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# Traffic Violations Versus Driving Errors of Older Adults: Informing Clinical Practice

Sherrilene Classen, Orit Shechtman, Kezia D. Awadzi, Yongsung Joo, Desiree N. Lanford

## KEY WORDS

- accidents, traffic
- aged
- aged, 80 and over
- automobile driving
- risk

Certain driving errors are predictive of crashes, but whether the type of errors evaluated during on-road assessment is similar to traffic violations that are associated with crashes is unknown. Using the crash data of 5,345 older drivers and expert reviewers, we constructed a violation-to-error classification based on rater agreement. We examined the effects of predictor variables on crash-related injuries by risk probability using logistic regression. Drivers' mean age was 76.08 (standard deviation = 7.10); 45.7% were women. Of drivers, 44.6% sustained crash-related injuries, and female drivers had a higher injury probability (44%) than male drivers (29%). Lane maintenance, yielding, and gap acceptance errors predicted crash-related injuries with almost 50% probability; speed regulation (34%), vehicle positioning (25%), and adjustment-to-stimuli (21%) errors predicted crash-related injuries to a lesser degree. We suggest injury prevention strategies for clinicians and researchers to consider for older drivers, especially older women.

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**Sherrilene Classen, PhD, MPH, OTR/L**, is Assistant Professor, Department of Occupational Therapy, College of Public Health and Health Professions; Adjunct Assistant Professor, Department of Epidemiology and Biostatistics; Affiliate Assistant Professor, Department of Behavioral Science and Community Health, College of Public Health and Health Professions; and Director, Institute for Mobility, Activity and Participation and the National Older Driver Research and Training Center, University of Florida, PO Box 100164, Gainesville, FL 32611-0164; sclassen@php.ufl.edu

**Orit Shechtman, PhD**, is Associate Professor, Department of Occupational Therapy, College of Public Health and Health Professions, and an affiliated researcher with the Institute for Mobility, Activity and Participation and the National Older Driver Research and Training Center, University of Florida, Gainesville.

**Kezia D. Awadzi, PhD**, is Postdoctoral Associate, Department of Occupational Therapy, College of Public Health and Health Professions, and an affiliated researcher with the National Older Driver Research and Training Center, University of Florida, Gainesville.

**Yongsung Joo, PhD**, is Assistant Professor, Department of Statistics, Dongguk University, Seoul, Korea.

**Desiree N. Lanford, MOT, CDRS**, is Staff Occupational Therapist, Department of Occupational Therapy, College of Public Health and Health Professions, and Certified Driving Rehabilitation Specialist, Institute for Mobility, Activity and Participation and National Older Driver Research and Training Center, University of Florida, Gainesville.

As the U.S. population ages, older driver safety continues to evoke public health concern. In 2005, of the 29 million licensed drivers  $\geq$  age 65 in the United States, 177,000 experienced nonfatal injuries and 3,086 sustained fatal injuries from motor vehicle crashes (Centers for Disease Control and Prevention [CDC], 2007, 2008; National Highway Traffic Safety Administration, 2008). On the basis of the number of miles driven, this figure is higher than for most other age groups. When adjusted on the basis of number of miles driven, older drivers ( $\geq 65$ ) have lower crash rates than younger drivers, but because of age-related frailty, older drivers are at an increased risk for crash-related injury or death (Awadzi, Classen, Hall, Duncan, & Garvan, 2008; Bédard, Guyatt, Stones, & Hirdes, 2002).

In addition to a higher risk of crash-related injuries and fatalities, a sex effect is apparent for older drivers. For example, the rate for motor vehicle-related injury was twice as high for older men as for older women (Stamatiadis, 1996; Stevens & Dellinger, 2002), but the proportion of fatalities was higher for older women (Awadzi et al., 2008; Baker, Falb, Voas, & Lacey, 2003). In fact, researchers have projected that from 1975 to 2015, the number of motor vehicle fatalities involving older female drivers will increase by 373% compared with a 271% increase for older male drivers (Bédard, Stones, Guyatt, & Hirdes, 2001). Consequences of motor vehicle crash-related injuries and fatalities extend beyond the loss of function and life to a major impact on health care and economic costs. For example, the estimated annual cost of crash-related injuries and deaths (across all ages) exceeds \$150 billion, contributing greatly to the national health care costs burden (CDC, 2005).

As such, occupational therapists—generalists and driving rehabilitation specialists (DRSs) alike—can play a major role in identifying drivers at risk

(American Occupational Therapy Association, 2004a, 2004b, 2005). Through appropriate screening (generalist function) and driving evaluation and rehabilitation (DRS function), they can help to identify unsafe drivers, make recommendations to clients who need to stop driving, provide intervention strategies for those with remedial potential, and assist others with optimizing driving skills that may be affected by age-related conditions. To better accomplish this mission, occupational therapists need to more clearly understand the nature of driving errors underlying crash-related injuries and adapt their driving evaluation practices accordingly—that is, to identify, manage, and prevent such errors appropriately.

## Crashes and Driving Errors

### *Crashes*

With about 20% of its drivers being  $\geq$  age 65, Florida emulates the U.S. 2030 demographics, when 25% of drivers are expected to be  $\geq$  age 65. Florida is a model state for older driver research and lends itself well to studying crash and driving error characteristics among older drivers (Classen & Awadzi, 2008).

A *crash* constitutes a culmination of events, such as making critical driving errors (e.g., not stopping), driving in adverse environmental conditions (e.g., poor visibility), or driving a vehicle that is not well maintained (e.g., brake failure; Braitman, Kirley, Ferguson, & Chaudhary, 2007; Classen, Awadzi, & Mkanta, 2008; Reason, Manstead, Stradling, Baxter, & Campbell, 1990; Stamatiadis, 1996; Stamatiadis, Jones, & Aultman-Hall, 1999). In analyzing crash data sets, researchers found that driving errors underlie crash involvement for older adults. Such errors include seeing another vehicle but misjudging the time available to proceed, failing to yield the right of way, making improper turns or improper stops, failing to see another vehicle, and speeding (Awadzi et al., 2008; Bédard et al., 2002; Braitman et al., 2007; Classen et al., 2008; Stamatiadis, 1991, 1996; Stamatiadis et al., 1999).

Violations that result in crashes and crash-related injuries or fatalities can be determined from a state crash database. One such database is the 2005 Florida Traffic Crash Records Database (2005 FTCRD; Florida Department of Highway Safety and Motor Vehicles, 2005). This database contains crash data submitted by law enforcement officers under the following conditions: when a crash results in death or personal injury; a driver leaves the scene of a crash after damage to a vehicle or property; or a driver is under the influence of alcohol, drugs, or chemical substances, resulting in an unlawful blood alcohol level.

### *Driving Errors*

DRSs, who are generally occupational therapists with advanced training, assess driving errors during a comprehensive driving evaluation, which includes administering a battery of off-road clinical tests and an on-road driving assessment. Although no uniform driving assessment exists, this comprehensive driving evaluation is considered the criterion to indicate fitness to drive (DiStefano & Macdonald, 2005; Reimer, D'Ambrosio, Coughlin, Kafriksen, & Biederman, 2006). During an on-road assessment, driving errors are recorded by assigning a performance score that represents a variety of maneuvers, such as lane maintenance, speed, and positioning (Classen, Schectman, et al., 2007; DiStefano & MacDonald, 2003).

The National Older Driver Research and Training Center has implemented a comprehensive driving assessment on the basis of experts' opinions obtained through an international consensus conference (Stephens et al., 2005). The road course has been standardized (Justiss, 2006), rater agreement has been established (Posse, McCarthy, & Mann, 2006), and predictability of clinical tests to passing or failing the road course has been reported (Stav, Justiss, McCarthy, Mann, & Lanford, 2008). In this on-road assessment, driving errors were identified as vehicle position, lane maintenance, speed regulation, yielding, signaling, adjustment to stimuli or traffic signs, gap acceptance, and visual scanning. These driving errors are described in detail elsewhere (Justiss, 2006) but may be defined as follows:

- *Vehicle position*: the position of the vehicle (anterior or posterior) in relation to other vehicles or objects and pavement markings, including following distance during forward movement and vehicle spacing during lane changes and merges. An example of such an error is inadequate space cushion during merge or lane change.
- *Lane maintenance*: the lateral positioning of the vehicle during driving maneuvers (turns, straight driving, lane changes) and while stopped, indicating the ability to maintain steering control. An example of such an error is drifting out of the driving lane.
- *Speed regulation*: the ability to follow and maintain speed limits and maintain adequate control of the vehicle's acceleration and braking features. An example of such an error is traveling too slow or too fast.
- *Yielding*: giving the right of way when appropriate, indicating the ability to recognize common rules of road safety. Yielding is assessed at four-way or two-way stop intersections, right turns on red, and merges.

- *Signaling*: the proper use of turn signals. An example of such an error is leaving the turn signal on or not using the turn signal when turning.
- *Adjustment to stimuli and traffic signs*: the ability to appropriately respond to driving situations such as changing road sign information, vehicle movements, pedestrian movements, or potential hazards. An example of an error is choosing an improper lane from posted signage or an improper response to traffic or pedestrian movement.
- *Gap acceptance*: choosing an appropriately safe time, spacing distance, or both to cross in front of oncoming traffic, such as during an unprotected turn. An example of such an error is faulty driver judgment in estimating distances that are either too short or too long for the given speed and distance to be traveled.
- *Visual scanning*: demonstrating visual scanning of the driving environment. An example is not checking the blind spot or not looking left and right before proceeding through intersection.

### *Rationale and Significance*

Although certain driving errors are known to be predictive of crashes, whether types of driving errors evaluated during on-road assessments are similar to those associated with traffic violations or crashes is yet unknown. A gap exists in relating driving violations identified in crashes to driving errors identified during an on-road assessment. Our purpose in this project was to examine whether violations that occurred during crashes are related to driving errors and whether violations can be classified into driving errors committed during an on-road driving assessment and then to quantify how those driving errors predict crash-related injuries. We proposed to do so by using a state crash database, the 2005 FTCRD, and operational definitions of driving errors used in the National Older Driver Research and Training Center's on-road driving assessment (Justiss, 2006). Our findings will inform occupational therapists of the type and probability of driving errors predictive of crash-related injuries. As such, we can recommend potential strategies for driving evaluation and rehabilitation practice and suggest future research opportunities for injury prevention among older drivers.

### *Objective*

Our objective was to elucidate the practical meaning of driving errors associated with crash-related injuries as it pertains to occupational therapy practice by (1) using Monte Carlo simulations to match violations associated with crashes to driving errors committed during on-road assessments; (2) quantifying the effects of age, sex, and types

of violations (expressed as driving errors) on crash-related injury; and (3) identifying the probability of violations (expressed as driving errors) to predict crash-related injuries.

## **Method**

This study was approved by the university's institutional review board.

### *Procedure*

From the 2005 FTCRD's driver population of 526,833, we excluded drivers who were < age 65; those in crashes involving other than motor vehicles (*motor vehicles* include automobiles, vans, light trucks, or pickups); those involved in nighttime crashes (to allow for the same conditions, i.e., daytime driving, between the 2005 FTCRD and the National Older Driver Research and Training Center data sets); and those who had missing data on age, sex, and injury severity. Using those criteria, the final sample consisted of 5,345 older drivers.<sup>1</sup>

To achieve the first objective of matching driving violations recorded in the 2005 FTCRD to driving errors, we identified 32 driving violations from the database and presented those electronically to three experts knowledgeable of driving violations and driving errors. The experts consisted of the Florida Highway Patrol's most senior commander (who had 15 yr of law enforcement experience) and two occupational therapists: one certified DRS with 6 yr experience and one occupational therapist trained in driving evaluation with 2 yr experience. We provided operational definitions for each driving error and asked the expert raters to choose up to 2 of the 7 driving error types (i.e., vehicle positioning, lane maintenance, speed regulation, yielding, signaling, adjustment to stimuli, gap acceptance) that matched each violation. Examples of violations can be viewed in Table 1. We instructed the raters to select only 1 driving error for a given traffic violation if they believed with great confidence that only this one error was related to the violation.

On the basis of the raters' responses, we assigned matching points to each error. When a rater chose two errors, we assigned 1 point to each error. When a rater chose only one error, we assigned 2 points to the error. Then, to calculate the total scores, we summed points from all three raters for each driving error. For example, for the traffic violation of failing to yield for an emergency vehicle, Rater 1 chose the driving errors yielding and adjustment to stimuli or traffic signs as corresponding

<sup>1</sup>A procedure for database management of the 2005 FTCRD is on file with the first author of this study (Classen).

driving errors, but Rater 2 and Rater 3 chose only adjustment to stimuli or traffic signs. Thus, 5 points were assigned to adjustment to stimuli or traffic signs; 1 point to yielding; and 0 points to the other errors. In summary, according to our system of matching errors and violations, we can say that the violation of failing to yield for an emergency vehicle has the strongest relationship to the driving error adjustment to stimulus or traffic signs because it had the best rater matching and therefore the best score. In a similar way, all the other traffic violations were matched to a driving error.

After the first round of expert ratings and matching, we selected the violation-to-error classifications with a low level of rater endorsement (score <4). The violation-to-error classifications included failed to yield, failed to stop, right turn on red light, improper turn or u-turn, and improper backing up. Using this set of classifications, we asked the raters to reclassify the violation into one driving error type. The expert raters had complete agreement on failed to yield but not on any of the other violations; we therefore used failed to yield and all the violation-to-error classifications from the first round of reviews in the subsequent analyses, whereas we excluded other driving error categories.

In summary, on the basis of study criteria we selected 32 violations that were classified by three expert raters into seven types of driving errors. We selected the violation-to-error classification with a high level of matching agreement as described during a first and second review by the expert raters (first round: selected ratings with a score  $\geq 4$ , range = 1–6; second round: violation-to-error classification was selected with perfect agreement among raters). This procedure helped us discern, on the basis of expert opinion, the violation-to-error classifications that we used in subsequent analyses.

## Analyses

We used SAS 9.1 (SAS Institute, Cary, NC) for all statistical analyses. For Objective 1, we determined the significance of the relationship between a traffic violation and the highest matching score for each of the seven driving errors as explained in the Procedure section. Using Monte Carlo simulations (a problem-solving technique used to approximate the probability of certain outcomes by running multiple trial runs or simulations with random variables), we calculated the probability of having a specific score when three raters chose two driving errors at random. The probabilities for rater scores (1–6) were as follows: 1 = .044, 2 = .669, 3 = .252, 4 = .033, 5 = .002, and 6 < .001. When the choices of raters was not random

(i.e., raters easily classified a violation into a driving error), the best score should be high. Therefore, a score of  $\geq 4$  has a probability of .0347 (.0326 + .0021 + .0000), which is >.05. We concluded at the first round of reviews that a driving error is found to be significantly related to a traffic violation when the best score assigned by raters is  $\geq 4$  (Table 1).

For Objective 2, we computed the descriptive statistics using Proc Univariate (Table 2). Next we used  $\chi^2$  to identify the main predictors of injury (yes–no) after a crash, and from those statistically significant results we performed logistic regression analysis using Proc Genmod (Table 3–5). Logistic regression analysis presents the odds ratios at the 95% confidence interval level for demonstrating the probability of each independent variable to predict crash-related injury (Table 3). For Objective 3, we used the lsmean function to calculate the mean probabilities of each error category to predict crash-related injury (Table 4). Using the pdiff function, we conducted pairwise comparisons of driving errors by probabilities of sustaining a crash-related injury (Table 5).

## Results

Table 1 presents the driving violations classified into driving errors, with the rater agreement (expressed as a matching score) and the probability ( $p < .05$ ) of non-random rater choice. The violations are expressed in number and percentage of the sample who committed the violation ( $N = 5,345$ ). The highest frequencies of violations occurred for failed to yield, failed to obey required traffic control, and speed. With the exclusion of signaling, violation-to-error classification chosen by raters represented all the other driving error types. These violation-to-error classifications were endorsed (matching score of  $\geq 4$ , range = 4–6) by all raters at a level of agreement beyond chance ( $p < .05$ ).

Table 2 presents summary statistics of demographic variables for the drivers  $\geq$  age 65 in the 2005 FTCDR ( $N = 5,345$ ). The mean age was 76.08 (standard deviation = 7.10), with 2,445 (45.7%) women. The three highest frequencies of driving errors were yielding, 4,179 (78.2%); gap acceptance, 406 (7.6%); and speed regulation, 394 (7.4%). Crashes resulted in 2,382 (44.6%) drivers being injured.

Using  $\chi^2$ , we identified the main predictors of injury (yes or no) after a crash. Significant predictors were sex (female,  $\chi^2[1] = 138.96$ ,  $p < .0001$ ), driver age (older drivers,  $\chi^2[1] = 12.5$ ,  $p < .0004$ ), and driving errors ( $\chi^2[5] = 74.37$ ,  $p < .001$ ). (For all  $\chi^2$  analyses,  $N = 5,345$ .)

**Table 1. Driving Violations by Frequency (Percentage) With Corresponding Driving Errors and Probability of Raters' Agreement Beyond Chance**

Violations From 2005 FTCDR	<i>n</i>	%	Violation-to-Error Classification Chosen by Raters	Rater Agreement Expressed as a Matching Score (Range = 0–6)	<i>p</i> (Rater Agreement Beyond Chance)
Failed to yield (all)	4,165	78	Yielding	Agreement after the 2nd round of reviews	NA
Left turn	1,569				
Intersection	1,116				
Alley or driveway	448				
Failed to yield	1,032				
Failed to obey required traffic control device	406	7.6	Gap acceptance	6	<.001
Speed related	395	7.4	Speed regulation	6	<.001
Following too closely	166	3.1	Vehicle positioning	5	.002
Failure to drive in single lane	96	1.8	Lane maintenance	5	.002
Pedestrian violations	46	0.9	Adjustment to stimuli	4	.033
Failed to yield for emergency driver	18	0.3	Adjustment to stimuli	5	.002
Violation of right of way	14	0.3	Yielding	5	.002
Violation of flashing light	13	0.2	Adjustment to stimuli	4	.033
Improper parking	8	0.1	Adjustment to stimuli	6	<.001
Parking on highway	6	0.1	Adjustment to stimuli	4	.033
No passing zones	5	0.1	Adjustment to stimuli	6	<.001
Passed a stopped school bus	3	0.1	Adjustment to stimuli	5	.002
Driving in wrong direction on one-way	2	0.0	Adjustment to stimuli	6	<.001
Drive through safety zone	2	0.0	Adjustment to stimuli	5	.002
Failed to yield to flagman or worker	1	0.0	Adjustment to stimuli	4	.033

Note. *N* = 5,345; FTCDR = Florida Traffic Crash Record Database; NA = not applicable.

Table 3 presents logistic regression results and a summary of each independent variable as a predictor of injury. We noted that for every 1-year increase in driver's age, the odds of injury increased by 1% ( $p < .001$ ). Men had 48% lower odds ( $p < .0001$ ) of being injured in a crash than did women. Compared with vehicle positioning (reference group), the errors of lane maintenance, yielding, gap acceptance, and speed regulation were all statistically significant predictors of postcrash injuries.

Table 4 presents the mean crash-related injury probability ( $p \leq .05$ ) of each independent variable. From this table, one can clearly see that female drivers have a higher probability (44%) than male drivers (29%) of being injured in a crash. The driving errors lane maintenance, yielding, and gap acceptance mostly predicted crash-related injuries with an almost 50% probability, whereas speed regulation (34%), vehicle positioning (25%), and adjustment to stimuli (21%) predicted crash-related injuries to a lesser degree.

Table 5 presents pairwise comparisons of crash-related injury probabilities among groups of driving errors. From this table, one finds that lane maintenance, yielding, and gap acceptance have similar (but not significantly different) probabilities for predicting postcrash injuries. These errors, however, have significantly higher probabilities of injuries than do speed regulation, vehicle position, and adjustment to stimuli or traffic signs. Also,

speed regulation has a significantly higher probability of injury than vehicle position or adjustment to stimuli or traffic signs. We surmise that three groups of errors exist: those with high probability for injury, which include lane maintenance, yielding, and gap acceptance; those with moderate probability for injury, which include speed regulation; and those with low probability for injury, which include vehicle position and adjustment to stimuli or traffic signs.

## Discussion

Our objective in this study was to elucidate the practical meaning of driving errors that are associated with

**Table 2. Descriptive Statistics for Age, Sex, Error Type, and Injury Outcomes in the 2005 Florida Traffic Crash Records Database**

Demographics	<i>M</i> ( <i>SD</i> ) or <i>n</i> (%)
Age years; <i>M</i> [ <i>SD</i> ]	76.08 (7.10)
Female ( <i>n</i> [%])	2,445 (45.7)
Errors ( <i>n</i> [%])	
Yielding	4,179 (78.2)
Gap acceptance	406 (7.6)
Speed regulation	394 (7.4)
Vehicle positioning	166 (3.1)
Adjustment to stimuli or traffic signs	104 (1.9)
Lane maintenance	96 (1.8)
Injury (yes; <i>n</i> [%])	2,382 (44.6)

Note. *N* = 5,345; *M* = mean; *SD* = standard deviation.

**Table 3. Logistic Regression Results for Each Independent Variable Predicting Crash-Related Injury**

Variable	Degree of Freedom	Estimate	Standard Error	Confidence Interval		<i>p</i>	Odds Ratio
				Lower Bound	Upper Bound		
Intercept		-1.86	0.35	0.08	0.31	<.0001	
Driver age		0.01	0.00	1.01	1.02	<.001	1.01
Sex							
Male	1	-0.66	0.06	0.46	0.58	<.0001	0.52
Female (reference category)	0	0.00	0.00	1.00	1.00	—	—
Errors							
Vehicle positioning (reference category)	0	0.00	0.00	1.00	1.00	—	—
Yielding	1	1.01	0.19	1.91	3.98	<.0001	2.76
Gap acceptance	1	0.99	0.21	1.78	4.07	<.0001	2.69
Speed regulation	1	0.47	0.21	1.06	2.45	.03	1.61
Adjustment to stimuli or traffic signs	1	-0.23	0.34	0.41	1.57	.51	0.80
Lane maintenance	1	1.09	0.28	1.72	5.11	<.0001	2.97

Note. *N* = 5,345. Dashes indicate no value.

crash-related injuries as it pertains to occupational therapy practice by (1) matching violations associated with crashes to driving errors committed during on-road assessments; (2) examining the effects of age, sex, and types of violations (expressed as driving errors) on crash-related injury; and (3) identifying driving errors as those with a high, moderate, or low probability to predict crash-related injuries.

This research provides, on the basis of expert raters' agreement, a framework for classifying violations to driving errors. This information is useful for occupational therapists when reviewing the performance patterns of older adults, such as driving history or violation records (Classen et al., 2008). For example, a violation of failed to obey a required traffic control device may be interpreted on the basis of our results as potential for having difficulty with gap acceptance. Further but more focused testing of client factors (e.g., cognition), performance skills (such as visual perception), activity demands (such as sequencing and timing), or contextual demands (such as roadway dynamics) underlying such a driving error may be necessary. In this way, occupational therapists (generalists and specialists) may discern the underlying challenges for the older adult and choose adequate intervention strategies to best address such challenges.

The age and sex demographics presented are in line with current older driver crash literature (Bédard et al., 2002; Classen et al., 2008; Classen, Schectman, et al., 2007). Crash studies have shown evidence that some errors may be similar to those we identified, for example, misjudging adequate time to proceed (failure to yield or gap acceptance errors); failing to see another vehicle (adjustment to stimuli; Braitman et al., 2007); insufficient searching for visual information (adjustment to stimuli); and attention errors (gap acceptance or yielding errors; Bédard et al., 2002; Braitman et al., 2007; Larsen,

2004; Larsen & Kines, 2002). Our study, however, found overwhelmingly that about 50% of the older drivers who were involved in a crash sustained injuries and that approximately 80% of those drivers had potentially committed a yielding error.

The main predictors of injury—that is, advancing age, female sex, and five types of driving errors—are well supported by previous crash literature (Awadzi et al., 2008; Bédard et al., 2002; Braitman et al., 2007; Classen et al., 2008; Larsen, 2004; Stamatiadis, 1996; Stamatiadis et al., 1999; Stamatiadis, Taylor, & Mckelvey, 1991). What is particularly significant is that the client factor of female sex demonstrates a high risk for injuries. This finding must compel occupational therapists to better understand the activity demands embedded in the driving task as it pertains to older female drivers.

For example, the social demands of older female drivers are different from those of older male drivers. Generally, in their cohort and within their cultural context, older women are not the primary drivers in their household. Older women, however, more often outlive

**Table 4. Mean Probability of Each Independent Variable to Predict Crash-Related Injury at the *p* ≤ .05 Level**

Independent Variable	Estimate	Standard Error	Mean Probability of Postcrash Injury
Male	-0.90	0.08	0.29
Female	-0.24	0.08	0.44
Vehicle positioning	-1.12	0.19	0.25
Yielding	-0.11	0.03	0.47
Gap acceptance	-0.14	0.10	0.47
Speed regulation	-0.65	0.11	0.34
Adjustment to stimuli or traffic signs	-1.35	0.29	0.21
Lane maintenance	-0.04	0.21	0.49

**Table 5. Pairwise Comparisons (*p* Values) of Driving Errors by Probability of Sustaining a Crash-Related Injury**

Group	1	2	3	4	5	6	7
1. Probability of injury	—	.49	.47	.47	.34	.25	.21
2. Lane maintenance	.49	—	.73	.67	.009	<.0001	.0002
3. Yielding	.47	.73	—	.81	<.0001	<.0001	<.0001
4. Gap acceptance	.47	.67	.81	—	.0005	<.0001	<.0001
5. Speed regulation	.34	.0088	<.001	.0005	—	.027	.024
6. Vehicle positioning	.25	<.0001	<.0001	<.0001	.027	—	.51
7. Adjustment to stimuli	.21	.0002	<.0001	<.0001	.02	.51	—

*Note.* Dashes = not applicable. Nonstatistically significant values have been rounded off to the second decimal.

their spouses (Foley, Heimovitz, Guralnik, & Brock, 2002). The question is, How do decreased driving skills and a continued need to stay independent with community mobility relate to crash-related injuries? Also, older women may be more physically frail than their male counterparts, specifically considering that osteopenia and hand grip strength are biomarkers of physical frailty and older women may perform worse on those indicators than men (Klein, Klein, Knudtson, & Lee, 2003). As such, occupational therapists may want to consider personal protective adaptations or client education on crash and injury prevention specifically for older female drivers. Moreover, occupational therapists may make a significant contribution in recognizing older female drivers as a high-risk group and perhaps intervene primarily with role competence strategies (e.g., practice opportunities for behind-the-wheel training to increase driving skill) or self-efficacy training (e.g., experiential learning) or motor learning (e.g., relearning of driving-related maneuvers), and in so doing prevent crashes and related injuries. These suggestions must translate into future research to study the effects of such strategies in preventing crash-related injuries among older female drivers.

Compared with vehicle positioning (reference group), the results for the errors lane maintenance (odds ratio [OR] = 2.97), yielding (OR = 2.76), and gap acceptance (OR = 2.69) indicate that drivers had almost 3 times higher odds—and for speed regulation (OR = 1.61) almost 2 times higher odds—of incurring crash-related injuries. Occupational therapists may prioritize focusing on these errors and incorporate strategies (e.g., remediation of performance skills deficits) to improve out-of-practice driving skills underlying such errors. Prevention strategies may include reeducating the older driver on the activity demands (e.g., importance of sharing the road with other motorists, cyclists, or pedestrians) and contextual demands (e.g., obeying road and overhead signs at intersections) underlying these errors.

The implications of driving error probabilities for injury must receive attention from occupational therapists so that they can adapt their practices accordingly. We can think of six direct implications for practice:

1. DRSs need to pay special attention to high-probability errors resulting in injury, that is, lane maintenance, yielding, and gap acceptance errors. These errors must be carefully evaluated as a high-risk category during on-road assessments and be noted as such.
2. Client factors (such as body structures, e.g., frailty), performance skills (such as motor skills, e.g., response time), process skills (e.g., processing speed), and contextual characteristics (e.g., demands of the physical roadway environment) underlying these errors must be evaluated, identified, and remediated.
3. DRSs should weight their on-road assessment scoring system to account appropriately for errors with a high probability of injury.
4. Drivers who make errors that fall within this category, and their family members and physicians, need to be educated on the potential risks associated with such errors.
5. Drivers prone to making these errors must be referred to a driving rehabilitation program for remediation of client factors (e.g., behind-the-wheel training), adaptation to the vehicle (e.g., adjustment to seat height for proper positioning), or referral to other specialists providing interventions (e.g., ophthalmologist).
6. If the errors are irremediable, as determined in follow-up evaluations, more rigorous steps should be taken, such as recommending the use of alternative forms of transportation or driving cessation.

The errors with a moderate probability for injury (i.e., speed regulation) and low probability for injury (vehicle position and adjustment to stimuli) should not be ignored but should perhaps be weighted at a lower level of risk than those with a high probability. Likewise, remediation, compensation, and adaptation strategies, as well as

prevention strategies (referral, education), must be considered in addressing the specific performance skills, performance patterns, client factors, contextual demands, and activity demands underlying such driving errors.

The biggest limitation of this cross-sectional study is that occurrences were measured at one point in time during 2005, which introduces the possibility of bias through over- or underestimation of the risk for crash-related injury. Although temporality cannot be inferred, our findings are in line with those of other crash studies documented in the older driver literature, which suggests the plausibility of our work. Crashes may be underrepresented in this study and may thus influence the validity of the data. Our inclusion criteria focused on a subset of crashes, and we excluded crashes occurring during night driving, occurring as a criminal offense (e.g., driving under the influence of alcohol), or committed during nonmoving violations (e.g., getting a parking ticket); thus, this information can only be generalized to a group that meets this study's inclusion criteria.

Of course, we cannot infer cause and effect from the predictor variables. For example, we do not know exactly why (more severe crash involvement or frailer body types) older female drivers have a higher risk of sustaining crash-related injuries. However, by studying older female drivers further in prospective research or cohort studies, we may better understand how crash-related injuries can be prevented or be able to identify specific injury prevention strategies for older female drivers and the oldest old drivers. In essence, this research opens an opportunity for occupational therapy clinicians and researchers to embark further on examining crash-related injury prevention strategies for older drivers, particularly older female drivers.

## Conclusion

This research helps occupational therapists to understand the meaning of traffic violations generally assessed by law enforcement officers in terms of potential driving errors that may occur. Identifying the probability with which driving errors contribute to crash-related injuries suggests that occupational therapists can engage in more focused clinical testing of the client factors, performance skills, context demands, and activity demands underlying these errors.

Female drivers emerge as a high-risk group for crash-related injuries. Further empirical evidence is necessary to elucidate whether older female drivers are making different types of errors than male drivers. We also need to better understand the client factors and social demands that contribute to older female drivers' increased risk for crash-

related injuries. We have suggested strategies for clinicians to help prevent crash-related injuries among older female drivers, but their effectiveness requires further testing in research.

Lane maintenance, yielding, gap acceptance, and speed regulation are errors that independently predict crash-related injury. The first three errors indicate a high probability for injury, whereas speed regulation indicates a moderate probability for injury and vehicle positioning and adjustment to stimuli a low probability. This is, to our knowledge, the first time that specific errors have been quantified in terms of a probability for crash-related injury outcomes. We have suggested guidelines for driving evaluators that may improve the measurement of driving errors and clinical guidelines that therapists may follow to help prevent crash-related injuries. We have also created opportunities for future researchers to test the effectiveness of such strategies. ▲

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