SOCIO-ECOLOGICAL DETERMINANTS OF INJURY AMONG YOUNGER AND OLDER ADULTS INVOLVED IN FATAL MOTOR VEHICLE CRASHES IN THE UNITED STATES

By

KEZIA DZIFA AWADZI

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To my parents, Dr. Kwablah Awadzi and Mrs. Patricia Awadzi,
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Kezia Dzifa Awadzi

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Chair: Name R. Paul Duncan
Cochair: Sherrilene Classen
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Using a socio-ecological model, the Precede-Proceed model of health promotion (PPMHP) and the 2003 Fatality Analysis Reporting System database, this study examined determinants of injuries among older drivers involved in a fatal crash, comparing them with younger drivers (35 to 54 years). The study also explored relationships between age-related license renewal policies and injury outcome for older adults. Significant risk and protective factors for older drivers were number of passengers, whether the driver was the registered vehicle owner, the principal point of impact, and previous number of motor vehicle convictions (e.g., failure to stop at a light).

For both age groups, most of the significant risk and protective factors were environmental, with actions taken by the driver just before the crash (most harmful event), having astronomical risks of injury, with the odds of injury between 31 and 266. Females had a higher risk of injury in a crash compared to males. Behavioral variables (e.g., restraint system use) and the predisposing variable (vehicle maneuver) were significantly associated with injury for younger and older drivers.

Older drivers from states with age-related license renewal polices had lower injury prevalence rates compared with drivers with licenses from states without any license renewal policies. States requiring in-person renewal had lower injury rates than drivers from states without in-person renewal. However, drivers with licenses from states with reduced renewal cycles and vision/medical tests did not significantly differ in injury rates from drivers with licenses from states without those requirements. Using the PPMHP to examine risk and protective factors for motor vehicle injury among younger and older drivers in the U.S. demonstrated that a socio-ecological approach is needed to understand the factors associated with injury—an approach not yet utilized in the existing older driver literature. Many of the findings showed relevance to drivers from both age groups, with only a selected few pointing to older adults, meaning that injury prevention measures, when developed and implemented, may benefit older and younger drivers alike.

CHAPTER 1
INTRODUCTION

Overview of the Research Topic

This research topic is part of a project funded by the Centers for Disease Control and Prevention (CDC) (Classen, 2004). The objective of the project is to develop a public health model to promote safe elderly driving. The project has three specific aims: (a) use a socio-ecological model as a framework to conduct a systematic literature review (SLR) of older driver studies, (b) evaluate the fit of existing data on older drivers with the model, and (c) develop a model-driven older driver safety program, showing the interaction of prediction factors and plan for pilot testing (Classen, 2004). To meet the first objective of the project a structural model was created from the results of a SLR (Classen et al., 2006). For the second aim of the project, quantitative and qualitative data from existing sources were used to test findings from the SLR. This dissertation is the quantitative phase of the *Public Health Model to Promote Safe Elderly Driving* project. A national secondary database, the 2003 Fatality Analysis Reporting Systems (FARS) was used to ascertain relationships among the determinants of motor vehicle–related injuries among older drivers and injury outcomes. Findings from the quantitative and qualitative phases will be integrated to plan an older driver injury prevention program (Classen, 2004).

Specific Aims

Using the Precede-Proceed model of health promotion (PPMHP) as the organizing framework with the findings from the SLR, this study examined the relationships among socio-ecological variables to the level of injury outcomes in motor-vehicle crashes. To identify the age effect in the relationships, and better understand the determinants of motor-vehicle related injuries among older drivers, I compared two age groups: 35 to 54 years and 65 years and older (using the 35 to 54 age group as a control). The 35 to 54 year age group was selected because it had a lower prevalence of motor vehicle traffic fatality rates between 1995 and 2005 compared to the 65 years and older group (NHTSA, 2006a).

The aims of the study were to:

(1) examine the relationship among the socio-ecological variables to injury within each of the two age groups (old 65 years and older; young, 35 to 54 years);
(2) examine if there are age differences between the socio-ecological variables and injury outcomes following a motor vehicle crash;
(3) examine the relationship between state licensure renewal policies and motor vehicle injuries for older drivers.

Why Examine Older Drivers and Injury-Related Crashes?

Motor vehicle injuries are classified as unintentional injuries because the injury occurs over a short time, the harmful outcome was not sought, and the injury resulted from physical energy in the environment (Waller, 1985). Most unintentional injuries (no longer called “accidents”) are avoidable because they are predictable events with identifiable origins and risk factors (Christoffel & Gallagher, 2006).

Older drivers (65 years and older) are more likely than other adult drivers to pose injury and fatality risk to themselves and older passengers in their vehicle than the occupants of other vehicles (Braver & Trempel, 2004). Unlike other age groups who display unsafe behaviors such as speeding, alcohol abuse and reckless driving (CDC, 2004; NHTSA, 2006b), older driver crashes often stem from physical, sensory, and cognitive declines as a result of the normal aging process (Carr, 1993). Other contributory crash factors include medical conditions and medication use (Ray, Thapa, & Schor, 1993). On the other hand, older adults are more likely to be wearing seatbelts and to limit their driving to favorable driving conditions than other age groups (Bauer, Adler, Kuskowski, & Rottunda, 2003), and are less likely to be driving under the influence of alcohol or substance abuse than other adults (NHTSA, 2006b).

The population 65 years and older will represent about 20% of the entire U.S. population by 2030 (He, Sengupta, Velkoff, & DeBarros, 2005). In 2004, there were approximately 28 million licensed drivers age 65 and older in the U.S. (NHTSA, 2006a). The number of older drivers is increasing, with over 40 million projected older adult licensed drivers by 2020 (Centers for Disease Control and Prevention, 2005). In 2001, except for very young drivers, and based on miles driven, drivers (65 years and older) had the highest rates of fatal crashes (NHTSA, 2001; Li, Braver & Chen, 2003). In fact, in 2005, the 65-plus population comprised 15% of motor vehicle fatalities (NHTSA, 2006a). Currently, the 65-plus age group is the third highest for motor vehicle traffic fatalities, with 16 to 20 year old drivers being first, and 21 to 34 year old drivers being second (NHTSA, 2006a).

Past and current trends indicate that the percentage of older drivers on the road are increasing and will continue to do so because of the rise in numbers of older drivers and the aging U.S. population. Apart from high motor vehicle injuries and fatalities among older adults and the changing demographics in the U.S. population, another reason for understanding the relationship between the determinants of motor vehicle injuries and older adults is the role of driving in the lives of older American adults.

Driving and Older Adults

Generally, mobility, that is, the use of vehicle conveyance or travel from one place to another, is an important facet of American living, and the lack of being able to move from one place to another has practical and psychological ramifications to individuals and the society. The mission of the Federal Transit Administration (DOT), based on the Civil Rights Act of 1964, is enhancing the social and economic quality of life for all Americans by providing nondiscriminatory transportation (FTA, 2006).

Older adults may stop driving for reasons such as age-related declines and chronic health conditions. Although the availability and accessibility of alternative transportation vary from location to location (e.g., rural areas having fewer alternative transportation opportunities than urban areas) elderly Americans rely primarily on driving automobiles for access to employment, commerce, family, and friends (Houser, 2005; Ritter, Straight, & Evans, 2002; Burkhardt, Berger, Creedon, & McGavock, 1998). Older adults may stop driving or self-restrict driving because of age-related declines and acute and chronic health conditions taking their toll on functioning. In fact, Foley, Harley, Heimovitz, Guralnik & Brock (2002) indicate that the lifespan of Americans exceed their driving life expectancy. Men 70 to 74 years have approximately 7 years of dependency on alternative transportation, while women 70 to 74 years have about 10 years of reliance on alternative transportation.

Older Americans view driving as a symbol of independence; in fact, driving cessation among older drivers has been associated with increased depression (Marottoli et al., 1997) and a decreased societal participation (Marottoli et al., 2000). Others (Ragland, Satariano, & MacLeod, 2005; Ritter et al., 2002; and Burkhardt et al., 1998) also found driving cessation among older adults to be associated with isolation, loss of independence, and depression.

In summary, this research is important because (a) motor vehicle injury is preventable; (b) older drivers are increasing in numbers and driving longer; (c) older drivers are at the third greatest risk for injuries and fatalities in motor vehicle crashes (NHTSA, 2006a); (d) driving is an integral facet of living for older adults; and (e) the lack of accessible, affordable and appropriate alternative transportation services for older adults have implications for public health and possibly health services.

Fit of Socio-ecological Determinants of Older Driver Injury to Health Services Research

The economic cost of motor vehicle crashes in the United States is $231 billion, of which $36.2 billion (14%) was due to medical costs (Blincoe et al., 2002). For non-fatal injuries (all age groups), 25% of the total cost resulted from medical care (Blincoe et al., 2002).

Although specific information on the economic cost of traffic-related injuries for older drivers is not available, previous studies demonstrate the impact motor vehicle injury costs have on society as a whole. Older drivers are likely to get injured in motor vehicle crashes, and their fragility due to age and preexisting medical conditions make them more likely to require hospitalization, longer and more expensive healthcare, and a less complete recovery (Dobbs & Carr, 2005; Richmond, Kauder, Strumpf, & Meredith, 2002). Freeman, Gange, Munoz, and West (2006) found that older adults who had ceased driving, never driven, or who did not have drivers in their home had an increased risk of entering a long-term care facility compared with current drivers. Motor vehicle crashes are the second leading cause of traumatic brain injuries in the U.S. for all age groups (Coronado, Thomas, Sattin, & Johnson, 2005).

This study is foundational research for older driver studies in health services settings. By establishing risk and protective factors associated with motor vehicle injuries for older drivers on a population-based study, subsequent studies can examine how access and utilization of healthcare services may impact motor vehicle injury prevention. This study is germane to health services research in many ways, including health education, screening, assessing, and counseling older drivers. Since the healthcare costs of treating older adults are predominantly borne by the tax-supported Medicare program, improved understanding of this impact has significant implications for healthcare policy and healthcare financing.

CHAPTER 2
LITERATURE REVIEW

In this chapter I discuss the history and philosophy of injury epidemiology, describes the PPMHP, and notes findings from an older driver systematic literature review (SLR). I then discuss studies on motor vehicle-related injuries among older drivers within the framework of the Precede framework of the PPMHP. I conclude with a discussion on gaps in the older driver literature.

Motor Vehicle–Related Injuries in the US

Motor vehicle injury is a pertinent public health concern in the United States and has implication in health services and the U.S. economy as a whole. Older drivers have the highest rates of hospital admission resulting from crashes, followed by senior passengers (Peek-Asa, Dean, & Halbert, 1998) and older drivers are more likely to die or be hospitalized compared with middle-aged drivers (Finison & Dubrow, 2002). Motor vehicle crashes are the second leading cause of traumatic brain injuries in the U.S. for older adults (Coronado, Thomas, Sattin, & Johnson, 2005).

Using population-based data from the Centers for Disease Control and Prevention (CDC) traumatic brain injury (TBI) surveillance system from 15 states, Coronado et al. (2005) examined epidemiological and clinical characteristics of 17,657 older adults hospitalized with TBI in 1999. They stratified the sample into three age groups: 65 to 74 years, 75 to 84 years, and 85 years and older. Motor vehicle-related TBI injury rates were also categorized by driver, passenger, pedestrian, and “other”. Common comorbid conditions for older adults with motor vehicle-related TBI were hypertension, diabetes, cardiac arrhythmias, chronic pulmonary disease, and fluid and electrolyte disorders. Motor vehicle injuries were the second cause of TBI hospitalizations for all age groups, regardless of whether the older adult was a driver, passenger, or pedestrian. Specifically for drivers, TBI hospitalizations increased with age among the 65 to 75 (11.9 per 100,000) and the 75 to 84 (15.3 per 100,000) age groups, and declined for the 85 years and older group (12.7 per 100,000). Across all age groups, drivers had the highest motor vehicle-related TBI hospitalizations. Older adults who died in hospital or were discharged into residential facilities increased with age. Richmond, Kauder, Strumpf, and Meredith (2002) had similar findings in a retrospective study examining the characteristics and outcomes of TBI among 38,707 older adults (65 years and older) in Pennsylvania between 1988 and 1997. TBI injury from motor vehicle was the second cause of TBI hospitalization. Risk factors for mortalities, complications, and whether the older adult was discharged to return home or into skilled nursing facility include injury severity, comorbid or medical complications (e.g., cardiovascular and pneumonia), and age. Compared to having a low injury score (0–9), older adults with injury scores greater than 25 (*OR* = 25.51; *CI* = 14.5–44.8), injury score 16-25 (*OR* = 4.65; *CI* = 2.9–7.4), and injury score 10-15 (*OR* = 2.76; *CI* = 1.7–4.4) had increased risks for mortality. Approximately 33% were discharged into a skilled nursing facility, a rehabilitation center, or another hospital.

Freeman, Gange, Munoz and West (2006) found significant associations among older adults (65 to 84 years old) who had never driven or had ceased driving and admittance into long-term care facilities. The sample comprised of 1,593 older adults living in Maryland selected from a previous study using the Health Care Financing Administration Medicare database. Data on their driving status and entry into long-term care facilities were obtained via self-report or from a proxy. After adjusting for health conditions and demographic factors using Cox time-dependent regression analyses, former drivers (*HR* = 4.85; 95% *CI* = 3.26–7.21) and adults who had never driven (*HR* = 3.53; 95% *CI* = 1.89–6.58) had an increased hazard ratio of admission in a long-term care facility. Also, not having a driver at home was a significant risk factor for admission into a long-term care facility.

In summary, compared to younger age groups, older motor vehicle injuries among older adults is associated with increased risks of mortality, exacerbated by comorbid conditions. Secondly, older drivers have higher hospitalization rates for TBI compared with other persons involved in motor vehicle crashes, and thirdly, older adults discharged from hospital may be admitted into another healthcare facility. In the following section, I discuss the epidemiology of motor vehicle injury in the United States.

Epidemiology of Motor Vehicle Injuries

In order to understand how to prevent or decrease motor vehicle-related injuries among older adults, one has to comprehend the epidemiology of injury. Injury is defined as damages to the body produced by energy exchanges that are manifested within 48 hours or usually within considerably shorter periods (Haddon, 1980). A few decades ago, injuries were viewed as *accidents* (random and uncontrollable), with some persons deemed more prone to accidents than others. The term *accident* is from an era when there were no scientific explanations for, or means of dealing with, plagues and natural disasters (Haddon, 1999, p.231). In the last few decades, the concepts of injury has evolved to include environmental (e.g., vehicle) and social contexts (Christoffhel & Gallagher, 2006). Injury is classified as intentional (e.g., homicide) and unintentional (e.g., motor vehicle injuries). Gordon (1949) was the first to use epidemiology in conceptualizing injury prevention. He demonstrated that injury, like other health conditions, had patterns of distribution within the population. These included seasonal variations, geographic, socioeconomic, and rural-urban distributions which behave in similar fashion as infectious diseases (Gordon, 1949; Haddon, 1980, p.412). Like diseases, injury is caused by a combination of factors including host (e.g., the driver), the agent (e.g., kinetic energy), the environment (e.g., the highway), and the vector (e.g., the motor vehicle) with these factors interlinked and influencing one another. Gordon (1949) defined the environment as the physical environment (geographic location), the biologic environment, and the socio-economic environment.

Haddon (1963) suggested that although the causes of accidents are multifaceted, it is fitting to investigate any commonality between these various factors and injury in order to prevent injury. Using that approach, Haddon classified injuries into two groups: (a) injury caused by interference with normal whole body exchange (e.g., drowning or strangulation), and (b) injuries caused by delivery of energy (mechanical, thermal, or chemical) to the body that exceeds the body's threshold levels, (e.g., motor vehicle injuries).

Haddon postulated that if injury cannot be prevented, then its severity can be minimized in one of the following 10 ways:

1. Avert excess amounts of energies to the body at the early stages of events leading up to the injury.

2. Prevent events from occurring (i.e., prevent or amend the release of the energy). This can be achieved for through improved vehicle designs (Haddon, 1999).

3. Attempt to remove the person from the surrounding area.

4. If (1) to (3) fail, introduce a barrier that would block or decrease its effect on the person.

5. Separate in space or time the energy being released (e.g., divided highways).

6. Separate by interposition of a material barrier (e.g., airbags in motor vehicles)

7. Modify appropriately the contact surface, subsurface, or basic structure (e.g., highway modification).

8. Strengthen the structure, living or nonliving that is otherwise damaged by the energy transfer (e.g., minimum standard for motor vehicles manufacturers).

9. Move rapidly to detect and evaluate damage that is occurring or has occurred.

10. After injury has occurred, improve repercussions via emergency care, health care, rehabilitation, and injury prevention programs (Haddon, 1963, Haddon, 1973).

Haddon developed a two-dimensional matrix to help organize the factors that contribute to motor vehicle injuries into pre-crash events, crash events, and post-crash events in order to enable minimum loses (Haddon, 1972; Haddon 1980). Haddon's two-dimension matrix examines the sequence of events—pre-crash, crash, and post-crash events—in relation to the factors involved (human, vehicles and equipment, physical environment and roadway, and socioeconomic environment). The advantage of using Haddon's matrix is that different effective interventions can be evaluated on a cell-by-cell level. Haddon advocated for as much or greater emphasis be put on proven measures in the passive measures such as improving the vehicle's crashworthiness or highway engineering, rather than the active areas of injury prevention that places emphasis on changes in behavior (Haddon, 1972). Gielen and Sleet (2003) define passive strategies as dependence on changing products or environment to make them safer for all regardless of behavior, and passive strategies to injury prevention as entailing or encouraging people to play an active role in protecting themselves despite hazards in the environment (p.65).

Successive researchers such as Gielen (1992) and Runyan (1998) suggest limitations in that although Haddon's matrix included behavioral intervention strategies, the matrix failed to emphasize them, and greater importance should be placed on active measures (e.g., behavior) as well passive injury intervention strategies. Glanz and Rimer (1995) classified injury-related behavior on three levels: (a) the intrapersonal level (e.g., the effect of individual's knowledge, attitudes, and beliefs on behavior); (b) the interpersonal level (e.g., the influence of family members, friends, and coworkers on an individual's behavior); and (c) the community level (e.g., organizational settings and their influence and other society influences such as poverty). Because behavioral injury interventions are usually policy-related, it would be effective to develop behavioral intervention strategies on a community level instead of an individual perspective (Gielen & Sleet, 2003). A single strategic approach to reducing motor vehicle injuries is not enough, but strategies combining both environmental modification and behavioral change are needed (Sleet, 1987). Intervention models such as the Precede-Proceed model of health promotion (PPMHP), approach prevention strategies from a socio-ecological perspective and accounts for the health (e.g., age), behavioral (e.g., seatbelt use), environment (e.g., highway design), educational (e.g., screening and assessment), and policy (e.g., state age renewal policies) perspectives.

The Precede-Proceed Model of Health Promotion

In this section, I (a) describe the domains of the PPMHP, and (b) discuss the application of the PPMHP from population health studies and health services research.

Description of the Precede-Proceed Model of Health Promotion

The PPMHP consists of the PRECEDE (phases 1–4) and the PROCEED (phases 5–8). PRECEDE, the acronym for Predisposing, Reinforcing, and Enabling Constructs in Educational/Ecological Diagnosis and Evaluation, is a series of assessments that enables researchers to collect information used to guide decisions (Green & Kreuter, 2005). PROCEED, the acronym for Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development, is the process of planning and carrying out interventions based on information from the Precede assessments (Appendix A).

This dissertation focuses on the PRECEDE framework because the focus of the Public Health Model to Promote Safe Elderly Driving project is to gather information for the PROCEED phase intervention stage. The PRECEDE framework comprises of four assessments: (a) quality of life, (b) epidemiological assessment, (c) educational and ecological assessment, and (d) administrative and policy assessment (Green & Kreuter, 2005).

Domains of the precede-proceed model of health promotion

Social assessment: This is defined as "the assessment in both objective and subjective terms of high-priority problems or aspirations for the common good, defined for a population by economic and social indicators and by individuals in terms of their quality of life" (Green & Kreuter, G-8). In the PPMHP, the social assessment phase has one domain—quality of life. During the social assessment phase, needs and aspirations of the target population are assessed from the population's perspective on individual and community (e.g., city, state, region, or county) levels (Green & Kreuter, 2005).

Epidemiological assessment: The aim of the epidemiological assessment is two-fold: (a) identify health problems or goals that may affect the quality of life of the target population, and to (b) identify etiological factors in the three domains of the epidemiological phase (genetics, behavior, and environment) and their direct and combined effect on health. The epidemiological assessment enables researchers to prioritize health problems of the community and their direct and combined effect on health (Green & Kreuter, p.81).

The International Classification of Functioning Disability and Health (ICF) model is incorporated in the health domain of the PPMHP. The ICF model was developed by the World Health Organization in 2001 to include the classification of non-fatal disease outcomes. The ICF model consists of (a) body functions, body structure, and participation, and (b) environmental and personal factors (Dahl, 2002; Ustun, Chatterji, Bickenbach, Kostanjsek, & Schneider, 2003).

In the ICF model, health comprises of three components: (a) body functions (e.g., mental function), (b) body structures (e.g., structures of the nervous systems), and (c) activities and participation (mobility).

Educational and ecological assessment: During the educational and ecological assessment the researcher examines factors within the predisposing, reinforcing, and enabling domains that are likely to influence health behavior, environmental factors, and the interaction between genetics, behavior, and environment (Green & Kreuter, 2005, p. 14). This phase prioritizes behavioral and environmental factors related to health and quality of life issues after identifying health determinants and social conditions (Green & Kreuter, p. 147).

A predisposing factor is defined as “any characteristic of a person or population that motivates behavior prior to the occurrence of the behavior” (Green & Kreuter, G-6). Predisposing factors are influenced by sociodemographic factors, such as age, race/ethnicity, and socioeconomic status. They are the beliefs, attitudes, perceived needs, and abilities that govern individual or group behavior and are forbearers of behavioral change (Green & Kreuter, 2005), and are therefore important to consider when assessing a target population. An example related to older drivers in the United States is the value placed on independence in the American culture.

An enabling factor is defined as “any characteristic of the environment that facilitates action and any skill or resource required to attain a specific behavior” (Green & Kreuter, G-3). Examples of older driver resources are healthcare providers, and older adult advocate groups. Assessment of enabling factors is critical to the PRECEDE phase because it enables researchers ascertain available resources to the population under investigation.

A reinforcing factor is defined as “any reward or punishment following or anticipated as consequence of a behavior, serving to strengthen the motivation for the behavior after it occurs”

(Green & Kreuter, G-7). Reinforcement may occur through negative or positive feedback from society, professionals, or peers (Green & Kreuter), or through policy enforcement such as motor vehicle citations.

The administrative and policy assessment: This is defined as “the analysis of policies, resources, and circumstances prevailing in an organizational situation to facilitate or hinder the development of the health program” (Green & Kreuter, G-1). This stage is attained after data have been obtained from the social assessment, health, and the educational and ecological phases of the model. This is the beginning of the PROCEED phase of the model. The PROCEED phase of the model, which is not discussed in detail within the context of my dissertation, comprises of the following phases: (a) implementation of the health program, (b) process evaluation, (c) impact evaluation, and (d) outcome evaluation.

Application of the precede-proceed model of health promotion

The PPMHP has been used over 30 years in more than 950 studies (Green & Kreuter, 2005). It is very suitable for population health studies that examine risks and disease burdens among different social groupings within a population (Labonte, Polanyi, Muhajarine, McIntosh, & Williams, 2005). The PPMHP has been applied in health promotion studies, defined as “any planned combination of educational, political, regulatory, and organizational supports for actions and conditions of living conducive to the health of individuals, groups or communities” (Green & Kreuter, 2005, p. 506). The model has also been applied within the healthcare setting, in areas such as disease prevention, and disease management programs. It has also been applied as a framework in most unintentional injury research by assessing risk factors then to design programs for intervention (Trifiletti, Gielen, Sleet, & Hopkins, 2005). Areas of relevance for the PPMHP include population-based intervention planning and program evaluation such as compliance with child passenger safety laws in Washington (Chang, Ebel, & Rivara, 2002), and planning an intervention program for child pedestrian injury (Howat, Jones, Hall, Cross, & Stevenson, 1997). The PRECEDE framework has been used to assess behavioral and environmental risk and protective factors to prevent alcohol-related crashes (Simons-Morton et al., 1989). Application of the PPMHP in health services research include evaluating programs among health professionals (Chande & Kimes, 1999), assessing the attitudes and beliefs of health professionals toward domestic violence (Sugg, Thompson, Thompson, Maiuro, & Rivara, 1999), assessing physician roles in disease management (Mann & Putnam, 1989; Mann, Lindsay, Putnam, & Davis, 1997), and improving physician services (Solomon, Hashimoto, Daltroy, & Liang, 1998). The PPMHP has been applied in preventive programs such as the implementation of breast cancer screening (Mahloch, Taylor, Taplin, & Urban, 1993; Taylor et al., 1998), cervical cancer screening (Taylor et al., 1999), and prostate cancer (Weinrich, Weinrich, Boyd, & Atkinson, 1998). In some studies, researchers targeted both health professionals and patients to evaluate intervention programs in hospitals (Brink, Simons-Morton, & Zane; 1989).

In summary, although the PPHMP has been widely applied in population health studies and health services research, up to date, it has not been used in motor vehicle injury-related studies for the older adult population. Studies on motor vehicle injury prevention studies have focused on children. In the following section, I describe the PPMHP structural model from the SLR, which is the foundational work for this dissertation.

The precede-proceed model of health promotion structural model

In this dissertation, I used the PPMHP structural model based on the older driver SLR conducted by the *Public Health Model to Promote Safe Elderly Driving* project in 2005 (Appendix B). The PPMHP structural model is based on the analysis of 201 primary studies on older driver safety. The inclusion criteria were: (a) published and unpublished sources, (b) sources published in English, (c) studies pertaining to adults (60 years and older), (d) U.S.

sources that were published or completed between January 1985 and April 2005, (e) studies relating to safe or unsafe driving (e.g., motor vehicle injuries, motor vehicle fatalities, and motor vehicle citations). Exclusion criteria were (a) sources with no primary findings, (b) duplications of primary studies, and (c) studies pertaining to simulator studies (Classen et al., 2006).

Data from sources were extracted using the Systematic Process for Investigating and Describing Evidence Based Research (SPIDER) tool developed by the Public Health Model to Promote Safe Elderly Driving team. Meta-Synthesis and content analysis were used to analyze data from the SLR, and ascertain risk and protective factors for older driver safety. The structural model explained significant relationships among independent variables and driving safety outcomes. Findings indicated that majority of studies focused on the health domain (61%) and less on environmental (20%), health education (2%), behavioral (10%) and the predisposing (1%), reinforcing (3%), and enabling (2%) domains (Classen, et al., 2006).

Determinants of Injuries among Older Adults

Using the PPMHP, the older driver literature next discussed, identifies risk and protective factors for injuries within the context of the health, behavioral, environmental, and enabling domains of the PPMHP. Although I have grouped the studies under specific domains, they are not mutually exclusive e.g., some environmental studies also contain information on behavior and health variables. Literature in this section broadly pertains to the health, behavior, environment, and enabling factors.

Health

Under the health domain of the PPMHP, risk and protective factors identified from the SLR on older drivers include age, gender, acute and chronic physical conditions, mental conditions, and number and classes of medications used by the older driver (Classen, et al., 2006).

Older adults comprise of 7% of motor vehicle injuries (NHTSA, 2006a). Older adults (65 years and older), are the third highest age group for fatal injuries (Figure 2-1). Older drivers are likely to get injured in motor vehicle crashes, their fragility due to age and preexisting medical conditions makes them more likely to require hospitalization, longer and more expensive health care, and a less complete recovery (Dobbs & Carr, 2005; Richmond, Kauder, Strumpf, & Meredith, 2002). Older drivers involved in crashes are more likely to die from injures than younger drivers. Though compared to younger drivers, older adults have less mileage exposure, the risks of crashes, injuries, and fatalities increase with age, (Dellinger, Langlois, & Li, 2002).

Differences in motor vehicle fatality outcomes for older adults vary within the 65 years and older population (Figure 2-2). Ten-year data (1995 to 2005), indicated differences in motor vehicle fatality rates among five older adult groups: (a) 65 to 69 years old, (b) 70 to 74 years old, (c) 75 to 79 years old, (d) 80 to 84 years old, and (e) 85 years and older. The 80 to 84 age group has the highest motor vehicle fatality rates. Over a decade, the 80 to 84 and the 85 years and older groups showed decline in motor vehicle fatalities, however, the age groups 65 to 69 and 70 to 74, maintained stable motor vehicle fatality rates. The 35 to 54 age group has lower motor vehicle fatality rates compared to older drivers (65 years and older). Latest motor vehicle fatality data indicates that older adults (65 years and older) have a motor vehicle fatality rate of 21 per 100,000 residents. Within the older driver population, the 65 to 74 age group has the lowest motor vehicle fatality rate (16.2 per 100,000). The motor vehicle fatality rates increase for the 75 to 84 age group (24.9 per 100,000), and the 85 years and over age group (28.8 per 100,000) (National Center for Health Statistics [NCHS], 2006). When exposure (miles driven) is taken into consideration, people age 75 and older have more motor vehicle fatal injuries per 100,000 population and higher fatality rates from motor vehicle crashes per mile driven than other groups except people younger than 25 (FHWA, 2006 Hing, Stamatiadis, & Aultman-Hall, 2003). Similar findings were observed in a study using 1990 FARS data, 1990 General Estimates System (GES) data, and the 1990 Nationwide Personal Transportation Survey. Very young drivers (16 to 19 years) and older drivers (75 and above), had higher odds of being fatally injured in a motor vehicle crash after controlling for miles traveled (Massie & Campbell, 1993).

There are racial differences for motor vehicle fatality rates (NCHS, 2006). Based on 2003 data, within the male gender, Hispanic or Latino males have the highest motor vehicle fatality rates per 100,000 resident population (29.2), followed by the Black male (28.9 per 100,000), the White non-Hispanic male (28.6 per 100,000), the American Indian or Alaska native male (25.4 per 100,000) and the Asian or Pacific Islander male (20.1 per 100,000) Among the female gender, the American Indian or Alaska native female has the highest motor vehicle fatality rates across both male and female racial groups (32.3 per 100,000), followed by the Asian or Pacific Islander female (16.2 per 100,000), the White non-Hispanic female (15.8 per 100,000), the Hispanic or Latino female (13.1 per 100,000), and the Black or African American female (12.4 per 100,000).

Gender differences in motor vehicle crash outcomes have been found, specifically for older adults. Generally, older female drivers have higher injury (including fatal injuries) rates compared to male drivers. Using the 1975 to 1988 FARS data, Bedard, Guyatt, Stones, & Hirdes (2002) studied driver, vehicle, and crash factors to determine their relationships to fatal injuries, and stratified the data by age to determine any differences among age groups. Results indicated although there were no gender differences for younger drivers, older male drivers had a higher proportion of fatal injuries compared with older females. However, in a multivariate logistic regression, females had a 54% increased risk of fatal injury compared to males.

Using 1982 to 2001 FARS data, Baker, Falb, Voas, & Lacey (2003) studied the driving characteristics of women 70 years and older in the U.S. over the 5-year period and compared with women in age groups 30 to 49 and 50 to 69. The objective of the study was to identify environmental factors (vehicle and road) associated with crashes among older females. The areas of interest to the researchers were times and conditions of motor vehicle crashes, types of crashes, conditions of the vehicles, characteristics of collisions, and propensity of getting injured. A series of loglinear analyses were used to examine the relationships among the environmental variable and crashes, and the estimates used to ascertain the relationships among environmental variables and crash was the likelihood ratio.

Females 70 years and older were more likely to have crashes in good weather, in daytime, and on roads with low speed limits. There were also a significantly larger proportion of older females who collided with fixed objects in a motor vehicle crash (Baker, Falb, Voas, & Lacey, 2003). For the FARS variable *most harmful event*, older women had a higher risk of collision with a fixed object (LR = 1.11) compared with collision with another motor vehicle (not statistically significant), collision with a moving object (LR = 0.94), and non-collision (LR = 0.92). For the *initial point of impact* (the angle at which the car was struck first), older women were at a greater risk of being struck in front (LR =1.04), compared to the passenger (LR = 0.93) and driver side (LR = 0.97), which both had a lesser risk of being struck in the crash.

A study of 300 adults 62 to 89 years of age indicated that generally for both males and females, driving patterns change with the chances of driving every day decreasing by about 6% after the age of 72, with females having 3 times the odds of reducing their driving compared with males. Bauer et al (2003) surveyed older drivers and collected information on driving history, driving patterns, and demographic information. Using bivariate analysis and a binary logistic regression method, they predicted changes in driving behavior and destinations based on age and gender (Bauer et al., 2003). Other gender differences included driving habits, with women less likely to driver in adverse conditions, and 75% ($p = 0.02$) more likely to reduce night driving compared with males, with the odds of driving less everyday 3.14 ($CI = 1.94–5.13$) times more for women than men (p.8).

Finison and Dubrow (2002) used the Maine Crash Outcome Data Evaluation System (CODES), a dataset that links police crash data to hospital and death certificate data in this study Age was stratified into young drivers (16 to 24 years), middle-aged drivers (25 to 64 years), and older drivers (65 years and over). Bivariate analyses and a multivariate logistic regression were conducted. Outcomes of interest included crashes, injury, fatalities and hospitalization, and mortality. Independent variables consisted of driving behavior variables such as failure to yield, and environmental variables such as, light conditions, road conditions, and rural/urban location. On the univariate and bivariate levels, compared with middle-aged drivers, older drivers were more likely to crash at lower speeds, intersections, and in urban area. They were also more likely compared with middle-aged drivers, to driver-related factors such as failure to yield or making a left turn.

With regard to the outcome variables, adults were at higher risk of injury resulting in hospitalization and/or death, compared with younger and middle-aged drivers, and the risk of fatality and hospitalization increased by age for the older driver. For older drivers only, female had a 1.62 odds of getting hospitalized or dying from the crash compared with males ($CI = 1.01–2.59$).

Age-related declines in sensory conditions include loss in vision (e.g., increased sensitivity to glare, reduced contrast sensitivity, and poor night vision) and hearing loss.

Decreases in cognitive abilities include the reduced ability to rapidly process information and the reduced ability to quickly switch attention between tasks—both of which are necessary skills in practicing safe driving. Physical declines pertinent to driving include the reduced range of motion of the neck and head, slowing down response time to execute vehicle control (Staplin, Lococo, Byington, & Harkey, 2001). These age-related conditions are aggravated by medical conditions, medications, and/or medication interactions.

Physical and mental conditions such as Alzheimer's have been shown to influence driving outcomes among older adults. Carr (1993) classifies skills required for safe driving into perception (vision, hearing, and range of motion), cognition (cognitive-related symptoms may be due to acute or chronic diseases), and execution (coordination and motor). In a study comparing a group with Alzheimer's disease with a control group, Rizzo, Anderson, Dawson, Myers, & Ball (2000) found that people with Alzheimer's disease performed less satisfactorily on attention, visual function, and visual processing speed. Older drivers may be prone to vision impairments that may make them more susceptible to motor vehicle injury. These vision impairments include cataracts, glaucoma, diabetic retinopathy, and age-related macular degeneration. Areas of concern are visual acuity, visual fields, contrast sensitivity, and Useful Field of View (UFOV). Visual acuity and visual fields are tested in vision tests administered by Divisions of Motor Vehicles in the U.S., although the standards may vary from state to state. However, contrast sensitivity and UFOV are not measured by DMVs (Owsley & McGwin, 1999). Among visual and cognitive factors, visual attention and mental status were the strongest predictors of motor vehicle crashes (Owsley, Ball, Sloane, & Bruni, 1991; Owsley et al, 1998).

The contribution of medications to older driver injuries in motor vehicle crashes can be classified by (a) the number of medications (polypharmacy), (b) classes of medications used, (c) side effects of medications, and (d) interaction effects due to adverse reactions, compliance, and medical errors that may influence the drug metabolism of older adults differently from other age groups as a result of aging. These include reduced body mass and basal metabolic rate, reduced proportion of body water, increased proportion of body fat, and decreased cardiac output (Hammerlein, Derendorf, & Lowenthal, 1998). Polypharmacy is defined as one of the following: (a) the use of many medications at the same time, (b) the prescription of more medications than is clinically indicated, or (c) a medical regimen consisting of five or more medications. Polypharmacy may result in adverse drug reactions and interactions (Beer, 1997). Effects of polypharmacy include vision, cognitive, or psychomotor disorders and indicates an increased risk of motor vehicle crashes for older adults (Carr, 1993; Lococo & Staplin, 2006). Certain classes of medications have been identified which negatively affect the safety of older drivers because they have the propensity of impairing the function of the central nervous system and, indirectly, the driving of older adults (Cowart, & Kandela, 1985). Classes of medication that have shown some association with unsafe driving behavior include benzodiazepines, cyclic antidepressants, hypoglycemic medications, narcotic analgesics, and antihistamines (Ray, Gurwitz, & Decker, 1992; Ray, Thapa, & Shorr, 1993). Overall, twenty-eight medications have been identified to have the propensity of being harmful to older adults compared with younger counterparts (Beers, 1997).

In summary, previous older driver studies indicate that health factors (e.g., age, race, gender, and physical health) are associated with injury, fatality, and crash outcomes among adult drivers, and that some differences have been observed among younger, middle-aged, and older drivers.

Behavior

Behavior factors that are predictors of motor-vehicle related injuries include self-regulation, drug use, alcohol and driving, and seatbelt use. Generally, older drivers self-regulate, with crashes occurring in broad daylight under non-adverse conditions, and are more likely to be wearing a seatbelt at the time of the crash, and less likely to be under the influence while driving compared with younger drivers (NHTSA, 2006b). Ball, Owsley, Stalvey, Roenker, Sloane, and Graves (1998) studied 257 licensed older drivers (55 years and older) in Alabama. They examined the association between visual and cognitive impairment and avoidance of taxing driving conditions, and the interrelationships among functional impairment, driving avoidance, and crash risk. Subjects were given an eye health examination and were given tests to measure visual acuity, contrast sensitivity and visual field sensitivity. The cognitive function and the size of the useful field of view were also measured. A structured questionnaire (the Driving Habits Questionnaire), was used to collect data on how often the subjects drove (driving exposure) and the evasion of potentially challenging driving situations. There were seven items on the Driving Habits Questionnaire pertaining to driving avoidance. The items covered potentially challenging situations such as driving at night, driving in high-volume traffic, driving on expressways or interstate, driving alone, executing left hand-turns across oncoming traffic, and driving in the rain. Ball et al. (1998) performed spearman correlations among the avoidance items on the questionnaire, visual and cognitive function, eye health, and driving exposure.

Older drivers with vision and cognitive problems were likely to self-regulate the driving, e.g., not driving under adverse conditions, and drove for fewer times a week. The relationship between the driving avoidance items and mental status, driving alone had a strong relationship with mental status. Ball et al (1998) also classified the subjects into six groups based on levels of functional impairment. They performed a multivariate analysis of variance to ascertain whether there were significant differences among the groups and their patterns of driving avoidance. The results suggested that there were differences among the groups in their driving avoidance patterns based on their level of visual functioning. However, there were not significant differences for night avoidance.

A separate analysis comparing subjects with cataract and those without any cataract showed that there were significant differences among the two groups, with the cataract group having significantly higher avoidance, but there were no differences for avoidance at night driving and making a left turn. A correlation analysis was performed to investigate the relationship among the driving avoidance items and crash history. The number of crashes in the five years prior to the study was significantly associated with driving avoidance items such as avoiding driving in the rain, making left hand turns, and driving in rush hour traffic. In summary, Ball et al. (1998) showed association among visual and function impairment and self-regulation (driving avoidance). The levels of visual impairment were associated with the type of driving avoidance. Freeman, Munoz, Turano, and West (2006) had similar results. In a study of 2,520 older adults (65 to 84 years old), they measured cognition, depressive symptoms, and comorbid conditions. Visual acuity, contrast sensitivity, and lower peripheral visual fields were also measured at baseline and follow-up two years later. A questionnaire was administered at baseline and follow up to obtain demographic information, medical history, health behavior, and driving history. The study had three outcomes: (a) driving reduction to fewer than 3,000 miles per year for those who were driving 3,000 or more miles at baseline, (b) night driving cessation, and (c) cessation of driving in unfamiliar settings. Statistical analyses comprised of chi-square tests between each independent variable and outcome variables and five logistic regressions for the vision variables to control for the age effect. Results from the bivariate analysis showed statistically significant relationships between age, gender, race, health condition and decreasing driving mileage. Subjects, who were older, female, African-American, cognitively impaired and in fair or worse health condition were more likely to decrease driving mileage at follow up.

In summary, older adults appear to self-regulate their driving based on health conditions, how confident they feel, and their perceived level of risks. Vision and cognition are some of the reasons why older drivers may change their driving behaviors.

Environment

The environment is made up of the economic environment, the physical environment, and the social environment (Green & Kreuter, 2005). Most previous older driver studies pertain to the physical and social environment.

The physical environmental factors pertinent to older drivers include vehicle conditions, road conditions, highway design, and traffic patterns. The outcome of a motor vehicle crash for older drivers may be exacerbated by vehicle designs that do not accommodate age-related frailty and fragility (e.g., due to body shrinkage from the normal aging process). For instance, headlights that reduce the incidence of glare at night may improve the safety outcome for older drivers (Schieber, 1994; Wang & Carr, 2004). Another vehicle factor that particularly influences types of injuries in motor vehicle crashes is the position of the seat. Hill & Boyle (2006) demonstrated that for small females, rearward seat positions were associated with chest injuries compared to forward seat positions, while males were more prone to chest injuries with forward positioned seats. The type of injury incurred appeared to be associated with gender. Regarding highway design, older drivers are more likely to get injured or die in crashes at intersections (NHTSA, 2006b; Awadzi, Classen, Garvan, and Komaragiri, 2006; CDC, 2004). Other road-related factors associated with motor vehicle crashes include road surface conditions, time of day, speed limits, rural vs. urban, and whether the highway was divided or not. Yan, Radwan, and Abdel-Aty (2005).conducted to investigate environmental (driver, vehicle and road) risk factors associated with rear end crashes at intersections with signals. The sample was stratified by five age groups ranging from less than 26 years of age, to greater than 75 years of age. Health (age, and gender) and behavioral (alcohol and drug use) were also examined. The data used in the study was the 2001 Florida accident database. The quasi-induced exposure method was used to calculated relative accident involvement risk ratios (RAIR). The type of crashes was classified as rear end or non-rear end crashes, and a binary logistic regression was used to ascertain measures of association between independent variables and type of crashes. The level of statistical significance was set at $p \leq 0.01$.

Female drivers were at a less risk of striking another vehicle in the crash (*OR* = 0.90; *CI* = 0.84–0.96). Drivers who struck another vehicle in a crash were more likely to be less than 26 years of age and male, or older than 75 years, while the drivers whose vehicles were struck, were more likely to be older adults. Alcohol use was significantly associated with crashes. Environmental variables that had significant association with type of crash (rear-end crashes) included number of lanes, undivided versus divided highway, time of crash, rural/urban, and speed limits. The risk of rear-end crashes was highest in 6-lane roads, and on roads that were undivided. Also, the risk of rear-end crashes in the nighttime was less than during the day time (*OR* = 0.50; *CI* = 0.66–0.80). Drivers on wet (*OR* = 3.3; *CI* = 2.26–4.84), and slippery roads (*OR* = 1.79; *CI* = 1.64–1.97), had a greater risk of rear-end crashes compared with drivers traveling on dry roads. The manner of vehicle and relation to junction are also associated with motor vehicle crashes (Baker et al., 2003).

The social environment comprises of the care networks passengers, and stakeholders. Services include alternative transportation and community mobility (Green & Kreuter, 2005). An example of social environment that is associated with motor vehicle crashes among older adults is the presence and number of occupants in the motor vehicle with the older driver. Studies indicate that passengers in the motor vehicle may influence unsafe actions displayed by older drivers, thus influencing the probability of a crash. With 1975–1998 FARS data, Bedard and Meyers (2004) demonstrated an association between the number of occupants in a motor vehicle and unsafe actions performed by the older driver. The objective of the study was to examine whether an older adult driving with passengers would be associated with risks of performing unsafe actions. Using FARS data (1975 to 1998), and a logistic regression model, Bedard and Meyers used, and compared unsafe actions performed by the older driver (stratified by age) when alone, with unsafe actions performed when the older drivers had passengers.

Older drivers 65 to 79 years old with four or more passengers had a 27% decreased risk of performing unsafe driver actions (*OR* = 0.73; *CI* = 0.61–0.86). However, the presence of passengers in the vehicle could be protective or detrimental, depending on the type of unsafe action performed by the older driver. The presence of passengers is a protective factor for speeding, lane-related actions, inexperience, following and driving the wrong way (*OR* = 0.37; *CI* = 0.30–0.46), neutral for passing and disadvantageous for obeying signs/warning/right of way, turning, and lane changing (*OR* = 1.18; *CI* = 1.15–1.22).

Hing et al. (2003) used police reports from Kentucky for older drivers (65 years and older) and compared single and multi vehicle crashes and stratified the sample by number of passengers (no passenger, one passenger, and two or more passengers). Hing et al. used the relative accident involvement ratio (RAIR) to calculate the ratio of passengers who were at fault, to those who were not at fault in a crash and controlled for time of day, gender, road condition, road type and number of lanes. Logistic regression was used to ascertain the association among independent variables and at fault crashes. Hing et al established that time of day is associated with whether the presence of occupants is a risk or protective factor. For older drivers during the daytime, having two or more passengers is a risk factor in single and multi-vehicle crashes, but a protective factor in the nighttime.

Environmental variables encompass vehicle, highway, and social factors. Highway design, angle at which the vehicle was struck, time of day, road conditions, and the presence and number of passengers in the car, are some variables significantly associated with crashes, injuries and fatalities.

Enabling

Older driver enabling factors for older drivers are stakeholders that provide resources to facilitate safe driving. In the U.S, these include federal agencies, state agencies, professional organizations, and consumer organizations. Older driver stakeholders provide information on (a) safe mobility programs and guides, (b) driver assessment and rehabilitation programs, (c) driver self-assessment tools, (d) vehicle adaptations, (e) social service programs, (f) assisting with transportation options, and (g) increasing community awareness on older driver safety (Eberhard et al., 2006).

Federal agencies: Federal agencies, such as the National Highway Traffic Safety Administration (NHTSA), the Federal Highway Administration (FHWA), and the CDC, conduct internal research and provide data on older driver safety issues. For example, the NHTSA finds external researchers to establish national safety standards for motor vehicles in the U.S. and provide annual surveillance data on motor vehicle crashes and related injuries on demographical levels through its national secondary databases the GES and the FARS. NHTSA has partnered with government and private groups to help older drivers maintain their safe mobility (Eberhard et al., 2006). Areas of emphasis include alcohol-impaired driving, older drivers, teenage driving, and child passenger safety (CDC, 2004). The CDC has conducted research on motor vehicle fatalities among adults age 65 and over and found variations by gender, race, and ethnicity. NHTSA and FHWA regularly provide the public with information on behavioral, health, environmental, and vehicle factors that impact safe or unsafe driving practices of the elderly population.

License renewal policies: State agencies, to different extents, have developed statutes to monitor and regulate older drivers. Currently, about half of the states have some form of age-related driver licensure renewal laws. There is indication that the type of renewal policies in a state may be linked to the number of motor vehicle fatalities among older adults (Grabowski, Campbell, & Morrisey, 2004; Levy, 1995). Driver licensure renewal policies related to older adults include shorter or "accelerated" renewal cycles, in-person driver license renewals (where the older adult's fitness may be challenged based on appearance), or special tests, e.g., a vision test (Grabowski & Morrisey, 2001). Grabowski et al. (2004) used 10 years of FARS data (1990 to 2000) to investigate the influence of elderly licensure laws on motor vehicle fatalities and compared older drivers (65 years and older) to a younger group (35 to 64 years of age). The authors examined variables that included the types of elderly licensure renewal laws such as in-person renewal, vision test, road test, and the renewal period. Besides that, they included other variables considered to confound, such as state speed limits, type of seatbelt laws (primary vs. secondary), blood level alcohol, and administrative license suspension, as well as per capita income and unemployment rates, in the analysis. Findings indicated that states with vision test requirements, road tests and, and reduced renewal cycles were not significantly associated with risks of fatality, however, in-person renewal was significantly associated with reduced risk of injury fatality ($RR = 0.83$; CI = 0.72–0.96).

States vary in their guidelines requirements based on age, length of time until renewal, type of testing required, and whether the license is renewed in person or by mail (Wang, Kosinski, Schwartzberg, & Shanklin, 2003; National Academy on Aging, 2001). Six states (Florida, Maine, Oregon, South Carolina, Vermont, and Virginia) and the District of Columbia require a vision test for older adults. The age requirements for vision tests (that test only visual acuity) vary from state to state. Maryland requires a vision test during license renewal for people 40 years and older. New Hampshire and Illinois are the only states that require seniors 75 years and older to take a road test. Most states have a four or five-year renewal policy; however, this policy varies, with some states having up to eight years (Wang et al., 2003). Fourteen states have an accelerated renewal policy for older drivers. However, the starting age for this accelerated program varies from state to state. The special renewal test requirements for older adults vary from state to state (Levy, 1995; Molnar & Eby, 2005). State licensing and renewal policies may contribute to driving behavior and driving cessation among older adults. Koulikov (2005) used the Asset and Health Dynamics of the Oldest Old data to examine the relationship among state licensing and renewal policies and driving cessation among older drivers. Results from a factor analysis suggested that states with mental testing, in-person renewal at age 70, and restricted licensing requirements were significantly related to the older adults' decision to stop or reduce driving (Koulikov, 2005).

Professional and consumer organizations provide guidelines and resources for older drivers and stakeholders. Examples of professional organizations pertinent to older driver safety are the American Occupational Therapists Association (AOTA) and the American Medical Association which developed policy guidelines for physicians to assess health condition of patients that may negatively impair driving (Wang et al., 2003).

Consumer organizations have collaborated with state and local governments to make programs available to older adults. For example, the American Association of Retired Persons (AARP), the American Society on Aging, the American Automobile Association (AAA), and the AOTA developed the CarFit program for older drivers and driver rehabilitation specialists. The CarFit program enables trained personnel to determine the fit of the older adult to the vehicle. AARP has driver safety refresher course for adults 50 years and older to enable them to improve driving skills; learn about normal age-related physical changes; reduce traffic violations, crashes, and chances for injury; improve safe driving outcomes; and have automobile insurance discounts (AARP, 2006). The AAA Roadwise Review is an interactive CD-ROM which is a self-assessment tool for older drivers to assess their functional ability to drive safely (AAA, 2005).

In summary, older drivers have enabling resources on the federal, state, and local levels. On the federal level, the NHTSA provides minimum safety requirements for motor vehicles, and on the state level, some states have age-renewal license policies for older drivers. Professional and consumer organizations offer resources and services to facilitate safe driving among older adults.

Gaps in Literature

The older driver systematic literature review showed that previous older driver studies focused more on the health domain and less on behavioral, environmental, and health education/policy (Classen et al., 2006). It is therefore important to use a socio-ecological approach to examine how health, environmental, behavior, predisposing, reinforcing, and enabling variables are associated with motor vehicle injuries and fatalities.

Epidemiological data generally focus on motor vehicle crashes and fatal injuries, and not injuries. While it is important to examine the associations among factors and crashes or fatal injuries, it is also imperative in planning an older driver injury prevention program, to comprehend the relationship among health, behavior, environment and injury.

The Precede-Proceed model of health promotion has been used in studies within the healthcare system and injury intervention studies for children; however, it has not been used in addressing risk and protective factors for motor vehicle-related injuries among older adults. This study will address older driver safety from a socio-ecological perspective and explore the relationship between licensure policy for older adults and injury prevalence rates. Using younger drivers (35 to 54 years) as a comparison group allows the examination of risk and protective factors of motor vehicle injuries among older adults. Findings from these analyses will be integrated with qualitative data to plan an intervention program for safe driving among older adults.

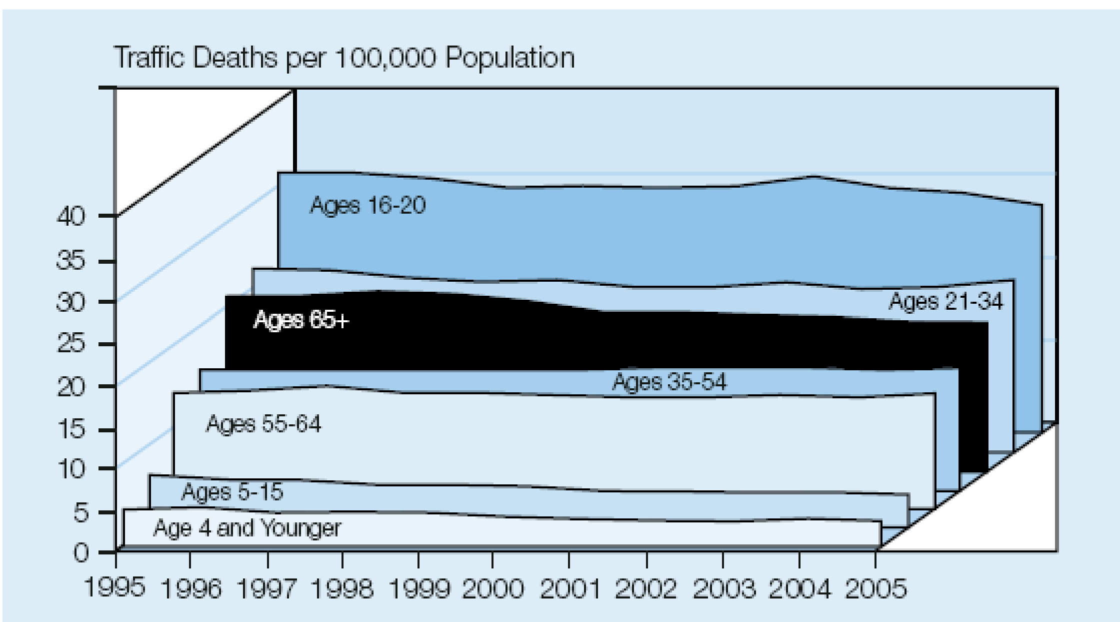


Figure 2-1. Motor Vehicle Traffic Fatality Rates by Age Group, 1995–2005. National Highway Traffic Safety Administration (NHTSA, 2006)

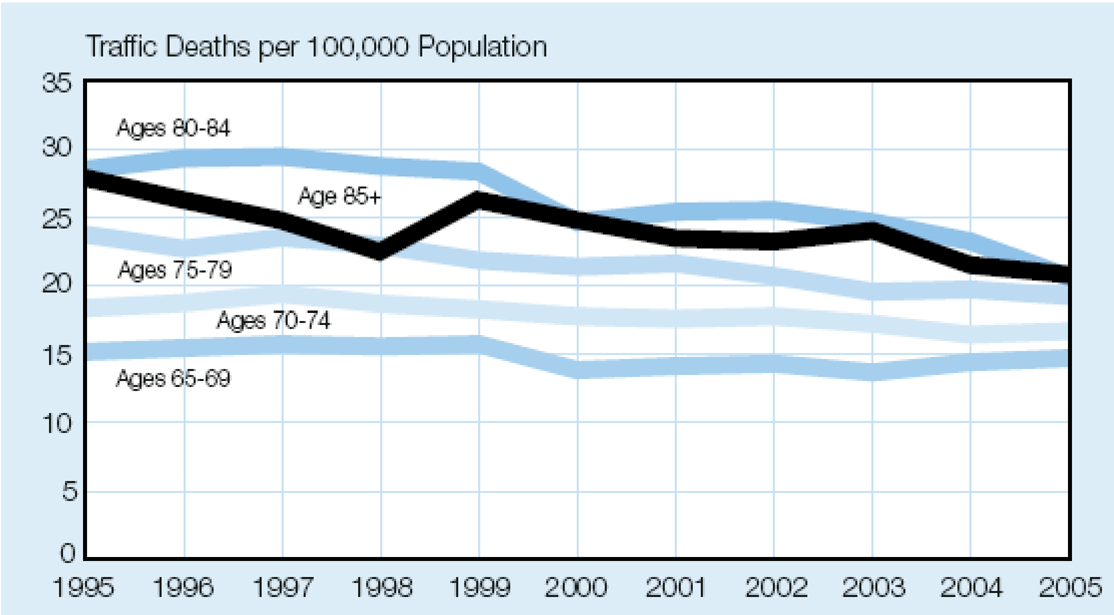


Figure 2-2. Motor Vehicle Traffic Fatality Rates by Age Group, 1995–2005. NHTSA (2006)

CHAPTER 3
METHODOLOGY

In this chapter, I present (a) the research questions and hypotheses of the study, (b) the scope of the FARS secondary database and the procedure used to include cases in the dataset, (c) the sample selection process, (d) the operationalization of dependent and explanatory variables, and (e) an outline of the methodology used in answering the research questions of the study.

Research Questions and Hypotheses

Using the PPMHP, the PPMHP structural model, and a national crash dataset, FARS 2003 (DOT, 2003a), I asked three questions:

1. What is the prevalence of the main determinants (risk and protective factors) and motor vehicle injury for younger drivers (35 to54 years) and older drivers (65 years and older)?

2. What are the measures of association among socio-ecological determinants (behavioral, environmental, predisposing, and reinforcing factors) confounding variables (age), and motor injury (injury: yes/no) for younger and older drivers?

3. What is the prevalence of injuries for older drivers among states with age-related license renewal policies compared to states without any age-related license renewal policies (enabling factors)?

Research Question #1

Ho: Younger drivers will not have lower prevalence rates for motor vehicle injuries compared to older drivers (65 years and older).

Ha: Younger drivers (35 to54 years) will have lower motor vehicle injury prevalence rates compared to older drivers (65 years and older).

Research Question #2

Ho: Younger drivers (35 to 54 years) will not have lower measures of associations for environmental variables (e.g., *hour of day*, and *most harmful event*), predisposing variables (*vehicle maneuver*) and injury, compared with older drivers (65 years and older).

Ha: Younger drivers (35 to 54 years) will have lower measures of associations for environmental variables (e.g., *hour of day*, and *most harmful event*), and predisposing variables (*vehicle maneuver*) and injury, compared with older drivers (65 years and older).

Research Question #3

Ho (1): There will be no difference in motor vehicle injury prevalence rates for older drivers between states with no age-related licensure renewal procedures (enabling variables) and those with age-related licensure renewal procedures.

Ha (1): There will be differences in motor vehicle injury prevalence rates for older drivers between states with age-related licensure renewal procedures (enabling variables) and states with no age-related licensure renewal procedures.

Description of the Fatality Analysis Reporting System Database (FARS)

This section focuses on the scope and procedure of the FARS secondary dataset, the rationale for using the FARS dataset, and limitations of FARS.

Scope of the FARS database

This section covers the description of the FARS dataset and the procedure of the FARS data collection. I discuss the background on the FARS database, its universe and unit of observation, origin of data in the dataset, period of the data collection, and rationale for using the 2003 FARS dataset in this study.

Created by the National Center for Statistics and Analysis (NCSA) of the National Highway Traffic Safety Administration (NHTSA), FARS contains data on a census of fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico. National highway safety communities, state governments, local governments, and researchers use the FARS data for motor vehicle injury and fatality trend analyses.

NHTSA has funded the FARS datasets since 1975. The dates of data collection are from 1975 to 2005. Inclusion criteria for FARS are motor vehicles involved in crashes while traveling on traffic ways normally open to the public, and a resulting death within 30 days of the crash. The unit of observation in the FARS dataset is a crash.

Data are obtained from coded data elements reported on the following forms containing information pertaining to four main areas: (a) the *Accident* from, (b) the *Vehicle* form, (c) the *Driver* form, and (d) the *Person* form. In 1987, FARS integrated data from the Multiple Cause of Death file from the National Center for Health Statistics. This dataset provides information on the deceased with matching death certificates on educational level, occupation, specific cause of death, specific injuries, race, and ethnicity. FARS began recording race and ethnicity information of the fatally injured from death certificates in 2002 (NHTSA, n.d.).

FARS database

NHTSA has an agreement with individual U.S. states to gather information from Police Accident Reports, State Vehicle Registration Files, State Driver Licensing Files, State Highway Department Data, Vital Statistics, Death Certificates, Hospital Medical Reports, and Emergency Medical Services Reports in a standard format on fatal crashes occurring in the state.

Each fatal crash reported encompasses 125 different coded data elements. On a daily basis, data are entered in local computers, and then transferred to the main NHTSA computer. Data are checked automatically for consistency, timeliness, and accuracy (NHTSA, n.d.). Files are available in SAS and sequential ASCII file formats and convertible into other statistical software programs.

Rationale of selecting the FARS dataset

The FARS database contains health (age, gender, race, physical and mental health conditions), behavioral (restraint system use, alcohol and drug use), environmental (physical and social), predisposing (vehicle maneuver), and reinforcing (number of previous motor vehicle convictions) variables that are useful for analyses using a socio-ecological framework. I used the 2003 dataset because it was the latest year of available FARS crash data, and thus reflected current crash data. Next, I will discuss the process of selecting the dependent, independent, and confounding variables from the 2003 dataset.

Process of sample selection

Inclusion criteria: Drivers were included when they fell within the two age groups: (a) 35 to 54 years (younger drivers), and (b) drivers 65 years and older (older drivers).

Exclusion criteria: Subjects were excluded when there was age-related missing data; were non-drivers of motor vehicles (e.g., passengers, pedestrians, and drivers of motorcycles); drove heavy trucks (e.g., school buses and motor homes); drove vehicles with unknown body types; or they drove vehicles that do not normally travel on public roads (e.g., snowmobiles and farm equipment).

Study design: This study used a cross-sectional design.

Sample: The sample size in the study consisted of 14,038 younger drivers, and 5,744 older drivers (*N*=19,782).

Process of merging data files: The 2003 FARS sample databases consisted of three main files—the *accident*, *vehicle*, and *person* files. There were also blood alcohol levels files, but these were not included in the analyses. Data files were downloaded from the NHTSA website in April 2006 and stored on a secure server at the College of Public Health and Health Professions (University of Florida). The files (initially in SAS format) were merged using three variables: The *Vehicle Number*, *Person Number*, and *State Number*, which, in combination, form unique identifiers. The merged database was converted into SPSS 14.0. The data consisted of 178 FARS variables and 102,102 motor vehicle crashes. After the data were saved, a copy of the merged file was created and used in subsequent analyses. I created a new file excluding cases of non-drivers, cases with unknown ages, cases with crashes involving unknown vehicle types, cases with ages less than 35 years of age and ages between 55 and 64 years of age, and cases involving heavy vehicles. This resulted in a final sample size of 19,782 drivers, comprising of 14,038 younger drivers (35 to 54) years of age, and 5,744 older drivers (65 and over).

Description of Dependent and Independent Variables

In this section, I describe the process of selecting independent and dependent variables. For the variables included in bivariate analyses and the binary logistic regression analysis, I describe variables as they were operationalized by NHTSA, and explain the rationale behind selecting and collapsing levels of certain variables.

I used the conceptual definitions from the FARS dataset to operationalize the dependent and independent variables in the study. The conceptual definitions of all FARS variables are available in the *FARS Analytic Reference Guide (1975–2002)* and the *2004 FARS Coding and Validation Manual* available at www.nhtsa.gov. Independent variables described in this section are limited to the 34 variables used in analyses (1 dependent variable and 33 independent variables).

Dependent variable

The dependent variable in this study was *injury*. In the FARS dataset, the variable *injury severity* consisted of eight levels of categories: No injury, possible injury, non-incapacitating evident injury, capacitating injury, fatal injury, injury (severity unknown), died prior to crash, and unknown if injured. For the purpose of the analyses, *injury* was operationalized as whether a driver sustained an injury in the crash or not (injury: yes/no). *Injury Severity* was collapsed as follows: (a) Non-incapacitating evident injury, (b) capacitating injury, (c) fatal injury, and (d) injury, severity unknown were placed in the injury category *injury yes*. *No injury* formed another category. Levels consisting of possible injury, unknown if injured, and died prior to crash were treated as missing data, because it was difficult to ascertain whether the group of people in those levels of injury severity were injured or not.

Independent variables

I used four approaches to select independent variables pertinent to the research questions. These approaches were: (a) previous older driver studies, primarily, the FARS structural model based upon the SLR (Classen et al, 2006) (Appendix A), (b) consultation with the *Public Health Model to Promote Safe Elderly Driving* team, a NHTSA FARS database manager, (c) realism and manageability, and (d) percentage of missing data. These approaches are discussed below.

FARS structural model: The structural model (Appendix A), developed from the PPMHP was framework used in selecting FARS variables in the study. I selected FARS variables based on whether they fitted within a domain of the PPMHP. I modified the PPMHP structural model by replacing broad categories from the SLR with specific FARS variables.

Consultations: Consultations began prior to analyses. I referred to the FARS manuals for the operationalization of the variables. Appendix C illustrates the initial examination of the 2003 FARS *Accident*, *Vehicle*, *Person,* and *Driver* sections of the Analytical and Validation Manual and the rationale for including and excluding variables. To establish rigor and reliability in variable selection, there were consultations throughout the process. This included consulting with dissertation committee members and the *Public Health Model to Promote Safe Elderly Driving* Team (including a biostatistician). Consultations occurred throughout the six-month process of data examination, variable selection, and collapsing levels variables where necessary.

Realism and manageability: Seventy variables were initially selected after first screening of the FARS database. All of the 70 FARS could not be used in the multivariate analysis. It was necessary to use realism to decide what would be manageable within the scope of the study. One of the methods I used was to examine the operationalized definition of the variables to find out whether some variables had similar conceptual definitions. In such instances, to reduce multicolinearity which could confound the analyses, I selected the variable that best described the factor of interest. An example of such an instance was the environmental variables *first harmful event* and *most harmful event*. Both variables captured actions the driver engaged in prior to the crash. However, the *first harmful event* measured the initial action, while the *most harmful event* described the action that may have contributed most to the crash. Univariate analysis showed that frequencies for levels of each variable were similar, and had the same amount of missing data. Therefore, I selected *most harmful event* for the multivariate analyses.

Percentage of missing data: When conducting the multivariate analyses, I wanted to ensure that the analysis was not compromised because of many missing data. Early analyses indicated that variables with high percentages of missing data resulted in a regression model that used as low as 50% of the sample. A way of resolving this was to examine frequencies of independent variables and identify those that had high percentages of missing data. Variables with more than 8% missing data were excluded from subsequent analyses. I chose the cut-off point after examining frequencies and ascertaining the range of missing data among the variables. For example, the variable *police reported drug involvement* was excluded because it had 69% missing data; that is, either it was unknown whether there was an indication of drug use at the time of the crash, or it was unknown whether it was reported.

Collapsing of data: I used descriptive statistics (e.g., frequencies), to examine data pertaining to all independent variables. In instances where a variable had many levels and the frequencies in most levels were few, I collapsed the data into fewer levels to facilitate analysis.

For example, *most harmful event* had 46 levels. This was eventually collapsed into four categories: non-collision, collision with motor vehicle, collision with objects not fixed, and collision with fixed objects. I applied two strategies, described below, in the process of collapsing the data.

One of the strategies was to use information from the *FARS Analytic Reference Guide (1975–2002)* and the *2004 FARS Coding and Validation Manual*. For variables with several levels, FARS usually coded the variables under broad as well as specific categories. For example, rural vs. urban (FARS code *road function class*), had 15 levels. Seven levels of the variable are rural-related (rural principal arterial—interstate, rural principal arterial—other, rural minor arterial, rural major collector, rural minor collector, rural local road or street, and rural unknown). Seven levels of *road function class* are urban-related (urban principal arterial—interstate, urban principal arterial—other, urban minor arterial, urban major collector, urban minor collector, urban local road or street, and urban unknown), and one level is *unknown*. I collapsed this variable, using broad categories, into *rural vs. urban* as the variable had few percentages for every category and I was primarily interested in whether the crash occurred in a rural or an urban area, and not the type of type of rural or urban area. I went through this process for all the collapsed variables.

The second approach in collapsing the data was to examine variables with many levels and give separate categories to levels that had relatively higher frequencies.

Operationalization of independent variables by PPMHP domains

In this section, I describe the 32 independent variables selected for analyses, within the context of the PPMHP by describing the type of variable (e.g., continuous or categorical) and their operational definition in FARS. I also describe the rationale behind collapsing and recoding the variables used for analyses in this study (Table 3-1).

Health domain

Age: *Age* was a continuous variable in the FARS dataset. Age ranged from 0 to 96 years (actual age), and 97 years and older. After the cases that did not meet our inclusion criteria were removed from the sample, the ages of drivers left in the sample were 35–54 years, and 65+. Thus, age was grouped into two categories, the younger and older drivers.

Gender: *Gender* comprised of male and female.

Behavioral domain

Variables in the behavioral domain were *restraint system use*, *driver drinking*, and *driver license compliance*.

Restraint system use: This variable consisted of types of restraints in vehicles and motorcycles for all types of passengers. *Restraint system use* comprised nine levels: (a) none used/not applicable, (b) shoulder belt (c) lap belt, (d) lap and shoulder belt, (e) child safety seat, (f) bicycle helmet, (g) safety belt used improperly, (h) child safety seat used improperly, (i) helmets used improperly, (j) restraint used—type unknown, and (k) unknown. Four levels were eliminated due to the exclusion criteria. As the focus of the domain was on the behavior of the driver rather than the type of restraint system used, the variable was recoded as *restraint system used* (no/yes).

Driver drinking*:* There were five variables pertaining to alcohol in the FARS dataset: (a) police reported alcohol involvement, (b) method of alcohol determination by police, (c) alcohol test type/alcohol test results, (d) driver drinking and (e) drunk drivers. *Driver drinking* is a derived variable from the *vehicle* file. For the purposes of the study, I used *driver drinking* (no/yes) (option d). Data for *driver drinking* are obtained from blood alcohol content (BAC) data or police reported alcohol involvement (NHTSA, 2002).

Driver license compliance: The FARS dataset contained four variables pertaining to the status of the driver with respect to their drivers' license. The variables were (a) non-CDL license type/status, (b) commercial motor vehicle license status, (c) license compliance with class of vehicle, and (d) compliance with license restrictions. The focus of the study is on whether the driver's license was valid or not, so the variable (option c) selected for the analysis was *License compliance with class of vehicle*.

Environmental domain

Physical environment: The physical environment comprised of the variables *day of week*, *hour of day*, *registered vehicle owner*, *number of lanes*, *road surface condition, road surface type*, *road alignment*, *road profile*, *rural vs. urban*, *national highway system*, *vehicle body type*, *most harmful event*, *relation to junction*, *principal impact*, *trafficway flow*, *traffic control device functioning*, *light condition*, *weather condition, construction/maintenance zone*, and *airbag deployment*.

Day of week: This variable was not collapsed, and contained cases of crashes for all days of the week (Sunday to Saturday).

Hour of day: This was obtained from the variable *Accident Time*, and comprised two variables—hour and minute of the crash. The hour (a discrete numerical variable) was used in these analyses. *Hour of day* ranged from 0 to 24 hours (military time). To ascertain times of the day that may have risk or protective factors for crashes, I collapsed the variable into three levels to enable examination of the influence of various traffic patterns on injury (e.g., peak hours in the morning and evening, and night driving): (a) 9p.m.–7a.m., (b) 8a.m.–1p.m., and (c) 2p.m.–8a.m.

Registered vehicle owner: This variable had eight levels: (a) not applicable/vehicle not registered, (b) driver in the crash was a registered owner, (c) vehicle was registered as a business/company/government vehicle, (d) vehicle was registered as rental vehicle, (e) vehicle was stolen (reported by police), (f) driverless vehicle, and (g) unknown. There were few frequencies (0.8%) for whether the vehicle was a business or rental vehicle. To facilitate further analyses with this variable, it was coded as (a) driver was registered owner and (b) driver was not registered vehicle owner.

Number of lanes: This was a continuous variable, with number of lanes varying from one to seven. Since there were cases with four or more lanes, I collapsed this variable into (a) one lane, (b) two lanes, (c) three lanes and, (d) four to seven lanes.

Roadway surface condition: The roadway surface condition was the condition of the road at the time of the crash, which may or may not have contributed to the crash. The levels were as follows: (a) dry, (b) wet, (c) snow or slush, (d) ice, (e) sand, dirt, oil, (f) other and (g) unknown. There were very few cases (4.2%) in the snow or slush, and sand, dirt, oil categories. *Roadway surface condition* was collapsed into two levels: (a) favorable and (b) adverse roadway surface conditions.

Roadway surface type: This variable had the following levels (a) concrete, (b) blacktop, (c) brick or block, (d) slag, gravel or stone, (e) dirty, (f) other, and (g) unknown. About 85% of the frequencies were in the *blacktop* category, with very few in the other categories. The variable was collapsed as follows: (a) concrete, (b) blacktop, and (3) other (brick or block, slag, gravel, snow, and dirt).

Roadway alignment: This variable comprised three levels: (a) straight, (b) curve, and (c) unknown. The variable was used as it appeared in the database, and the unknown category was treated as missing data in analyses.

Roadway profile: This variable had the following levels: (a) level, (b) grade, (c) hillcrest, and (d) sag. About 71% of cases were in the first category of the variable, with very few cases in the other categories, thus data were collapsed into (a) level and (b) other.

Rural vs. urban: Roadway function class had 14 levels, but was broadly classified by NHTSA into rural and urban roadways. The focus of the study was whether the crash occurred in a rural or urban roadway, and thus, the data was collapsed into those categories.

National highway system (NHS): This comprises the interstate stem, principal arterial system routes, and some Strategic Highway Network connectors (NHTSA, 2004). The road where the crash occurred was classified as (a) this section IS NOT on the NHS, (b) this section IS ON the NHS and (c) unknown if this section is on the NHS. The first two levels were used in the analyses.

Vehicle body type: This variable had about 80 levels. It comprised all vehicle types. Heavy vehicles (school buses, mobile homes, heavy trucks) and vehicles of unknown body types were removed from the databases. The rest of the data were categorized into three levels: (a) automobile and automobile derivatives, (b) SUVs, and (c) light trucks and pickups.

Most harmful event: This is the major event for the vehicle involved in the crash. It consisted of 46 levels, but were grouped under four broad categories used in the analyses in this study: (a) non-collision (e.g., overturn, fire/explosion), (b) collision with motor vehicle (e.g., motor vehicle in transport on the same roadway), (c) collision with object not fixed (e.g., pedestrian or animal), and (d) collision with fixed object (e.g., boulder or utility pole).

Relation to junction: Relation to junction is the location of the first harmful event that contributed to the crash. The variable has 18 levels and was grouped under three categories, (a) non-junction, (b) non-interchange and (c) interchange area.

Principal impact: This is the impact point of the crash. The FARS dataset has both the initial point and the principal point. Both variables use clock points to indicate the position of injury 0 for non-collision, (1–12), and 13 (top) and 14 (undercarriage). The initial point is the first impact point that produced property damage or personal injury, while the principal point is the impact point that produced the most property damage or personal injury (NHTSA, 2004). The descriptive analyses (frequencies) indicated that both the initial and the principal point of impact had similar distributions within the various impact levels. To reduce multicolinearity, only one variable, the principal impact was selected in the analyses. Since some of the levels had few frequencies, the variable was collapsed into the following levels: (a) 1–3 o'clock, (b) 4–6 o'clock, (c) 7–9 o'clock, (d) 10–11 o'clock, (e) 12 o'clock, and (f) top and undercarriage.

Trafficway flow: This variable was grouped as follows: (a) not physically divided (two-way traffic-way), (b) not physically divided (with two-way continuous left-turn lane), (c) divided highway, median strip (without traffic barrier), (d) divided highway, median strip (with traffic barrier), (e) one-way traffic-way, and (f) entrance/exit ramp. For the purposes of this research, the variable was collapsed into the following levels: (a) divided highway, (b) not divided highway, (c) one-way traffic-way, (d) not physically divided, and (e) entrance/exit ramp.

Traffic control device functioning: There are two variables pertaining to traffic control devices in the FARS dataset—traffic control device, and traffic control device functioning. There were 37 traffic control devices grouped under highway traffic signals, regulatory signs, school zone signs, warning signs, miscellaneous not at railroad crossing, at railway grade crossing, and whether or not the device was at a railroad grade crossing. The focus of the variable in the study was whether the traffic control device was present or not, rather than the type of traffic control device, so for the purpose of the study, the variable *traffic control device functioning* was used in the analyses. This variable had four levels: (a) no controls, (b) device not functioning, (c) device functioning improperly, and (d) device functioning properly. The variable was collapsed into two categories: (a) no controls, and (b) device functioning properly. *Device not functioning* and *device functioning improperly* were removed from subsequent analyses.

Light conditions: This was coded as (a) daylight, (b) dark, (c) dark but lighted, (d) dawn, and (e) dusk. The variable was collapsed into three categories: (a) light, (b) dark, and (c) other (dark but lighted, dawn and dusk).

Weather conditions: This variable contained the following levels: (a) no adverse atmospheric conditions, (b) rain, (c) sleet (hail), (d) snow, (e) fog, (f) rain and fog, (g) sleet and fog, and (h) other. This was collapsed into two categories: (a) adverse and (b) favorable (no adverse) conditions.

Construction/maintenance zone: This pertained to whether the crash occurred in a maintenance or utility zone. The variable was collapsed into two categories: (a) none, and (b) construction, maintenance, or utility zone.

Airbag deployment: The variable airbag deployment is used to indicate whether the airbag was available for the person and whether it deployed or not, or was turned off. The variable had 11 levels and was recoded as (a) did not deploy or no airbag and (b) deployed.

Social environment: This comprised a discrete numeric variable *number of occupants*. Based on the older driver literature, and frequency distribution it was recoded into the following levels: (a) driver only, (b) one passenger, and (c) two or more passengers.

Predisposing domain

Vehicle maneuver: This variable captures the driver's action, or intended action, before commencement of the crash situation (a reflection of driver skill), and had 17 levels. These levels were collapsed into the following categories: (a) going straight, (b) lane-related, (c) maneuvers (making a right, making a U-turn, parking or leaving a parked position, making a controlled maneuver to avoid an object, or backing up) (d) making a left, and (e) negotiating a curve or changing lanes/merging.

Reinforcing domain

This domain comprised five discrete numerical variables pertaining to the drivers' conviction (ticketed offenses) history within three years prior to the crash: (a) number of previous motor vehicle accident convictions, (b) number of previous motor vehicle speeding convictions, (c) number of previous motor vehicle suspension convictions, (d) number of previous DWI (drug and alcohol impairment) convictions, and (e) number of other previous motor vehicle convictions (failure to yield, running a stop sign or red light, and lane-related). The reinforcing variables were not collapsed in the analyses.

Enabling domain

Licensing state: The licensing state was the only variable applicable to the enabling domain of the PPMHP. This variable was not used in the multivariate analyses. Instead, a sub-analysis was performed for older drivers only because this study explored the relationship among age-related license renewal policies and injury outcomes. States were classified as having age-related license renewal policies or not having age-related licensure renewal policies, and bivariate analyses performed to ascertain the relationship with injury, for four age-related renewal policy factors I derived from *license state*. Table 3.2 summarizes states with and without age-related license renewal policies.

Data Collapsing and Data Cleaning

The next step of the analysis was to examine the variables in light of the PPMHP structural model created from the SLR, and the domains of the PPMHP. A preliminary selection of the variables was done. A codebook was created, using the *1975–2003 FARS Analytical Reference Guide* and the *2004 FARS Coding and Validation Manual* to ascertain the definitions of each variable. The majority of the variables were categorical or ordinal in nature, with levels of variables varying between 2 and 50. For the purposes of conducting bivariate and regression analyses, it was important to collapse some of the FARS variables. The codebook for the initial examination of the FARS variable analyses is presented in Appendix C.

After the initial merging of the FARS variables, we had an initial number of 178 variables. The next step in analysis involved attaching labels to the variables in SPSS to ensure accuracy of data analysis. Subsequently, in this stage I performed univariate statistics of the variables to examine levels of variables for missing data. This enabled me to eliminate variables that were applicable to the research question but contained too many missing data points. For example, two environmental variables that contained information on the longitude and latitude of where the crash occurred had 100% missing data. After all the variables had been collapsed into smaller levels where applicable, univariate analysis was conducted once more. The initial modus operandi was to conduct a bivariate analysis, select variables that were statistically significant at the $p \leq 0.05$ level, and use those variables for subsequent analyses (particularly, the binary logistic regression). However, due to the large sample size, almost all the variables showed up as significant at that level of analysis. The bivariate analysis was used to examine frequencies in the cells, and further collapse data where necessary.

For the multivariate analyses, the frequencies of the variables were examined and those with less than 8% missing data were selected for further analyses. This strategy appeared to be a more effective one in the analysis. Thirty-two variables were selected for bivariate and logistic regression analyses.

Statistical Analyses

Statistical analyses were performed using SPSS 14.0 (SPSS, 2005). Statistical analyses consisted of univariate analysis, bivariate analysis, binary logistic regression, and a descriptive summary of age-related state license renewal policies for older drivers.

Univariate analyses

The univariate analysis served three purposes: (a) to provide information on the distribution of the data, making it easier to see which variables needed to be collapsed, (b) to provide a frequency distribution for the data for the descriptive portion of the study, and (c) to provide a means of variable selection for the binary logistic regression analysis. I performed univariate analyses for the younger group, the older group, and the overall sample.

Bivariate analyses

I performed bivariate analyses to examine the relationships between independent variables and injury outcome. The initial objective was to use this level of analysis to select variables for the logistic regression. However, this was not used since all the variables turned out to be significant at that level of analysis. I performed cross tabulations to ascertain the prevalence rates of injury/no injury among the population as well as for the younger and older groups. For numerical variables such as motor vehicle convictions, independent t-tests were performed to ascertain differences in the means between each reinforcing variable and injury outcome for the younger and older groups.

Prevalence is defined as “the number of events, e.g., instances of a given disease or other conditions in a given population at a designated time” (Last, 2001, p.140). The prevalence rate is a measure of the number of people who have a health condition in a population at a given time

(Mausner & Kramer, 1985, p.44). In the FARS database, all drivers were involved in a motor vehicle crash and it was not possible to measure prevalence as defined, as all drivers were exposed. To calculate injury prevalence rates among the independent variables, I used the crosstabulation function in SPSS 14.0 and selected the observed frequency option (with percentages for rows, columns and total). I calculated the proportion of drivers who were injured within each level of a variable. For example, for *gender* (younger drivers), 68.8% were male and 31.2% were female. Within the levels of *gender* the proportion of males injured was 73.0% were male, and 76.8% female, thus, the injury prevalence for males in the sample is 73.0%. I also selected the chi-square test option to determine whether there was any statistically significant relationships among independent variables and injury (no/yes) at $p \leq 0.05$ level.

I used a series of bivariate analyses to answer the research question on age-related licensure renewal policies for older drivers. The U.S. states were grouped by factors: (a) state age-related licensure renewal policy (no/yes) (Table 3-2), (b) reduced renewal cycles for older adults (no/yes) (Table 3-3), (d) in-person renewal (no/yes) (Table 3-4), and (b) vision and medical tests required (no/yes) (Table 3-5). The four categories of age-related license renewal policies are not mutually exclusive categories. I performed a series of chi-square tests to ascertain whether there were significant relationship among the four age-related renewal policy factors and injury (no/yes). To group the *license state* variable into four derived variables, I used information on age-related license renewal policies in 2003. Information on state age-related license renewal polices was obtained from *Physician's Guide to Assessing and Counseling Older Drivers* (Wang, Kosinski, Schwartzberg, & Shanklin, 2003). Thus, Florida, which has a vision test for license renewal for drivers over 79 years old, was classified as a state with no age-renewal policy for older drivers because the effective date for the law was January 2004.

Multivariate analyses

In selecting the independent variables, I wanted to choose variables that would result in the best model to answer the research questions. Hosmer and Lemeshow (1989) offer three approaches in modeling variables in a regression. One approach is to enter all variables in the logistic regression model regardless of whether variables contribute significantly to the model. The downside of this approach is that it may result in overestimated standard errors and estimated coefficients. The second approach is to aim for the most parsimonious model that would still explain the data. Hosmer and Lemeshow (1989) suggest that variable selection for the logistic regression start with a careful univariate analysis of each independent variable, and a crosstabulation with the dependent variable to ascertain zero data in cells of the table. The third approach for variable selection is to do a selection based on statistical criteria, such as a stepwise method. The disadvantage of using statistical methods to select variables is that irrelevant variables may be selected by the computer software (p.87). I used the second approach in this study.

Variables with less than 8% missing data were selected for the logistic regression analysis. To test the interaction between independent, confounding variables and injury outcome, a binary regression analysis was performed. The binary regression model is a method used to ascertain relationships between independent variables and an outcome (dependent) variable with two levels. The binary logistic regression enables the researcher to find out the estimates for each exploratory variable to the outcome variable. In a binary logistic regression, the probability of the occurrence of the dependent variable (varying between 0 and 1) is transformed into odds that express the likelihood of an occurrence relative to the likelihood of a non occurrence (Cox, 1989; Hosmer & Lemeshow, 1989) Unlike a linear regression that examines the relationship of how the dependent variable changes when the independent variable increases by one unit, the logistic regression model examines how the natural log of the odds that the dependent variable Y = 1 (π), varies as a function of the linear predictor (Jaccard, 2001). The relationship between the log odds of the dependent variable (logit) and independent variables is illustrated by the equation:

logit (π) = $\alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k$, where α is the intercept, β the regression coefficient, and X the predictor (independent) variables (Jaccard, 2001).

Apart from the 32 independent variables that were used in the regression model, age interactions were also done for all the variables. Jaccard (2001) defines an interaction effect as when the effect of an independent variable on a dependent variable differs depending on the value of a moderating variable (p. 12). The interaction model for two predictor variables can be presented as:

logit (π) = $\alpha + \beta_1 X + \beta_2 Z + \beta_3 XZ$, where X is an independent variable and Z a moderating variable.

The statistical outputs obtained from the regression model include (a) a classification table, (b) estimated odds ratios, and (c) Hosmer-Lemeshow goodness-of-fit statistic and R^2.

Classification table: This is used to evaluate the accuracy of the predictive property of the model (Pampel, 2000).

Estimated odds ratios: The odds ratios enable one compare two different odds, and estimate the likelihood of getting injured in a crash and, thus, enabled us to ascertain which variables were determinants (risk and protective factors) of injury.

Hosmer-Lemeshow goodness-of-fit statistic: The Hosmer-Lomershaw estimate enabled me examine the model fit (how well the model fits the data).

Pseudo R-square: The Cox and Snell R-square, and the Nagesqure R-square estimates. The Cox and Snell R-square is a measure of the pseudo-variance explained by the binary logistic regression model. The Nagesqure R-square is an adjustment of the Cox and Snell estimate, and was reported in the multivariate analyses (Pampel, 2000). I reported the Nagesqure R-square estimates in this study.

Level of significance: For the analyses that examined the relationship among independent variables and injury, and for the binary logistic regression. I chose the level of significance to be $p \leq 0.05$. Because the study was exploratory in nature, I did not use a Bonferroni correction to account for the large sample size. Most of bivariate results for injury prevalence had statistical significance at $p < 0.001$, and a Bonferroni correction would not have made a difference in the statistically significance in the bivariate results. In the third research question that examined relationships among age-related license renewal policies and injury outcomes, I applied a Bonferroni correction in the analyses, because the categories used to group the states were not mutually exclusive. The level of significance was $p \leq 0.0125$.

In a large sample size, it is important to differentiate between statistical significance and practical significance because the power of the study is dependent on the sample sizes. According to Stevens (2002), sample sizes greater than 200 are likely to have many variables that are significant at $p \leq 0.05$. Ways of determining practical or statistical significance include (a) putting the findings in context by examining previous research, (b) Using Cohn's definition of small, medium and large effect sizes, (c) having normative definitions of clinical significance, (d) performing a cost-benefit analysis, and (e) using a null hypothesis that is harder to reject, such as testing whether differences between two population is at least 3 standard deviations (Haase, Ellis, & Ladany,1989; Stevens, 2002, p.12). In these analyses, I defined clinical significance mainly by using option (a) that is, placing the findings in the context of obtaining historical plausibility through previous research.

Limitations of FARS

Using FARS encompasses the disadvantages of a cross-sectional study. As data on the explanatory and outcome variables are collected at the same point in time, it is impossible to measure cause and effect as one cannot establish the temporal sequence of events (Mausner & Kramer, 1985). Secondly, because of missing data, some PPMHP variables could not be included in the multivariate analysis. For example, health variables such as drug test results (a variable that contained information on different classes of medications) and driver-related factors such as some physical and mental health conditions were not used in subsequent analyses.

Specifically, FARS has the following limitations: (a) results will not be representative of drivers; (b) all subjects were involved in a fatal crash; thus, comparisons cannot be made with drivers who were crash free; (c) FARS has inadequate information on the social assessment domain of the PPMHP; (d) FARS lacks some socioeconomic variables (e.g., income). Race, a variable present in the 2003 FARS data, had information on only the fatally injured, and could not be used in the multivariate analyses in this study. Thus, within the scope of this study, the contribution of some socio-demographic characteristics to injury outcome could not be ascertained; and (e) some of the FARS variables had large percentages of missing data

Strengths of FARS

Despite the limitations of the FARS dataset, it meets the criteria as an appropriate database to answer the research questions of this study. The dataset comprises a variety of socio-ecological variables representing all the major domains of the PPMHP, except the health promotion domain, that enable researchers to examine crash dynamics and how health, behavior, environment, predisposing, reinforcing, and enabling variables are associated with injury outcomes in crashes.

Table 3-1. 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 = Automobiles 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
	Road function class (rural	(2) nominal	1 = rural

Table 3-1. Continued.

	vs. urban)*		2 = urban
	National Highway System	(2) nominal	0 = no 1 = yes
	Most harmful event (type of collision)*	(4) nominal	1 = collision with object not fixed 2 = collision with a moving vehicle 3 = non-collision 4 = collision with a fixed object
	Relation to junction* (highway design feature)	(3) nominal	1 = non-junction 2 = intersection 3 = interchange
	Principal point of impact (point of impact using the clock method)*	(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 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 occupants (passengers)*	(3) nominal	1 = driver only 2 = 1 passenger 3 = 2 or more passengers

Table 3-1. Continued.

Predisposing			
	Vehicle maneuver (driver skill)*	(5) nominal	1 = going straight 2 = lane-related changes 3 = other maneuvers 4 = making a left 5 = negotiating a 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

Table 3-2. Age-related renewal policies in 2003

States with age-related renewal policies	States without age-related renewal policies
Alaska	Alabama
Arizona	Arkansas
California	Delaware
Colorado	Florida
Connecticut	Georgia
District of Columbia	Kentucky
Hawaii	Massachusetts
Idaho	Michigan
Illinois	Minnesota
Indiana	Mississippi

Table 3-2. Continued.

States with age-related renewal policies	States without age-related renewal policies
Iowa	Nebraska
Kansas	New Jersey
Louisiana	New York
Maine	North Dakota
Maryland	Ohio
Missouri	Oklahoma
Montana	South Carolina
Nevada	South Dakota
New Hampshire	Tennessee
New Mexico	Texas
North Carolina	Vermont
Oregon	Virginia
Pennsylvania	Washington
Rhode Island	West Virginia
Utah	Wisconsin
	Wyoming

Table 3-3. Reduced renewal cycle requirements in 2003

States with reduced renewal cycles	States without reduced renewal cycles		
Arizona	Alaska	Minnesota	Tennessee
Colorado	Alabama	Mississippi	Texas
Connecticut	Arkansas	Nebraska	Utah
Hawaii	California	New Jersey	Vermont
Illinois	Delaware	Nevada	Virginia
Indiana	District of Columbia	New Hampshire	Washington
Iowa	Florida	New York	West Virginia
Kansas	Georgia	North Carolina	Wisconsin
Maine	Idaho	North Dakota	Wyoming
Missouri	Kentucky	Ohio	
Montana	Louisiana	Oklahoma	
New Mexico	Maryland	Oregon	
Pennsylvania	Massachusetts	South Carolina	
Rhode Island	Michigan	South Dakota	

Table 3-4. In-person renewal requirements in 2003

States with in-person renewal requirement	States without in-person renewal requirement		
Alaska	Alabama	New Mexico	Wisconsin
Arizona	Arkansas	Pennsylvania	Washington
California	Delaware	Rhode Island	West Virginia
Colorado	Connecticut	Maryland	Wyoming
Idaho	District of Columbia	Massachusetts	
Illinois	Florida	Oklahoma	
Indiana	Georgia	Oregon	
Louisiana	Hawaii	New Hampshire	
	Iowa	New York	
	Kansas	North Carolina	
	Kentucky	North Dakota	
	Maine	Ohio	
	Michigan	South Carolina	
	Minnesota	South Dakota	
	Mississippi	Tennessee	
	Missouri	Texas	
	Montana	Utah	
	Nebraska	Vermont	
	New Jersey	Virginia	

Table 3-5. Vision, medical, or road test requirements in 2003

States with vision, medical or road test requirement	States without vision, medical or road test requirement		
District of Columbia	Alaska	Kentucky	Oklahoma
Illinois	Alabama	Louisiana	Rhode Island
Maryland	Arizona	Maine	South Carolina
Nevada	Arkansas	Massachusetts	South Dakota
Oregon	California	Michigan	Tennessee
Pennsylvania	Colorado	Minnesota	Texas
Utah	Connecticut	Mississippi	Vermont
New Hampshire	Delaware	Missouri	Virginia
	Florida	Montana	Washington
	Georgia	Nebraska	West Virginia
	Hawaii	New Jersey	Oklahoma
	Idaho	New York	Wisconsin
	Indiana	North Carolina	Wyoming
	Iowa	North Dakota	
	Kansas	New Mexico	
		Ohio	

CHAPTER 4
RESULTS

In this chapter I describe the younger and older driver population with respect to the dependent variable (injury: no/yes), independent variables from the health, behavior, environment, predisposing, reinforcing, and enabling domains of the Precede-Proceed model of health promotion (PPMHP), and confounding variable (age). The following results are presented: (a) univariate results for younger and older drivers, (b) bivariate results indicating percentages and prevalence rates for injury among younger and older drivers, (c) bivariate results for the exploratory research on the relationship between age-related license renewal polices (older drivers only), and (d) results from the binary logistic regression.

Description of the Sample

In this section I present results of the univariate analyses for independent variables used in the binary regression model. I discuss the univariate results in relation to the percentage of younger drivers, older drivers, and the overall sample injured in a motor vehicle crash.

Univariate Analyses

The distribution of crashes for the overall sample and by age groups (Table 4-1), contained 32 variables organized by the main domains (health, behavior, environment, predisposing, and reinforcing) of the PPMHP. I conducted univariate analyses with frequencies for categorical variables (27 variables), and means and standard deviations for discrete numerical variables (5 variables). The sample population consisted of 71% younger drivers (14,038) and 29% older drivers (5,744). For all drivers, 68.2% (13,492) were male and 31.8% (6,290) were female. Among the younger drivers, there were 68.8% (9,665) males, and 31.2% (4,373) females, while the gender distribution for older drivers was comprised of 66.6% (3,827) male and 33.4% (1,917) female (Table 4-1). Regarding injury severity, 77.4% (15,315) of all drivers experienced some form of injury, 74.1% (10,049) of younger drivers were injured in the crash, and 85.4% (4,906) of older drivers were injured in a crash (Figure 4-1).

In the behavior domain, compared to younger drivers, older drivers had lower percentages of non-compliance (having an invalid drivers' license for the vehicle they were driving at the time of the crash, indicating alcohol use, and not wearing a restraint system use). Approximately 19% of younger and older drivers, 18.8% (3,725) of drivers indicated having drunk alcohol at the time of the crash. However, a smaller percentage of older drivers had indication of drinking alcohol while driving (5.1%), compared to younger drivers (24.2%). In general, 66.8% of all drivers wore some form of restraint at the time of the crash. The majority of younger drivers 64.5% (8,295) and 72.5% (3,863) of older drivers were wearing a form of restraint during the crash.

For environmental variables, observable differences in frequency percentages between younger and older drivers were in the *hour of day*, *light conditions, relation to junction*, *traffic control device functioning, roadway alignment*, *vehicle body type*, *registered vehicle owner*, *principal impact*, and *most harmful event.*

For the predisposing domain, *vehicle maneuver*, observable differences among levels of the variable for the two age groups are that 72% of younger drivers and 64% older drivers had were traveling straight prior to the crash. Also, there was a higher percentage of older drivers who were executing a left turn (16.8%) compared to younger drivers (4.8%). Regarding reinforcing variables, the mean number of convictions for younger and older drivers is presented in Table 4-1.

State age-related renewal procedures: Age-related renewal policies in the states were not mutually exclusive (Table 4-2). About half of the states had some form of age-related license renewal policy, and 37.9% of older drivers had drivers' licenses from states with one or more age-related renewal policies. Most states with renewal policies used the reduced renewal cycle for older drivers alone, or in conjunction with other age-related license renewal policies.

Summary of univariate analysis: Using the confounding variable age, with frequencies for nominal data and means and standard deviation for numeric data, I showed the frequency distribution among levels of independent variables from the health, behavior, environment, predisposing, and reinforcing domains of the PPMHP.

Bivariate Analyses

This section consists of bivariate results for PPMHP variables by domain (health, behavior, environment, and predisposing) and injury, and results for the chi-square analyses for the four age-related license renewal policies (enabling variables).

Bivariate analyses by age group: Table 4-3 summarizes the results of the bivariate analysis by age to examine relationships among exploratory variables in the health, behavioral, environmental, and predisposing domains, and the dependent variable (injury: no/yes) Results presented for selected variables were used in subsequent analyses (logistic regression), with chi-square analyses for categorical data and independent sample t-test for numerical data.

Health domain

For younger and older drivers, there were statistically significant differences in injury prevalence rates among males and females, with a higher proportion of females injured in motor vehicle crashes as shown in Figure 4-2.

Behavior domain

There were statistically significant differences in the prevalence of drivers injured with respect to the *driver drinking* variable for younger drivers χ^2 (1, N = 14,038) = 598.08, $p < 0.01$, and older drivers χ^2 (1, N = 5,744) = 11.25, $p < 0.01$. For both age groups, a higher proportion of drivers who reflected alcohol consumption prior to the crash were injured.

For *driver license compliance* (whether the license the driver was using was valid for the type of vehicle driven at the time of the crash), in the chi-square test, I observed statistically significant differences in injury rates among younger drivers χ^2 (1, N = 5,562) = 1.04, $p < 0.01$, but not a statistically significant difference in injury rates among older drivers χ^2 (1, N = 13,921) = 84.44, $p < 0.01$. For younger drivers, a smaller proportion of drivers in compliance were injured in the crash compared to those who were not in compliance (Figure 4-3).

A statistically significant difference exists among drivers injured who wore a form of restraint (seatbelt, lap belt, or both) during the crash and those who did not. Figure 4-4 presents injury rates for restraint system use, and injury for younger and older drivers. A larger proportion of drivers without a form of restraint were injured, compared to those wearing a form of restraint. This finding was statistically significant for both younger and older drivers.

Environmental domain

Day of week to injury outcome was not statistically significant for younger drivers χ^2 (6, N = 14,031) = 10.26, $p = 0.11$. However, among older drivers, there were statistically significant differences in injury outcomes for the *day of week*; χ^2 (6, N = 5,743) = 15.05, $p = 0.02$. In comparison with other days of the week, fewer injuries occurred on Sundays. The variables *weather conditions*, *light conditions*, *and National Highway System* indicated statistically significant differences in injury percentages for younger and older drivers. Crashes during favorable weather conditions had lower injury percentages compared to crashes during adverse weather conditions (rain, snow, sleet).

For daylight conditions, the greatest proportion of younger drivers injured occurred during dark hours, while for older drivers, the greatest proportion of injuries occurred in daylight conditions. Drivers not traveling on the National Highway System had lower injury percentages compared to drivers who were on the National Highway System at the time of the crash. For both age groups, there were statistically significant differences among injury rates for *hour of day*, younger driver, χ^2 (2, N = 13,936) = 98.21, p < 0.01; older driver, χ^2 (2, N = 5,722) = 48.73, p < 0.01. A greater proportion of younger and older drivers were injured in crashes during the 9p.m.–7a.m.hours (Figure 4-5).

For both age groups, drivers traveling on rural roads at the time of the crash had significantly higher percentages of injuries compared to drivers on urban roads. For *number of lanes*, there were statistically significant differences among younger and older drivers for injury prevalence. Crashes occurring in two-lane roads had the highest percentages of injury for both age groups. *Trafficway flow* (how the highway was divided) and *relation to junction* were environmental variables with statistically significant differences for injury prevalence in both age groups. However, *construction/maintenance zone* did not indicate statistically significant differences among drivers who crashed in construction, maintenance and utility zones, and those who did not. The finding was similar for younger drivers χ^2 (1, N = 14,038) = 0.31, p < 0.31, and older drivers χ^2 (1, N = 5,744) = 2.29, p <0.84.

Regarding *traffic control device functioning,* younger and older drivers had statistically significant differences in injury prevalence rates. Younger drivers had a higher percentage of injury (75.8% injury when traffic control devices were absent; 68.8% traffic control device present) χ^2 (1, N = 13,963) = 65.10, p <0.01. However, older drivers had a higher injury percentage when a traffic control was present compared to when there was no traffic controls present (84.2% injury when traffic control devices were absent; 87.2% when a traffic control device was present; χ^2 (1, N = 5,701) = 12.11, p <0.01. Four of the statistically significant environmental variables were road-related: (a) *roadway surface condition* (favorable vs. adverse), (b) *roadway surface type* (concrete, blacktop, or other), (c) *roadway profile* (level vs. other), and (d) *roadway alignment* (straight vs. curve).

For both younger and older drivers, the favorable road condition was associated with lower percentages of injury. For example, with *roadway surface condition*, favorable road conditions had a lower proportion of injury cases compared to adverse roadway conditions (e.g., sleet, snow, wet). For *vehicle body type*, crashes in *automobile and automobile derivatives* had higher injury percentages for both younger and older drivers, followed by s*ports utility vehicles (SUVs)*, and then *vans, light trucks and pick-ups;* younger driver; χ^2 (2, N = 14,038) = 134.43, $p < 0.01$, and older drivers χ^2 (2, N = 5,744) = 47.75, $p < 0.01$ (Figure 4-6).

The variable a*irbag deployment* had statistically significant differences in injury rates for younger and older drivers. Within both age groups, airbag deployment had statistically significantly higher injury cases than when there was no deployment of the airbag at the time of the crash. *Registered vehicle owner* had statistically significant differences in injury outcomes for younger and older drivers. Not being the registered vehicle owner had lower injury percentages in comparison to drivers who were the registered owner of the vehicle driven when the crash occurred.

For younger drivers, the *number of occupants* in the vehicle there was no statistically significant differences in injury percentages for drivers only, drivers with one passenger present, and drivers with two or more passengers present χ^2 (2, N = 14,038) = 2.93, $p < 0.12$. However, for older drivers, there was a statistically significant difference in percentages for injury outcomes for number of occupants χ^2 (2, N = 5,744) = 5.10, $p < 0.04$, with two or more passengers having lower injury percentage.

Principal impact, a variable that uses the clock to indicate the position on the car struck in a crash (e.g., 12 o'clock being head-on collision), indicated statistically significant differences in injury cases for both older and younger drivers, with highest percentages of injury occurring for both age groups in the 7–9 o'clock area. *Most harmful event* (type of collision just before the crash occurred) indicated statistically significant differences in injury percentages among all the four levels. Statistically significant differences were observed in the *collision with object not fixed* category, which had very low frequencies of injured drivers for both younger and older drivers (10% younger drivers; 17.0% older drivers), as shown in Figure 4-7. For younger and older drivers, collision with fixed objects (e.g., building or bridge rail) and non-collision (e.g., overturn or driver injured in vehicle) had the highest injury frequencies.

Predisposing domain

Vehicle maneuver (capturing the driver's action or intended action prior to the event leading to the crash) indicated statistically significant differences in injury outcomes for younger drivers χ^2 (4, N = 13,871) = 524.90, $p < 0.01$; and older drivers χ^2 (2, N = 5,695) = 48.50, $p<0.01$. Majority of injuries occurred in both age groups when the driver was negotiating a curve or changing lanes (90.8% for younger drivers and 94.1% for older drivers). Older drivers also had high percentages of injuries when making a left turn (94.0%), and going straight (84.5%), while younger drivers had high rates of injury while going straight (73.6%), but had lower percentages for lane-related injuries (58.1%), maneuvers (58.6%), and making a left (58.8%).

Reinforcing domain

I performed an independent sample t-test to ascertain whether there were differences for older and younger adults regarding injury outcomes. I also plotted the mean number of convictions by injury (yes) to ascertain if there were indications of age-interaction effects for the reinforcing variables.

Regarding *number of previous accident convictions* (number of accident convictions within the last three years prior to the crash) younger drivers had a mean of 0.16 convictions for those uninjured in the crash (*SD* = 0.43), and 0.16 (*SD* = 0.47) convictions for those who were injured. Older drivers had a mean of 0.13 (*SD* = 0.38) convictions for the uninjured drivers and 0.14 (*SD* = 0.41) for the injured drivers. There were no statistically significant differences in means between the number of previous accident convictions and injury outcome for younger, t (1, 3123) = -0.24, p = 0.98 (2-tailed), and older drivers t (5,433) = -0.21, p = 0.84 (2-tailed). There was no indication of an age interaction among younger and older drivers and injury outcome for this variable (Figure 4-8).

For the *number of previous DWI convictions* (driving while impaired) within the last three years prior to the crash, the mean number of previous DWI convictions were 0.02 (*SD* = 0.16) for uninjured younger drivers, 0.05 (*SD* = 0.24), for injured younger drivers 0.00 (*SD* = 0.08) for uninjured older drivers and 0.01 (*SD* = 0.00) for injured older drivers (Figure 4-9). There was a statistically significant difference between uninjured younger drivers and injured younger drivers t (1, 3869) = -6.08, p< 0.01 (2-tailed), but no statistically significant difference between older adults and injury outcome t(5,695) = -0.95, p = 0.34 (2-tailed). There was indication of age interaction among younger and older adults (Figure 4-9).

Regarding *number of previous suspension convictions*, there was no statistically significant differences in injury outcome for older drivers t(5,695) = 0.14, p = 0.89 (2-tailed), however, there were statistically significant differences in injury outcomes for younger drivers t(13,869) = -7.209, p < 0.01 (2-tailed). The mean number of convictions for the uninjured younger group was 0.16 (*SD* = 0.76) and 0.26 (*SD* = 0.92) for the injured younger group, and

0.02 (*SD* = 0.18) for uninjured older drivers and 0.02 (*SD* =0.18) for injured older drivers. There was indication of an age interaction among younger and older drivers (Figure 4-10).

Concerning *number of previous speeding convictions*, the mean number of speeding convictions for uninjured younger drivers was 0.22 (SD = 0.56), and 0.25 (*SD* = 0.68). For uninjured older drivers, the mean number of previous speeding convictions was 0.08 (*SD* = 0.31), and 0.06 (*SD* = 0.28) for injured older drivers. Older drivers had statistically significant differences in injury outcome $t(5,695) = 2.0$, $p = 0.05$ (2-tailed), while younger drivers did not show statistically significant differences $t(13,869) = -1.40$, $p = 0.16$ There was indication of age interaction between the two groups (Figure 4-11).

Number of previous other motor vehicle convictions (failure to yield, running a red light, lane-related convictions) and injury outcomes were not statistically significant for younger drivers $t(13,869) = -0.36$, $p = 0.72$ (2-tailed) but statistically significant for older drivers $t(5,695) = -1.82$, $p = 0.07$ (2-tailed) because the null hypothesis is directional. The mean for uninjured younger drivers was 0.18 (*SD* = 0.53), and the mean number of convictions for injured younger drivers was 0.20 (*SD* = 0.62). For older drivers, the mean number of previous other motor vehicle convictions was 0.11 (*SD* = 0.41) was non-injured drivers, and 0.08 (*SD* = 0.33) for injured drivers. There was indication of an age interaction effect (Figure 4-12).

The next section of the bivariate analyses shows the injury prevalence rates for younger and older drivers with respect to the enabling variables in the study.

Enabling domain

Age-related license renewal polices comprised of (a) age-related license renewal policy (no/yes), (b) reduced renewal cycles (no/yes), (c) in-person renewal required (no/yes), and (d) vision, medical, or road test required (no/yes). Bivariate results are presented in Table 4-4.

These results suggested lower injury prevalence among older drivers with licenses from states with some form of license renewal policy compared to drivers from states without some form of age-related license renewal policy (Table 4-4). Bivariate analyses for specific age-related license renewal policies indicated that these differences were statistically significant for only age-related renewal policies χ^2 (1, N = 5,725) = 8.67, p<0.01 and states with in-person renewal requirements for older adults χ^2 (1, N = 5,681) = 21.63, p<0.01. Drivers with licenses issued by states with reduced renewal cycles for older adults χ^2 (1, N = 5,725) = 0.30, p = 0.59, and states with vision, medical, or road test requirements χ^2 (1, N = 5,725) = 0.57, p = 0.46 did not show statistically significant differences in injury outcome.

Summary of bivariate results

Results of the bivariate analyses indicate that almost all independent variable representing domains of the PPMHP were statistically significant at $p \leq 0.05$. *Day of week* was not statistically significant for younger drivers, and *license compliance* was not statistically significant for older drivers. For the enabling variables, state age-related renewal polices were statistically significantly associated with injury, but regarding the type of renewal policies, there were statistically significant differences among the three age-related renewal policy variables.

Binary logistic regression

Regression model summary: Overall, the model correctly classified 87.9% of cases in predicting injury outcomes. The Hosmer and Lemoshow test (p = 0.68), suggested that the model fitted 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 at a 95% confidence interval.

Most of the statistically significant associations among exploratory variables (main effect and age interaction effects) with injury outcome were from the environmental domain (Table

4.5). Measures of association for statistically significant exploratory variables and statistically significant age interaction effects are presented in Table 4-6.

The 32 variables in the logistic regression represented five domains of the PPMHP: (a) health (2 variables), (b) behavior (3 variables), (c) environment (21 variables), (d) reinforcing, (5 variables), and (e) predisposing (1 variable). Table 4.5 illustrates the variables in the logistic regression model, and whether one or more levels of variables were statistically significant at $p<0.05$.

There were 20 statistically significant associations—4 associations with age-interactions and 16 main effects. Fourteen statistically significant variables were from the environmental domain, three from the behavioral domain, two from the health domain, one from the predisposing domain, and one variable from the reinforcing domain (Table 4-5).

Age interaction effects: Explanatory variables with statistically significant age interaction effects were (a) registered vehicle owner, (b) principal point of impact, (c) number of occupants, and (d) number of other previous motor vehicle convictions.

For *registered vehicle owner*, a marginally statistically significant variable, older drivers who were not the registered owner of the vehicle they were driving at the time of the crash were 53% (p = 0.05; *CI*; 0.48–1.00) less likely to be injured in the crash compared to drivers who were registered vehicle owners of the vehicle they drove when the crash occurred.

Regarding *principal point of impact*, with the 12 o'clock angle (front impact crashes) as the referent group, two categories of the variable the 1–3 o'clock angle (*OR* = 1.61; *CI*: 1.05–2.47) and 7–9 o'clock angle (*OR* = 4.75; *CI* = 2.87–7.86) were statistically significant risk factors for injury.

Number of occupants was marginally statistically significant for older drivers. Older drivers with two or more occupants present were 40% less likely to be injured in a crash, compared with older adults who drove alone (*OR* = 0.60; *CI*: 0.36–1.01).

Main effects: There were 16 variables with statistically significant main effects: health (1 variable), behavioral (3 variables), environmental (11 variables), and predisposing (1variable) domains. Health: Both age and gender had statistically significant associations with injury outcome. Age was an interaction term. Compared to males, females had an increased risk of injury in motor vehicle crashes (*OR* = 1.51; *CI* = 1.29–1.73).

Behavior: Three environmental variables—*driver license compliance*, *driver drinking*, and *restraint system use*— had statistically significant associations with injury outcomes for younger and older drivers. Drivers who did not have a valid license for the vehicle they were operating at the time of the crash had an increased risk of injury compared to drivers who had a valid license for the vehicle they were driving at the time of the crash (*OR* = 1.39; *CI* = 1.02–1.90). Not using a system restraint (e.g., seatbelt, lap belt) was associated with about 6 times the odds of injury compared to drivers who wore a form of restraint during the crash (*OR* = 6.20; *CI* = 5.03–7.63). For *driver drinking*, alcohol use was associated with 2 times the risk of injury, in comparison to drivers who had not drunk alcohol (*CI* = 1.57–2.54).

Environment: Among environmental variables, except for *roadway surface condition*, there were no statistically significant associations among road factors such as *roadway surface type* (e.g., concrete or blacktop), *roadway profile* (whether the road was level or not), *roadway alignment* (straight versus curved), *construction/maintenance zone*, and *trafficway flow* (how the highway was divided) with injury outcome. *Weather conditions* and *light condition*s did not have statistically significant associations with injury

Factors with statistically significant associations with injury were *day of week*, *hour of day*, *number of lanes*, *road surface condition*, *rural vs. urban*, *vehicle body type*, *most harmful event*, *relation to junction*, traffic *control device functioning*, *airbag deployment*, and *National Highway* System. For *day of week*, with Sunday as the day of reference, all days of the week except for Monday were associated with increased risk of injuries. Regarding *hour of day*, the daytime hours were protective factors for injury when compared with the nighttime hours; 8a.m.–1p.m. (*OR* = 0.72; *CI* = 0.57–0.90), and 2p.m.–8p.m. (*OR* = 0.63; *CI* = 0.53–0.76). For *number of lanes*, crashes in one-lane roads was protective in relation to two-lane roads (*OR* = 0.32; *CI* = 0.12–0.87). Regarding *roadway surface condition*, compared to favorable (dry) roadway surfaces, crashes in adverse roadway conditions (e.g., snow, sleet, and rain) had 1.5 times the risk of injury (*CI* = 1.16–1.95).

The variable *rural vs. urban* (road function class) was protective for crashes in urban areas in comparison to crashes in the rural area (*OR* = 0.61; *CI* = 0.52–0.71). Concerning *vehicle body type*, in reference to sports utility vehicles (SUVs), automobile and automobile derivatives were risks for injury (*OR* = 2.00; *CI* = 1.64–2.44). However, drivers of vans, trucks, and light pickups were 24% less likely of being injured (*OR* = 0.77; *CI* = 0.64–0.94).

Most harmful event was a risk factor for injury, and levels of the variable had extremely high odd ratios. In comparison with collision 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 moving 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).

For the *relation to junction* variable, in comparison to non-junction crashes, intersection-related crashes were protective (*OR* = 0.59; *CI* = 0.48–0.72). Interchange-related crashes were not statistically significant. The variable *traffic control device functioning* was a protective factor for injury when a traffic control device was absent, with drivers 21% less likely of sustaining an injury (*OR* = 0.79; *CI* = 0.65–0.95). Similarly, with the variable *airbag deployed* drivers were 75% less likely to be injured when the airbag did not deploy (*OR* = 0.25; *CI* = 0.21–0.29).

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

Summary of binary logistic regression results: The logistic regression showed associations and age-interaction effects among 32 independent variables and injury (no/yes) for younger and older drivers. Statistically significant, or marginally significant age interactions were evident for older drivers for *registered vehicle owner*, *principal impact*, *number of occupants*, and *other motor vehicle convictions*. For all drivers, statistically significant, differences were shown for both age groups.

Summary of Results

In this chapter I presented results from the univariate, bivariate, (regression variables and age-related license renewal policy), and the binary logistic regression with age-interaction terms. Bivariate findings indicated the majority of the regression variables had statistically significant relationships for injury outcomes. The bivariate findings for the exploratory study on age-related license renewal policy indicated that states with age-related renewal policies had lower injury prevalence rates. While this was true for states with in-person renewal requirements, reduced renewal cycles and vision, medical or road test requirements did not show statistically significant difference in injury rates.

Results from the binary logistic regression indicated that the model had a good fit with the data, and explained more than over half of the variance. Most of the statistically significant risk and protective factors emerged from the environmental domain; however, all five PPMHP domains were represented as having statistically significant age-related or main effect associations with injury outcomes.

Table 4-1. Health, behavioral, environmental, predisposing and reinforcing variables of the Precede-Proceed model of health promotion

Variables	Younger Drivers Number (%) *N* = 14,038	Older Drivers Number (%) *N* = 5,744	All Drivers Number (%) *N* = 19,782
Health			
Age	14,083 (71.0%)	5,744 (29.0%)	19,782 (100%)
Gender			
Male	9,665 (68.8%)	3,827 (66.6%)	13,492 (68.2%)
Female	4,373 (31.2%)	1,917 (33.4%)	6,290 (31.8%)
Behavior			
Driver License Compliance			
Not Valid	1,476 (10.6%)	145 (2.5%)	1,621 (8.3%)
Valid for Vehicle Type	12,445 (89.4%)	5,562 (97.5%)	18,007 (91.7%)
Driver Drinking			
No	10,606 (75.6%)	5,451 (94.9%)	16,057 (81.2%)
Yes	3,432 (24.4%)	293 (5.1%)	3,725 (18.8%)
Restraint System Use			
None	4,571 (35.5%)	1,464 (27.5%)	6,035 (33.2%)
All Types	8,295 (64.5%)	3,863 (72.5%)	12,158(66.8%)
Environment			
Day of Week			
Sunday	2,002 (14.3%)	696 (12.1%)	2,698 (13.6%)
Monday	1,838 (13.1%)	834 (14.5%)	2,672 (13.5%)
Tuesday	740 (12.4%)	854 (14.9%)	2,594 (13.2%)
Wednesday	1,838 (13.1%)	849 (14.8%)	2,687 (13.6%)
Thursday	1,849 (13.2%)	836 (14.6%)	2,685 (13.6%)
Friday	2,294 (16.3%)	879 (15.3%)	3,173 (16.0%)
Saturday	2,470 (17.6%)	795 (13.8%)	3,265 (16.5%)
Hour of Day			

Table 4-1. Continued.

Variables	Younger Drivers Number (%) N = 14,038	Older Drivers Number (%) N = 5,744	All Drivers Number (%) N = 19,782
9p.m.—7a.m.	5,066 (36.4%)	742 (13.0%)	5,808 (29.5%)
8a.m.–1p.m.	3,112 (22.3%)	2,419 (42.2%)	5,531 (28.2%)
2p.m.–8p.m.	5,758 (41.3%)	2,561 (44.8%)	8,319 (42.3%)
Weather Conditions			
Non-Adverse	12,048 (86.1%)	5,109 (89.3%)	17,157 (87.0%)
Adverse	1,940 (13.9%)	614 (10.7%)	2,554 (13.0%)
Light Conditions			
Daylight	7,712 (55.1%)	4,563 (79.6%)	12,275 (62.3%)
Dark	3,863 (27.6%)	622 (10.8%)	4,485 (22.7%)
Other	2,416 (17.3%)	533 (9.6%)	2,969 (15.0%)
National Highway System			
Not on the NHS	9,167 (65.5%)	3,926 (68.6%)	13,093 (66.4%)
On the NHS	4,830 (34.5%)	1,800 (31.4%)	6,630 (33.6%)
Rural vs. urban			
Rural	8,191 (58.5%)	3,184 (55.6%)	11,375 (57.7%)
Urban	5,812 (41.5%)	2,539 (44.4%)	8,351 (42.3%)
Number of Lanes			
One	120 (0.9%)	39 (0.8%)	159 (0.9%)
Two	10,413 (75.0%)	4,192 (74.0%)	14,605 (74.7%)
Three	1,043 (7.5%)	365 (6.4%)	1,408 (7.2%)
Four to Seven	2,302 (16.6%)	1,067(18.8%)	3,369 (17.2%)
Trafficway Flow			
Divided Highway	3,362 (24.1%)	1,359 (23.9%)	4,721 (24.0%)
Not Divided Highway	8,892 (63.7%)	3,673 (64.5%)	12,565 (63.9%)
One way Trafficway	1,186 (8.5%)	398 (7.0%)	1,584 (8.1%)
Not Physically Divided	412 (3.0%)	234 (4.1%)	646 (3.3%)
Entrance/Exit Ramp	102 (0.7%)	31 (0.5%)	135 (0.7%)
Relation to Junction			
Non-Junction	9,383 (70.2%)	3,029 (52.7%)	12,867 (65.1%)
Intersection-Related	3,766 (26.8%)	2,582 (45.0%)	6,348 (32.1%)
Interchange-Related	417 (3.0%)	130 (2.3%)	547 (2.8%)
Construction/Maintenance or Utility Zone			
Not on Construction Zone	13,676 (97.4%)	5,584 (97.2%)	19,260 (97.4%)
On Construction Zone	362 (2.6%)	160 (2.8%)	522 (2.6%)
Traffic Control Device Functioning			
No Controls Present	10,626 (76.1%)	3,585 (62.9%)	14,211 (72.3%)
Controls Functioning	3,337 (23.9%)	2,116 (37.1%)	5,453 (27.7%)
Roadway Surface Condition			
Dry	11,207 (80.2%)	4,827 (84.4%)	16,034 (81.4%)
Adverse	2,764 (19.8%)	891 (15.6%)	3,655 (18.6%)

Table 4-1. Continued.

Variables	Younger Drivers Number (%) N = 14,038	Older Drivers Number (%) N = 5,744	All Drivers Number (%) N = 19,782
Roadway Surface Type			
Concrete	1,283 (9.6%)	400 (7.4%)	1,683 (8.9%)
Blacktop	11,884 (88.7%)	4,985 (91.6%)	16,869 (89.6%)
Other	230 (1.7%)	53 (1.0%)	283 (1.5%)
Roadway Profile			
Level	10,026 (73.6%)	4,209 (76.0%)	14,235 (74.3%)
Others	3,597 (26.4%)	1,331 (24.0%)	4928 (25.7%)
Roadway Alignment			
Straight	10,869 (77.8%)	4,826 (84.4%)	19,690 (79.7%)
Curve	3,101 (22.2%)	894 (15.6%)	3,995 (20.3%)
Vehicle Body Type			
Sports Utility Vehicles	2,460 (17.5%)	373 (6.5%)	2,833 (14.3%)
Automobile & Auto Derivatives	6224 (44.3%)	3,895 (67.8%)	10,119 (51.2%)
Vans, Light Trucks & Pick-ups	5,354 (38.2%)	1,476 (25.7%)	6,830 (34.5%)
Airbag Deployment			
Did not deploy/None	7,965 (66.1%)	3,079 (61.4%)	11,044 (64.7%)
Deployed	4,090 (33.9%)	1,933 (38.6%)	6,023 (35.3%)
Registered Vehicle Owner			
No	4,374 (32.3%)	820 (14.5%)	5,194 (27.0%)
Yes	9,185 (67.7%)	4,830 (85.5%)	14,015 (73.0%)
Number of Occupants			
Driver Only	9,212 (65.6%)	3,800 (66.2%)	13,012 (65.8%)
One Passenger	2,865 (20.4%)	1,620 (28.2%)	4,485 (22.6%)
Two or More Passengers	1,961 (14.0%)	324 (5.6%)	2,285 (11.6%)
Principal Impact			
1–3 o’clock	1,620 (12.5%)	906 (16.4%)	2,526 (13.7%)
4–6 o’clock	868 (6.7%)	290 (5.2%)	1,158 (6.3%)
7–9 o’clock	1,368 (10.6%)	1,061 (19.2%)	2,429 (13.1%)
10–11 o’clock	977 (7.5%)	428 (7.8%)	1,405 (7.6%)
12 o’clock	7,732 (59.7%)	2,747 (49.7%)	10,479 (56.7%)
Top & Undercarriage	382 (3.0%)	95 (1.7%)	477 (2.6%)
Most Harmful Event			
Collision with Object Not Fixed	1,598 (11.4%)	471 (8.2%)	2,069 (10.5%)
Motor Vehicle in Transport	8,129 (58.1%)	3,979 (69.3%)	12,108 (61.3%)
Non-Collision	2,234 (15.9%)	473 (8.3%)	2,707 (13.7%)
Collision with Fixed Object	2,052 (14.6%)	815 (14.2%)	2,867 (14.5%)
Predisposing			
Vehicle Maneuver			

Table 4-1. Continued.

Variables	Younger Drivers Number (%) N = 14,038	Older Drivers Number (%) N = 5,744	All Drivers Number (%) N = 19,782
Going Straight	10,014 (72.2%)	3,666 (64.4%)	13,680 (69.9%)
Lane-Related	939 (6.8%)	416 (7.2%)	1,355 (6.9%)
Maneuvers	295 (2.1%)	169 (3.0%)	464 (2.4%)
Making a Left	663 (4.8%)	956 (16.8%)	1,619 (8.3%)
Negotiating a curve or Changing	1,960 (14.1%)	488 (8.6%)	2,448 (12.5%)
Reinforcing			
# Accident Convictions	*0.16 (0.46)	*0.13 (0.41)	*0.15 (0.44)
# Suspension Convictions	*0.23 (0.89)	*0.02 (0.18)	*0.17 (0.76)
# Driving while impaired (DWI) Convictions	*0.04 (0.22)	*0.01 (0.08)	*0.03 (0.19)
# Speeding Convictions	*0.25 (0.62)	*0.07 (0.29)	*0.19 (0.55)
# Other Motor Vehicle Convictions	*0.20 (0.58)	*0.09 (0.34)	*0.16 (0.53)

* Mean (SD)

Table 4-2. Age-related license renewal policies for older adults as of 2003 (N= 5,747).

Age-Related Renewal Policy	Number of States*	N (%)
Age-Related Renewal Policies		
No	26	3,554 (62.1%)
Yes	25	2,171 (37.9%)
Reduced Renewal Cycles		
No	37	4,455 (77.8%)
Yes	14	1,270 (22.2%)
In-Person Renewal Required		
No	43	4,629 (81.5%)
Yes	8	1,052 (18.5%)
Age-Related Testing		
No	44	5,244 (91.6%)
Yes	7	481 (8.4%)

*Includes the District of Columbia

Table 4-3. Prevalence of drivers injured in a crash by age group for health, behavior, environment, and predisposing domains.

	Younger Drivers		Older Drivers	
	%	p-value	%	p-value
Health				
Gender		<0.01*		<0.01*
Male	73.0		84.1	
Female	76.8		88.1	
Behavior				
Driver License Compliance		<0.01*		0.19

Table 4-3. Continued.

	Younger Drivers %	Younger Drivers *p*-value	Older Drivers %	Older Drivers *p*-value
Not Valid	84.0		88.3	
Valid for Vehicle Type	72.9		85.2	
Driver Drinking		<0.01*		<0.01*
No	69.0		85.0	
Yes	90.0		92.2	
Restraint System Use		<0.01*		<0.01*
None	94.8		97.0	
All Types	63.5		81.2	
Environment				
Day of Week		0.11		0.02*
Sunday	75.9		82.0	
Monday	73.3		87.6	
Tuesday	74.9		87.0	
Wednesday	71.8		84.8	
Thursday	74.6		86.4	
Friday	73.9		85.9	
Saturday	74.3		83.4	
Hour of Day		<0.01*		<0.01*
9p.m.–7a.m.	78.5		78.7	
8a.m.–1p.m.	73.8		88.6	
2p.m.–8p.m.	70.1		84.3	
Weather Conditions		<0.01*		0.04*
Non-Adverse	73.3		85.2	
Adverse	79.0		87.8	
Light Conditions		<0.01*		<0.01*
Daylight	74.1		88.1	
Dark	80.4		79.9	
Other	64.2		69.4	
National Highway System		<0.01*		<0.01*
Not on the NHS	73.3		85.4	
On the NHS	75.9		87.4	
Road Function Class		<0.01*		<0.01*
Rural	82.9		90.4	
Urban	61.9		79.0	
Number of Lanes		<0.01*		<0.01*
One	70.0		84.6	
Two	77.8		87.0	
Three	62.7		80.5	
Four to Seven	63.9		81.3	
Trafficway Flow		<0.01*		<0.01*
Divided Highway	70.9		84.5	
Not Divided Highway	77.8		86.8	
One way Trafficway	65.4		82.9	
Not Physically Divided	49.0		73.9	

Table 4-3. Continued.

	Younger Drivers		Older Drivers	
	%	*p*-value	%	*p*-value
Entrance/Exit Ramp	83.7		90.3	
Relation to Junction		<0.01*		0.61
Non-Junction	78.6		85.4	
Intersection-Related	62.8		85.3	
Interchange-Related	73.4		88.5	
Construction/Maintenance or Utility Zone		0.62		0.84
Not on Construction Zone	74.1		85.5	
On Construction Zone	75.4		81.3	
Traffic Control Device Functioning		<0.01*		<0.01*
No Controls Present	75.8		84.2	
Controls Functioning	68.8		87.5	
Roadway Surface Condition		<0.01*		<0.01*
Dry	72.8		84.8	
Adverse	79.5		89.0	
Roadway Surface Type		<0.01*		<0.01*
Concrete	72.0		86.0	
Blacktop	74.4		85.4	
Other	86.5		88.7	
Roadway Profile		<0.01*		<0.01*
Level	72.4		84.7	
Others	79.8		88.2	
Roadway Alignment		<0.01*		<0.01*
Straight	70.5		84.1	
Curve	86.8		92.7	
Vehicle Body Type		<0.01*		<0.01*
Sports Utility Vehicles	73.9		83.9	
Automobile & Auto Derivatives	78.6		87.5	
Vans, Light Trucks & Pick-ups	69.1		80.1	
Airbag Deployment		<0.01*		<0.01*
Did not deploy/None	68.7		81.7	
Deployed	91.0		95.8	
Registered Vehicle Owner		<0.01*		<0.01*
No	75.7		82.2	
Yes	73.2		85.9	
Number of Occupants		0.23		0.08
Driver Only	74.3		85.2	
One Passenger	74.7		86.7	
Two or More Passengers	72.6		82.1	
Principal Impact		<0.01*		<0.01*
1–3 o'clock	73.8		84.4	

Table 4-3. Continued.

	Younger Drivers		Older Drivers	
	%	*p*-value	%	*p*-value
4–6 o'clock	56.6		75.2	
7–9 o'clock	78.0		94.8	
10–11 o'clock	73.6		84.8	
12 o'clock	73.7		83.3	
Top & Undercarriage	67.8		63.2	
Most Harmful Event		<0.01*		<0.01*
Collision with Object Not Fixed	10.0		17.0	
Motor Vehicle in Transport	74.6		89.3	
Non-Collision	97.2		98.5	
Collision with Fixed Object	97.9		99.0	
Predisposing				
Vehicle Maneuver		<0.01*		<0.01*
Going Straight	73.6		84.5	
Lane-Related	58.1		81.5	
Maneuvers	58.6		76.9	
Making a Left	58.8		87.1	
Negotiating a curve or Changing	90.8		94.1	
Reinforcing**				
#Previous accidents		0.26		0.57
# Previous suspensions		<0.01*		0.92
# Previous Driving While Intoxicated (DWI)		<0.01*		0.54
# Previous speeding		0.01		0.12
#Previous other motor vehicle convictions		0.09		0.05*

NHS: National Highway System

Table 4-4. Prevalence of drivers injured by type of age-related license renewal policy

	Injury	
	%	*p*-value
Age-related renewal policy		<0.01*
No	86.4	
Yes	83.6	
Reduced renewal cycle		0.59
No	85.5	
Yes	84.9	
In-person renewal required		<0.01*
No	86.4	
Yes	80.8	
Vision, medical or road test required		0.46
No	85.5	
Yes	84.2	

*$p \leq 0.01$

Table 4-5. Precede-Proceed model of health promotion variables in logistic regression model by domain and statistical significance

Domain	Variable	Significant at $p \leq 0.05$	Age interaction effect
Health			
	Age	X	N/A
	Gender	X	
Behavior			
	Driver license compliance	X	
	Driver drinking	X	
	Restraint system use	X	
Environment			
	Day of week	X	
	Hour of day	X	
	Registered vehicle owner	X	X
	Number of lanes	X	
	Roadway surface condition	X	
	Roadway surface type		
	Rural vs. urban	X	
	Roadway profile		
	Roadway alignment		
	Vehicle body type	X	
	Most harmful event	X	
	Relation to junction	X	
	Principal impact	X	X
	Traffic way flow		
	Traffic control functioning	X	
	Light conditions		

Table 4-5. Continued.

Domain	Variable	Significant at $p \leq 0.05$	Age interaction effect
	Weather conditions		
	Construction/maintenance zone		
	Number of occupants	X	X
	Airbag deployment	X	
	National Highway System	X	
Predisposing			
	Vehicle maneuver	X	
Reinforcing			
	# previous accident convictions		
	# previous suspension convictions		
	# previous Driving while impaired (DWI) convictions		
	# previous speeding convictions		
	# previous other motor vehicle convictions	X	X

Table 4-6. Binary logistic regression model showing statistically significant age interactions and statistically significant explanatory variables from the Precede-Proceed model of health promotion with injury (yes/no)

Dependent Variable: Injury (yes/no)	*p*	*OR*	*Lower CI*	*Upper CI*
Health Domain				
Gender				
Male	(Referent)			
Female	<0.01*	1.51	1.29	1.73
Behavior Domain				
Driver license compliance				
Valid	(Referent)			
Not Valid	0.04*	1.39	1.02	1.90
Driver drinking				
Not drinking (Referent)	(Referent)			
Drinking	<0.01*	2.00	1.57	2.54
Restraint system use				
Yes	(Referent)			
None	<0.01*	6.20	5.03	7.63
Environment Domain				
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
Friday	0.01*	1.36	1.07	1.74

Table 4-6. Continued.

Dependent Variable: Injury (yes/no)	*p*	*OR*	*Lower CI*	*Upper CI*
Saturday	0.03*	1.29	1.02	1.62
Hour of day				
9p.m.–7a.m.	(Referent)			
8a.m.–1p.m.	0.01*	0.72	0.57	0.90
2p.m.–8p.m.	<0.01*	0.63	0.53	0.76
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 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
Road surface condition				
Favourable	(Referent)			
Adverse	<0.01*	1.50	1.16	1.95
Rural vs. urban				
Rural	(Referent)			
Urban	<0.01*	0.61	0.52	0.71
Body Type				
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
Most harmful event				
Collision with object not fixed	(Referent)			
Collision with fixed object	<0.01*	249.55	152.61	408.03
Motor vehicle in transport	<0.01*	30.99	23.82	40.31
Non-Collision	<0.01*	265.68	155.37	454.32
Relation to Junction				
Non-Junction	(Referent)			
Intersection-Related	<0.01*	0.59	0.48	0.72
Interchange-Related	0.94	0.98	0.64	1.51
Principal impact x Age				
12 o'clock	(Referent)			
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
Roof or undercarriage	0.95	0.96	0.28	3.33
Traffic control device				
Functioning	(Referent)			
Not Present	0.01*	0.79	0.65	0.95

Table 4-6. Continued.

Dependent Variable: Injury (yes/no)	*p*	*OR*	*Lower CI*	*Upper CI*
Number of occupants x Age				
Driver only x Age	(Referent)			
One Passenger x Age	0.34	1.18	0.84	1.64
≥ Two Passengers x Age	0.05*	0.60	0.36	1.01
Airbag deployment				
Deployed	(Referent)			
Did Not Deployed	<0.01*	0.25	0.21	0.29
National highway system				
On NHS	(Referent)			
Not on NHS	<0.01*	0.77	0.65	0.91
Predisposing Domain				
Vehicle maneuver				
Going straight	(Referent)			
Lane-related				
Maneuvers	<0.01*	0.64	0.50	0.81
Making a left	0.02*	0.59	0.38	0.92
Negotiating a curve/changing	<0.01*	0.66	0.51	0.87
	0.35	1.15	0.86	1.54
Reinforcing Domain				
** Number previous other MV convictions x Age	0.03*	0.65	0.44	0.97

*$p \leq 0.05$ **MV = motor vehicle convictions

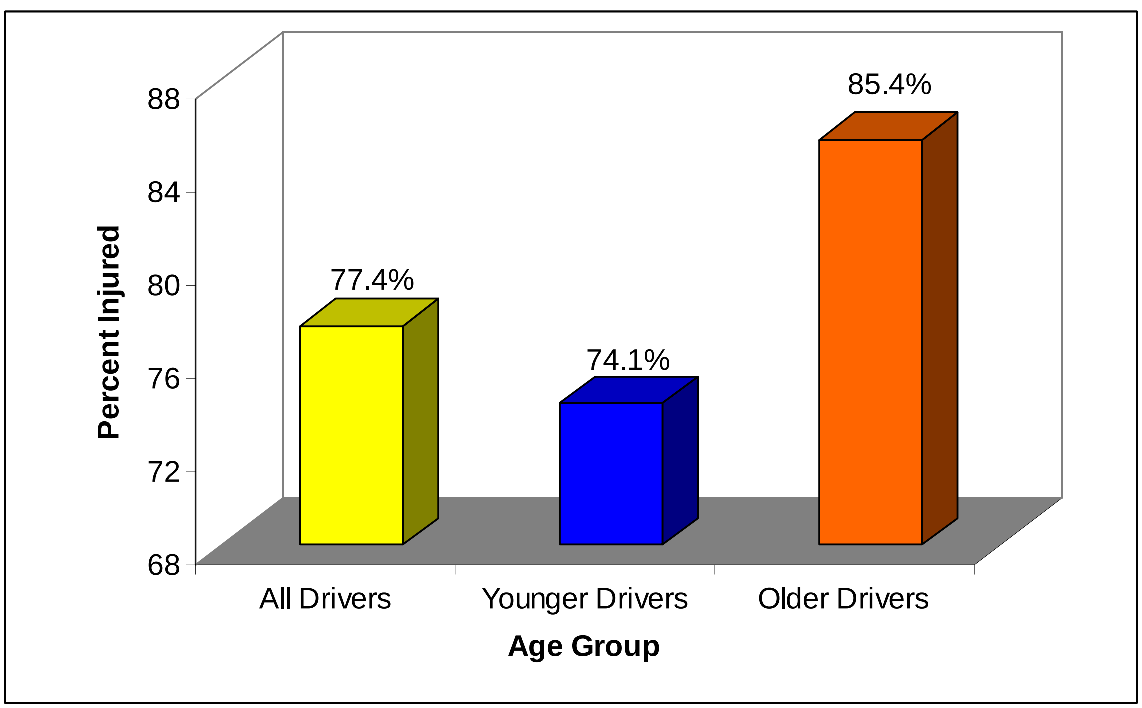


Figure 4-1. Drivers injured by age group

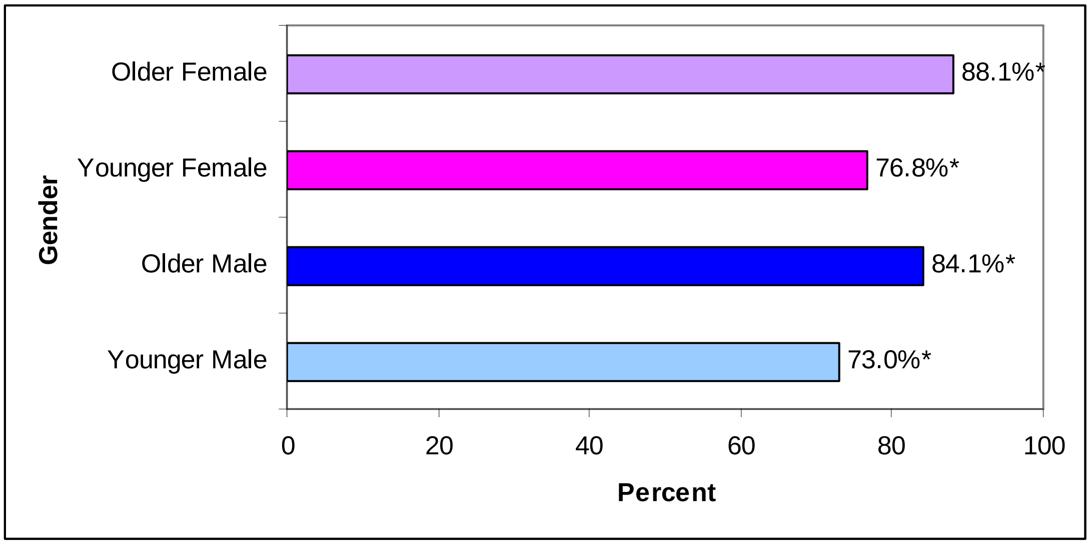
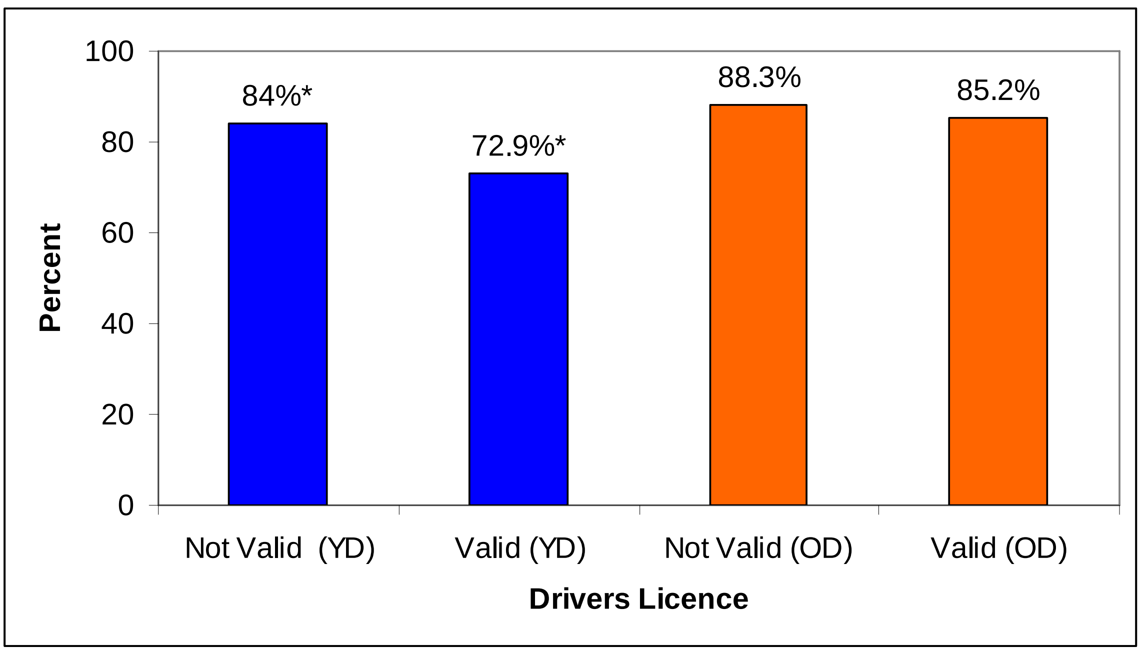
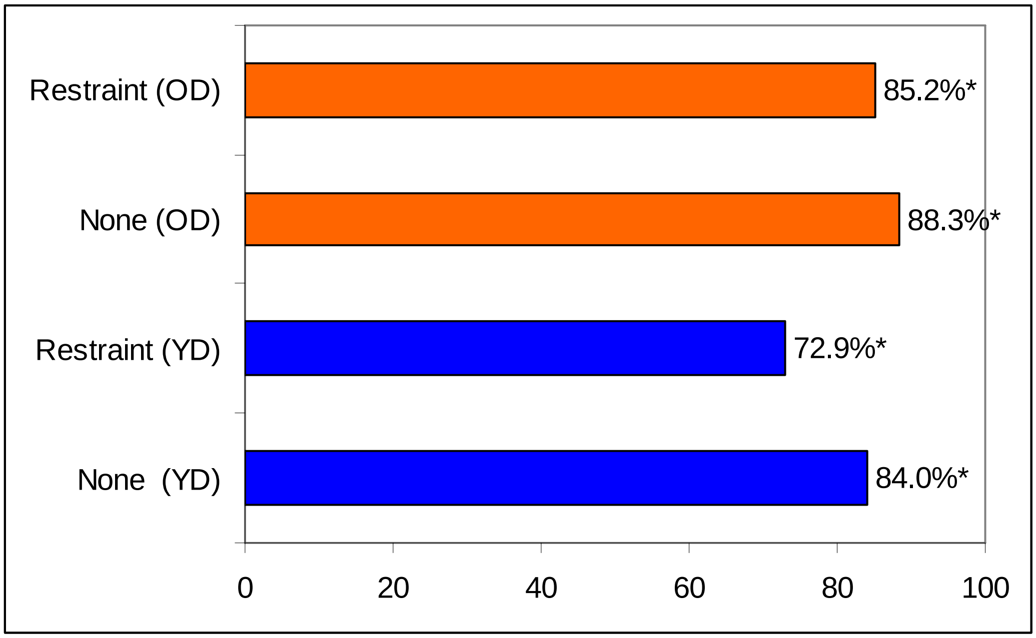


Figure 4-2. Drivers injured in crash by gender

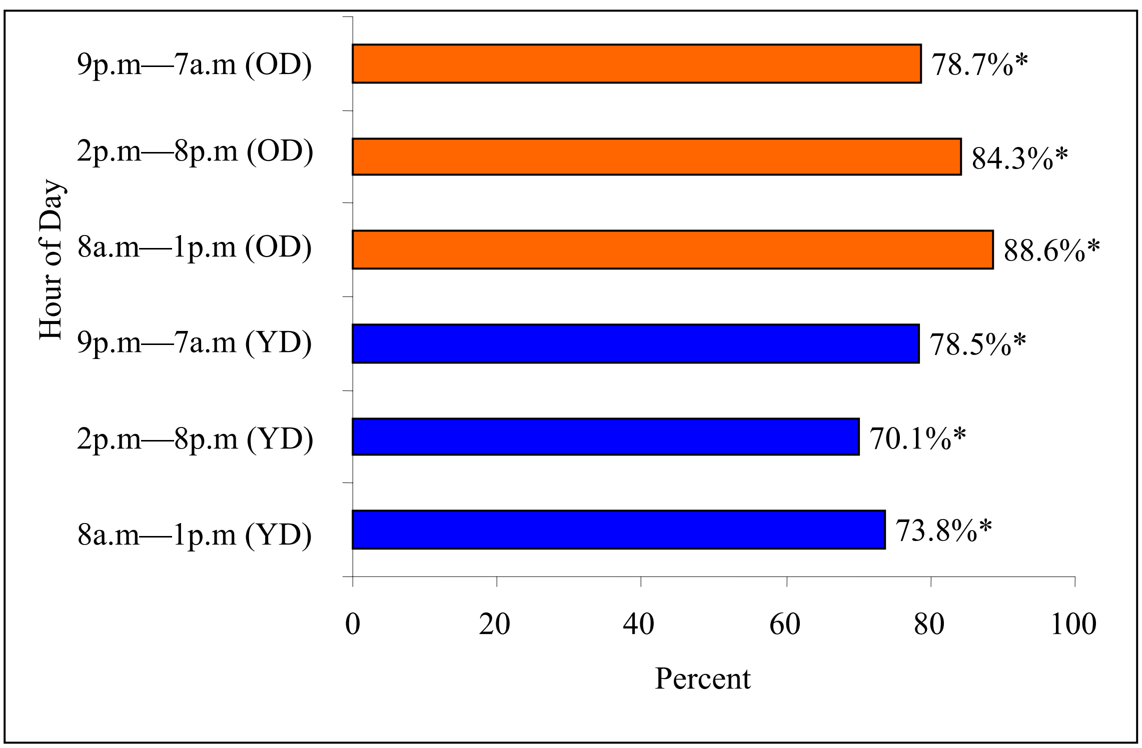


*p < 0.05; YD = Younger Driver; OD = Older Driver

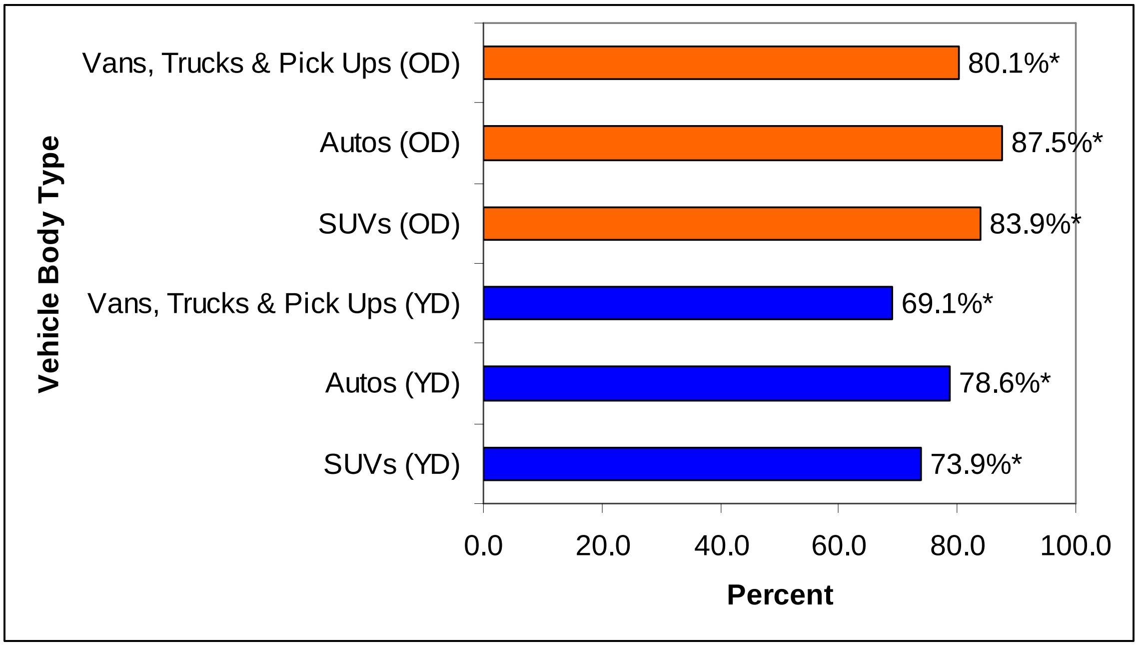
Figure 4-3. Drivers injured in crash by driver license compliance



*$p \leq 0.05$; YD = Younger Driver; OD = Older Driver
Figure 4-4. Drivers injured in crash by restraint system use

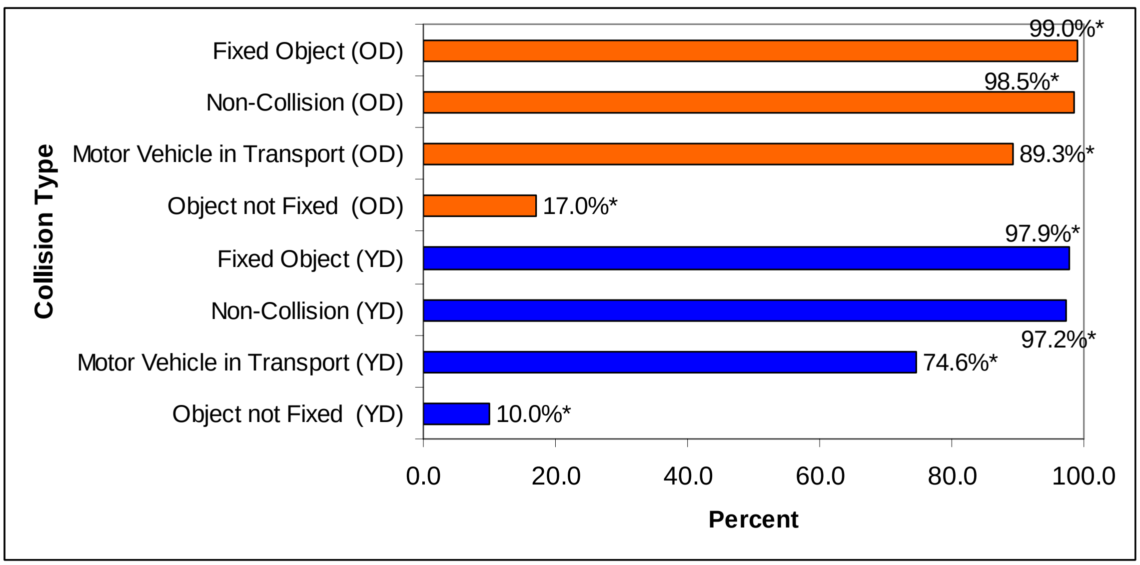


*$p \leq 0.05$; YD = Younger Driver; OD = Older Driver
Figure 4-5. Drivers injured in crash by time of day



*$p \leq 0.05$; YD = Younger Driver; OD = Older Drive

Figure 4-6. Drivers injured in crashes by vehicle body type



*$p \leq 0.05$; YD = Younger Driver; OD = Older Driver

Figure 4-7. Drivers injured in crash by most harmful event type

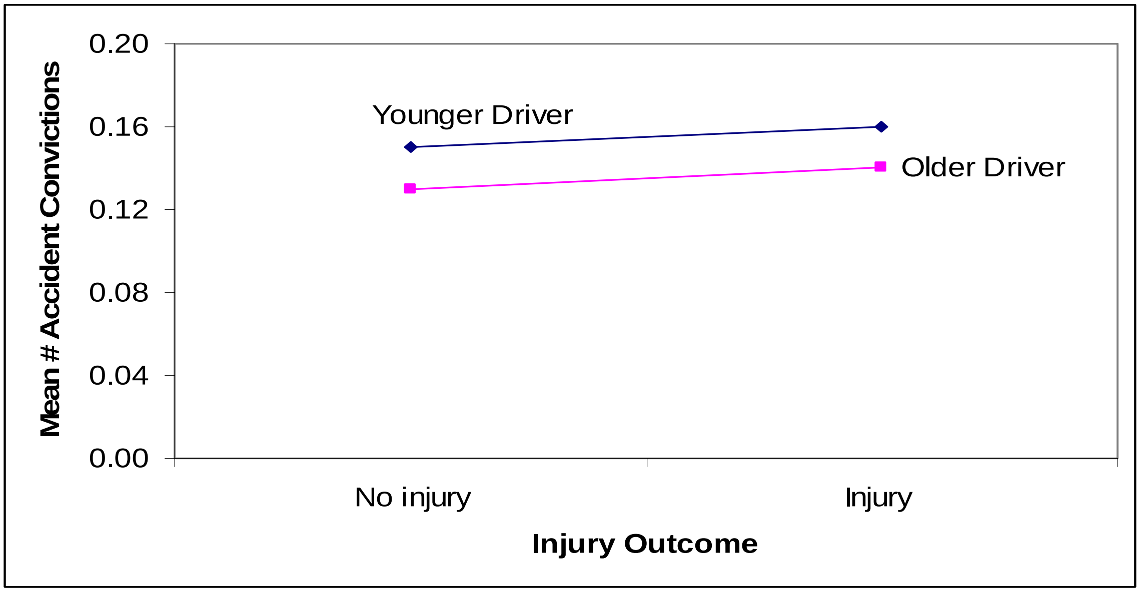


Figure 4-8. Previous accident convictions by injury outcome and age group

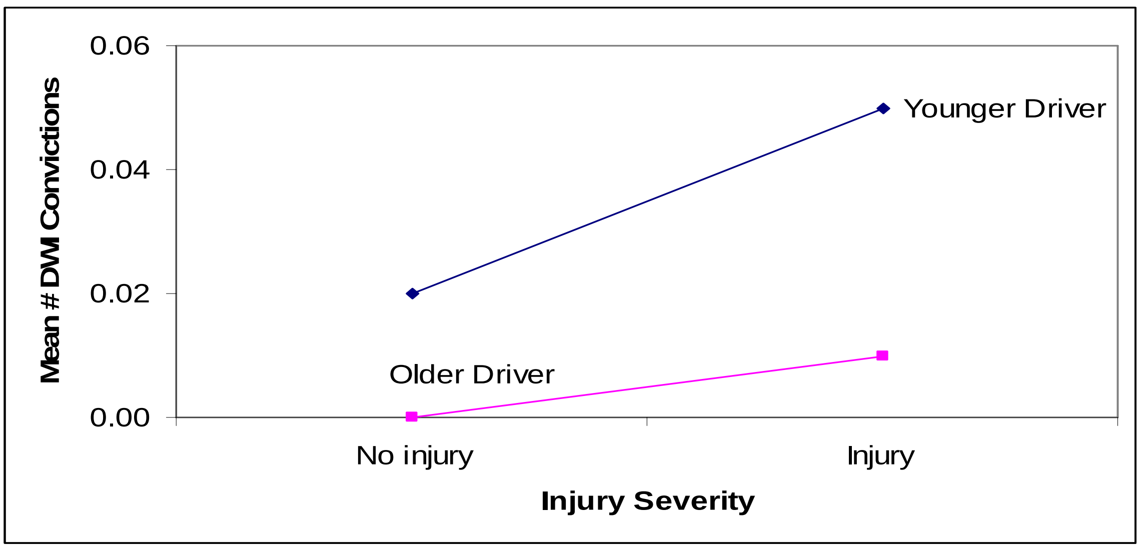


Figure 4-9. Previous driving while impaired (DWI) convictions by injury outcome and age group

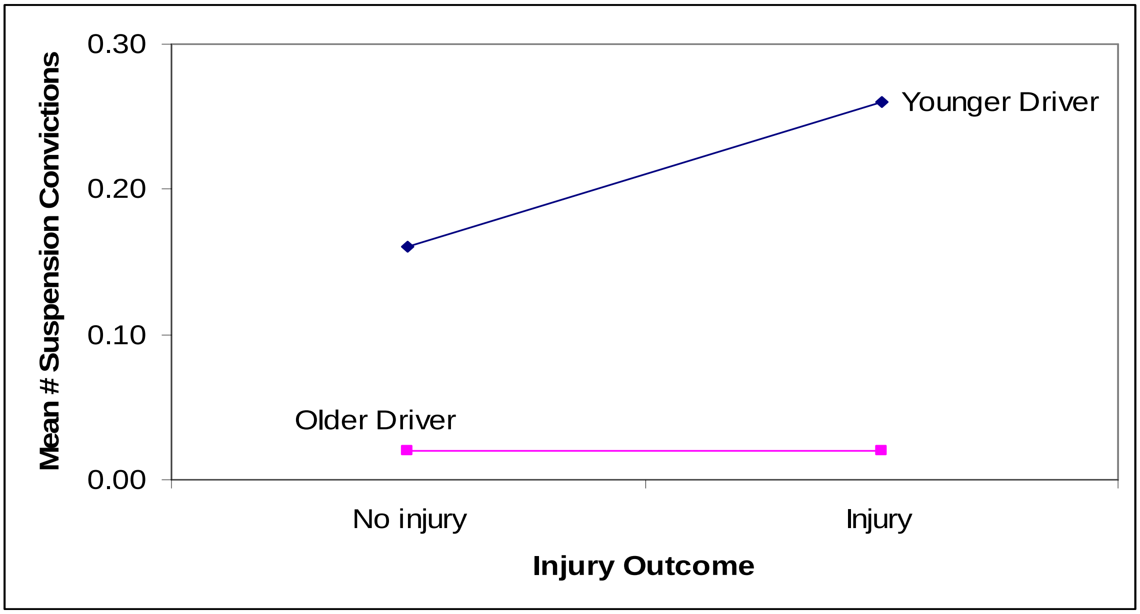


Figure 4-10. Previous suspension convictions by injury outcome and age group

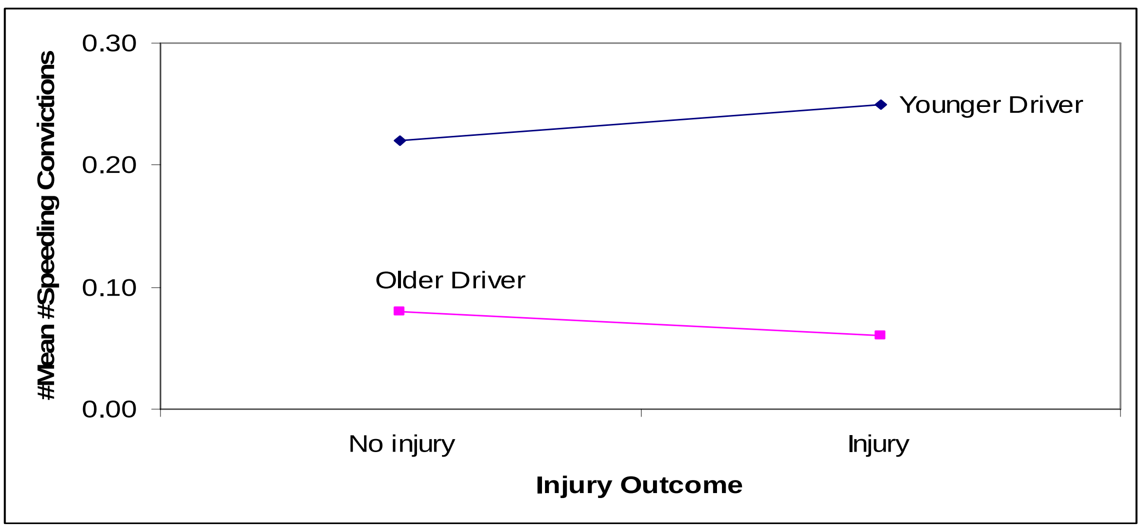


Figure 4-11. Previous speeding convictions by injury outcome and age group

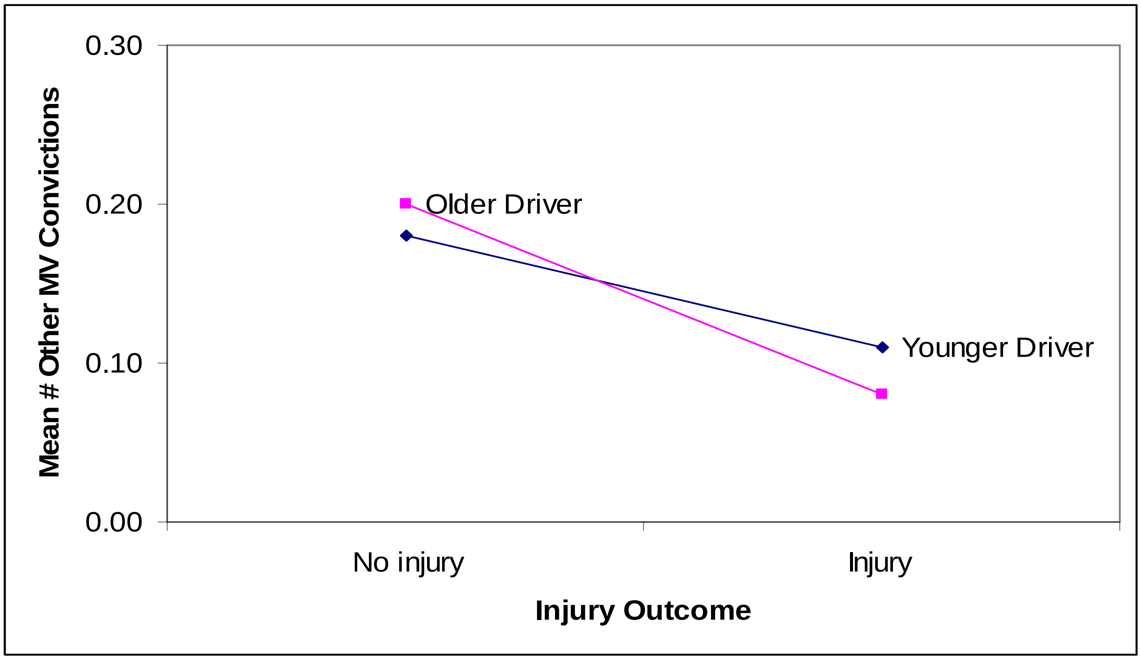


Figure 4-12. Other motor vehicle convictions by injury outcome and age

CHAPTER 5
DISCUSSION

Overview

The main objective of this study was to use a crash database and a socio-ecological public health model, the Precede-Proceed model of health promotion (PPMHP), to investigate the socio-ecological determinants of motor vehicle injuries among older drivers (65 years and older) in the United States, using younger (35 to 54 years) drivers as a comparison group. The aims of the study were to (a) describe drivers in the 2003 FARS dataset with respect to their level of injury in motor vehicle crashes, (b) examine the relationship between the determinants of motor vehicle injuries and injury outcome, and (c) for older drivers, examine the effect of state licensure renewal policies on motor vehicle injuries.

Limitations of the Study

As previously discussed, the study has the limitations of a secondary dataset and a crash dataset. Specific to the FARS crash dataset, (a) all drivers were involved in a fatal crash (at least one person died), making the inclusion criteria for the dataset narrow; (b) there was no comparison with a sample of drivers who were not involved in crashes; (c) unreported crashes were not represented in the FARS database; (d) a driver may have been involved in a fatal crash more than once in 2003, and thus more than one crash involving the older driver may have been in the 2003 FARS dataset; (e) data collection for environmental, predisposing, and some behavioral variables is based mainly on police accident reports, and all states do not routinely report all the FARS elements on the police reports (Massie & Campbell, 1996); and (f) there were not available data on socio-demographic variables such as income and education that may have given a complete picture of their association with injuries.

Specific to the study, for the bivariate analyses, almost all independent variables were statistically significant at $p \leq 0.05$ level, possible because of the huge sample size. For the study on state age-related license renewal policies, some states belong to more than one category (type of policy was not mutually exclusive), and thus, the method was not a rigorous analysis. Secondly, the age-renewal policy reduced renewal cycle, had a wide state variation of the ages at which the policy was implemented, and the renewal cycle (years).

Regarding the binary logistic regression, while I was able to determine associations among independent variables and injury, it was difficult to disentangle the contribution of complex variables such as *relation to junction*, *vehicle maneuver*, and *most harmful event*, and injury. It was in part because the sample was comprised of drivers who had been involved in a crash. I was also not able to establish whether the driver involved in the crash was at fault or not, due to the inadequate data on variables that may have provided more information (accident-related factors, violations charged, and vehicle-related factors).

Procedure of the Study

I accomplished these objectives in three ways. Using the findings and structure created by a preceding research study—a systematic literature review on older driver safety, the PPMHP structural model, several consultation meetings with the *Project to Promote Safe Elder Driving* team at the University of Florida, and a National Highway Traffic Safety Administration (NHTSA) consultant, I selected apposite variables for the analyses.

I used univariate and bivariate analyses to examine the data and collapse levels of categories where necessary and conducted a bivariate analysis to ascertain the level of injury for exploratory variables for both younger and older drivers. I performed a binary logistic regression model to examine measures of associations (odds ratios) between the socio-ecological determinants of motor vehicle injuries and injury outcome in a motor vehicle crash. Thirdly, I grouped U.S. states by four factors pertaining to age-related license renewal policies and conducted exploratory bivariate analyses to investigate the relationship among states with and without age-related license renewal policies and injury outcome.

Findings in Light of Research Questions and Hypotheses

In this section, I discuss the results from the perspective of the research questions and hypotheses.

Injury Prevalence among Independent Variables for Younger and Older Drivers

Research Question #1: What is the prevalence of the main determinants (risk and protective factors) and motor vehicle injury for younger drivers (35 to54 years) and older drivers (65 years and older)?

Ho: Younger drivers will not have lower prevalence rates for motor vehicle injuries compared to older drivers (65 years and older).

Ha: Younger drivers (35 to 54 years) will have lower motor vehicle injury prevalence rates compared to older drivers (65 years and older).

To achieve this objective, I examined the relationship among the determinants of motor vehicle injury (exploratory variables) and injury (dependent variable) separately for younger and older drivers using chi-square tests for categorical variables and independent sample t-tests for numerical variables. Older drivers did have higher injury rates among all the determinants of motor vehicle injury and injury outcome. However, not all determinants had statistically significant differences in injury prevalence rates. *Driver license compliance* (whether the driver had a valid license for the vehicle operated at the time of the crash) had a statistically significant relationship with injury for younger drivers, but not for older drivers. *Day of the week* had statistically significant differences in injury outcomes for older drivers, but not for younger drivers. Also, all variables in the reinforcing domain of the PPMHP (numbers of previous accidents, suspensions, DWI (driving while impaired), speeding and other motor vehicle convictions) had statistically significant relationships with injury outcomes for younger drivers. However, only *other motor vehicle convictions* (failure to yield, lane-related, and running a red light) was statistically significantly different for older drivers. Based on these findings, I reject the alternative hypothesis that younger drivers will have lower motor vehicle injury prevalence rates. These findings are descriptive in nature and give an overview of younger and older drivers regarding the determinants of motor vehicle injury outcomes.

Measures of Association among Independent Variables and Injury

Research Question #2: What are the measures of association among socio-ecological determinants (behavioral, environmental, predisposing, and reinforcing factors) confounding variables (age), and motor injury (injury: yes/no) for younger and older drivers?

Ho: Younger drivers (35 to 54 years) will not have lower odds ratios for environmental variables (e.g., *hour of day*, and *most harmful event*) and predisposing factors (*vehicle maneuver*) and injury, compared with older drivers (65 years and older).

Ha: Younger drivers (35 to 54 years) will have lower odds ratios for environmental variables (e.g., *hour of day*, and *most harmful event*) and predisposing factors (*vehicle maneuver*) and injury, compared with older drivers (65 years and older)

To achieve this objective, I conducted a binary logistic regression between 32 variables from five domain of the PHMHP (with age-interaction terms) and injury outcome (no/yes). There were four significant age interaction effects in the model (significant associations between older driver group and injury outcome), three from the behavioral domain (*registered vehicle owner*, *principal impact*, and *number of occupants*), and one from the reinforcing domain (*number of previous other motor vehicle convictions*). Although there were three environmental variables for older drivers only, on the whole, statistically significant risk and protective factors pertained to both younger and older adults. I therefore reject the alternative hypothesis.

Age-related License Renewal Policies

Research Question #3: What is the prevalence of injuries for older drivers among states with age-related license renewal policies compared to states without any age-related license renewal policies?

> **Ho:** There will be no difference in motor vehicle injury prevalence rates between states with no age-related licensure renewal procedures and those with age-related licensure renewal procedures.
>
> **Ha:** There will be differences in motor vehicle prevalence rates between states with age-related licensure and states with no age-related licensure renewal procedures.

This exploratory study grouped U.S. states by factors: age-related renewal policy, reduced renewal cycle, in-person renewal, and vision/medical testing. Generally, drivers with licenses from states with age renewal policies had lower injury prevalence rates than drivers with licenses from states with no age-related renewal policies. However, for reduced renewal cycles for older drivers, there was no difference in injury prevalence rates between states with reduced renewal cycles and those without. I therefore reject the null hypothesis of no difference between states with and without age-related policy renewals and accept the alternative hypothesis as stated above.

Implications for Policy, Practice and Research

I will discuss findings from the binary logistic regression model for the 20 significant associations among independent variables and injury as well as the bivariate analyses for age-related license renewal policies in light of epidemiology, policy, and health services implications.

Findings from the final model

The risk and protective determinants of injury that were associated for both age groups included health (*gender*), behavior (*driver license compliance*, *driver drinking*, *restraint system use*), environment (*time of day*, *hour of day*, *number of lanes*, *road surface condition*, *vehicle body type*, *most harmful event*, *relation to junction*, *traffic control device*, *airbag deployment* and *National Highway System, rural vs. urban*), and predisposing (*vehicle maneuver*).

Female drivers were 1.5 times more likely to be injured in a crash compared to male drivers. The gender differences in driver safety outcomes (crashes, injuries and fatalities) are sustained by previous studies (Finison & Dubrow, 2002; Baker, et al., 2003; Bauer, et al., 2003; and NHTSA 2006a), and lend historical plausibility to the results of this study. This finding has societal implications as older women generally live longer than older men. Thus, older women are likely to require transportation in the latter years of their lives. They may, therefore, require interventions such as motor vehicle injury prevention program. This finding has epidemiological implications for research specifically targeted at older female drivers.

Behavioral factors (alcohol involvement, lack of seatbelts, and invalid drivers' license) were risk factors for injuries for both age groups. 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 for alcohol use and driving, and seatbelt use. Over the years, the monitoring of these driving behavioral factors has been associated with decreased crashes and injuries among drivers. Continual surveillance of alcohol and seatbelt adherence by state governments may be one of the best approaches to decrease injuries among younger and older adults.

For environmental factors, *registered vehicle owner*, not being the registered vehicle owner for the motor vehicle was a protective factor for injury. The reason for this is unclear and there is no available research to buttress this finding. However, I postulate that older drivers who drive vehicles not registered in their names are younger and appear healthy (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. 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 (Hermanson, 2005). Two reasons offered for this phenomenon was *safety* and *socialization*. Older adults (especially those 75 years and older) selected someone else to drive because they did not feel safe driving themselves, or wanted to meet with people (Hermanson, 2005). Older drivers are finding ways of maintaining independence (having a motor vehicle), and yet practicing safety precautions by having a designated driver when they do not feel safe to drive, and may be a self-regulatory strategy of some older drivers, and has implications for older driver research. The finding also 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).

Regarding *principal impact* (the direction at which the vehicle was struck during the crash), the 1–3 o'clock angle (front passenger side) and 7–9 o'clock angle (the back side portion of the motor vehicle) were significant injury risk factors for the older driver group. 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 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. 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. To better understand these mechanisms, another analysis such as a loglinear analysis would have to be performed to understand the inter-relationships among certain environmental variables (e.g., speed, relation to junction, most harmful event, vehicle maneuver), and principal impact. However, this finding has implications for policy enforcement interventions in the area of improving minimum standards for safety in motor vehicles, such as side airbag protection.

The number of passengers in the vehicle at the time of the crash was a marginally significant protective factor for older drivers who had two or more passengers in the vehicle. Research by Bedard and Meyers (2004) suggests that the presence of four or more passengers is protective for older drivers 65–79 years old; this was associated with less risk of crashes for some unsafe actions such as driving the wrong way and was not significantly associated with passing, but was associated with higher risks of other driver actions such as ignoring signs and warning, with higher risks for drivers 80 years and older. Baker et al. (2003) found that either two passengers or three or more passengers were protective for crashes among older female drivers, while driving alone was a risk factor for crashes. Hing et al. (2003) related time of day to number of passengers on the safety of older adults, with results indicating that while drivers 75 years and older had higher crash ratios than other age groups, driving at night was protective for crashes.

The results from this study, in conjunction with previous studies, indicate that the presence of passengers may be protective for older drivers but the protection may vary depending on other factors such as time of day, gender, and type of most harmful event (collision with a fixed object) the driver was engaged in at the time of the crash. The three studies focus on different outcome variables and various combinations of exploratory variables for the analyses; thus, to have a clearer picture of the factors involved in the number of passengers as a protective factor in injury, more information would be necessary. Further analyses such as a loglinear analysis exploring the relationship among variables such as health-related factors, time of day, most harmful event, and injury may better explain the relationship between passengers and injury outcome for older adults. A qualitative study, such as a focus group examining older drivers' perceptions of passengers would help buttress findings from the quantitative analyses.

The number of previous motor vehicle convictions was marginally protective for older drivers; that is, for every increase in the number of other motor vehicle convictions, there was a decreased risk in injury. It is difficult to ascertain using quantitative data alone why previous number of motor vehicle convictions for failure to yield, running a red light, or lane-related changes was significantly associated with reduced risk of injuries for the older driver group. However, 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 the findings, policy enforcement of motor vehicle violations may be pertinent to older adult injury prevention. To better examine the influence of reinforcement on injury, further research (e.g., focus group study) that include family/caretaker roles in older adults' decisions to drive may have to be taken into account.

The hour of the day the crash occurred was protective for daylight hour injuries. Previous older driver research 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 (Finison & Dubrow 2002; Baker et al 2003; NHTSA, 2006b). The findings appear contradictory; however, the cited research used crashes as the outcome variable, while this study focuses on injury outcomes. The findings from this study suggest that drivers are at higher risks for injury during the daylight hours. Further research may ascertain whether there are differences in injury outcomes, controlling for the number of crashes.

Two-lane crashes was a protective factor for injury compared to one-lane crashes. Further 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. Regarding *roadway surface conditions*, crashes on adverse road conditions (e.g., wet, oil) had higher risks of injuries compared with crashes on dry road conditions. This opposes previous findings (Finison & Dubrow 2002; Baker et al., 2003) implying that crashes are more likely to occur on roads with favorable conditions for older drivers. It must be remembered that the data for this study comprised of both younger and older drivers, and has injury, not crashes, as the outcome variable of interest.

Automobile and automobile derivatives were risk factors for injury compared with SUVs, while light trucks, vans, and pickups were protective for injury. 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. NHTSA 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.

The *most harmful event* had very high odds ratios for injury for non-collision crashes, collisions with other motor vehicles, and collision with fixed objects. Environmental engineering of roadways such as replacing fixed objects (e.g., concrete divides) with non-fixed objects, such as cable barriers, may reduce impact severity of crashes and injuries among drivers. For vehicles, improving technology such as anti-rollover devices may reduce non-collision crashes.

Compared to drivers traveling on non-junctions (e.g., rail road crossing or bridges), the level intersection–related crashes was protective for injury. This may be because intersections are usually more structured (e.g., traffic lights) compared with 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, Shechtman, Stephens et al., 2006; Shechtman, Classen, Stephens et al., 2006).

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 the crash. The reason for this is not clear. I postulate that roads with traffic control devices may be generally more complex than roads without traffic control devices.

From the results of this study not *having airbag deployment* in the crash was protective for injury. This may be because airbag deployment is associated with front and high impact crashes (i.e., serious crashes) and thus may be more likely to result in injury. One implication of this result is considering follow-up driver education to ensure proper positioning of the seat in relation to the airbag.

Crashes on the National Highway System was a risk factor for injury. It may be because roads not on the NHS are likely to be less traveled on and less complex than roads on the National Highway System. Compared to rural areas, crashes in *urban areas* were less likely to result in injury. This 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, Higher risk of injury in urban areas may be explained by the fact that urban areas are more likely to have more complex roads and traffic patterns. The high traffic density 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.

Compared to going straight, drivers engaged in lane related maneuvers and making a left turn had a lesser chance of being injured in a traffic crash. This may be possibly 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.

Findings from the behavioral domain suggest that regulating driver behavior through enforcement may be a good way of reducing injuries among all drivers. Environmental factors—physical (vehicle factor, highway factors) and social (number of occupants)—contributed significantly as risk and protective factors for injuries for both age groups. However, vehicle factors such as *vehicle owner* or *principal point of im*pact contributed as risk and protective factors for older drivers only.

Findings from age-related license renewal policies

Findings from the exploratory bivariate analyses of state age-related license renewal laws showed that reduced renewal cycles and vision/medical test requirements did not have statistically significant association with injury. This may have been because the states had different reduced renewal cycles (years) and, also, the ages for implementing this policy varied from between 60 and 79 years. A more complex analysis, such as a hierarchal linear analysis, may be required to investigate the effects of the different years of renewal and the age of inception. In-person renewals, however, had decreased prevalence of injury compared to states with no in-person renewals. This is plausible because in-person renewals entail some form of physical assessment, which would screen drivers who have obvious vision or physical disabilities.

Research on the effects of age-renewal policies on older driver safety outcomes is contradictory. In-person renewal has been associated with reduced fatality rates among drivers over 85 years, with other age-renewal policies such as vision and road tests insignificantly associated with injury (Grabowski et al., 2004). However, Levy, Vernick, & Howard (1995) found that a state mandated vision test was associated with reduced fatal crash risk for drivers 70 years and older. It is possible that states with vision test requirements may not have differences in injury prevalence rates because state vision requirements are mainly tests of visual acuity and do not measure other important vision components such as visual field loss, and contrast sensitivity (Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Owsley, Ball, Sloane, Roenker, & Bruni, 1991).

Conclusion

This study used the Precede-Proceed model of health promotion (PPMHP) to investigate relationships among socio-ecological variables and motor vehicle injury outcomes for older drivers (65 years and older) and compared them with younger drivers (35–54 years). The source of data was the 2003 Fatality Analysis Reporting System (FARS), a national secondary crash database. Prevalence rates and measures of associations (odds ratios) among independent variables and injury were reported for younger and older drivers. An exploratory sub-analysis (older drivers only), compared injury prevalence rates among states with age-related license renewal polices against states without age-related license renewal policies.

Regarding age-related renewal policies, states with age-related license renewal polices, and states requiring in-person renewal were associated with lower injury rates. The final model yielded that the environmental domain, a domain not well studied in the existing 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 reveal the multiple factors associated with injury. Many of the findings showed relevance to drivers from both age groups, with a selected few pointing to older adults, meaning that injury prevention measures, when developed and implemented, may potentially benefit older and younger drivers alike.

The significant findings from the behavioral (alcohol, driver license compliance, and seatbelt use), environmental (improvement of vehicle crashworthiness and highway design), and enabling (age related policy renewal) domains hold therefore important implications for injury prevention programs. For example, preliminary injury prevention strategies to be examined include continued policy enforcement, environmental engineering (e.g. highway design or crashworthiness of vehicles) and driver educational programs.

Policy enforcement is considered the most effective strategy for decreasing motor vehicle injury rates (World Health Organization, 2004). Enforcement of seatbelts and alcohol laws may continue to decrease injury rates among older and younger drivers, while age-related license renewal laws may primarily benefit older drivers. In the event of a crash, policies designed to improve crashworthiness of motor vehicles may benefit older and younger drivers and passengers alike.

This study also emphasizes that differences exist in the dynamics underlying motor vehicle crash outcomes and motor vehicle injury outcomes. For example, a driver may be involved in a motor vehicle crash but may not necessarily be injured as a result of maintaining low speed or using the in vehicle restraints properly—both factors associated with injury prevention/reduction. Many of the factors contributing to injury may not be explained by the data contained in the aggregated findings of this study. Therefore, if the socio-ecological determinants associated with injury are to be understood, then further research addressing these specific areas is of utmost importance.

Additional research is underway in the *Public Health Model to Promote Safe Elderly Driving* project to shed more light on the complexities involved in injury outcomes. For example a qualitative study is planned to next examine crash related injuries among older adults from their personal perspectives. Ongoing quantitative research includes a log linear analysis to examine the relationships and interaction effects among variables that had statistically significant associations with injury.

Although this study does not have direct implications for health services research at this point in time, it lays the foundation for injury prevention programs. As such, it creates plausible research and policy making opportunities for working towards accessible and affordable injury prevention programs, especially for older drivers.

APPENDIX A
PRECEDE-PROCEED MODEL OF HEALTH PROMOTION

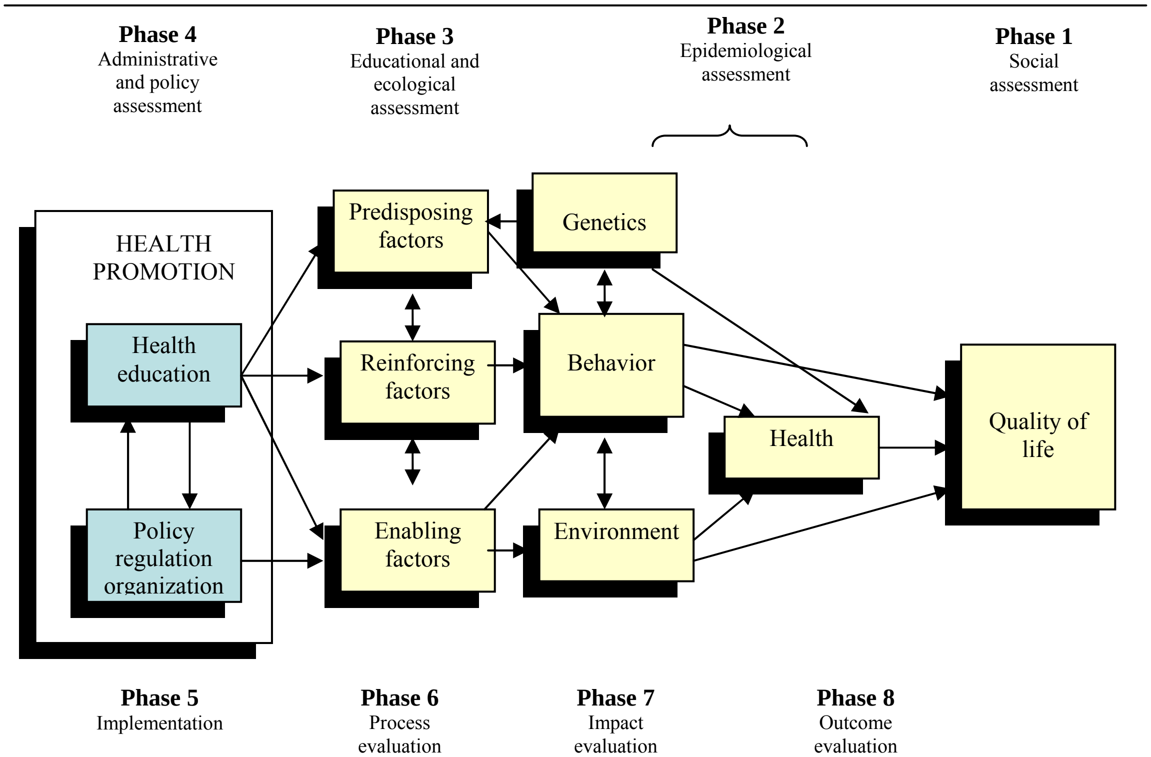


Figure A-1. Precede-Proceed Model of Health Promotion.

[Re-printed with permission from Green, L.W., & Kreuter, M.W. (2005). *Health Program Planning: An Educational and Ecological Approach*. (4th ed.). (Page 10, Figure 1-2) McGraw-Hill Companies, Inc. NY]

APPENDIX B
STRUCTURAL MODEL OF OLDER DRIVER SAFETY

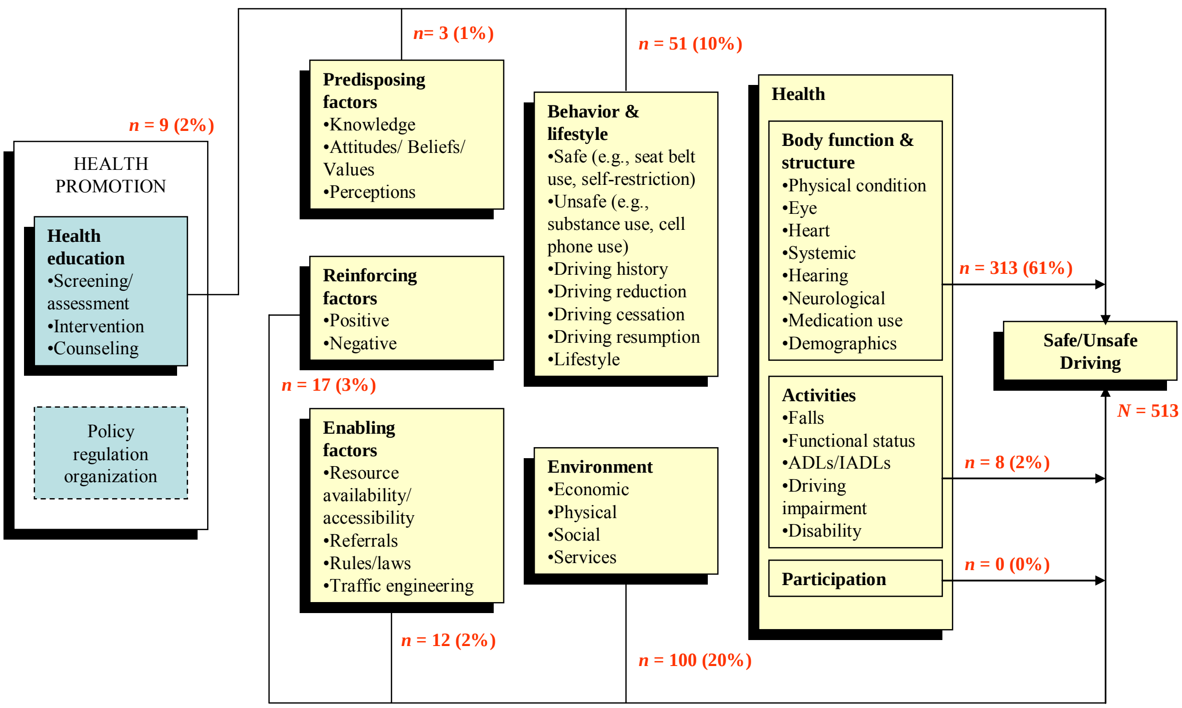


Figure B-1. Precede-Proceed model of health promotion structural model from older driver systematic literature review.

[Reprinted with permission from Classen, S., Garvan, C.W., Awadzi, K., Sundaram, S., Winter, S., Lopez, E.D.S. et al (2006). Systematic literature review and model for older driver safety. *Topics in Geriatric Rehabilitation, 22,* 2: 87-98. (Page 95 Figure 2). Lippincott Williams & Wilkins, Inc]

APPENDIX C
INITIAL EXAMINATION OF VARIABLES & RATIONALE FOR INCLUSION/EXCLUSION BASED ON CONSENSUS MEETINGS

Table C-1. Fatality Analysis Report System (FARS) accident level variables[a]

Element	Levels	Note	PPMHP (yes/no)	Code[b]	Variable # and page # in FARS manual[c]
Case number state number		Present in all level files Important for merging	N/A	N/A	A1
Consecutive number		Number assigned to forms	No	N/A	A2 p. 24
Vehicle number		Number assigned to vehicle	No	N/A	A3
County	N/A		Physical environment	32	A6 p. 29
City	N/A		Physical environment	32	A6 p. 29
Accident date	Month: 01–12 Day: 0–13		Physical environment	32	A8 p. 31
Accident time			Physical environment	32	A9 p. 35
National Highway system	0, 1 levels; and 9	Interstate system, principal arterial system routes and strategic network connected	Physical environment	32	A10 p. 37
Roadway function class	19 levels	Rural: 1–9 Urban: 11–19	Physical environment	32	A11 p. 39
Route signing	9 levels	Interstate, U.S. highway, state highway, county road.	Physical environment	32	A12 p. 45
Traffic identifier	*Consider leaving out		Physical environment	32	A13 p. 49

Table C-1. Continued.

Element	Levels	Note	PPMHP (yes/no)	Code[b]	Variable # and page # in FARS manual[c]
Mile point	Actual number *Consider leaving out		Physical environment	32	A14 p. 53
Global position	*Consider leaving out	Geographic location of crashes. Expressed in degrees, minutes, and seconds of latitude, and same for longitude.	Physical environment	32	A15 p. 55
Special jurisdiction	0–9 levels *Consider collapsing	Where accident occurred in a special jurisdiction	Physical environment	32	A16 p. 59
First harmful event	About 60 levels, but grouped under: • noncollision • collision with motor vehicle • collision with object not fixed • Collision with object fixed.	First property damage (including vehicle) or injury-producing event	Physical environment	32	A17 p. 61
Manner of collision	12 levels *Recode as: • Front • Rear • Side	Point of impact	Physical environment	32	A18 p. 75
Relation to junction	20 levels grouped as (a) interchange, (b) non-interchange and (c) unknown *Recode as: • Intersection • Entry/exit • Hazardous crossing • Unknown	Location of first harmful event	Physical environment	32	A19 p.81

Table C-1. Continued.

Element	Levels	Note	PPMHP (yes/no)	Code[b]	Variable # and page # in FARS manual[c]
Relation to roadway	01–11, and 99 *Too detailed. Consider dropping	Part of the road, e.g., on roadway, median, shoulder	Physical environment	32	A20 p. 89
Trafficway flow	1–6 levels; and 9 *Recode as: • Not divided • Divided • One-way • Exit/entrance • Unknown	Road design	Physical environment	32	A21 p. 95
Number of travel lanes	1–7 levels; and 9 *Consider dropping	Number of travel lanes	Physical environment	32	A22 p. 97
Speed limit	Actual posted limit; 00 for no statutory limit, and 99 for unknown *Consider dropping	Posted speed limit m/hour	Physical environment	32	A23 p. 99
Road alignment	1–2 levels; and 9	Straight or curve	Physical environment	32	A24 p.103
Roadway profile	1–4 levels; and 9	Road profile	Physical environment	32	A25 p.105
Road surface type	1–8 levels; and 9 *Recode as: • stable • unstable • unknown	E.g., concrete, brick, slug, dirt	Physical environment	32	A26 p.107
Road surface condition	1–8 levels; and 9 *Recode as: • dry • adverse • other/unknown	E.g., dry, wet, snow	Physical environment	32	A27 p.109
Construction or maintenance zone	0–4 levels *Recode as: • Yes • No		Physical environment	32	A28 p.111

Table C-1. Continued.

Element	Levels	Note	PPMHP (yes/no)	Code[b]	Variable # and page # in FARS manual[c]
Traffic control device	Several levels. Can be classified as 1) no controls, 2) highway traffic signals 3) regulatory signs, 4) school zone signs, 5) warning signs, 6) miscellaneous not at railroad crossing; 7) at railroad grade crossing *Recode as: • No • Yes		Physical environment	32	A29 p.113
Traffic control device functioning	0–3 levels; and 9		Physical environment	32	A30 p.119
Light condition	1–5 levels; and 9 *Recode as: • light • dark		Physical environment	32	A31 p.121
Atmospheric conditions	1–8 levels; and 9 *Recode as: • adverse • non-adverse		Physical environment	32	A32 p.123
Hit and run	1–4 levels		Behavior	23	A33 p.125
Notification time EMS	Time (military time)		Social environment	33	A36 p. 133
Arrival time EMS	Time (military time)		Social environment	33	A37 p.137
EMS time at hospital	Time (military time)	Time EMS arrived with victims of accident	Social environment	33	A38 p.141

Table C-1. Continued.

Element	Levels	Note	PPMHP (yes/no)	Code[b]	Variable # and page # in FARS manual[c]
Related factors-accident level	1–22 levels; and 99 *Recode as: 1. Highway design 2. Environmental factors • Extraneous • Personal 3. Care network systems-Tertiary	Information on events that may have contributed to crash	Physical environment	32	A39 p.145

[a] School bus related & rail grade crossing identifier were not included in this list
[b] Codes derived from Older Driver Systematic Literature Review (Classen et al., 2005).
[c] 2004 FARS Coding and Validation Manual
*Suggestions

Table C-2. FARS vehicle level variables[a]

Element	Levels	Note	PPMHP (yes/no)	Code [b]	Variable # and page #in FARS manual[c]
Case number-state number		Present in all level files Important for merging	N/A	N/A	V1
Consecutive number		Number assigned to forms	No	N/A	V2
Vehicle number		Number assigned to vehicle	No	N/A	V3 p.153
Number of occupants	Actual number	Coded for each vehicle involved in the accident	Social environment	33	V4 p.155
Registration state	56 levels; 92–99	State in which vehicle was registered	No	33	V5 p.159
Registered vehicle owner	0–6 levels; and 9		No	33	V6 p.163
Travel speed	Actual miles per hour		Behavior	21, 22	V15 p. 281
Vehicle maneuver	1–17 levels; 98 and 99 • Lane changes • Turning • Adjustment to stimuli • Parked vehicle • Speed variations & stopping • Going straight • Other/unknown	Driver's action or intended action prior to crash	Behavior	32	V16 p.283

Table C-2. Continued.

Element	Levels	Note	PPMHP (yes/no)	Code [b]	Variable # and page #in FARS manual[c]
Crash avoidance maneuver	0–8 levels • No avoidance maneuver • Braking • Steering • Other/steering and braking • Not reported	Action taken by driver to avoid crash	Predisposing	41	V17 p.285
Rollover	0–2 levels	Vehicle overturning during accident	Physical environment	32	V18 p.287
Initial point of impact	0–14 levels	Initial point that produced property damage or personal injury (part of vehicle)	Physical environment	32	V20 p.291
Vehicle role	0–3 levels; and 9	Whether vehicle was stuck or did the striking	Physical environment	32	V21 p.299
Sequence of events	About 50 levels. Categorized as: • Non–collision • Collision with motor vehicle collision with objects not fixed • Collision with fixed objects		Physical environment	32	V32 p.343

Table C-2. Continued.

Element	Levels	Note	PPMHP (yes/no)	Code [b]	Variable # and page #in FARS manual[c]
Most harmful event	1–43 levels; and 99 Categorized as: • Non–collision • Collision with motor vehicle • collision with objects not fixed • Collision with fixed objects	Used when first harmful event is minor for a particular vehicle compared to some subsequent event. Otherwise they are both coded the same per vehicle	Physical environment	32	V33 p.355
Related factors—accident level	1–42 levels; and 99 (similar to accident–level variable) Recoded: 0 = none 1 = 19 (fault on vehicle) 2 = hit and run 3 = vehicle went airborne 4 = other vehicle contributory factors 99 = unknown	Information on events that may have contributed to crash	Physical environment		V34 p.365

[a] vehicle make, model, body type, model year, vehicle ID #, bus use, special use emergency use, jackknife, underside/override, extent of deformation, manner of leaving scene, motor carrier ID #, vehicle configuration, vehicle trailing, number of axes, gross vehicle weight rating, cargo body type, and hazardous cargo were not included in this list.
[b] Codes derived from Older Driver Systematic Literature Review (Classen et al., 2005).
[c] 2004 FARS Coding and Validation Manual
*Suggestions

Table C-3. FARS driver level variables[a]

Element	Levels	Note	PPMHP (yes/no)	Code	Variable # and page # in FARS manual[c]
Case number state number		Present in all level files Important for merging	N/A	N/A	D1
Consecutive number		Number assigned to forms	No	N/A	D2
Vehicle number		Number assigned to vehicle	No	N/A	D3 p. 375
Driver presence	1–3 levels; and 9	*Should not be applicable to our dataset	No	N/A	D4 p. 377
License state	1–56 levels; 94–99	Either state where driver got license or residence state of driver	Yes	63	D5 p. 381
Driver zip code	Actual values	N/A			D6 p. 385
NON-CDL License type/status	0–9 levels Categorized as: • License type • Graduated driver licenses • License status *Use license status variables 1–6 levels; and 9	License status	Enabling	21 or 22 63	D7 p. 387
Commercial motor vehicle license status	0–8 levels; and 9	Status for driver's commercial driver's license	Enabling	21 or 22 63	D8 p. 397

Table C-3. Continued

Element	Levels	Note	PPMHP (yes/no)	Code	Variable # and page # in FARS manual[c]
Compliance with license endorsements	0–3 levels; and 9	Whether vehicle driven required endorsements and whether driver was in compliance	Behavior	21 or 22 63	D9 p. 403
License compliance with class of vehicle	0–3 levels; and 8–9	Type of license possessed or not for vehicle driven	Behavior	21 or 22 63	D10 p.407
Compliance with license restrictions	0–3 levels; and 9	Compliance with physical and imposed restrictions	Behavior	21 or 22 63	D11 p.411
Driver height	Actual feet		Health		D12 p.415
Driver weight	Actual weight in pounds		Health		D13 p.417
Date of first and last accident, suspension conviction	Month and year	Actual month and year	Behavior or reinforcing	23 or 52	D19 and D20 p. 425

Table C-3. Continued

Violations charged	0–99 levels. Categorized as: • reckless/hit and run type • impairment offenses • speed–related offenses • rules of the road–traffic signs and signals • rules of the road–turning, yielding, signaling • rules of the road–wrong side, passing and following • rules of the road–land usage • non–moving–license and registration violation • equipment • license, registration and other violations	Behavior or reinforcing (need to find out whether 1) the information is duplicated 2) is this past violations or current?	23 or 52	D21 p. 429
Related factors-driver level	0–99 levels *need to recode	Behavior health	9 22	D22 p. 435

[a] Previous other harmful MV convictions not included in the list
[b] Codes derived from Older Driver Systematic Literature Review (Classen et al., 2005).
[c] 2004 FARS Coding and Validation Manual
*Suggestions

Table C-4. FARS person level variables[a]

Element	Levels	Note	PPMHP (yes/no)	Code	Variable # and page # in FARS manual[c]
Case number-state number		Present in all level files Important for merging	N/A	N/A	P1
Consecutive number		Number assigned to forms	No	N/A	P2
Vehicle number	00–99	Number assigned to vehicle	No	N/A	P3 p. 453
Person number	01–99	Coded consecutively	No	N/A	P4 p. 457
Age	0–up to one year 01–96 (actual age); and 97–99	65-75 76-85 86+	Health	20a	P6 p. 459
Sex	1–2; and 9		Health	20g	P7 p. 461
Person type	1–2 levels; and 9	Important! Will be used to select inclusion sample (only crashes with person type = 1 will be included)	N/A	N/A	P8 p. 463
Seating position	0–55; and 99		N/A	N/A	P9 p. 473
Restraint system use	0–8 levels; and 99	Type of restraint used None used/NA Shoulder belt Lap belt Shoulder/lap Restraint unknown Unknown	Behavior	21/22	P10 p. 479

Table C-4. Continued.

Element	Levels	Note	PPMHP (yes/no)	Code	Variable # and page # in FARS manual[c]
Air bag availability	0–32 levels; and 99 Categorized as: • Deployed • No deployed • Unknown if deployed • Not available	Record of airbag availability and deployment	Behavior Physical environment	21/22 or 32	P11 p. 483
Police-reported alcohol involvement	0–1 level; 8 and 9 Collapse unknown/not reported		Behavior	22	P16 p. 497
Police-reported other drug involvement	0–1 level; 8 and 9 Collapse unknown/not reported		Behavior	22	P19 p. 511
Drug test results	0–999 Collapse:	Type of drugs	Behavior Health	9 or 22	P21 p. 519
Injury severity	0–6 levels; and 9 Collapse: • No injury • Injury		Outcome	81	P22 p. 529
Taken to hospital or treatment facility	0–1; and 9		Physical environment	33	P23 p. 533
Died at scene/en route	0; 7–9 levels		Outcome	81	P24 p. 535
Death date	Month/date/year	*Will help determine how long victim lived	N/A	N/A	P25 p. 537
Death time	Military time	*Will help determine how long victim lived	N/A	N/A	P26 p. 541

Table C-4. Continued

Element	Levels	Note	PPMHP (yes/no)	Code	Variable # and page # in FARS manual[c]
Related factors-person level	0–99 levels *Recode Add these variables 1–3		Behavior Health Environmental	22 9 32	P27 p. 543

[a] ejection, ejection path, extrication, non-motorist location, method of alcohol determination by police, alcohol test type/alcohol test results, method of other drug determination, death certificate number, and fatal injury at work variables not included in the list.

[b] Codes derived from Older Driver Systematic Literature Review (Classen et al., 2005).

[c] 2004 FARS Coding and Validation Manual

*Suggestions

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BIOGRAPHICAL SKETCH

Kezia Dzifa Awadzi was born in Ghana, West Africa. Her parents, Dr. and Mrs. Awadzi, encouraged their three children to develop a love for reading from an early age.

Kezia graduated from the University of Ghana in 1993 with a bachelor's degree in home economics and a minor in Food Science. Interested in a writing career, she participated in a national writing competition organized by Step Publishers, Ghana in 1994 and won first prizes in the True Life and Drama Categories. Ms. Awadzi worked on the editorial board of Step Publishers for two years and left for graduate study in Mass Communication at the University of Florida in 1997. She graduated with a Masters in mass communication (journalism) in December 1999. Her thesis focused on the U.S. media–influenced opinions about Africa. Ms. Awadzi's experiences in developing a survey, data collection, and data analysis awakened an interest in research. Ms. Awadzi's parents had careers in healthcare and Kezia wanted to do a program in a related field. In Fall 2001, she enrolled in the doctoral program Health Services Research in the department of Health Services Research, Management and Policy, University of Florida. While in the doctoral program, Ms. Awadzi worked on projects within and outside of health services, including the *Biological Control of Brazilian Peppertree in Florida* in the Department of Entomology and Nematology, University of Florida.

In January 2005, Kezia had an opportunity to work as a research assistant on the Centers for Disease Control and Prevention project—the *Public Health Model to Promote Safe Elderly Driving.* This job made her interested in older driver safety issues, provided exposure to secondary database analyses, and became the focus of her dissertation work.

Kezia has published in *Topics in Geriatric Rehabilitation*, *Consumer Studies in Home Economics*, and *Environmental Entomology*. She graduated in Fall 2006.