PREDICTORS OF INJURY AMONG YOUNGER AND OLDER ADULTS IN FATAL MOTOR VEHICLE CRASHES

Name: Kezia D. Awadzi
Adviser: Sherrilene Classen

Summary (99 words)

I examined relationships among specified (health, behavior, environment, predisposing and reinforcing) predictors of motor vehicle injuries among younger and older drivers in the United States. With logistic regression analysis, I compared younger drivers (35–54 years old) and older drivers (65 years and older). The dependent variable was injury (no/yes). There were 20 statistically significant associations—4 associations with age-interactions with 16 main effects.

Many of the findings showed relevance to drivers from both age groups, with some pointing to older adults, meaning that injury prevention measures, when developed and implemented, may potentially benefit older and younger drivers alike.

Description

In January 2005, I began work as a Research Assistant in the *Public Health Model to Promote Safe Elderly Driving Project* funded by the Centers for Disease Control and Prevention [(# K01 CE000497 (2004 - 2007)]. The project has three aims: 1) to conduct a systematic literature review on older drivers and ascertain risk and protective factors to older driver safety 2) based on the systematic literature review, study the predictors using national secondary databases (quantitative and qualitative), and 3) plan an intervention study for safe driving. Over the past two years, I have been involved in all aspects of the project. As a team, we developed a data capture tool for the systematic literature, tested its psychometric properties and conducted a systematic literature review of 201 studies. Using a mixed-methods approach, we analyzed the results which have been disseminated through conference presentations and publications. My major contribution to the aging field has been in the secondary database analyses. I analyzed two secondary national crash databases: The 2003 General Estimates System (GES) and the 2003 Fatality Analysis Reporting System (FARS) databases (both managed by the National Highway Transportation and Safety Administration).

With the GES study, I examined the associations among risk and protective factors and injury outcomes among older drivers (65 years and older). I have published the findings in *Topics in Geriatric Rehabilitation*. My dissertation was based on the FARS study, and examined the risk and protective factors for injury outcomes among younger (35-54 years old) and older drivers (65 years and older). Findings from the FARS study have been presented at the 2006 Geriatric Society of America (GSA) conference, and have been submitted for review in *Traffic Injury Prevention*. My analyses were also triangulated with the qualitative results to offer a more complete representation on older driver safety issues.

I have been co-author on four publications involving older driver safety issues and have presented at the Geriatric Society of America (GSA) conference, the International Conference on Aging, Disability and Independence (where I won a scholarship to present my findings), the American Occupational Therapists Association (AOTA), and the College of Public Health and Health Professions Research Day.

Currently, I am assisting in planning an older driver crash and injury prevention program.

In the past two years I have taken courses (mainly independent studies) that have contributed my career in aging research. These courses include research method courses to select appropriate secondary databases for research, assess the psychometric properties of instruments, studying a public health model for older drivers (the Precede-Proceed Model of Health Promotion), and a course on the epidemiology of older driver injury prevention planning (RSD 6930 Section 0316: *Public Health Model for Injury Prevention: Program planning and evaluation*).

This research is based on my dissertation work. Dr. Sherrilene Classen was the supervisor. My dissertation committee members were Dr. R. Paul Duncan (Chair), Dr. Sherrilene Classen (Co-chair), Dr. Allyson Hall, and Dr. Cynthia Garvan. I started the data acquisition in January 2006 and completed the project in December 2006. This work was submitted for review to the *Traffic Injury Prevention* on February 12, 2007.

INTRODUCTION

In 2004, there were approximately 28 million licensed drivers age 65 and older in the U.S. (NHTSA, 2006a). However, with senior adults (65 years and older) projected to represent about 20% of the entire U.S. population by 2030 (He et al., 2005), we expect numbers of older adults licensed drivers to exceed 40 million older adult licensed drivers by 2020 (Centers for Disease Control and Prevention, 2005).

Older drivers (65 years and older) are more likely than other adult drivers to pose injury and fatality risks to themselves and other older passengers in their vehicle than the occupants of other vehicles in a crash (Braver & Trempel, 2004). Older driver are also more likely to die from their injuries compared to younger driver although they have less mileage exposure (Dellinger et al., 2002).

Older driver crashes often stem from risk factors such as motor, sensory, or cognitive declines as a result of the normal aging process (Carr, 1993), and unsafe behaviors may be associated with these related declines (Rizzo et al., 2000; Owsley et al., 1991; and Freeman et al., 2006). On the other hand, protective factors for older adults include wearing seatbelts and limiting their driving to favorable driving conditions compared with drivers of other age groups (Bauer et al., 2003), and fewer cases of driving under the influence of alcohol, or substance abuse (NHTSA, 2006b).

Older drivers are likely to be injured when involved in motor vehicle crashes, and their fragility due to age and pre-existing medical conditions, make them more likely to require hospitalization, longer and more expensive healthcare, and make a less complete recovery than drivers of other age groups (Richmond et al., 2002). Motor vehicle crashes are the second leading cause of traumatic brain injuries in the U.S. for older adult drivers, passengers, or pedestrians (Coronado et al., 2005). Thus, injuries sustained from motor vehicle crashes affect the older adults (quality of life and mortality), the healthcare sector, and economy of the United States.

Significance of the Study

This study reexamines the predicators of motor vehicle injuries following a crash from a socio-ecological perspective. Previous older driver studies have focused primarily on issues consistent with the health factors, or to a lesser extent on the environmental or behavior factors (Classen et al., 2006). Using an integrated socio-ecological approach to quantify the determinants of motor vehicle injury among older drivers will allow us to simultaneously identify the most significant risk and protective factors across various areas (e.g., behavior and environment), and identify how they predict injury. We therefore asked**,** to what degree are specified risk and protective factors associated with motor injury for younger (35 to 54 years) and older drivers (65 years and older) in the United States?

METHODS

The study used a cross-sectional design. We used a national secondary database, the 2003 Fatality Analysis Reporting System (FARS) dataset for the analyses (Department of Transportation [DOT], 2003). Created by the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration, FARS contains data on a census of traffic crashes on public roads within the 50 states, the District of Columbia, and Puerto Rico that resulted in a fatality up to 30 days after the crash. Although a crash is the unit of analysis for the FARS dataset, the unit of analysis in our study was the driver. FARS contains data for the period 1975-2005. We used the 2003 dataset because it was the latest year of available FARS crash data, and thus reflected current crash data at that point in time we conducted the study.

We included drivers 35 to 54 years (younger drivers), and drivers 65 years and older (older drivers). Subjects were excluded when there were age-related missing data; they were non-drivers of motor vehicles (e.g., passengers, pedestrians, and drivers of motorcycles); drove heavy trucks; drove vehicles with unknown body types; or they drove vehicles that do not normally travel on public roads (e.g., snowmobiles and farm equipment).

Procedure

The 2003 FARS database consisting of three main files—the *accident*, *vehicle*, and *person* files were downloaded from the NHTSA website. The files (initially in SAS format) were merged and converted into SPSS 14.0. After meeting the inclusion and exclusion criteria, the final sample was 19,782 drivers, comprising of 14,038 younger drivers (35 to 54) years of age, and 5,744 older drivers (65 and older). The data file consisted of 178 FARS variables. To better understand the relationship among variables, we used a socio-ecological model, the Precede-Proceed Model of Health Promotion (Green & Kreuter, 2005) as an organizing framework. Previous research on the Precede-Proceed Model of Health Promotion and older drivers is published elsewhere (Classen et al, 2006; Classen & Lopez, 2006; Awadzi et al., 2006).

The dependent variable was injury. In the FARS dataset, *injury severity* consisted of eight levels of categories (no injury, possible injury, non-incapacitating evident injury, incapacitating injury, fatal injury, injury—severity unknown, died prior to crash, and unknown if injured). For the purpose of analyses, we operationalized injury as whether a driver sustained an injury in the crash or not (injury: yes/no).

Independent variables were selected from 178 variables in the 2003 database. From the perspective of the socio-ecological model (PPMHP) used, these variables represented health (age, gender, race, physical and mental health conditions), behavioral (restraint system use, alcohol and drug use), environmental (e.g., point of impact the vehicle was struck, and number of passengers), predisposing (e.g., driver skill), and reinforcing (number of previous motor vehicle convictions within three years prior to the crash) items. We refined our selection of independent variables based on the percentage of missing data, by excluding variables that had more than 8% missing data. For accuracy in variable selection, we had team consultations throughout data examination, and consulted with a National Highway Traffic Safety Administration (NHTSA) database manager when necessary. To reduce multicolinearity and to select the variables that best described the factor of interest, we excluded those variables with similar definitions.

The final set of independent variables comprised of 32 variables representing five of the nine domains of the PPMHP (health, behavior, environment, predisposing, and reinforcing). We used descriptive statistics to examine data pertaining to all independent variables. In instances where a variable had many levels and the frequencies in most levels were few, we collapsed the data, after consultation and careful decision, into fewer levels. The independent variables within the context of the PPMHP, the type of variables, and number of levels, are illustrated in Table 1.

Insert Table 1 about here

Data analysis

We performed univariate, bivariate, and binary logistic regression analyses using SPSS 14.0 (SPSS, 2005). Univariate analyses provided information on data distribution, making it easier to see which variables needed to be collapsed and offered a means of variable selection for the binary logistic regression analysis. With bivariate analyses, we examined relationships between each independent variable and injury outcome. We used cross-tabulations for nominal data to examine levels within variables, and collapsed variable levels accordingly.

We used a binary logistic regression to obtain estimates for each independent variable and injury. In selecting the independent variables, we wanted a combination of variables that would result in the best model to answer the research questions. To test the interaction between the independent variables and injury, we used age as an interaction term with each independent variable.

RESULTS

Descriptives

About 77% of all drivers experienced some form of injury. The sample consisted of 71% younger drivers and 29% older drivers. For all drivers, 68.2% were male and 31.8% were female. The gender distributions among younger and older drivers were similar to that of the overall sample. A greater percentage of older drivers (85.4%) were injured compared with younger drivers (74.1%). About 67% of drivers wore some form of restraint at the time of the crash, with the majority of younger 64.5%, and even more older drivers (72.5%) wearing a form of restraint.

Bivariate

Results of the bivariate analyses indicate that almost all independent variables were statistically significant at $p \leq 0.05$. There was no statistically significant relationship among *day of week* and *injury* for younger drivers, and *license compliance* was not statistically significant for older drivers.

Binary Logistic Regression

Using independent variables selected from the bivariate analysis the regression model correctly classified 87.9% of cases in predicting injury outcomes. The Hosmer and Lemeshow test (p = 0.68), suggested that the model fit the data well. The Nagelkerke R-Square indicated that 57.2% of the variance in the model was explained by the data. All odds ratios were determined at the 95% confidence interval.

There were 20 statistically significant associations—4 associations with age-interactions with 16 main effects (Table 2). Findings are presented in the context of significant (1) age-interaction effects, (2) risk factors, and (3) protective factors.

Insert Table 2 about here

Age-interaction effects—Risk factor: Using the clock method, the 12 o'clock angle (front impact crashes) as the referent group, and two categories; the 1–3 o'clock angle (*OR* = 1.61; *CI*: 1.05–2.47) and the 7–9 o'clock angle (*OR* = 4.75; *CI* = 2.87–7.86) showed statistically significant risk for injury.

Age-interaction effects—Protective factors: *Number of passengers* and *registered vehicle owner* were marginally significantly associated with injury among older adults. Although marginally statistically significant, *number of passengers* was included among significant interaction effects because of its relevance in older driver literature. Drivers with two or more passengers were 40% less likely to be injured in a crash, (*OR* = 0.60; *CI*: 0.36–1.01) in comparison to older adults alone at the time of the crash.

Drivers who were not the registered vehicle owners were 53% (*OR* = 0.05; *CI*; 0.48–1.00) less likely to be injured in the crash compared to registered vehicle owners. Of the variables pertaining to the crash history of the driver, only *previous other motor vehicle convictions* (e.g., failure to yield and lane-related errors) was significantly associated with injuries (*OR* = 0.65; *CI* = 0.44-0.97) for older drivers.

Main risk factors: In comparison with collisions with an object that was not fixed, drivers who collided with a fixed object had 249 times the likelihood of being injured (*CI* = 152.61–408.03), while drivers in collision with other motor vehicles had 31 times the odds of being injured (*CI* = 23.82–40.31). Drivers in non-collision crashes were 266 times at risk of injury (*CI* = 155.37–454.32).

Risk behaviors (i.e., lack of restraint system use, driver drinking, and driver license compliance) were statistically significance for injury in a crash. Lack of *system restraint use* (e.g., seatbelt, lap belt) was highly associated with injury in a crash compared to drivers using a form of restraint during the crash (*OR* = 6.20; *CI* = 5.03–7.63), while *driver drinking* was associated with 2 times the risk of injury, in comparison to drivers who did not test positive for alcohol use at the time of the crash (*CI* = 1.57–2.54). Compared with SUVs, drivers of automobiles had a higher risk for injury (*OR* = 2.00; *CI* = 1.64–2.44). However, drivers of vans, trucks, and light pickups were 24% less likely to be injured (*OR* = 0.77; *CI* = 0.64–0.94).

Younger and older adults females had a higher risk of injury in motor vehicle crashes compared to males (*OR* = 1.51; *CI* = 1.29–1.73). Compared with crashes in dry roadway conditions crashes in adverse roadway conditions (e.g., snow, sleet, and rain) had 1.5 times the risk of injury (*CI* = 1.16–1.95). An invalid driver's license for the vehicle operated at the time of the crash was associated with an increased risk of injury (*OR* = 1.39; *CI* = 1.02–1.90).

Main protective factors: These included *airbag deployment*, *number of lanes*, *highway design*, *time of day*, *geographic location*, *national highway system*, *driver skill*, and *traffic control device*. The absence of airbag deployment was protective for injury in a crash, with drivers 75% less likely to be injured (*OR* = 0.25; *CI* = 0.21–0.29). Similarly, the absence of a functioning traffic control device was protective for crash injury (*OR* = 0.79; *CI* = 0.65–0.95). Compared to the nighttime hours, the daytime hours were protective for injury; 8 a.m.–1 p.m. (*OR* = 0.72; *CI* = 0.57–0.90), and 2 p.m.–8 p.m. (*OR* = 0.63; *CI* = 0.53–0.76). In relation to two-lane roads, crashes in one-lane roads was protective for injury (*OR* = 0.32; *CI* = 0.12–0.87). Crashes in urban areas was protective for injury compared to crashes in the rural area (*OR* = 0.61; *CI* = 0.52–0.71), while intersection-related crashes was protective for injury (*OR* = 0.59; *CI* = 0.48–0.72). However, interchange-related crashes were not statistically significant.

Actions taken by the driver before initiation of the crash indicated that compared to going straight, drivers in lane-related crashes (e.g., changing lanes or passing) were less likely to be injured. (*OR* = 0.64; *CI* = 0.50–0.81). These lane related crashes entailed maneuvers such as making a right, making a U-turn, parking or leaving a parked position, making a controlled maneuver to avoid an object, backing up (*OR* = 0.59; *CI* = 0.38–0.92), or making a left (*OR* = 0.66; *CI* = 0.51–0.87).

In summary, we identified risk and protective factors for injury among younger and older drivers. There were four statistically significant variables that pertained to older drivers only, however most of the risk and protective factors were associated with injury for both younger and older drivers.

DISCUSSION

The objective of this study was to investigate the risk and protective factors for motor vehicle injuries among younger and older drivers involved in a fatal motor vehicle crash. We achieved this by performing a binary logistic regression analysis with 32 independent variables and age-interaction effects and injury. We used the PPMHP as the organizing framework of the study with variables from the health, behavior, environment, predisposing, and reinforcing domains. We discuss our findings in light of statistically age-interaction effects, risk and protective factors, and the socio-ecological model (PPMHP).

Age-interaction Effects

We postulate that older drivers who drive vehicles not registered in their names are younger and healthier (physical, mental, and cognitive) as it is likely that involving a third party would require some sort of precursory assessment of the drivers' ability to operate the vehicle. A sub-analysis lent credence to our thinking that older adults who drove vehicles not registered in their names were younger (p=0.01, mean age 74.15, SD=6.55) than who drove vehicles registered in their names (p=0.01, mean age 76.29, *SD*=7.20). About 10% of older Americans (55 years and older) consent others (family or other) to drive their motor vehicles when the older adult prefers not to drive for safety and socialization reasons (Hermanson, 2005). This finding has implications for policy, specifically with regard to automobile insurance. If older adults are maintaining their automobiles so that others can drive them, automobile insurance companies may have to account for car-sharing in their premium rates, and yet be flexible enough to meet the needs of older adults (Hermanson, 2005).

Front-side impact crashes may be high-risk areas for injuries among older drivers because of kinetic or mechanical forces that directly impact the driver, and because of the frailty and fragility of older drivers. A study on airbags by NHTSA indicated that airbags in passenger cars are most effective in protecting passengers from injuries when the car is struck at the 12 o'clock angel (front impact crashes), with no rollovers (Kahane, 1996). Airbags are less effective when the vehicle is struck from the 1 o'clock, 2 o'clock, 10 o'clock, 11 o'clock, or 12 o'clock with subsequent rollover (Kahane, 1996). However, from this analysis, it is difficult to ascertain why the 7–9 o'clock angle was a high-risk angle for older drivers. A contributory factor may be the lack of side airbags in the motor vehicles that make older drivers vulnerable to side impact crashes. To better understand these mechanisms, further research is needed to understand the inter-relationships among certain environmental variables (e.g., speed, relation to junction, most harmful event, vehicle maneuver), and point of impact. This finding still has implications for policy enforcement interventions in the area of improving minimum standards for safety in motor vehicles, such as side airbag protection.

Previous studies (Bedard and Meyers, 2004; Hing et al, 2003; and Baker et al., 2003) suggest that the presence of passengers may be protective for crashes among older adults, with the level of protection dependent on other factors such as time of day, gender, and type of collision. Currently, we are planning a qualitative study using in-depth interviews to examine older drivers' perceptions on the contribution of passengers to motor vehicle crashes and injuries.

Using quantitative data alone it is difficult to discern why crash history (failure to yield, running a red light, or lane-related changes) was significantly associated with reduced risk of injuries for the older driver group. This may have occurred as a result of family and/or caretaker interventions after an older driver got involved in a motor vehicle crash. From our findings, we postulate that policy enforcement of motor vehicle violations may be pertinent to older adult injury prevention. To better examine the influence of crash history, further research that include police involvement and family/caretaker roles in older adults' decisions to drive, may be considered.

Main Risk Factors

Environmental engineering of roadways such as replacing fixed objects (e.g., concrete divides) with non-fixed objects (e.g., cable barriers), may reduce the impact severity of crashes and injuries among drivers. For vehicles, improving technology such as anti-rollover devices may reduce injuries as a result of non-collision crashes. Compared to drivers traveling on non-junctions (e.g., rail road crossing or bridges), intersection–related crashes was protective for injury. This may be because intersections are usually more structured (e.g., traffic lights) compared to non-junctions, which enable speed reduction and increased awareness of the environment. Research indicates that roads with enhanced intersections (using the Federal Highway Administration's recommendations) by and large benefit the safe driving performance of both younger and older drivers (Classen et al., 2007).

Behavioral factors (alcohol involvement, lack of seatbelts, and invalid drivers' license) were risk factors for injuries for younger and older adults. Although 24% of younger drivers had alcohol involvement compared with 5% of older drivers, older drivers were equally at risk for injury in crashes as younger drivers when there was alcohol involvement. Currently, there are policies at state levels to control alcohol use and driving, and seatbelt use. Over the years, these policies have proven to be effective in decreased crashes and injuries among drivers. Continual surveillance of alcohol and seatbelt adherence by state governments is still one of the best approaches to decrease injuries among younger and older adults.

Concerning the vehicle body type, SUVs are generally larger and therefore the kinetic forces are bigger compared with an automobile. A possible intervention is to improve vehicle minimum standards and educate the public on safe vehicles. Congress has devised future laws to improve vehicles by including anti-rollover devices and currently rates vehicles by their crashworthiness, making this rating available to buyers (NHTSA, 2006c). Thus continual policy enforcement of minimum standards for motor vehicles would be beneficial to drivers of all ages in injury reduction.

Gender differences in driver safety outcomes (crashes, injuries and fatalities) are supported by previous studies (Finison & Dubrow, 2002; Baker, et al., 2003; Bauer, et al., 2003; NHTSA 2006a), and therefore lend historical plausibility to the results of this study pertaining to the findings on gender. These findings has societal implications as older women generally live longer than older men and are likely to require transportation in the latter years of their lives. They may, therefore, require interventions such as driver education classes and skill therapy which may help reduce crashes and prevent injuries.

Main Protective Factors

Previous older driver research (Finison & Dubrow 2002; Baker et al 2003; NHTSA, 2006b) suggests that daylight hours are riskier for crashes involving older drivers compared with other age groups that are more at risk for crashes during the night hours. The findings appear contradictory to findings in this study that suggested that daytime driving is protective for injury for both younger and older drivers. However, the cited research used crashes as the outcome variable, while this study focused on injury outcomes. Further research may ascertain whether there are differences in injury outcomes, controlling for the number of crashes.

Regarding number of lanes, analyses considering other factors, including *trafficway flow* (how the highway was divided), might need to be taken into consideration before the implications of these results can be acted upon. Results pertaining to the adverse road surface conditions did not show significant difference among younger and older drivers. Previous findings (Finison & Dubrow 2002; Baker et al., 2003) that imply that crashes are more likely to occur on roads with favorable conditions for older drivers.

In contrast to roads with functioning traffic control devices, younger and older drivers on roads without traffic control devices were less likely to be injured in a crash although the reasons for this is not absolutely transparent one explanation is that roads with traffic control devices may be generally more congested than roads without traffic control devices, holding a greater risk for injuries. Not having airbag deployment in the crash was protective for injury. This may be because airbag deployment is associated with more severe crashes occurring at higher speeds, front and high impact crashes (i.e., serious crashes). This is especially important for older drivers who are more susceptible to chest injuries as a result of airbag deployment. One implication of this result is considering follow-up driver education for younger and older drivers to ensure proper positioning of the seat in relation to the airbag.

The protective nature of urban crashes and injury somewhat contradicts previous research that suggests that crashes are more likely to take place in urban areas compared to rural areas (Finison & Dubrow 2002). However, increased risk of injury in urban areas may be related to having more congested traffic flow. Also, the high traffic density in urban areas may be more likely to result in low speed crashes that are less likely to result in injury. Thus, continued speed enforcement may help enforce speed restrictions. The findings on driver skill may be because performing maneuvers (e.g., making a left turn) require the driver to decrease traveling speed, resulting in decreased crash impact, and risk of injury.

Not traveling on the National Highway System was associated with a decreased risk of injury, probably because roads not on the NHS are less likely to be traveled on and are less congested than roads on the National Highway System. This finding speaks to training and educating older drivers to better equip them to manage highways.

Precede-Proceed Model of Health Promotion

Using this model, it is clear that a variety of socio-ecological variables are involved in injuries (health, behavior, environment, predisposing and reinforcing factors); strengthening our hypothesis that injury reduction can only occur when intervention occurs from a system's perspective.

Conclusion

The final model underscored the importance of environmental risk and protective factors, variables not well reported in the existing older driver literature (Classen et al, 2006), emerged as predominant to explain important associations with injury. Examining risk and protective factors for motor vehicle injury among younger and older drivers in the U.S. demonstrated that a socio-ecological approach—an approach not yet utilized in the existing older driver literature, is needed to identify the multiple factors associated with injury. This research was a first step in that direction. However the complexities, such as the effects of various interactions of these factors, require further investigation. Many of the findings showed relevance to drivers from both age groups, with some pointing to older adults, meaning that injury prevention measures, when developed and implemented, may potentially benefit older and younger drivers alike.

Significant behavioral (alcohol, driver license compliance, and seatbelt use), and environmental variables (improvement of vehicle crashworthiness and highway design) findings hold implications for injury prevention programs, such as preliminary injury prevention strategies to be examined must include continued policy enforcement, environmental modification (e.g. highway design or crashworthiness of vehicles) and older driver educational programs.

A unique contribution of this study is that it examined injury of motor vehicle crashes involving older (and younger) adults, thus focusing on predictors of injury, rather than crashes. As such these exploratory findings set the stage for further hypothesis formulation as we develop injury prevention programs.

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TABLES

Table 1. Description of independent FARS variables, variable types and levels

Precede-Proceed Domain	Variable*	Number of level/type	Description of levels
Health	Age*	(2) nominal	1 = 35–54 years 2 = 65+ years
	Gender	(2) nominal	1 = male 2 = female
Behavior			
	System restrain use*	(2) nominal	0 = no 1 = yes
	Driver drinking	(2) nominal	0 = no 1 = yes
	Driver license compliance*	(2) nominal	0 = not valid 1 = valid
Environment			
	Day of the week	(7) nominal	1 = Sunday 2 = Monday 3 = Wednesday 4 = Thursday 5 = Friday 6 = Saturday 7 = Saturday
	Hour of the day*	(3) nominal	1 = 9p.m.–7a.m. 2 = 8a.m.–1p.m. 3 = 2p.m.–8a.m.
	Registered vehicle owner*	(2) nominal	1 = no 2 = yes
	Vehicle body type*	(3) nominal	1 = Automobile 2 = SUVs 3 = Vans, light trucks and pick-ups
	Number of lanes*	(4) nominal	1 = 1 lane 2 = 2 lanes 3 = 3 lanes 4 = 4 to 7 lanes
	Roadway surface* conditions	(2) nominal	1 = favorable 2 = adverse
	Roadway surface type*	(3) nominal	1 = concrete 2 = blacktop 3 = other
	Roadway alignment	(2) nominal	1 = straight 2 = curve
	Roadway profile*	(2) nominal	1 = level 2 = other
	Geographic location* (Road function class)	(2) nominal	1 = rural 2 = urban
	National Highway System	(2) nominal	0 = no 1 = yes
	Type of collision*	(4) nominal	1 = collision with

Precede-Proceed Domain	Variable*	Number of level/type	Description of levels
	(Most harmful event)		object not fixed 2 = collision with a moving vehicle 3 = non-collision 4 = collision with a fixed object
	Highway design feature* (Relation to junction)	(3) nominal	1 = non-junction 2 = intersection 3 = interchange
	Point of impact using the clock method* (Principal point of impact)	(6) nominal	1 = 1–3 o'clock 2 = 4–6 o'clock 3 = 7–9 o'clock 4 = 10–11 o'clock 5 = 12 o'clock 6 = top and undercarriage
	Trafficway flow*	(5) nominal	1 = divided highway 2 = not divided highway 3 = one way trafficway 4 = not physically divided 5 = entrance/exit ramp
	Traffic control device* (Traffic control device functioning)	(2) nominal	0 = not present 1 = functioning properly
	Light conditions*	(3) nominal	1 = daylight 2 = dark 3 = other
	Weather conditions*	(2) nominal	1 = favorable 2 = adverse
	Construction/maintenance zone*	(2) nominal	0 = no 1 = yes
	Airbag deployment*	(2) nominal	0 = no 1 = yes
	Number of passengers* (Number of occupants)	(3) nominal	1 = driver only 2 = 1 passenger 3 = 2 or more passengers
Predisposing			
	Driver skill* (Vehicle maneuver)	(5) nominal	1 = going straight 2 = lane-related changes 3 = other maneuvers 4 = making a left 5 = negotiating a

Precede-Proceed Domain	Variable*	Number of level/type	Description of levels
			curve
Reinforcing			
	Number of previous motor vehicle accident convictions in last 3 years (ticketed)	Discrete numerical	
	Number of previous motor vehicle speeding convictions in last 3 years (ticketed)	Discrete numerical	
	Number of previous motor vehicle suspension convictions in last 3 years (ticketed)	Discrete numerical	
	Number of previous Driving while impaired (DWI) convictions (ticketed)	Discrete numerical	
	Number of other previous motor vehicle convictions (failure to yield, running a red light, lane-related errors) in last 3 years (ticketed)	Discrete numerical	

*levels of variable were collapsed; Variables in parenthesis are original FARS names.

Table 2. Binary logistic regression model with significant age interactions, risk and protective factors for injury

Dependent Variable: Injury (yes/no)	*p*	*OR*	*Lower CI*	*Upper CI*
Age-interaction effects				
1- 3 o'clock	0.03*	1.61	1.05	2.47
4 - 6 o'clock	0.50	1.20	0.71	2.05
7 - 9 o'clock	<0.01*	4.75	2.87	7.86
10 -11 o'clock	0.15	1.47	0.87	2.48
Top or undercarriage	0.95	0.96	0.28	3.33
Number of passengers x Age				
Driver only x Age	(Referent)			
One Passenger x Age	0.34	1.18	0.84	1.64
$\geq$ Two Passengers x Age	0.05*	0.60	0.36	1.01
Registered vehicle owner x Age				
Driver was registered owner x Age	(Referent)			
Driver was not owner x Age	0.05*	0.69	0.48	1.00
Number previous other MV convictions (ticketed offenses) x Age (e.g., failure to yield, failure to stop, within 3 years prior to the year 2003)	0.03*	0.65	0.44	0.97
Risk factors				
Type of collision				
Collision w/object not fixed	(Referent)			
Collision w/ fixed object	<0.01*	249.55	152.61	408.03
Collision while motor vehicle is moving	<0.01*	30.99	23.82	40.31
Non-Collision (e.g. rollover)	<0.01*	265.68	155.37	454.32
System restraint use				
Yes	(Referent)			
None	<0.01*	6.20	5.03	7.63
Driver drinking				
Not drinking	(Referent)			
Drinking	<0.01*	2.00	1.57	2.54
Type of vehicle				
SUVs	(Referent)			
Auto & Auto Derivatives	<0.01*	2.00	1.64	2.44
Vans, Trucks, & Light Pick-Ups	0.01*	0.77	0.64	0.94
Day of week				
Sunday	(Referent)			
Monday	0.18	1.17	0.93	1.48
Tuesday	0.02	1.33	1.05	1.69
Wednesday	<0.01*	1.64	1.27	2.13
Thursday	<0.01*	1.46	1.14	1.86

Dependent Variable: Injury (yes/no)	*p*	*OR*	*Lower CI*	*Upper CI*
Friday	0.01*	1.36	1.07	1.74
Saturday	0.03*	1.29	1.02	1.62
Gender				
Male	(Referent)			
Female	<0.01*	1.51	1.29	1.73
Road surface condition				
Favorable	(Referent)			
Adverse	<0.01*	1.50	1.16	1.95
Driver license compliance				
Valid	(Referent)			
Not Valid	0.04*	1.39	1.02	1.90
Protective factors				
Airbag deployment				
Deployed	(Referent)			
Did Not Deployed	<0.01*	0.25	0.21	0.29
Number of lanes				
Two	(Referent)			
One	0.03*	0.32	0.12	0.87
Three	0.41	0.32	0.68	1.17
Four-Seven	0.29	0.89	0.75	1.09
Highway design				
Non-Junction (e.g. railroad crossing)	(Referent)			
Intersection-Related	<0.01*	0.59	0.48	0.72
Interchange-Related (T-junction or dead end)	0.94	0.98	0.64	1.51
Geographic location				
Rural	(Referent)			
Urban	<0.01*	0.61	0.52	0.71
Hour of day				
9PM-7AM	(Referent)			
8AM-1PM	0.01*	0.72	0.57	0.90
2PM-8PM	<0.01*	0.63	0.53	0.76
National highway system (NHS)				
On NHS	(Referent)			
Not on NHS	<0.01*	0.77	0.65	0.91
Traffic control device				
Functioning	(Referent)			
Not Present	0.01*	0.79	0.65	0.95
Driver skills				
Going straight	(Referent)			
Making lane-related changes	<0.01*	0.64	0.50	0.81
Making a left	<0.01*	0.66	0.51	0.87

Negotiating a curve	0.35	1.15	0.86	1.54
Other (stopping, braking, overtaking; entering and exiting ramps)	0.02*	0.59	0.38	0.92

Legend: $*p \leq 0.05$; for each of the four significant age interactions, we did not include the values of the main effects.