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Urban and Rural Differences in Older Drivers' Failure to Stop at Stop-signs

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Abstract

Our purpose was to determine visual and cognitive predictors for older drivers' failure to stop at stop-signs. 1425 drivers aged between ages 67 and 87 residing in Salisbury Maryland were enrolled in a longitudinal study of driving. At baseline, the participants were administered a battery of vision and cognition tests, and demographic and health questionnaires. Five days of driving data were collected with a Driving Monitoring System (DMS), which obtained data on stop signs encountered and failure to stop at stop signs. Driving data were also collected one year later (Round two). The outcome, number of times a participant failed to stop at a stop sign at round two, was modeled using vision and cognitive variables as predictors. A Negative binomial regression model was used to model the failure rate. Of the 1241 who returned for Round two, 1167 drivers had adequate driving data for analyses and 52 did not encounter a stop sign. In the remaining 1115, 15.8% failed at least once to stop at stop signs, and 7.1% failed to stop more than once. Rural drivers had 1.7 times the likelihood of not stopping compared to urban drivers. Amongst the urban participants, the number of points missing in the bilateral visual field was significantly associated with a lower failure rate. In this cohort, older drivers residing in rural areas were less likely to stop at stop-sign intersections than those in urban areas. It is possible that rural drivers frequent areas with less traffic and better visibility, and may be more likely to take the calculated risk of not stopping. In this cohort failure to stop at

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stop signs was not explained by poor vision or cognition. Conversely in urban areas, those who have visual field loss appear to be more cautious at stop signs.

Keywords

Older drivers; stop signs; vision; cognition; rural

1. Introduction

Older drivers comprise the fastest growing segment in the United States' driving population and represent a larger percentage of the driving public than ever before. In 2006, 30 million, or 15 percent, of all licensed drivers were aged 65 and older in the United States, and the National Highway Traffic Safety Administration (NHTSA) has projected that this figure could go up to 25% by the year 2030.(National Highway Traffic Safety Administration, 2008b) Risk of crash involvement per mile driven begins to increase from age 65 and by age 85 is approximately 2.5 times higher than that of the average driver(Cerrelli, 2007) and the likelihood for driver responsibility increases from age 63.(Williams and Shabanova, 2003) In addition, age increases the likelihood of fatal injury in road crashes(Li, Braver and Chen, 2003; Meuleners, et al. 2006) by as much as 9 times per mile driven in drivers 85 years and older compared to 25-69 year olds.(Cerrelli, 2007) The increased crash risk has been associated with cognitive, visual and physical changes associated with aging(Hu et al. 1998; Owsley et al. 2007; Sims et al. 1998) and vulnerability to serious injury has been attributed to the frailty of older age.(Li et al., 2003;Meuleners et al., 2006)

National data from the US on all crash fatalities reported that 21% of all fatal crashes in 2006 occurred at intersections and 9% of these were controlled by stop signs.(NHTSA, 2008c) Braitman and colleagues (2007) have investigated the factors leading to older drivers' intersection crashes and find that the majority of crashes occur when the drivers fail to yield to the right-of-way, mostly at stop-sign controlled intersections. Hence, we were interested to investigate older drivers' driving behavior at stop signs and the possibility that visual and cognitive function influenced the likelihood of failing to stop at stop signs.

The Salisbury Eye Evaluation Driving study was instituted to study driving patterns and errors in older drivers. This longitudinal study involved following a cohort of drivers and obtaining information on several cognitive and visual function domains, as well as observing their driving behavior over a five-day period using a Driving Monitoring System. Our objective in this paper was to report the frequency of failure to stop at stop signs and the factors predictive of failure in this cohort of older drivers.

2. Material and methods

2.1. Sample

Recruitment for the Salisbury Eye Evaluation Driving Study was via mail from the Maryland Department of Motor Vehicles to all licensed drivers aged 67-87 years of age in 2005 who were resident in Wicomico County, Maryland as defined by zip codes. Details are described elsewhere.(Zhang et al. 2007) In summary of 8380 registered licensees, 4503 (54%) returned postcards. Of that group, 6.0% were no longer driving, 1.6% were deceased, and 2.3% were no longer living in the eligible area. Of the remainder, 42% agreed to participate and 83% of these were recruited to the baseline clinic exam (n=1425). Driving performance data collected for round 2 of SEEDS was evaluated for this analysis (n=1241).

The data collection consisted of a home interview, a clinic examination with a battery of visual and cognitive tests, which has been described in detail by Zhang and colleagues (2007) and the installation of a sophisticated Driving Monitoring System (DMS).(Baldwin, Duncan and West, 2004) The DMS data were used to track each participant's driving behavior at all stop sign intersections during the 5-day period of observation.

2.2. Variables

Visual acuity (VA), contrast sensitivity (CS) and visual field (VF) were measured for each participant. Visual acuity was measured using a high contrast ETDRS acuity chart with standard illumination, at a distance of 3 meters, using forced choice protocols.(Ferris et al. 1982) This variable was coded as the number of letters recognized correctly and scored as LogMAR acuity by assigning a value of -0.02 for each letter recognized. Monocular CS was measured using the Pelli Robson CS chart at a distance of 1 meter. This variable was coded as the number of letters correctly identified.(Elliott, Whitaker and Bonette, 1990) The bilateral VF was measured by combining the results from the left and right eye full field 81 point tests with a quantify-defects test strategy, on the Humphrey field analyzer II, to obtain a 96 point bilateral visual field.(Nelson-Quigg, Cello and Johnson, 2000) This variable was coded as the number of points missed from this 96 point bilateral field.

In addition to measuring the visual field, the Attentional Visual Field (AVF) was assessed. The AVF is the visual field over which a person can effectively divide their attention and extract visual information within a glance. This test was performed using custom written software on a computer, a touch screen monitor, a keyboard and a mouse. This test assessed the AVF extent out to 20° radius in a divided attention protocol. A detailed description of the test is available elsewhere.(Hassan et al. 2008)

The time taken to brake in response to a visual stimulus was measured using an apparatus described previously. (Zhang et al. 2007) The Brake Reaction Time (BRT) was the total time in milliseconds taken for the participant to remove their foot from the accelerator and depress the brake pedel using the average for five test sequences presented at random time intervals.

Overall cognitive function was assessed using the Mini-Mental State Exam (MMSE). Visuo-motor integration was assessed using the Beery-Buktenica Developmental test of visual motor integration.(Kulp and Sortor, 2003) In this test, a series of 27 figures of increasing complexity was copied and scored for accuracy by trained observers. Psychomotor and visual scanning speed was assessed using Trails Making Test, Parts A and B (TMT Part A and TMT Part B). TMT Part A comprised of numbers from 1-25 in circles placed randomly on a sheet of paper. The participants were required to connect, beginning with the smallest numbered circle, to the next higher number until 25 was reached. TMT Part B involved both numbers (1-13) and letters (A-L) enclosed in circles placed randomly over a sheet of paper. The participants were required to join the next higher number alternated with the next sequential alphabetic character. The time for completion of these tests was measured, up to a maximum of 300 seconds. The Brief Test of Attention (BTA)(Schretlen D., Brandt J. and Bobholz J.H., 1996) was used to assess participants' executive function, attention, and working memory. In this task, participants listened to a series of tape-recorded lists of letters and numbers of increasing length. They were asked to respond with the number of letters in each sequence and scored based on the accuracy of their recall. The planning and problem solving aspect of executive function was determined using the “Tower of Hanoi” test which was comprised of three pegs A, B, and C, and which had three successively larger discs with holes in the center stacked on peg A. The goal is to move all the discs in the respective order from peg A to peg C, making sure that at no time a larger disc was on top of a smaller disc. Both the time and the number of moves were recorded for this test.

The residential address of the participants was categorized as either urban or rural, based on zip code. We used the vicinity of services such as shops, pharmacies, banks, post offices and doctors' offices to determine if the address was rural or urban. The Salisbury Bypass road to the east created a natural border for the urban area of Salisbury; residences within this border were classified as “urban” and all outside this area as “rural”.

2.3. Outcome

The outcome of interest, failure to stop at a stop-sign, was obtained from real time driving data collected using the DMS system. The system has been described in detail previously by Baldwin and colleagues (2004) and is summarized here. Each DMS unit consists of 5 systems, which include a high dynamic-range color camera, a monochrome camera with night vision, a GPS receiver, a magnetic compass, and a two-axis accelerometer. The positioning of the cameras was such that the color camera would capture images from the road in front and the monochrome camera would capture images of the driver (Figure 1). The GPS receiver would provide the location and velocity data at a rate of 1Hz, and the magnetic compass provided heading information at a rate of 8 Hz. The accelerometer provided the lateral and axial accelerations at a rate of 10 Hz. This information was stored on the on-board hard-drive, which was then retrieved and analyzed.

Custom analysis software was used to integrate the data from all the systems to provide information on driving behavior, including stopping at stop-signs. The GPS information was integrated with a database of stop signs in the Greater Salisbury driving area. A 20 second window of data (1Hz data rate) centered about the stop sign position was used to estimate minimum passing speed. Our criteria for a pass was that the minimum passing speed was less than or equal to 5 miles per hour.. If there was evidence of stopping at the stop-sign location, then the event was automatically passed. If the accelerometer data did not indicate stopping then a technician scored the event either way after reviewing the video footage at the intersection. If there was no evidence of stopping, defined by no optical flow in the video footage capturing the road, and no other reason to ignore the stop sign (policeman signal, etc), it was scored as a failure to stop.

2.4. Data analyses

The outcome variable for the analyses is count data, representing the number of failures to stop at a stop-sign for a given participant. We chose to use a negative binomial regression model because of evidence of over-dispersion (dispersion coefficient was significantly greater than 1). The number of stop signs encountered was used as an offset, thus modeling failure rate i.e. failures per stop sign encountered. The base line data on visual and cognitive function were used to predict the failure rate at round two data collection, 12 months later. We hypothesized that the explanatory variables for the failure rate for the rural drivers could be different from those of the urban drivers. To investigate this further, we performed a stratified analyses of the dataset based on the driver's rural/urban residence. The stratified datasets were compared on distribution of stop signs encountered and found to be similar.

3. Results

The baseline data was collected on a total of 1425 participants, of whom 1241 returned at one year for a repeat driving assessment using the DMS. Of the 1241, 3% could not have the DMS installed in their car and another 4% had unreliable data from the DMS. Thus, 1155 participants had data from baseline and from driving assessment in Round two for these analyses. A total of 52 participants did not encounter a stop sign during their 5-day monitoring period, and one person had missing data for this variable. These people were eliminated from further analysis because they did not have an opportunity to fail. The sample was comprised of 48% females and 12% African Americans (Table 1). The average age for this cohort was 78 years, and in general they demonstrated good visual and cognitive function.

Of the 1115 participants who encountered a stop-sign 177 (15.8%) failed at least once. As shown in Table 2, there is a significant association between the stop signs encountered and the failure rate, with more stop signs encountered resulting in higher failure rate, ranging from 2.8% in the lower quartile to 4.1% in the upper quartile.

On an exploration of the relationship between failure to stop and variables in the domain of vision, cognition, and demographics, the only significant predictor of stopping failure was rural/urban residence (Table 3). The failure rate for the rural drivers was 1.72 times that of the urban drivers. Those who performed better in two cognitive tests, including the time taken to complete the Tower of Hanoi or the Trail Making Test Part B, had a higher failure rate, but these associations were not statistically significant (p=0.06).

Because the circumstances under which one might encounter a stop sign in a rural area versus an urban area might differ, we performed stratified univariable analyses by urban/rural residence. For rural drivers, there were no significant predictors of failure rate, however a trend was observed for higher failure rate with better performance on the Tower of Hanoi (Table 4). In the urban group, two factors were found to be significant. African American participants had significantly lower failure rates than Caucasian participants. Also, the greater the number of points missed on the visual field, the lower the failure rate. In a multivariable analysis of the urban participants, the effect of race was not significant, and only the lost points on visual field remained significant.

4. Discussion

In this cohort of older drivers, violations at stop-sign intersections were not rare events and 16% of the drivers in our study failed to stop at least once during a 5-day period of monitoring. While we investigated a comprehensive range of visual and cognitive function parameters, the strongest predictor of the failure to stop at stop-signs, in our study, was found to be the place of residence i.e. living in a rural neighborhood versus living in an urban neighborhood. The rural areas around Salisbury are largely farmland and flat plains, with good visibility down roads and minimal traffic. We believe that higher failure rate in residents of rural areas may be related to lesser traffic, more visibility around the stop sign area and a perception that it is safe to proceed through, or turn in the intersection without stopping.

In our evaluation of habitual driving and stop sign intersections, counter-intuitively, those with better performance on the test of visual field were more likely to fail to stop. This is in conflict with the hypothesis that individuals with failing visual or cognitive function would be more likely to fail to stop. In part our original hypothesis was driven by the findings of deficits related to another outcome, risk of crashes. Studies of crash risk in older drivers have suggested a relationship between deficits in contrast sensitivity(Owsley et al. 2001; Rubin et al., 2007) and attentional visual field,(McGwin et al. 2005;Rubin et al. 2007) glare sensitivity(Rubin et al. 2007) and visual field loss(Rubin et al. 2007) and crash risk. There is also some evidence of a link between functional status and poor driving performance but these observations have been confined to test courses.(Bedard et al. 2008) Clearly, while failure to stop at a stop sign is a marker of poor driving performance, the predictors in this population suggest a different pattern to that observed previously.

In the urban population, we found that better visual fields were a significant predictor of failure to stop at stop signs. As suggested by Keeffe and Chalton (2007) the relationship between visual field loss and driving is complicated due to self-regulation, avoidance of difficult driving situations and capacity to adopt compensatory eye and head movements. It appears that drivers who had poor visual fields may have been more careful to compensate for their vision and hence had a lower failure rate.

Amongst the rural drivers, there was a trend observed that those with better performance on planning tests of executive function may have been more likely to integrate the visual scene at the stop sign intersection and make a decision that stopping was unnecessary.

Race was not consistently found to be associated with failure rate but did appear to be a factor for urban older drivers where African-American drivers were more likely to stop. However, African Americans also had poorer visual fields, and once both variables were modeled, those, regardless of race, who had poorer visual fields tended to be more likely to stop at stop signs. We specifically asked participants about awareness of peripheral visual field loss, to see if those who were most aware were also those likely to stop at stop signs. However, there was no clear pattern of awareness of loss and driver performance at stop signs.

While many of the driving behaviors in older adults might be explained by deficits in function or medical conditions, other factors, such as personality may play an important role.(Owsley, McGwin, Jr. and McNeal, 2003) While we found a significant proportion were not stopping at stop signs, observational studies suggest that older drivers as group are more likely to wear seat belts(Glassbrenner D, 2005) and stop at red traffic lights(Yang CY and Najm WG, 2007) than younger drivers and intermediate aged drivers.

Risk benefit trade-offs are acknowledged as part of the motivational factors for committing various types of traffic violations.(Glendon, 2007) For example some drivers may believe that driving slightly above the speed limit is justifiable driving behavior. These individuals might consider this practice to be relatively safe, the risk of getting a traffic infringement notice low and the benefit of arriving at their destination sooner appealing. Elliott and colleagues(2003) found that the intent to comply with speed limits and the driver's perceived behavioral control predicted subsequent speeding. While this type of hypothesis has not been applied directly to stop sign violations, it is conceivable that the same principles may apply.

The traffic conditions and terrain may also contribute to the risk-benefit equation. Seat belt use (NHTSA, 2008a) is lower in rural than urban areas in the US and this may be due to a belief that police patrols are fewer in urban areas reducing the likelihood of an infringement notice or perhaps that driving in rural areas is intrinsically safer. Similarly, greater red-light violations have been reported in low traffic volume intersections in a study investigating red light violations in rural and urban Jordan.(Al-Omari and Al-Masaeid, 2003) These previous observations corroborate our findings that running stop-signs is higher in rural areas.

The Salisbury Eye Evaluation Driving Study has many advantages compared to other studies found in literature. The previous techniques to evaluate driving performance involved test-courses(Wood et al., 2008) driving simulators(Lee, Lee, Cameron and Li-Tsang, 2003) and fixed route in-vehicle monitoring,(Porter and Whitton, 2002) all of which were either invasive or did not capture driving data in the driver's natural environment. Others have observed the behavior of consecutive drivers at intersections(Austin et al. 2006) but this does not allow exploration of the link to individual driver characteristics, such as vision and cognitive status. The DMS system was created to be minimally invasive, while capturing driving data in the participant's own car, and on a personal day-to-day driving route. Thus the data was acquired in the most natural environment of the driver. Further, the study has a large sample size, longitudinal followup and comprehensive functional testing allowing detailed exploration of the associations between driver characteristics and habitual driving performance.

There are limitations to our study. It is likely this is a highly functional group of older drivers, as our sampling method (using the DMV) did not allow us to recruit a truly random sample of drivers. Thus, the rate of failure may be an underestimate, and we may miss failures that are the direct result of more extreme vision loss than occurred in our sample. It may also result in identifying those persons at higher ranges of function who are willing to take risks, such as not stopping at stop signs. However, it is likely that acuity and other measures of vision would be good in older persons who are still drivers, as opposed to all older persons, because they are still driving.

5. Conclusions

Unlike our previous hypotheses about deficits leading failure to stop at stop signs, our data suggest an element of some form of pre-meditation in stop sign violations amongst older drivers. However, we have no other data to corroborate or refute this supposition. It is also of interest that in urban settings, where traffic is more complex, persons with visual field loss have lower failure rates suggesting some effort at self-regulation. It did not seem to matter if the participant was aware specifically of peripheral field loss in terms of reducing risk of running stop signs. Thus, it is harder to argue that the carefulness was attributable to compensation for visual field loss, unless the participants were unable to specifically link their symptoms of visual field loss to our question of awareness of loss of peripheral fields.

In summary, our study suggests some role of cognitive and visual field status in explaining stop sign violations, but a greater role for rural or urban driving conditions. These findings contribute to the understanding of older driver behavior at intersections.

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REFERENCES

Al-Omari BH, Al-Masaeid HR. Red Light Violations at Rural and Suburban Signalized Intersections in Jordan. Traffic Inj Prev 2003;4:169–172. [PubMed: 16210202]

Austin J, Hackett S, Gravina N, Lebbon A. The Effects of Prompting and Feedback on Drivers' Stoing at Stop Signs. J Al Behav Anal 2006;39:117–121.

Baldwin KC, Duncan DD, West SK. The Driver Monitor System: A Means of Assessing Driver Performance. Johns Hopkins APL Technical Digest 2004;25:1–10.

Bedard MF, Weaver B, Darzins P, Porter MM. Predicting Driving Performance in Older Adults: We Are Not There Yet! Traffic Inj Prev 2008;9:336–341. [PubMed: 18696390]

Braitman KA, Kirley BB, Ferguson S, Chaudhary NK. Factors Leading to Older Drivers' Intersection Crashes. Traffic Inj Prev 2007;8:267–274. [PubMed: 17710717]

Cerrelli, EC. Crash Data and Rates for Age-Sex Groups of Drivers, 1996. National Highway Traffic Safety Administration; 2007.

De Raedt RF, Ponjaert-Kristoffersen I. The Relationship Between Cognitive/Neuropsychological Factors and Car Driving Performance in Older Adults. J Am Geriatr Soc 2000;48:1664–1668. [PubMed: 11129759]

Elliott MA, Armitage CJ, Baughan CJ. Drivers' Compliance With Speed Limits: an Alication of the Theory of Planned Behavior. J Appl Psychol 2003;88:964–972. [PubMed: 14516256]

Elliott DB, Whitaker D, Bonette L. Differences in the Legibility of Letters at Contrast Threshold Using the Pelli-Robson Chart. Ophthalmic Physiol Opt 1990;10:323–326. [PubMed: 2263364]

Ferris FL III, Kassoff A, Bresnick GH, Bailey I. New Visual Acuity Charts for Clinical Research. Am J Ophthalmol 1982;94:91–96. [PubMed: 7091289]

Glassbrenner, D.; NHTSA Research Note. Safety Belt Use in 2005: Use in the States and Territories. 2006. p. 1-5.http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/RNotes/2006/809970.pdf. Demographic Results

Glendon AI. Driving Violations Observed: an Australian Study. Ergonomics 2007;50(No 8):1159–1182. [PubMed: 17558663]

Hassan SE, Turano KA, Munoz B, Munro C, Bandeen-Roche K, West SK. Cognitive and Vision Loss Affects the Topography of the Attentional Visual Field. Invest Ophthalmol Vis Sci 2008;49:4672–4678. [PubMed: 18502999]

Hu PS, Trumble DA, Foley DJ, Eberhard JW, Wallace RB. Crash Risks of Older Drivers: a Panel Data Analysis. Accid.Anal.Prev 1998;30:569–581. [PubMed: 9678211]

Keeffe JE, Charlton JL. Visual Fields and Driving. Clin Experiment.Ophthalmol 2007;35:594–595. [PubMed: 17894677]

Kulp MT, Sortor JM. Clinical Value of the Beery Visual-Motor Integration Sulemental Tests of Visual Perception and Motor Coordination. Optom Vis Sci 2003;80:312–315. [PubMed: 12692488]

Lee HC, Lee AH, Cameron D, Li-Tsang C. Using a Driving Simulator to Identify Older Drivers at Inflated Risk of Motor Vehicle Crashes. J Safety Res 2003;34:453–459. [PubMed: 14636667]

Li G, Braver ER, Chen LH, Fragility. Versus Excessive Crash Involvement As Determinants of High Death Rates Per Vehicle-Mile of Travel Among Older Drivers. Accid.Anal.Prev 2003;35:227–235. [PubMed: 12504143]

McGwin G Jr. Xie A, Mays A, Joiner W, DeCarlo DK, Hall TA, Owsley C. Visual Field Defects and the Risk of Motor Vehicle Collisions Among Patients With Glaucoma. Invest Ophthalmol Vis Sci 2005;46:4437–4441. [PubMed: 16303931]

Meuleners LB, Harding A, Lee AH, Legge M. Fragility and Crash Over-Representation Among Older Drivers in Western Australia. Accid Anal Prev 2006;38:1006–1010. [PubMed: 16713982]

National Highway Traffic Safety Administration. Seat Belt Use in 2008 - Overall Results 2008a:1–4.

National Highway Traffic Safety Administration. Traffic Safety Facts 2006 Data: Older Population. 2008b

National Highway Traffic Safety Administration. Traffic Safety Facts 2006: A Compilation of Motor Vehicle Crash Data From the Fatality Analysis Reporting System and the General Estimtes System. 2008c

Nelson-Quigg JM, Cello K, Johnson CA. Predicting Binocular Visual Field Sensitivity From Monocular Visual Field Results. Invest Ophthalmol Vis Sci 2000;41:2212–2221. [PubMed: 10892865]

Owsley C, McGwin G Jr. McNeal SF. Impact of Impulsiveness, Venturesomeness, and Empathy on Driving by Older Adults. J Safety Res 2003;34(No 4):353–359. [PubMed: 14636657]

Owsley C, Stalvey B, Wells J, Sloane ME. Older Drivers and Cataract: Driving Habits and Crash Risk. J Gerontol.A Biol.Sci Med Sci 1999;54:M203–M211. [PubMed: 10219012]

Owsley C, Stalvey BT, Wells J, Sloane ME, McGwin G Jr. Visual Risk Factors for Crash Involvement in Older Drivers With Cataract. Arch Ophthalmol 2001;119:881–887. [PubMed: 11405840]

Porter MM, Whitton MJ. Assessment of Driving With the Global Positioning System and Video Technology in Young, Middle-Aged, and Older Drivers. J Gerontol.A Biol.Sci Med Sci 2002;57:M578–M582. [PubMed: 12196494]

Rubin GS, Ng ES, Bandeen-Roche K, Keyl PM, Freeman EE, West SK. A Prospective, Population-Based Study of the Role of Visual Impairment in Motor Vehicle Crashes Among Older Drivers: the SEE Study. Invest Ophthalmol Vis Sci 2007;48(No 4):1483–1491. [PubMed: 17389475]

Schretlen D, Brandt J, Bobholz JH. Validation of the Brief Test of Attention in Patients With Huntington's Disease and Amnesia. The Clinical Neuropsychologist 1996;10:90–95.

Sims RV, Owsley C, Allman RM, Ball K, Smoot TM. A Preliminary Assessment of the Medical and Functional Factors Associated With Vehicle Crashes by Older Adults. J Am Geriatr.Soc 1998;46:556–561. [PubMed: 9588367]

Williams AF, Shabanova. Responsibility of Drivers, by Age and Gender, for Motor-Vehicle Crash Deaths. J Safety Res 2003;34:527–531. [PubMed: 14733986]

Wood JM, Anstey KJ, Kerr GK, Lacherez PF, Lord SA. Multidomain Aroach for Predicting Older Driver Safety Under In-Traffic Road Conditions. J Am Geriatr.Soc. 2008doi:10.1111/j.1532-5415.2008.01709

Yang CY, Najm WG. Examining Driver Behavior Using Data Gathered From Red Light Photo Enforcement Cameras. J Safety Res 2007;38:311–321. [PubMed: 17617240]

Zhang L, Baldwin K, Munoz B, Munro C, Turano K, Hassan S, Lyketsos C, Bandeen-Roche K, West SK. Visual and Cognitive Predictors of Performance on Brake Reaction Test: Salisbury Eye Evaluation Driving Study. Ophthalmic Epidemiol 2007;14:216–222. [PubMed: 17896300]

Figure 1.
Driving monitoring system installed in a vehicle. Image shows the forward facing color camera which captures footage on the road and the monochrome camera capturing the driver both mounted on the passenger side of the vehicle

Table 1

Round 2 participant's characteristics by inclusion in the failure to stop at a stop sign analysis

Characteristic	Included N=1115	Excluded N=126*	p-value
Demographics			
Age (mean (sd))	77.7 (5.2)	77.0 (5.2)	0.20
% Female	48.4	63.5	0.014
% African American	11.9	14.3	0.44
Place of Residence Rural	34.9	29.3	0.23
Physical and Vision Variables			
Best Eye Contrast Sensitivity (# letters)	35.3 (2.2)	34.5 (2.6)	0.02
Visual field (per point missed)	2.0 (5.1)	3.5 (8.3)	0.05
Visual Acuity (LogMAR)	-0.01 (0.11)	0.01 (0.12)	0.02
Attentional VF Average (degrees)	12.7 (5.1)	11.0 (5.5)	0.003
Total Brake Reaction Time (milliseconds)	7.8 (3.4)	8.5 (3.7)	0.04
Cognitive and Executive function			
Mini-Mental State Exam	28.4 (1.7)	28.1 (2.3)	0.29
# Errors on Motor Free Visual Perception	3.4 (2.5)	3.8 (2.6)	0.11
Visual Motor Integration	18.3 (3.4)	17.7 (3.8)	0.06
Brief Test of Attention	6.4 (2.4)	6.6 (2.7)	0.30
Time to complete Tower of Hanoi (minutes)	2.0 (1.7)	2.1 (1.9)	0.55
Trail Making part A (seconds)	48.9 (22.8)	56.5 (32.4)	0.01
Time Trail Making part B (seconds)	125.1 (72.8)	139.7 (73.9)	0.04

chi-square to compare proportions, t-test to compare means

* 74 did not have reliable DMS and 52 did not encounter any stop signs

Table 2

Failures to stop at stop signs and failure rate stratified by number of stop signs encountered

	Stop Signs Encountered*				
	0	**1-4**	**5-7**	**8-12**	**>=13**
Number of participants	52	338	256	256	265
Failed at least once** (n(%))	----	25 (7.4%)	33 (12.9%)	45 (17.6%)	74 (27.9%)
Total number of failures	----	30	48	83	200
Failure Rate/stops encountered (mean (sd))	-----	0.0284 (0.1072)	0.0304 (0.0890)	0.0328 (0.0841)	0.0406 (0.0910)

*The Categories are based on Quartiles

Table 3

Univariate analysis of the demographic, physical, visual and cognitive factors which predict failure to stop at a stop sign 1 year later using bivariate regression models.*

Parameter	Incident rate ratio	95% Confidence Limits	p-value
Demographics			
Age (per year increase)	0.99	0.96-1.02	0.54
Male/Female	1.18	0.84-1.66	0.35
African American	0.81	0.49-1.37	0.43
Rural Place of Residence	**1.72**	**1.22-2.44**	0.002
Physical and Vision Variables			
Best Eye Contrast Sensitivity (per letter increase)	0.96	0.89-1.03	0.22
Visual field (per point missed)	0.96	0.91-1.00	0.09
Visual Acuity (LogMAR) (per line lost)	1.04	0.89-1.21	0.67
Attentional VF Average (per degree increase)	0.99	0.96-1.02	0.48
Total Brake Reaction Time (per unit increase)(BRT)	0.99	0.94-1.04	0.65
Cognitive and Executive function			
Mini-Mental State Exam (per point)	0.95	0.86-1.05	0.34
Visual Motor Integration (per unit increase)	1.01	0.96-1.06	0.59
Brief Test of Attention (per unit increase)	0.97	0.90-1.04	0.38
Time to complete Tower of Hanoi (per minute increase)	0.90	0.81-1.00	0.06
Trail Making Test part A (per 10 sec increase)	0.96	0.89-1.03	0.25
Trail Making Test part B (per 10 sec increase)	0.98	0.95-1.00	0.06

[*] Fitted using a negative binomial distribution with offset equal to the logarithm of number of stops signs encountered

Table 4

Univariate analysis of the factors predicting failure rate at stop for participants living in rural areas (bivariate associations)

Factors	Incident rate ratio	95% Confidence Limits	p-value
Demographics			
Age (per year increase)	0.99	0.95-1.05	0.87
Male Gender	1.13	0.66-1.92	0.65
African American	1.08	0.54-2.28	0.83
Physical and Vision Variables			
Best Eye Contrast Sensitivity (per letter increase)	0.98	0.88-1.09	0.70
Points Missing in Visual field (per point missed)	1.01	0.94-1.09	0.82
Visual Acuity (LogMAR) (per line lost)	0.99	0.77-1.27	0.91
AVF Average (per degree increase)	0.98	0.93-1.03	0.40
Total Brake Reaction Time (BRT) (per unit increase)	0.97	0.88-1.06	0.57
Cognitive and Executive function			
Mini-Mental State Exam (per unit increase)	1.00	0.85-1.16	0.98
Visual Motor Integration	1.02	0.95-1.10	0.53
Brief Test of Attention (per unit increase)	0.97	0.87-1.07	0.53
Time to complete Tower of Hanoi (per minute increase)	0.84	0.68-1.03	0.09
Trials A (per 10 sec inc)	0.98	0.89-1.09	0.75
Trials B (per 10 sec inc)	0.98	0.94-1.02	0.32

Table 5

Univariate analysis of the factors predicting failure rate at stop for participants living in urban areas (bivariate associations)

Factors	Incident rate ratio	95% Confidence Limits	p-value
Demographics			
Age (per year increase)	1.00	0.96-1.04	0.99
Male Gender	1.06	0.67-1.66	0.81
African American	**0.45**	**0.20 - 0.98**	**0.046**
Physical and Vision Variables			
Best Eye Contrast Sensitivity (per letter increase)	0.91	0.82-1.01	0.08
Points Missing in Visual field (per point missed)	**0.89**	**0.79 - 0.97**	**0.018**
AVF Average (per degree increase)	1.00	0.95-1.04	0.89
Visual Acuity (LogMAR) (per line lost)	1.11	0.92-1.35	0.28
Total Brake Reaction Time (BRT) (per unit increase)	1.00	0.94-1.07	0.97
Cognitive and Executive function			
Mini-Mental State Exam (per unit increase)	0.92	0.80-1.04	0.17
Visual Motor Integration	1.00	0.94-1.06	0.96
Brief Test of Attention (per unit increase)	0.97	0.88-1.06	0.48
Time to complete Tower of Hanoi (per minute increase)	0.96	0.85-1.09	0.55
Trials A (per 10 sec inc)	0.91	0.80-1.02	0.13
Trials B (per 10 sec inc)	0.97	0.94-1.01	0.11

Note: In multivariate analyses, African American race was no longer significant once adjusting for visual field results.