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Predictors of Lane-Change Errors in Older Drivers

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Abstract

Objectives—To determine the factors that predict errors in executing proper lane changes among older drivers.

Design—Cross-sectional analysis of data from a longitudinal study.

Setting—Maryland's Eastern Shore.

Participants—One thousand eighty drivers aged 67 to 87 enrolled in the Salisbury Eye Evaluation Driving Study.

Measurements—Tests of vision, cognition, health status, and self-reported distress and a driving monitoring system in each participant's car, used to quantify lane-change errors.

Results—In regression models, measures of neither vision nor perceived stress were related to lane-change errors after controlling for age, sex, race, and residence location. In contrast, cognitive variables, specifically performance on the Brief Test of Attention and the Beery-Buktenicka Test of Visual-Motor Integration, were related to lane-change errors.

Conclusion—The current findings underscore the importance of specific cognitive skills, particularly auditory attention and visual perception, in the execution of driving maneuvers in older individuals.

Keywords

lane changes; driving errors; elderly; cognition; vision

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Older drivers involved in a motor vehicle collision are far more likely than younger individuals to suffer medical complications resulting in death.[1] Older individuals are more likely than younger persons to have cognitive vulnerabilities, such as illnesses associated with cognitive disorders (cerebrovascular disease, incipient neurodegenerative disorders) that render them at risk of committing driving errors as a result of cognitive failure. They are also more likely than younger individuals to have problems with vision that hinder their ability to perform driving maneuvers successfully.

Lane changing is one of the most dangerous maneuvers in driving; more than 250,000 accidents occur every year in the United States because of lane-change errors, which amounts to one accident every 2 minutes.[2] Changing lanes is a vehicle maneuver that may involve substantial risks for several reasons. First, it causes the individual to straddle traffic flows and be exposed to two streams of vehicles. Second, it requires the driver to make rapid, often incorrect, judgments about sufficient spacing. Third, it increases the hazard related to other vehicles approaching along the driver's blind spot. Fourth, it disrupts the traffic pattern for following vehicles that may in turn have an accident.[3]

The likelihood of lane-change accidents has been shown to relate to factors affecting vision. In a previous study,[4] obstructions to vision caused by body pillars (the structural supports around the windows) were associated with lane-change crashes. Visual factors have also been shown to relate to successful performance of steering maneuvers during lane changes in a driving simulator. A previous study found that, when receiving no visual feedback, drivers failed to initiate the return phase of the steering maneuver. The authors concluded that their findings evinced the importance of vision, even during the well-practiced steering task of lane changing.[5]

Although factors related to vision are related to the ability to perform lane changes successfully, driving task errors appear to account for the largest percentage of causal factors for crashes due to faulty lane changes. These types of errors have been categorized using various taxonomies (see Stanton[6] for a review), most of which include some component of cognitive skill as integral to driving performance. Of the various aspects of cognition, driver distraction appears to be the most significant factor for the encroaching vehicle in most scenarios involving lane-change crashes.[2] Numerous studies have documented the detrimental effects of inattention, a major component of which is driver distraction, on driving behavior and crash risk.[7,8]

For older drivers, cognitive skills other than attention have been shown to relate to driving outcomes as well. A meta-analysis, found that, of various cognitive domains, visuospatial skills were related to on-road driving measures in patients with dementia.[9] In a study of predictors of failure on a standardized road test, older age and performance on the Trail Making Test Part B (Trails B)[10] emerged as the two primary predictors.[11] In a prospective study of elderly drivers, two cognitive tests, Trials B[10] and the Motor-Free Visual Perception Test,[12] predicted subsequent at-fault motor vehicle collisions.[13] These studies highlight the importance of particular cognitive domains, rather than overall cognitive functioning, in driving in older adults.

Based on prior studies documenting the importance of visual factors in performing lane changes, it was hypothesized that performance on measures of vision would predict the likelihood of lane-change errors. Based on evidence that cognition plays a role in lane change errors, it was hypothesized that cognitive test performance would be related to lane-change errors. Because of the apparent importance of distraction in drivers of all ages, it is hypothesized that self-reported physical and emotional distress would be related to lane-change errors. The aim of this study was to determine, from among visual factors, cognitive test performance, and self-reported distress, the individual characteristics that best predict lane-change errors in a large cohort of older drivers.

Method

Subjects

Subjects were selected from participants of the Salisbury Eye Evaluation and Driving Study (SEEDS). SEEDS is a longitudinal study of vision, cognition, and driving in older individuals on Maryland's Eastern Shore. To be recruited into SEEDS, residents of the greater Salisbury, Maryland, metropolitan area were invited to participate through letters sent by the Maryland Department of Motor Vehicles to all drivers aged 67 and older registered as of May 1, 2005. The letters outlined the study and requested participation, indicated by return of a postcard. Potential subjects were then contacted to arrange a home visit, during which they provided written informed consent.

Demographic characteristics and medical conditions were asked about using structured questionnaires. Subjects were then scheduled for a clinic visit, during which they underwent assessments of vision and cognition through tests administered by trained technicians, after which a driving monitoring unit was installed in their vehicles. The current results are from the 1,080 subjects (from the original 1,425 participants) who returned for Round 3 of data collection (July 2007 to June 2008). SEEDS is conducted under the auspices of the the Johns Hopkins Medical Institutions' review board.

Study Procedures

Study visits were conducted in two parts. First, data were collected on demographic and medical information. Second, participants were seen in the SEEDS clinic, during which they underwent assessments of vision and cognition and completed questionnaires concerning their mood and perceived stress. At the clinic visit, a driving monitoring system (DMS), which was used to track driving patterns, was installed into each participant's vehicle and removed after approximately 5 days. The DMS allowed for the quantification of lane change errors.

Driving Monitoring System

Each DMS unit consists of five systems: a high-dynamic-range color camera, a monochrome camera with night vision, a global positioning system (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. The GPS receiver would provide location and velocity data at a rate of 1 Hz, and the magnetic compass provided heading information at a rate of 8 Hz. The accelerometer provided information regarding lateral and axial accelerations at a rate of 10 Hz. This information was stored on the onboard hard-drive, which was then retrieved and analyzed.

Custom analysis software was used to integrate the data from all of the systems to provide information on driving behavior, including lane changes. The DMS software was programmed to monitor an object at the end of the road and to identify instances of possible lane changes by determining whether the object moved across at least one-third of the driver's field of view. In such instances, trained technicians visually inspected the video record of the possible lane change to determine whether a lane change occurred. In cases of definite lane changes, a “failure” was assigned if the driver did not look in his or her rearview or side view mirror or turn his or her head to look ahead into the turn in the 5 seconds preceding the lane change. It was decided to allow for either type of blind-spot checking so that there would be a conservative estimate of errors.

Measures of Vision

Visual Acuity—

Visual acuity was measured using a high-contrast Early Treatment Diabetic Retinopathy Study (ETDRS) acuity chart with standard illumination at a distance of 3m using forced-choice protocols.[14] This variable was coded as the number of letters recognized correctly and scored as the logarithm of the minimum angle of resolution (LogMAR) visual acuity by assigning a value of −0.02 for each letter recognized. Thus, visual acuity of 20/200 equates to a Log-Mar value of 1.00, whereas visual acuity of 20/20 is equivalent to a LogMar of 0.0.

Contrast Sensitivity—

Monocular contrast sensitivity (CS) was measured using the Pelli Robson CS chart at a distance of 1 m. This variable was coded as the number of letters correctly identified.[15]

Visual Field—

The bilateral visual field was measured by combining the results from the full left and right eye field 81-point test with a quantify-defects test strategy on the Humphrey field analyzer II to obtain a 96-point bilateral visual field. 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 an individual can effectively divide his or her attention and extract visual information within a glance. This test was performed using custom 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.[16]

Cognitive Test Battery

Mini-Mental State Examination—

The Mini-Mental State Examination (MMSE)[17] is a 30-item gross cognitive screening measure that assesses orientation, attention, language, and construction. Higher scores indicate better performance.

Brief Test of Attention—

For the Brief Test of Attention (BTA),[18] a divided auditory attention task, participants listen to tape-recorded lists of letters and numbers of increasing length and are required to state how many letters or numbers were contained within each list. Each item is scored as correct or incorrect. For this study, only the first 10 (of the total 20) trials were administered. Higher scores indicate better performance.

Trail Making Test—

The Trail Making Test[10] measures visuomotor skills and flexibility to shift sets under time pressure. Part A requires a subject to consecutively connect circles numbered 1 to 25, as quickly as possible. Part B (Trails B) requires a subject to consecutively connect circles while alternating between numbers (1–13) and letters (A-L), as quickly as possible. Performance is based on time required to complete each part. Higher scores, measured in seconds, indicate longer durations to complete each of the two tasks and hence worse performance.

Hopkins Verbal Learning Test—Revised—

The Hopkins Verbal Learning Test—Revised, a word-list learning task,[19] requires the examinee to recall a list of 12 words (4 words from each of three semantic categories), after each of 3 oral presentations. After approximately 20 minutes, delayed recall is assessed, followed by a yes–no recognition trial. Higher scores indicate better performance.

Beery Buktenicka Developmental Test of Visual-Motor Integration—The Beery Buktenicka Developmental Test of Visual-Motor Integration (VMI)[20] is a test of visuoconstruction that requires the participant to copy 24 figures of progressive difficulty. Items are scored as pass or fail. Total number of pass scores are summed; higher scores indicate better performance.

Tower of Hanoi—The original Tower of Hanoi test consists of three vertical pegs on which disks of different sizes are placed. At the beginning of the test, the disks are stacked in order of size of the first (leftmost) peg, with the smallest disk at the top. The objective of the test is to move the disks from the first peg to recreate the stack of disks on the third peg while obeying two rules; only one disk may be moved at a time, and no disk may be placed on top of a smaller disk. The goal is to complete the task using as few moves as possible. A computerized version of this test, created specifically for SEEDS, was used.

Statistical Analysis

Characteristics of Round 3 participants (demographics, medical history, self-reported distress, cognition, visual function, and visual attention) were described using percentages for categorical variables and means, standard deviations, and interquartile ranges were used to describe continuous variables. Urban versus rural area of residence was included with age, sex, race, and level of education because it was found to be a predictor of driving errors in prior work (unpublished data). Participants with and without lane-change data were compared on each characteristic using the chi-square test, the Fisher exact test, or the *t*-test as appropriate to assess differences.

To explore the association between lane-change failure rate (per lane change encountered) and participant characteristics, binomial regression methods were used to model the number of lane change failures. The log of the number of lane changes encountered was included in the model as an offset variable to adjust for exposure. Results are presented as estimated incidence rate ratios and associated 95% confidence intervals. An incidence rate ratio is the factor that multiplies the failure rate when a categorical variable changes level or when a continuous variable is increased or decreased. First, only a single characteristic was included in each model (univariate analysis). Next, a multivariate model including demographic characteristics as covariates was estimated. Explanatory variables were selected from the remaining characteristics with regression parameters significant at the .05 level in univariate analyses, using the stepwise method. For a variable to enter and remain in the model, the multivariate regression parameter for that variable was required to be significant at the .05 level.

All analyses were performed using SAS version 9.1 (SAS Institute, Inc., Cary, NC).

Results

Demographic Data

Table 1 summarizes participant demographic characteristics. Ages ranged from 67 to 88. Participants were predominantly Caucasian, healthy, and cognitively high functioning.

Comparison of Individuals with and without Data on Lane-Change Errors

The DMS unit was installed for a mean of 5.8 ± 1.1 days. Although the range for all participants was 2 to 15 days, the number of days that 97.5% of participants had the unit installed ranged from 4 to 7. Over the course of monitoring, participants' average driving segment was 163.4 ± 128.4 minutes (minimum = 1.3, maximum = 1,157.2). Data on lane-change errors were not available for all participants in whom data should have been gathered for reasons included as part of Table 2. As shown in Table 2, individuals without data on lane-change errors were more likely to be African American, have lower scores on the VMI, require longer to complete Trails B, and have a more constricted visual field.

Lane-Change Failure Rate

The rate of failure in executing lane changes was essentially consistent across number of lane changes encountered, except for participants who encountered the greatest number of lane changes (Table 3). Individuals with more than 35 lane changes over the course of monitoring by the DMS had a greater failure rate than those with fewer lane changes.

Univariate Predictors of Lane-Change Failure Rate

Table 4 summarizes the observed rate ratios of lane-change failure for all potential variables. As shown in Table 4, the only demographic characteristic associated with a higher rate of lane-change failure was residence in a rural as opposed to an urban area. Presence of particular medical conditions was not associated with higher lane-change failure rates. Similarly, self-reported physical and emotional distress were not associated with higher failure rates.

In contrast, poorer cognitive test performance on several measures was associated with higher rates of lane-change failure. Specifically, poorer performance on the Brief Test of Attention, the Trails B, and the VMI was associated with higher failure rates. Performance on tests of overall cognitive status (MMSE) and problem solving (Tower of Hanoi), were not associated with higher rates of lane-change failure. Decreased visual attention, vertically and horizontally, was associated with a higher rate of lane-change failure.

Multivariate Model Predicting Rate of Lane-Change Failure

Of the variables examined in this study, those that remained predictive of rate of lane-change failure in the multivariate model were area of residence (with rural location predicting a greater rate of lane change failure) and cognitive test performance (Table 5). Specifically, poorer auditory divided attention (Brief Test of Attention) and visuoconstruction (VMI) predicted a higher rate of lane-change failure.

Discussion

The aim of this study was to determine individual characteristics that best predict lane-change errors in a cohort of elderly drivers in whom vision, cognition, medical history, and self-reported distress were assessed. After controlling for age, sex, race, education, and place of residence (urban vs rural), it was found that tests of auditory attention (Brief Test of Attention[18]) and visuoconstruction (VMI[20]) were most strongly predictive of failure to execute proper lane changes.

Similar to findings of prior studies predicting crash risk,[21–23] overall cognitive functioning as measured using the MMSE was not related to likelihood of lane-change failure. Although the MMSE is well recognized for its use as a screening tool rather than a diagnostic tool because of its lack of sensitivity to subtle cognitive problems, the current findings underscore the need for more-comprehensive assessment of cognitive and functional ability in informing decisions regarding driving ability, rather than relying solely on MMSE score as an indicator of driving success. All participants in the current study were, on average, functioning with normal cognition, which further attenuates the ability of a cognitive screening measure to predict driving errors.

It has been suggested that specific cognitive skills best relate to abilities required for safe driving,[21] and the findings of the current study support this suggestion. In particular, visuoconstruction, which requires visual perception as well as constructional praxis, predicts rate of lane-change failure. That visual measures were not independently predictive of lane-change errors suggests that visuoconstruction is more important than visual perception alone. This requires further study.

Perhaps the most surprising finding was that auditory, but not visual, attention predicted the likelihood of committing lane-change failures. Prior studies have identified the importance of attention in driving performance,[22,23] but to the authors' knowledge, studies assessing visual and auditory attention in the same subjects have not been conducted. The findings of the current study suggest that the ability to divide one's attention is important in driving behavior. This finding has implications for susceptibility to distraction, such as that occasioned by cell phone use (for a review, see[24]). Whether older drivers who have poorer auditory attention are more prone to error in the face of distraction than those with greater attentional capacity remains to be determined.

It was also found that drivers who reside in rural rather than urban areas are less likely to execute lane changes properly. The reasons for this finding are unclear. It might be that, in rural areas, there are often no other cars on the road, obviating the need to check the position of other vehicles before changing lanes. It is possible, therefore, that rural drivers are responding to their environments appropriately rather than committing errors while changing lanes. This assertion assumes that these individuals drive almost exclusively in the rural areas in which they reside, which is unlikely. An alternative explanation is that drivers who typically drive in little or no traffic develop unsafe driving habits due to their expectation that there are few if any other drivers sharing the road. Future studies on the relationship between the degree of congestion and lane-change errors are needed to clarify the reasons why rural residents have a higher rate of lane change failures.

This study has several limitations. First, this sample includes only drivers aged 67 and older. The results are therefore generalizeable only to this cohort. Moreover, the participants in this study tended to be healthy and to perform well on measures of cognition and vision. Thus, there was a restricted range of health, cognitive, and visual status upon which to base predictions.

Second, it was not possible to determine the characteristics of the individuals who refused to participate in the study because of restrictions placed on recruitment by the Motor Vehicle Administration. Prior work in the same geographic area suggests that study participants were more likely to have better acuity and better cognitive status than the total population of drivers.[25] Hence, the rate of lane-change failure may be higher in other samples of older drivers.

Third, it is possible that, knowing that their driving was being monitored, participants drove more carefully than they would have otherwise. Although this is a possibility, the participants uniformly informed us that they forgot that the system was on after only 1 or 2 minutes. Judging from some of the behavior that was witnessed in the car, captured on the driver video, this reporting seems correct. Nevertheless, an effect on driver behavior by the DMS system cannot be excluded as explaining these findings.

A fourth limitation is the loss of a portion of the sample for whom lane-change data were not available. These individuals were more likely to be African American, have lower scores on the VMI and Trail Making Test, and have more-restricted visual attention than those for whom data were available. If these individuals also committed more lane-change errors, it is possible that race and visual attention would be predictors of lane-change failure rate in the multivariate model, but the differences were small, and the number of participants for whom lane-change data were unavailable was also small (n = 37). Therefore, the likelihood that the inclusion of their data would change the results is small.

This study has several strengths. First, it is the largest study of elderly drivers that includes comprehensive assessment of vision and cognition. Second, the naturalistic setting in which drivers were assessed increases the external validity of the study; drivers were assessed under conditions routinely encountered, rather than on unfamiliar routes. Similarly, unlike other studies, driving was monitored without an observer. This technique reduces the likelihood of drivers engaging in atypical driving behavior while allowing data to be collected over a longer time period than is possible in studies in which an observer is in the car. The data are therefore likely to more accurately reflect real-world driving behavior than data collected using alternative methods.

Conclusion

The current study found that specific cognitive, but not visual or overall cognitive, skills were related to the like-lihood of committing lane-change errors, a major predictor of accidents. It is of particular interest that a test of auditory attention was predictive of failure rate. Interventions aimed at reducing driver distraction or improving attention may prove effective at reducing driver errors. Furthermore, these findings provide valuable direction for those involved in screening for fitness to drive.

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Table 1
Characteristics at Round 3 of 1,080 Participants Who Participated in Round 3

Characteristic	N	Value
Demographic		
Age, mean ± SD (IQR)	1,080	77.8 ± 5.2 (8.4)
Female, %	1,080	51.0
African American, %	1,080	11.9
Education, years, mean ± SD (IQR)	1,080	13.6 ± 2.6 (4.0)
Rural, %	1,080	34.4
Medical history and self-reported distress		
History of arthritis, %	1,080	11.8
History of stroke, %	1,080	2.4
Pain score (range 0–5), mean ± SD (IQR)	1,080	0.72 ± 0.95 (1.00)
Perceived Stress Scale score (range 0–4), mean ± SD (IQR)	1,080	0.84 ± 0.59 (0.80)
Geriatric Depression Scale score (range 0–30), mean ± SD (IQR)	1,080	3.7 ± 3.6 (4.0)
Cognition		
Mini-Mental State Examination score (range 0–30), mean ± SD (IQR)	1,080	27.6 ± 2.2 (2.0)
Brief Test of Attention score (range 0–10), mean ± SD (IQR)	1,080	6.3 ± 2.6 (3.0)
Hopkins Verbal Learning Test score, Trials 1–3 (range 0–36), mean ± SD (IQR)	1,078	22.7 ± 5.5 (8.0)
Hopkins Verbal Learning Test, Delayed Recall score (range 0–12), mean ± SD (IQR)	1,078	7.2 ± 3.4 (5.0)
Tower of Hanoi, number of moves, mean ± SD (IQR)	1,054	11.4 ± 6.4 (7.0)
Trail Making Test Part B, time in seconds, mean ± SD (IQR)	1,073	129.9 ± 80.1 (69.0)
Visual-Motor Integration score (range 0–24), mean ± SD (IQR)	1,079	17.8 ± 3.5 (6.0)
Visual function		
Visual acuity		
LogMAR, mean ± SD (IQR)	1,080	0.01 ± 0.12 (0.15)
Snellen equivalent of mean LogMAR		20/20
Contrast sensitivity, number of letters read, mean ± SD (IQR)	1,080	34.9 ± 2.4 (2.0)
Bilateral visual fields, number of points missed, mean ± SD (IQR)	1,074	2.2 ± 5.3 (2.0)
Visual attention, °, mean ± SD (IQR)		
Vertical extent	1,060	14.1 ± 5.9 (9.2)
Horizontal extent	1,060	11.5 ± 5.7 (9.5)
Average extent	1,060	12.8 ± 5.4 (8.0)

At Round 3, 14 participants were no longer driving, two participants were not driving but expected to drive again, three participants did not have a car available, and three participants had a car available but the driving monitoring system could not be installed because of the voltage requirements, which precluded installation in the particular make of car (e.g., hybrid vehicle).

SD = standard deviation; IQR = interquartile range; LogMAR = logarithm of the minimum angle of resolution.

Table 2

Characteristics at Round 3 of 1,058 Participants Who Were Driving and Had a Car Available in Which a Driving Monitoring System (DMS) Could Be Installed, According to Availability of Lane-Change Data at Round 3

Characteristic	**With Lane-Change Data N = 1,021**	**Without Lane-Change Data N = 37**[*]	***P*-Value**[**]
Demographic			
Age, mean	77.7	78.8	.22
Female, %	50.2	64.9	.08
Education, years, mean	13.6	13.4	.69
African American, %	11.2	27.0	.003
Rural, %	34.9	24.3	.19
Medical history and self-reported distress			
History of arthritis, %	11.4	10.8	>.99
History of stroke, %	2.2	0.0	>.99
Pain score (range 0–5), mean	0.70	0.78	.68
Perceived Stress Scale score (range 0–4), mean	0.84	0.73	.27
Geriatric Depression Scale score (range 0–30), mean	3.6	3.9	.67
Cognition			
Mini-Mental State Examination score (range 0–30), mean	27.7	27.2	.18
Brief Test of Attention score (range 0–10), mean	6.3	5.5	.06
Hopkins Verbal Learning Test score, Trials 1–3 (range 0–36), mean	22.8	22.1	.49
Hopkins Verbal Learning Test, Delayed Recall score (range 0–12), mean	7.3	6.6	.23
Tower of Hanoi, number of moves, mean	11.4	11.1	.80
Trail Making Test Part B, time in seconds, mean	126.2	184.5	.01
Visual-Motor Integration score (range 0–24), mean	17.9	15.5	<.001
Visual function			
Visual acuity			
LogMAR, mean	0.007	0.027	.30
Snellen equivalent of mean LogMAR	20/20	20/21	
Contrast sensitivity, number of letters read, mean	35.0	34.7	.51
Bilateral visual fields, number of points missed, mean	2.1	2.6	.59
Visual attention, °, mean			
Vertical extent	14.3	11.9	.02
Horizontal extent	11.6	9.5	.03
Average extent	13.0	10.7	.01

[*] Lane-change data were not available in these individuals for the following reasons: DMS data were unreliable because of failure of some aspect of the hardware (e.g., the global positioning system), participant refused installation of the DMS, no driving segments were available for coding, and the participant was not positively identified as the driver during any driving segments.

[**] *P*-value from *t*-test, chi-square test, or Fisher exact test.

LogMAR = logarithm of the minimum angle of resolution.

Table 3

Rate of Lane-Change Failure for 1,021 Participants with Lane-Change Data at Round 3 According to Number of Lane Changes Encountered

	Lane Changes Encountered[*]					
Lane-Change Failure Rate	**0 (n = 40)**	**1–5 (n = 186)**	**6–12 (n = 213)**	**13–20 (n = 191)**	**21–35 (n = 196)**	**≥36 (n = 196)**
Mean ± standard deviation	—	0.16 ± 0.29	0.16 ± 0.21	0.17 ± 0.22	0.18 ± 0.21	0.24 ± 0.26

[*] The five largest categories are quintiles of the distribution of the number of lane changes encountered for participants with at least one lane change.

Table 4

Univariate Models Predicting Rate Lane-Change Failure for 980 Participants Encountering Lane Changes at Round 3

Characteristic	Incidence Rate Ratio (95% Confidence Interval)
Demographic	
Age (per unit increase)	1.00 (0.99–1.02)
Female (vs male)	1.10 (0.92–1.32)
African American (vs other)	1.27 (0.97–1.67)
Education (per unit decrease)	1.06 (1.02–1.10)*
Rural (vs urban)	1.55 (1.29–1.86)*
Medical history and self-reported distress	
History of arthritis	0.76 (0.57–1.01)
History of stroke	1.68 (0.92–3.07)
Pain score (range 0–5) (per unit increase)	1.03 (0.93–1.13)
Perceived stress mean score (range 0–4) (per unit increase)	1.06 (0.91–1.24)
Geriatric Depression Scale score (range 0– 30) (per unit increase)	1.02 (0.99–1.04)
Cognition	
Mini Mental State Examination score (range 0–30) (per unit decrease)	1.04 (1.00–1.09)
Brief Test of Attention score (range 0–10) (per unit decrease)	1.07 (1.04–1.11)*
Hopkins Verbal Learning Test Trials 1–3 score (range 0–36) (per unit decrease)	1.01 (1.00–1.03)*
Hopkins Verbal Learning Test Delayed Recall score (range 0–12) (per unit decrease)	1.03 (1.00–1.05)*
Tower of Hanoi, number of moves (per unit increase)	1.01 (1.00–1.03)
Trail Making Test, part B, time in seconds (per 10-unit increase)	1.02 (1.01–1.03)*
Visual-Motor Integration score (range 0–24) (per unit decrease)	1.05 (1.02–1.07)*
Visual function	
Visual acuity (per line loss)	1.01 (0.93–1.09)
Contrast sensitivity, number of letters read (per unit decrease)	1.01 (0.97–1.05)
Bilateral visual fields, number of points missed (per unit increase)	1.01 (0.99–1.03)
Visual attention, ° (per unit decrease)	
Vertical extent	1.02 (1.00–1.04)*
Horizontal	1.03 (1.01–1.04)*
Average extent	1.03 (1.01–1.04)*

*Significant predictor of lane changes.

Table 5

Multivariate Model Predicting Rate of Lane-Change Failure for 981 Participants Encountering Lane Changes at Round 3

Characteristic	Relative Incidence of Lane-Change Failures (95% Confidence Interval)
Demographics	
Age (per unit increase)	1.00 (0.98–1.02)
Female (vs male)	1.19 (1.00–1.42)
African American (vs other)	1.05 (0.80–1.38)
Education (per unit decrease)	1.03 (0.99–1.06)
Rural (vs urban)	1.55 (1.29–1.86)*
Cognition	
Brief Test of Attention score (range 0–10) (per unit decrease)	1.06 (1.02–1.10)*
Visual-Motor Integration score (range 0–24) (per unit decrease)	1.03 (1.00–1.06)*

*Significant predictor of lane changes.