabama at Birmingham, as described previously (Owsley et al. in press). The source population for the study sample consisted of adults aged 70 years old who resided in Jefferson County, Alabama or the border areas of contiguous counties. Potential participants were randomly identified from contact information available through a list of persons obtained from a direct marketing company (Pinpoint Technologies, Tustin CA). We then confirmed driver's license status through the Alabama Department of Public Safety (AL DPS), and eliminated those from the target population who did not hold licenses. Potential participants were mailed a letter describing the study, which was followed by a telephone call from the project coordinator to determine eligibility of the individual, and if eligible, the person was invited to participate. The inclusion criteria were: (1) age 70 or older, (2) held a current Alabama driver's license, (3) had driven within the last 3 months, (4) did not reside in a nursing home or other institution where comprehensive care was provided and/or community access and

driving opportunity were controlled, and (5) spoke English. For those individuals who were eligible and agreed to participate, an appointment was scheduled at the Clinical Research Unit in the Department of Ophthalmology, University of Alabama at Birmingham. For those who declined to participate, basic demographic information (age, race/ethnicity, gender) and driving status were obtained.

Interviewer-administered questionnaires collected information on demographics (age, gender, race/ethnicity, education, marital status) and general health status in terms of the presence of chronic health conditions typical of aging (Owsley et al. 2002). The Driving Habits Questionnaire (Owsley et al. 1999) was used to obtain information about the number of miles, places, trips, and days driven per week. Previous work has shown that drivers including older adults can provide valid information about the amount of driving they engage in (Murakami & Wagner 1997; Hu & Reuscher 2004). The Mini-mental State Examination (MMSE) was used to assess general mental status (Folstein et al. 1975).

Participants underwent three visual screening tests under habitual correction (wearing whatever glasses or contacts they used while driving, if any). Testing was binocular. Visual acuity was measured using the Electronic Visual Acuity (EVA) system (Beck et al. 2003) and expressed as log minimum angle resolvable (logMAR). Contrast sensitivity was measured using the Pelli-Robson Contrast Sensitivity Chart (Pelli et al. 1988), and scored by the letter-by-letter method (Elliott et al. 1991), and expressed as log sensitivity. Visual processing speed under divided attention conditions was measured using the UFOV® subtest 2 (see Edwards et al. 2005, Edwards et al. 2006 for detailed description). This computer-administered test involves the identification of a center target (silhouette of car versus truck) presented at fixation, which is simultaneously presented with a peripheral target (car) positioned at approximately 10° eccentricity in one of eight radial directions. After the participant identifies the center target, he/she also indicates the radial direction of the peripheral target. Responses are made by way of a touchscreen monitor. Performance is expressed as the minimum duration (in milliseconds, ms) needed to correctly discriminate the two centrally-presented targets 75% of the time. Scores can range from 16.67 to 500 ms.

Statistical analysis

For the purposes of analysis, visual acuity impairment was defined as worse than 20/40 (0.3 logMAR), contrast sensitivity impairment as < 1.5 log sensitivity, and slowed visual processing speed as > 350 ms. Reduced cognitive status was defined as a MMSE score < 27 . Measures of driving exposure were compared between participants with and without visual acuity, contrast sensitivity and visual processing speed impairment, with and without adjustment for demographic and health-related characteristics using analysis of variance. These analyses were conducted for all participants as well as stratified by cognitive status. To determine whether any observed associations were differential by cognitive status, an interaction term was included in the analyses. Statistical significance is defined as $p < 0.05$ (two-tailed).

Results

Participants ranged in age from 70 to 98 years old. Almost $\frac{3}{4}$ were in their 70s, and only 2% in their 90s (Table 1). There were slightly more men than women drivers in the sample. Eighty-two percent of the sample was white and 17.5% African American, which is highly reflective of the population in the geographic area of the study. The vast majority of drivers (93.3%) had completed high school or beyond. In terms of the number of medical comorbidities, 50% of the sample had ≥ 3 . The prevalence of vision impairment in the sample was as follows: 8.1% had visual acuity impairment (worse than 20/40), 9.7% had contrast sensitivity impairment (≤ 1.5), and 11.1% had slowed visual processing speed (> 350 ms). Approximately twenty-seven percent of drivers had reduced cognitive status (MMSE score ≤ 27).

Table 2 presents driving exposure comparing those with normal visual acuity to those with visual acuity impairment, which was also stratified by mental status. Visual acuity impairment was not associated (either unadjusted or adjusted) with any aspect of driving exposure assessed, nor was there a differential association according to mental status. Drivers with contrast sensitivity impairment had on average reduced driving exposure for annual mileage, and a decreased number of places and trips driven per week, but not for number of days driven per week (Table 3). After adjustment, the association with annual mileage and number of places driven per week remained, but the number of trips was no longer significant; none of these associations were differential according to mental status. Drivers with slowed visual processing speed had on average reduced driving exposure for all driving exposure measures (Table 4), but after adjustment for other variables, the only significant association that remained was between slowed processing speed and number of days driven per week. As with the other visual impairment measures, there was no differential effect according to mental status.

Discussion

In this population-based examination of older drivers 70+ years of age, contrast sensitivity impairment was independently associated with several types of reduction in driving exposure. Drivers with impaired contrast sensitivity reduced the number of places and trips they made per week and also their overall annual mileage. Our results imply that these drivers may be aware they are experiencing visibility problems on the road and self-regulate their driving, i.e., they adjust their driving behavior by limiting their excursions on the road. The cross-sectional nature of the association does not allow firm conclusions about whether the vision impairment came before driving modification, however previous prospective research suggests that this is an appropriate interpretation (Keay et al. 2009). Self-regulation is a highly adaptive strategy in the sense that it reduces exposure to MVC risk (Eberhard 1996; Gebers 2003; Charlton et al. 2003). Our results are consistent with previous reports that reduced driving exposure in older adults is associated with contrast sensitivity deficits (Ball et al. 1998; Stutts 1998; Freeman et al. 2006; Keay et al. 2009; Lyman et al. 2001; McGwin et al. 2000) and extend these findings by suggesting that reductions in mileage may be mediated by older drivers limiting the number of trips and places they drive per week.

Interestingly, impaired visual acuity was not associated with driving exposure. This finding is in agreement with Keay et al. (2009) but differs from other studies that reported an association between acuity deficits and decreased exposure (Ball et al. 1998; Stutts 1998; Freeman et al. 2006). Differences among studies may be due to the use of population-based versus convenience samples, cross-sectional versus prospective designs, methods for estimating driving exposure, geographic location, and other unknown factors. From the following framework, it is not surprising that visual acuity was not associated with driving exposure in our study. In spite of numerous studies to date, there is little to no evidence that drivers with visual acuity worse than 20/40 are at increased risk for MVC involvement (summarized in Owsley & McGwin 2010). While older drivers with worse than 20/40 visual acuity may notice impairment in their spatial resolution, they may also notice that it does not interfere with their ability to control a vehicle, and thus they may take no self-regulatory action to restrict their driving exposure.

Slowed visual processing speed is the strongest and most consistently reported risk factor for MVC involvement by older drivers (Owsley et al. 1998; Ball et al. 2006; Rubin et al. 2007; Sims et al. 2000; Clay et al. 2005). Although slowed visual processing speed was not related to annual mileage or number of trips and places driven per week, it was related to a reduced number of days driven per week, even after adjustment for other factors. This finding is consistent with previous research indicating that older drivers with slowed visual processing speed are more likely to have reductions in driving exposure including number of days driven per week (Vance et al. 2006; Ball et al. 1998).

One might expect that deficits in general mental status could impair an older driver's awareness of visual problems and thus interfere with the implementation of self-regulatory driving practices such as reducing the amount of time behind the wheel. However the present study suggests that among older drivers 70 years old who are legally licensed to drive and are current drivers, less than optimal cognitive status had no impact the association between vision and driving exposure. It might be argued that our definition of deficits in cognitive status as MMSE scores 27 minimized the likelihood of finding an impact of mental status on the vision and driving exposure relationship. However even choosing lower cutpoints, such as the cutpoint of 24 (traditional definition of cognitive impairment using the MMSE), still did not generate a significant impact of mental status on the vision and driving exposure relationship.

That some older drivers with visual impairment modify their driving habits and reduce their exposure has prompted the development of programs to educate older drivers about the merits of self-regulation (Stalvey & Owsley 2003; Molnar et al. 2010). Older drivers who are the best candidates for these programs are not drivers who are already aware of visual limitations and engage in self-regulatory practices, but rather, older individuals with visual impairments who have high levels of driving exposure and also have recent MVCs. Previous work suggests that self-regulatory practices can be taught to at-risk older drivers who participate in educational programs promoting self-regulatory practices in that they subsequently reduced their driving exposure (Owsley et al. 2004; Bédard et al. 2008).

Study strengths and limitations should be considered. A major strength of this study is that it is based on a population-based sample of almost 2,000 drivers ages 70 years old, which enhances its generalizability. Driving exposure questions are from a driving questionnaire (Owsley et al. 1999) that has established psychometric properties in the target population. Visual function was measured with established methodologies for vision research. The practicality of limitations in protocol time with individual participants did not permit detailed assessments about difficulty or avoidance of specific and challenging driving scenarios. Further prospective research on this cohort is addressing to what extent vision impairment and driving habits are associated with MVC involvement in this population.

In summary, drivers aged 70 years old and over who have contrast sensitivity impairment have less driving exposure in terms of number of trips and places they drive per week, as well as their annual mileage. These apparent self-regulatory practices should be viewed as adaptive since contrast sensitivity impairment elevates MVC risk and reduction in driving exposure reduces MVC risk.

Acknowledgments

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Table 1

Demographic and medical characteristics of the study sample

Age, years	N (%)
70–79	1433 (71.7%)
80–89	527 (26.4%)
90–99	40 (2%)
Gender	
Men	1130 (56.5%)
Women	870 (43.5%)
Race	
African American	351 (17.6%)
White	1640 (82%)
Other	9 (0.5%)
Education	
Less than high school graduate	133 (6.7%)
High school graduate or equivalent	550 (27.5%)
1–4 years of college	1018 (50.9%)
Post graduate degree	298 (14.9%)
Chronic medical conditions	
Heart condition	799 (40.0)
Circulation problems	318 (15.9)
High blood pressure	1,309 (65.5)
Low blood pressure	108 (5.4)
Neurological problems	208 (10.4)
Diabetes	421 (21.5)
Arthritis	1,092 (54.6)
Osteoporosis	277 (13.9)
Cancer (current or in remission)	629 (31.5)
Pulmonary problems	337 (16.9)
Digestive problems	565 (28.3)
Urinary problems	640 (32.0)
Kidney problems	180 (9.0)
Hearing problems	650 (32.5)

Table 2

Mean (M) and standard deviation (SD) of driving exposure variables stratified by visual acuity and mental status (N = 1,998)

	n (%)	Annual Miles Driven		Number of Places Driven per Week		Number of Trips Driven per Week		Number of Days Driven per Week					
		All	MMSE 28-30	MMSE 27	All	MMSE 28-30	MMSE 27	All	MMSE 28-30	MMSE 27			
		<hr/>											
Visual Acuity			M (SD)			M (SD)			M (SD)				
0.3 logMAR	1837 (91.9)	9649 (9495)	9905 (9472)	8910 (9534)	3.9 (1.5)	3.9 (1.5)	3.7 (1.5)	8.7 (5.2)	8.8 (5.2)	8.4 (5.1)	5.6 (1.7)	5.7 (1.7)	5.4 (1.9)
> 0.3 logMAR	161 (8.1)	8173 (8485)	8681 (8681)	7294 (6921)	3.6 (1.6)	3.7 (1.6)	3.5 (1.6)	8.5 (5.5)	8.2 (5.1)	8.9 (6.2)	5.4 (1.9)	5.4 (1.9)	5.4 (2.0)
p-value*		.057	.207	.208	.090	.180	.495	.601	.290	.513	.166	.078	.741
p-value [†]		.522	.682	.632	.412	.345	.988	.745	.491	.113	.557	.147	.249
p-value [‡]			.809				.799			.246			.191

* P-value comparing driving exposure measures between those with impaired and non-impaired visual acuity; unadjusted

† P-value comparing driving measures between those with impaired and non-impaired visual acuity; adjusted for age, gender, race, education, and number of medical co-morbidities

‡ P-value for interaction between visual acuity and mental status

Note: Statistical significance is defined as p 0.05.

Table 3
Mean (M) and standard deviation (SD) of driving exposure variables stratified by contrast sensitivity and mental status (N=1,999)

	n (%)	Annual Miles Driven				Number of Places Driven per Week				Number of Trips Driven per Week				Number of Days Driven per Week					
		All		MMSE 28–30		MMSE 27		All		MMSE 28–30		MMSE 27		All		MMSE 28–30		MMSE 27	
Contrast Sensitivity																			
> 1.5 log sensitivity		1806 (90.3)	9731 (9685)	9963 (9698)	9054 (9623)	3.9 (1.5)	4.0 (1.5)	3.7 (1.5)	8.8 (5.2)	8.8 (5.3)	8.7 (5.2)	5.6 (1.7)	5.7 (1.7)	5.4 (1.8)					
< 1.5 log sensitivity		193 (9.7)	7624 (6174)	8219 (5977)	6646 (6407)	3.4 (1.6)	3.5 (1.5)	3.2 (1.6)	7.7 (5.0)	8.0 (4.5)	7.4 (5.7)	5.5 (2.0)	5.6 (1.8)	5.2 (2.1)					
p-value*			.003	.053	.039	.0001	.002	.004	.008	.081	.051	.251	.649	.431					
p-value [†]			.041	.167	.118	.0006	.008	.030	.061	.155	.220	.439	.578	.693					
p-value [‡]					.655 (NS)			.703		.602			.677						

* P-value comparing driving exposure measures between those with impaired and non-impaired contrast sensitivity; unadjusted

[†] P-value comparing driving measures between those with impaired and non-impaired contrast sensitivity; adjusted for age, gender, race, education, and number of medical co-morbidities

[‡] P-value for interaction between contrast sensitivity and mental status

Note: Statistical significance is defined as p 0.05

Table 4

Mean and standard deviation of driving exposure variables stratified by visual processing speed and mental status

	n (%)	Annual Miles Driven				Number of Places Driven per Week				Number of Trips Driven per Week				Number of Days Driven per Week			
		All	MMSE 28-30	MMSE	27	All	MMSE 28-30	MMSE	27	All	MMSE 28-30	MMSE	27	All	MMSE 28-30	MMSE	27
		Visual Processing Speed															
350 ms	1778 (88.9)	9802 (9494)	9970 (9578)	9186 (9164)	3.9 (1.6)	3.9 (1.6)	3.8 (1.6)	8.8 (5.2)	8.8 (5.2)	8.7 (5.3)	5.7 (1.7)	5.7 (1.7)	5.5 (1.8)				
> 350 ms	221(11.1)	7345 (8583)	6861 (5880)	7565 (9595)	3.4 (1.4)	3.6 (1.4)	3.4 (1.4)	8.0 (5.3)	8.4 (5.5)	7.8 (5.1)	5.1 (2.0)	5.2 (1.9)	5.1 (2.1)				
p-value*		.0003	.008	.069	.0001	.066	.008	.048	.605	.074	.0001	.011	.015				
p-value [†]		.370	.304	.766	.111	.465	.211	.770	.754	.575	.003	.071	.121				
p-value [‡]			.310			.867		.485			.753						

* P-value comparing driving exposure measures between those with impaired and non-impaired visual processing speed; unadjusted

† P-value comparing driving measures between those with impaired and non-impaired visual processing speed; adjusted for age, gender, race, education, and number of medical co-morbidities

‡ P-value for interaction between visual processing speed and mental status

Note: Statistical significance is defined as p 0.05.