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Older Drivers and Failure to Stop at Red Lights

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Background. Despite sensational news reports, few studies have quantified the rates of poor driving performance among older drivers and the predictors of poor performance. We determined the rate of running red traffic lights among older drivers and the relationship of failure to stop to measures of vision and cognition.

Methods. Multiple measures of vision and cognition were collected at the baseline examination of a population of 1,425 drivers aged 67–87 years in greater Salisbury, Maryland. Each driver had real-time data collected on 5 days of driving performance at baseline and again at 1 year. Failure to stop at a red traffic light was the primary outcome.

Results. Overall, 3.8% of older drivers failed to stop at red traffic lights, with 15% of those who ran the light having failed 10% or more of the traffic lights they encountered. A narrowing of the attentional visual field (AVF; the extent of peripheral vision in which objects are detected while attention is also centrally fixated) was associated with failure to stop at traffic lights at baseline and predictive 1 year later (incidence rate ratio = 1.09 per degree lost, 95% confidence interval = 1.01–1.16). Persons with smaller vertical AVF were more likely to fail to stop. No demographic or vision variable was related to failure to stop.

Conclusions. Failure to stop at red lights was a relatively uncommon event in older drivers and associated with reduced ability to pay attention to visual events in the vertical field of vision.

Key Words: Vision—Visual attention—Cognition—Driving—Older population.

FAILURE to stop at a red light is an important measure of poor driving performance as it has been estimated to cause 260,000 crashes and 750 fatalities each year in the United States (1). However, individual factors predictive of running red lights are unknown.

Cognitive factors can impair driving ability and may lead to errors in driving (2). “High cognitive” demand situations, such as misread traffic signals, are associated with the type of crashes reported with dementia (3).

Several measures of visual function have also been linked to poor driving (4–7). In particular, older adults are affected by additional demands of dividing attention in their field of view. This restriction of the attentional visual field (AVF) could be the result of slow processing speed, inability to divide attention or ignore distractions, restricted visual fields, or a combination of these factors (8–10). Thus, a test for visual attention combines components of both visual and mental function and may capture relevant deficits for poor performance in a high demand situation, such as at a traffic light.

The purposes of this investigation were to report the rate of running red lights in an older cohort of drivers and to determine associated visual and cognitive risk factors.

Methods

We recruited participants from a complete listing of all Department of Motor Vehicle Administration (DMVA) licensees aged 67–87 years who resided in ZIP codes of the greater Salisbury metropolitan area. For legal reasons, a letter from the DMVA (specifically, the Department of Safety Research) was sent first to the population, and willingness to be contacted by the investigation was obtained (evidenced by returning an enclosed, stamped, and addressed postcard). We were not allowed to contact further any “no” postcards or any nonresponders. Of 8,380 registered licensees, 4,503 (54%) returned postcards. Of 4,503, 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 them were recruited to the clinic examination (N = 1,425).

A trained interviewer collected data on symptoms of pain in the feet, legs, knees, and hips and on currently taking medication for pain from arthritis. A composite score was created, ranging from 0 (no pain) to 5 (reported pain for all five items). Each participant underwent a series of vision tests. Presenting binocular visual acuity was tested using Early Treatment of Diabetic Retinopathy Study charts. Results were scored as Log Minimum Angle of Resolution acuity. Contrast sensitivity was tested for each eye using the Pelli-Robson contrast sensitivity chart. Results were coded as number of letters seen. The visual field was tested using the Humphrey Field Analyzer II, Full Field 81 Point test, with a Quantify-Defects test strategy. Number of points missed was recorded.

The participants undertook a test of AVF, described in detail elsewhere (11). The test assessed the AVF extent out to 20° radius in a divided attention protocol. Participants fixated on a circular target in the center of the monitor and attended to two numbers simultaneously presented for 250 milliseconds, one at the center of the circular target and the other located at fixed degrees out to 20° along one of four possible meridians (horizontal meridians: 0° and 180°, and vertical meridians: 90° and 270°) eccentric to the central number. At the same time the numbers were presented, seven filled circles were presented at the same eccentricity and with the same size as the eccentric number. Participants had to report correctly the central and outer numbers and the location of the outer number. The widest angle out to 20° for which the participant had correct responses was recorded in the vertical and horizontal meridians.

Participants were tested for overall cognitive status using the Mini-Mental State Examination test, which ranges from a low of 0 to a high of 30. They were also tested in the cognitive domains of psychomotor speed and auditory divided attention. We used the Trail Making Test Part B, which requires a participant to consecutively connect circles while alternating between numbers (1–13) and letters (A–L), as quickly as possible. The number of seconds to complete the task was scored. We used the Brief Test of Attention, which requires the participant to listen to 10 different series of combinations of letters and numbers and correctly count the number of letters contained in each series.

To measure the driving outcome, each participant's car was outfitted with a Driving Monitor System (DMS) created for this project for 5 days. The system has been described in detail previously (12). Each DMS unit utilized five sensors, which were monitored by a custom-developed computer system, consisting of two cameras, a GPS receiver, a magnetic compass, and a two-axis accelerometer. The color camera was oriented to capture images of the road, whereas the monochrome camera was positioned to capture images of the driver. Both video streams were recorded at a resolution of 352 × 240 pixels at a rate of 30 frames per second. The GPS receiver provided location and velocity data at a rate of 1 Hz, and the magnetic compass provided heading information at a rate of approximately 8 Hz. Finally, the accelerometers provided lateral and axial accelerations at a rate of 10 Hz. Data harvesting, time tagging, and storage were accomplished using a data acquisition software package created for the purpose.

The GPS record of the participant's travels for the 5 days was compared against a database of traffic light locations. When the participant was within 30 m of a traffic light, the time was noted and the analysis software cued the recorded driver and road video to that time. If the accelerometer or GPS data indicated evidence of stopping, the instance was given an automatic "pass" by the program. Pass was defined as follows: if the speed at the light was less than 5 mph or if deceleration was greater than 10 mph. If a pass was not given, the technician observed the road videos. If the technician observed in the road video a red light at any time the driver was going through the intersection, the encounter was graded as "fail." If a green or yellow light was observed, the encounter was graded as "pass." The camera was positioned in the vehicle such that the traffic light was only visible within the first third of the intersection, so a failure meant traversing the intersection when the light was already red or was turning red almost immediately upon entering the intersection. None of the intersections were outfitted with a red light camera.

Complete data were collected at round 1, and only driving data were collected at round 2, 1 year later.

Of the 1,425 participants, we were unable to obtain driving data on 181 (13%). The primary reason was a failure of the GPS unit, or video system, within the DMS system, despite numerous attempts at reinstallation. At round 2, 167 (11.7%) did not return: 29 had died, 112 refused, and 26 moved. Of the remainder, 41 no longer drove and 22 refused to have the unit reinstalled. We were unable to obtain driving data on 172 (14.5%) of the rest, primarily due to failure of the GPS unit. There were no significant differences by age, gender, race, and round 1 measure of cognitive status or vision status between those who did and did not have a DMS record for round 1 and between those who did and did not have a DMS record at round 2 (data not shown).

This study was reviewed and approved by the Johns Hopkins University Institutional Review Board. All participants provided informed written consent. Data were analyzed by the lead statisticians (B.E.M. and K.B.-R.).

Each traffic light encounter, and "pass" or "fail" for that encounter, was counted for each person. A failure rate was calculated as the number of failures per number of traffic lights encountered. Because failure was a rare event, a Poisson regression model was used. The auditory test of attention was not included because of the strong correlation with the visual test of attention, and inclusion would be overadjustment (11). Variables found to be associated with failure in round 1 were used in predictive models of failure to stop at a red light in round 2. The incidence rate ratio was used as the measure of association. Sensitivity analyses were done by transforming the outcome variable, or adjustment by number of traffic lights encountered, but the results did not change.

Results

This cohort of older drivers contained similar numbers of men and women, reflecting the reduced percentage of older women who were drivers (Table 1). In general, vision and cognition were good, as might be expected among those still driving.

Of those who encountered a traffic light at round 1, 3.8% of persons failed to stop appropriately. Offenders were modestly clustered, with 15% of offenders failing 10% or more of the traffic lights they encountered. There was no difference in the failure rate by number of traffic light

Table 1. Baseline Characteristics of 1,425 Participants in Sansbury Eye Evaluation Driving Study

Characteristic	*N*	% or *M*
Demographics		
Age, mean (*SD*, IQR)	1,425	75.2 (5.2, 8)
Female (%)	1,425	50.0
African Americans (%)	1,425	13.0
Medical history		
Taking medication for arthritis (%)	1,425	44.8
History of stroke (%)	1,425	9.2
Pain (0–5 score), mean (*SD*, IQR)	1,425	0.9 (1.1, 1.0)
Cognitive		
MMSE, mean score (*SD*, IQR)	1,425	28.3 (1.9, 2.0)
Brief Test of Attention, mean correct (*SD*, IQR)	1,419	6.4 (2.5, 4.0)
Trail Making Test Part B, time in s, mean (*SD*, IQR)	1,399	130.1 (76.7, 65.0)
Visual function		
Visual acuity, LogMAR score, mean (*SD*, IQR)	1,425	−0.01 (0.11, 0.16)
Contrast sensitivity, number of letters, mean (*SD*, IQR)	1,425	35.2 (2.3, 2)
Points missing in bilateral visual field, mean (*SD*, IQR))	1,414	2.16 (5.4, 2)
Visual attention		
Vertical extent, mean degrees (*SD*, IQR)	1,413	10.9 (5.6, 8.8)
Horizontal extent, mean degrees (*SD*, IQR)	1,413	13.9 (5.9, 9.5)
Average extent, mean degrees (*SD*, IQR))	1,413	12.4 (5.3, 8.2)

Note: IQR = interquartile range; MMSE = Mini-Mental State Examination; LogMAR = Log Minimum Angle of Resolution.

encountered, except no failures among those who encountered the fewest number of lights (Table 2).

At round 1, race, the cognitive measure of attention, and AVF were significantly related to failure to stop at a red light (Table 3). Because the cognitive test of attention is highly associated with the test of AVF, we could not enter both parameters in a predictive model. We believe that the AVF was more relevant to detection of a visual target than the auditory test of attention and so we chose the former. We chose the vertical extent of the AVF as the marker of visual attention based on the size of the association.

Loss of AVF was related to failure to stop at a red light at both rounds (Table 4). Race and pain score (at round 1) were not predictors of red light failure in round 2. In neither round was age (between the ages of 67 and 87 years) or the measure of psychomotor speed significantly related to failure to stop at a red light.

The median AVF in those who failed to stop at least once at a red light was close to 7° (Figure 1) compared with that in those who had no failures at 12°. Those who failed more than 10% of the traffic lights encountered had a median AVF of 6°.

Discussion

Failure to stop at a red light was relatively rare, in round 1 occurring in 3.8% of older drivers, when assessed over a

Table 2. Red Light Failure Rate Within Number of Traffic Lights Encountered

Traffic Lights Encountered*						
Number of traffic lights encountered	0	1–6	7–11	12–17	18–27	>27
Number of participants	64	290	190	224	241	235
Mean failure rate	—	0	0.0035	0.0018	0.0024	0.0020
SD	—	0	0.0192	0.0120	0.0110	0.0071

Note: * Categories were created according to quintiles of the distribution of number of traffic lights encountered.

5-day period. Others have reported that older drivers were less likely to run red lights compared with those younger than 30 years (13). Drivers aged 56 years and older were 70% less likely to report running a red light compared with those aged 18–25 years, but it is not possible to determine the prevalence rate for that age group from the data (14). We did not find an effect of age in our sample, but all the drivers were older, between ages 67 and 87 years.

Risk factors found in previous studies for failure to stop at a red light include failure to wear a seat belt and being African American (15). In a study of red light runners observed at traffic lights, ethnicity was not related to failure to stop (16). We found an increased risk for running red lights among African Americans in our cross-sectional data, but race was not a predictor for running a red light prospectively. Given this inconsistency, our data do not support a racial difference among older drivers in failure to stop at a red light.

We found an association between running a red light and increasing pain score on the cross-sectional analyses, which was not found longitudinally. However, the pain score is labile, and using the pain score from a year previous may not reflect pain experienced at the time of the second round. We did not collect data on pain at the second round.

Reduced AVF was significantly related to red light running. We have previously shown that AVF is associated with both cognition and the visual field (11). However, we did not find that, by itself, missing points in the visual field was related to stopping failure, suggesting that the cognitive component of the AVF is the component of interest. In fact, the test of auditory attention was also related to red light running, further supporting the role of attention in failure to stop. Our data suggest that those who have restriction of AVF to 7° might benefit from further evaluation of driving performance.

Interestingly, the stronger predictor of failure to stop at a red light was the loss of AVF in the vertical meridian. We hypothesize that, as older drivers approach an intersection and are paying attention to surrounding cars and traffic flow, the loss of vertical attentional field would hamper detection of the high-hanging traffic signal, which may have changed color. As the driver approaches the intersection, the traffic light moves to an increasingly more peripheral location in the vertical meridian, and if this location is part of the attentional field dropout, the older driver may not detect the change.

Table 3. Risk Factors Associated With Failure to Stop at a Red Light at Round 1

Characteristic (round 1)	Incidence Rate Ratio (95% CI)	Age-Adjusted Incidence Rate Ratio (95% CI)
Demographics		
Age (per year increment)	0.98 (0.93–1.04)	—
Male/female	0.94 (0.51–1.73)	0.95 (0.52–1.75)
Blacks/whites	**2.96 (1.49–5.87)**	**2.94 (1.45–5.96)**
Medical history		
History of arthritis	0.79 (0.37–1.68)	0.76 (0.35–1.62)
History of stroke	1.38 (0.54–3.50)	1.40 (0.55–3.58)
Pain (0–5 score; per unit increment)	1.26 (0.98–1.62)	1.26 (0.98–1.62)
Cognitive		
MMSE (per unit increment)	0.90 (0.79–1.03)	0.89 (0.78–1.02)
Brief Test of Attention (per unit increment better)	**0.88 (0.78–0.99)**	**0.86 (0.76–0.97)**
Trail Making Test Part B (per 10 s worse)	**1.03 (1.00–1.06)**	**1.04 (1.00–1.07)**
Visual function		
Visual acuity (per line loss)	1.10 (0.84–1.44)	1.13 (0.86–1.48)
Contrast sensitivity (per letter seen)	0.96 (0.84–1.09)	0.94 (0.82–1.08)
Visual Field (per point missed)	1.00 (0.93–1.07)	1.00 (0.93–1.07)
Visual attention		
Vertical extent (per degree increased)	**0.92 (0.86–0.97)**	**0.91 (0.85–0.97)**
Horizontal extent (per degree increased)	**0.94 (0.90–0.99)**	**0.94 (0.89–0.99)**

Notes: MMSE = Mini-Mental State Examination; CI = confidence interval.
*Significant values are in bold text.

Perceived traffic congestion has been reported to predict running red lights (15–17). As traffic volume increased within a light cycle, there appeared to be a greater likelihood of red light running. We were unable to determine the degree of congestion surrounding the instances of red light running in our study, but it is consistent with our hypothesis that as older drivers are forced to devote more attentional resources to increased centrally located visual distractions (provided by more traffic in the visual field), the vertical AVF shrinks and may lead to more red light running.

Our study has limitations. It is likely that the older drivers with good vision and good measures of cognition participated in the study. We were limited by the inability to recruit participants, or determine visual and cognitive characteristics of refusals, but our previous studies in Salisbury do suggest that this sample of older drivers had better visual and cognitive function than the total population of older drivers (18). Thus, the failure rate may be higher in other samples of older drivers.

Table 4. Multivariate Model of Number of Red Light Failures at Round 1 and Predicting Failure at Round 2

	Round 1	Round 2
Characteristic (round 1)	Incidence Rate Ratio (95% CI)	Incidence Rate Ratio (95% CI)
Age (per year increment)	0.98 (0.92–1.04)	0.96 (0.92–1.01)
Blacks/whites	**2.26 (1.05–4.83)**	0.97 (0.53–1.79)
Pain (0–5 score; per unit increase worse)	**1.28 (1.00–1.65)**	0.96 (0.79–1.17)
Trails B (per 10 s increase)	1.01 (0.97–1.05)	1.00 (0.97–1.03)
Visual attention		
Vertical extent (per degree increase better)	**0.92 (0.86–0.99)**	**0.93 (0.89–0.97)**

Notes: CI = confidence interval.
*Significant values are in bold text.

Another possible limitation is the potential for more good driving behavior due to the DMS in the vehicle. When asked, our participants uniformly stated that they forgot about the system while driving. Judging from some of the behavior captured on the driver video, this reporting seems correct. Nevertheless, an effect on driver behavior by the DMS system cannot be excluded.

Another limitation is the loss of the sample for whom we could not obtain driving data, although there was no significant difference between those for whom we had data and those without.

Finally, red light running may be related to the time allotted in the traffic signals to the amber color. We had no data on the time allotted to the amber color, and our definition of failure to stop would have preferentially picked up those at the intersections with the shortest time allotted to an amber

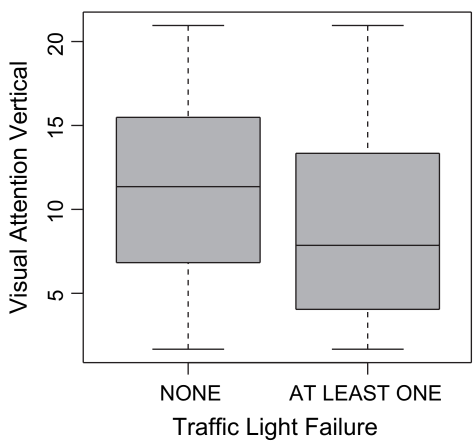

Figure 1. Attentional visual fields in persons who failed to stop at red lights at least once compared with those who never failed.

light. However, the fact that the red light was seen by the technician in the road video, which means the driver was likely only one third through the intersection, implies entering the intersection close to the end of the amber light. If anything, our definition was likely strict and may have resulted in a lower rate of red light running than if other definitions were used. However, the definition is not as strict as others have used (16).

The strength of this study lies in the objective assessment of actual driving performance using road conditions and routes routinely encountered in our older population. The drivers are not stressed to drive in a manner or on a route that is unfamiliar to them nor do we have an observer present, which is a limitation of other studies. Such studies can perforce capture only a small window of driving experience, whereas we have data on 5 days of driving experience. This longer time frame may minimize driver bias toward better performance and result in more accurate data on real driver performance.

These are the first data to report rates of traffic light failure per person, as well as per traffic light encountered, instead of relying on short driving episodes or having to observe drivers at an intersection. The finding that a simple test of visual attention, AVF, is related to red light running among older drivers points to possible countermeasures, such as improving signal visibility by placing traffic lights lower in the visual field. For older drivers who show decrements in the vertical meridians to 7°, caution about driving in high traffic situations may reduce their risk.

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