Older drivers and fatal motor vehicle crashes

by

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Abstract

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Historically, fatal motor vehicle crashes have not been an issue pertinent to older drivers. However, demographic trends are changing this reality. Yet, it is unclear how many older drivers will be involved in fatal crashes in coming years, what type of driving errors they commit, the situations in which they are more at risk to commit these errors, and what may protect them against fatal injuries in the event of a crash.

Data from every incident involving a U.S. traffic-related fatality from 1975 to 1998 were analyzed, confirming that while older adults (65+) accounted for 10% of all fatalities in 1975, this proportion may increase to 27% by year 2015.

The most frequent driving errors made by older drivers regarded road signs and warnings, and traveling off the lane or road. Compared to drivers aged 40 to 49, drivers aged 80+ were eight times more at risk to make errors involving road signs/warnings, six times more at risk to make errors entering/exiting traffic, and seven times more at risk to commit driving errors at junctions, where more than half of all crashes occurred.

Blood alcohol concentration, prior traffic crashes, license suspensions, convictions, and drug/medication use were related to a higher risk of driving errors. A higher number of passengers was associated with fewer driving errors among drivers aged 65+.

In the event of a crash, drivers aged 80+ were five times more at risk to be fatally injured than drivers aged 40 to 49. High blood alcohol concentrations, higher speeds, and smaller, recent vehicles were associated with higher risks of fatality. Seat belts were associated with a 50% reduction in the fatality risk.

Current preventive strategies need to be re-evaluated. Interventions for older drivers should focus on road signs/warnings and intersections, both of which were associated with a large proportion of driving errors by older drivers. Societal changes are imperative to maintain the independence afforded to older adults by the automobile, while reducing the risk of traffic-related fatalities.

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Dedication

The time spent working on this thesis was at the expense of Catherine, Geoffrey and Lori. I dedicate this work to them for their patience and understanding.

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Chapter 1. Traffic crashes and fatalities as a public health issue

Thesis framework

Traffic fatalities are a serious public health issue. In the U.S. alone, between 35,000 and 50,000 individuals die every year in traffic related events, most of them drivers or passengers of vehicle involved in crashes (Whitfield & Fife. 1987). A disproportionate number of these fatalities was attributed to young drivers.

Past safety initiatives have targeted young adults in an attempt to curb the large number of fatalities they account for. For example, initiatives aimed at decreasing drinking and driving have been credited for considerable reductions in fatalities among the youngest road users (Centers for Disease Control and Prevention. 1992a). On the other hand, few initiatives have been aimed at older adults. Although the absolute number of fatalities they account for has been, historically, less than 10% (Whitfield & Fife. 1987), traffic fatalities are the main cause of accidental deaths for adults aged 65 to 74, and the second most important cause of death, after falls, for adults aged 75 and over (Lilley, Arie, & Chilvers. 1995).

However, higher life expectancy leads to increasing proportions of older adults every year; a pattern expected to continue for several years to come (World Health Organization. 1999). In most industrialized countries, older adults will more than double in number by year 2030 (Stanfield. 1996; World Health Organization. 1999). Furthermore, whereas the ratio of adults aged 65 to people aged less than 20 was 12/100 in 1955, and 16/100 in 1995, it will reach 31/100 by 2025 (World Health Organization. 1999).

These demographic trends will have a profound impact on many public health issues. One set of issues relevant to the aging population is that of driving and traffic fatalities. Projected demographic trends suggest that an increasing number of older adults will be involved in traffic fatalities; we need to direct some safety efforts towards them. However, the extent, planning, and implementation of future safety initiatives will depend on the knowledge we can derive today, from data gathered in the past years (Stutts & Martell. 1992). Specifically, we need to determine what proportion of all future fatalities older adults will represent, and what is the expected number of fatalities? In what situations are older drivers more likely to initiate fatal crashes? Which older adults are more likely to initiate fatal crashes? And, in the event of a crash, what protective factors may prevent fatalities? The work presented in this dissertation was intended to provide some insight into these questions, and formulate directions for policy decision and future research.

Future trends

Information about future crash and fatality rates can be useful for researchers and planners (Stutts & Martell. 1992). First, it allows the prioritization of target groups for interventions where maximum benefit will be derived. For example, in the past years safety initiatives were primarily focused on young drivers who used alcohol and drove, because they accounted for a disproportionately large number of traffic crashes and fatalities. The knowledge that younger adults, especially those who drank and drove, were at increased risk of crash involvement and fatality, and the belief that the situation could be modified, was crucial in the decision to focus on young drivers, and on the drinking issue specifically.

Possibly because older adults have historically been associated with a marginal number of crashes and fatalities, little information is available regarding future trends. Whereas current demographic pressures will lead to an increase in the number of older adults, and especially women (Stutts & Martell. 1992), a shift in the current focus on younger adults towards older adults may be desirable. Therefore, a detailed examination of the involvement of older adults in past, and future crashes and fatalities is warranted.

Past crash and fatality rates across age groups and gender

Compared to younger drivers, older drivers (typically 65+) are less often involved in non-fatal and fatal crashes (where at least one person died). For example, using police-reported crashes per 100 licensed drivers per year from North Carolina for years 1974 to 1988, drivers less than 25 years of age were twice as likely to be involved in a crash compared to those 65+ (11 vs. 5)(Stutts & Martell. 1992). More recent U.S. data (1996) also paint a similar picture with crash rates of about 14 per 100 licensed drivers aged less than 25, 6 per 100 drivers aged 45 to 54, and a rate of about 5 for drivers aged 75+ (McGwin & Brown. 1999).

However, these numbers do not control for exposure. When distance traveled is taken into account older drivers represent a crash risk at least equivalent to that of younger drivers (Cooper. 1990). This pattern is consistent for non-fatal and fatal crashes. Crash risk usually follows a "U"-shaped curve, starting high for young drivers, declining and remaining steady for experienced drivers, and raising steadily with aging drivers (Graca. 1986; Massie, Green, & Campbell. 1997; Stutts & Martell. 1992; Williams & Carsten. 1989; Zhang, Fraser, Clarke, & Mao. 1998).

Swedish data covering the years 1977 to 1979 and 1983 to 1985 evidence this "U"-shaped crash risk pattern. Whereas the police-reported crash risk per million kilometers/year was 1.40 for drivers aged 18-19, it dropped to 0.28 for those aged 25-54, and climbed to 1.77 for drivers aged 75+ (Brorsson. 1989). Similarly, data from Western Australia showed a decline from 14.1 crash per million kilometers for drivers 17 to 19 to 3.29 for those aged 45 to 49, up to 10.4 for drivers aged 80+ (Ryan, Legge, & Rosman. 1998). Recent U.S. data (1996) also paint a similar picture. Crash rates using one million kilometers as the denominator led to approximate crash rates of 10 for drivers aged 15-24, 3 for drivers aged 45 to 54, and 6 for those 75+ (McGwin & Brown. 1999).

Rates of involvement in fatal crashes are lower than rates for police-reported crashes but retain the "U"-shaped distribution. Data for all U.S. jurisdictions based on FARS for 1983 (Williams & Carsten. 1989) and 1990 (Massie, Campbell, & Williams. 1995) showed similar fatal crash rates for younger and older drivers when distance was considered. In 1990 the rate of involvement in fatal crashes for drivers aged 16 to 19 was 0.057 per million kilometers. It dropped to 0.011 for drivers aged 40 to 44, and climbed to 0.071 for those 75+ (Massie, Campbell, & Williams. 1995).

Based on distance traveled, young and older adults are more likely to be involved in crashes causing pedestrian fatalities, a type of crash often equated with driver initiation, than middle-aged drivers (Brorsson. 1989; Evans. 1988a). However, because young and older drivers may travel more often in urban settings these statistics may inflate the difference. It is likely that using distance traveled exaggerates the risk of those who traveled mainly in urban areas (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993; Janke. 1991). A more adequate measure would be based on urban driving alone.

Although generally computed for the overall population, some researchers have provided separate crash rates for men and women. Separate estimates are important because women live longer than men and form a larger proportion of older adults (World Health Organization. 1999). Using FARS data for 1990, men had three times the crash rate of women on a per driver basis (Li, Baker, Langlois, & Kelen. 1998). In Ontario, for the year 1988 (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993), overall crash rates were also higher for men than women when examined on a per driver basis yet confirmed the "U"-shaped results found by others when comparing age groups.

Controlling for distance traveled produced different patterns. Adjusting the FARS data mentioned above for distance traveled revealed fatal crash rates of 3.16 per million kilometers for men and 3.53 for women (Li, Baker, Langlois, & Kelen. 1998). Using one million kilometers as the denominator, the "U"-shape of the Ontario results remained but differences between men and women were less convincing and interacted with age. Men aged 16-19 had a crash rate of 8.8 per one million kilometers compared to 5.8 for women of the same age. The crash rate decreased with age until it shot back for drivers aged 80+. Men aged 80+ had a crash rate of 5.9, compared to that of women at 10.1 (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993). Danish researchers found no gender effect on self-reported crash involvement after controlling for age and distance traveled (Lourens, Vissers, & Jessurun. 1999). Others reported higher involvement of men in fatal crashes but higher involvement of women in other injury producing crashes (Massie, Campbell, & Williams. 1995). Massie and colleagues (Massie, Green, & Campbell. 1997) used regression analysis to examine involvement rates by gender while controlling for distance traveled. They found reduced involvement rates for women compared to men. This effect was consistent when they examined fatal crashes, injurious but not fatal crashes, and crashes resulting in property damage only.

The inconsistencies found when comparing crash rates for men and women support the contention that distance traveled may not be the appropriate index to control for exposure when estimating crash rates (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1992; Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993; Janke. 1991; Stamatiadis & Deacon. 1997). Distance traveled as the denominator for crash rate may be inappropriate because men typically travel more than women, and the type of travel they do differs. Data from 1990 (U.S.) showed men traveled more than 20,000 km/year, compared to

12,000 for women (Massie, Campbell, & Williams. 1995). This difference, although more pronounced in middle-aged groups, was consistent across the age bands. Drivers with high mileage, typically men, do a larger proportion of their driving on major highways with restricted access as opposed to urban roads. Ontario men drove 56% more kilometers than women, yet they spent only 35% more time driving then their female counterparts (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1992). Because crash rates are lower on major highways than urban roads (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993), high distance drivers are less likely to be involved in crashes (Massie, Green, & Campbell. 1997), leading to an exaggeration of risk for drivers who do most of their driving in urban areas (Janke. 1991).

This potential exaggeration of the risk for urban drivers, typically younger and older drivers, and women, is a central issue because crash rates adjusted for distance are assumed to indicate relative liability (Janke. 1991). For example, because drivers age 75+ have a rate of involvement in fatal crashes of 0.071 per million kilometers compared to 0.011 for drivers 40 to 44 (Massie, Campbell, & Williams. 1995), some may infer that older drivers are six times more likely to initiate fatal crashes. This would be an erroneous and unfortunate assertion because these analyses do not consider responsibility for crash initiation (liability).

To avoid the problem introduced by distance traveled different methodologies to calculate crash rates are required. One method uses the time spent driving as the denominator, instead of the distance traveled. Using the

1988 Ontario crash data, similar crash rates for men and women were found when the denominator was based on the number of hours spent on the road, contrary to rates based on distance, which showed differences between men and women (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993). However, time spent driving still confounds liability with exposure. What is required is a method to control for liability.

Methods that control for liability include the induced exposure method, and logistic regression. Both are based on odds ratios, where the ratio of at-fault drivers of a certain category (e.g., men) to drivers not at-fault of the same category (men), is compared to the ratio of at-fault drivers of another category (e.g., women) to drivers not at-fault of the same category (women)(Pendleton. 1996). Logistic regression provides results similar to those based on induced exposure, and is an appropriate method to determine and test statistical associations between many independent variables and liability (Stamatiadis & Deacon. 1995).

Older drivers and crash responsibility

In a small sample of 769 Finnish drivers involved in fatal collisions, 74% of drivers aged 65+ were considered at-fault compared to 39% of the comparison group aged 26-40 (Hakamies-Blomqvist. 1993). The over-involvement of older adults in crash initiation in relation to the proportion of licensees became especially salient from age 70 onward (Hakamies-Blomqvist. 1993).

Crash rates based on induced exposure are believed to provide a better reflection of relative crash rates across groups of drivers because they rest on the assessment of responsibility (Janke. 1991; Pendleton. 1996; Stamatiadis & Deacon. 1995; Stamatiadis & Deacon. 1997). Assessment of responsibility was not always available in some earlier crash databases. However, using responsibility with existing databases allows researchers to remove the confounding effect of exposure, leading to more precise estimates of risk for groups of drivers. Even though the relationship between age and risk is not expected to disappear, the "...several-fold worse quality of the relationship..." is expected to be tempered (Janke. 1991).

Using all police-reported crashes for the state of Alabama in the year 1996, some investigators calculated ratios of drivers responsible for crash initiation to drivers not responsible (McGwin & Brown. 1999). A ratio of one indicated identical proportion of responsible and non-responsible drivers, ratios higher than one indicated higher proportion of responsible drivers, and ratios of less than one indicated lower proportion of responsible drivers. As hypothesized, drivers aged 16 to 24 had a ratio of 1.3, drivers aged 45 to 54 had a ratio of 0.7, and drivers aged 75+ posted a ratio of nearly 2.0.

Recent analyses based on data from the state of Kentucky also showed the association between age and crash responsibility (Stamatiadis & Deacon. 1995; Stamatiadis & Deacon. 1997). Using two-vehicle crashes, crash ratios followed the typical "U"-shaped curve observed with distance traveled and time spent traveling as control factors for exposure. Crash ratios ranged from 1.7 for drivers aged 16 to 19, to a low of 0.7 for drivers aged 40 to 44, and climbed to 1.2 for drivers aged 65 to 69, and 6 for drivers aged 80+ (Stamatiadis & Deacon. 1995).

However, these studies relied on two-vehicle crashes only; including single-vehicle crashes would have affected the estimates. Responsibility for single-vehicle crashes is usually attributed to younger drivers; crash ratio estimates for single-vehicle crashes exceed 1.0 only for younger drivers (Stamatiadis & Deacon. 1997). Therefore, the inclusion of these crashes would increase crash ratio for younger drivers and decrease it for older drivers (Janke. 1991).

Perneger and Smith examined two-car crashes with a case-control approach, where responsible drivers were labeled as cases, and non-responsible drivers as controls (Perneger & Smith. 1991). In multivariate analyses using logistic regression they found alcohol use to be the most important variable for crash liability (odds ratio = 11.53, 95% CI = 9.57 to 13.89). Second to alcohol use was age and its typical "U"-shaped association, with younger and older drivers more likely to initiate crashes. Logistic regression methodology provide consistent results to those using induced exposure methodology (Stamatiadis & Deacon. 1995), with the advantage that it provides direct tests of statistical associations.

To identify the contribution of gender to crash ratios Kentucky data (Stamatiadis & Deacon. 1995) and Alabama data (McGwin & Brown. 1999) were stratified according to gender, findings were analogous to those obtained for Ontario data with time spent driving as the control factor for exposure (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993). The authors found higher crash ratios for young men compared to young women, but lower ratios for older men compared to older women.

Crash involvement and older adults

The previous sections demonstrated that older adults were more likely to be involved in crashes, fatal or non-fatal, than middle-aged drivers. However, the real impact of safety initiatives will depend on the absolute number of older adults involved in crashes. Yet, the magnitude of the problem posed by older drivers appears small when we examine their absolute crash involvement.

In 1987, drivers 65+ were involved in 10% of all fatal crashes, even though they accounted for 16% of the population (Williams & Carsten. 1989). On the other hand, drivers aged less than 30 were involved in 56% of fatal crashes despite representing only 22% of the population (Williams & Carsten. 1989). In 1989, 3,319 drivers 65+ died on U.S. roads; representing only 13% of all driver fatalities (Barr. 1991). In Sweden, Brorsson (Brorsson. 1989) examined crashes resulting in injuries. He reported that the absolute number of older drivers involved in crashes is small, and that, compared to older drivers, drivers aged 18-19 represent "...a much greater safety problem." (p. 256) This position was echoed in 1999, when McGwin and Brown (McGwin & Brown. 1999) asserted that "...older drivers do not contribute significantly to the problem of traffic crashes in the United States." (p. 188)

There are two main explanations for the lesser involvement of older drivers in crashes, beyond demographic reasons: licensing rates and distance traveled. First, evidence showed fewer licensed drivers amongst older adults compared to younger age groups (Barr. 1991; Massie, Campbell, & Williams. 1995; Stutts & Martell. 1992). For example, in 1990, 63% of all American adults aged 75+ held a driver's license compared to 94% for adults aged 25 to 49 (Massie, Campbell, & Williams. 1995).

Second, licensed older adults drive less than middle-aged adults. In a Swedish survey, drivers aged 18-19 drove an annual average of 8,500 km, compared to 14,000 for drivers in the 25-54 category, and 6,500 for drivers aged 75+ (Brorsson. 1989). In the U.S., data for 1983 revealed that the typical 16-year old driver cumulated a yearly distance of 2,200 km, those from 35 to 39 drove 31,400 km, and those aged 65-69 drove 14,500 km (Evans. 1988a). Data from 1990 showed an approximate yearly mileage of 11,300 km for drivers aged 16 to 19, compared to 19,000 km for drivers aged 25 to 44, and 4,800 for drivers 75+ (Massie, Campbell, & Williams. 1995).

Although precise estimates may be difficult to obtain, the pattern is clear, fewer older adults hold valid driver's licenses, and those who do drive fewer kilometers than the typical middle-aged driver.

Past and future fatalities

The ultimate aim of safety initiatives is to save lives. To maximize their impact, these initiatives are generally directed at groups with high numbers of fatalities. Consistently, younger drivers have been the target of most safety initiatives because they are over-represented in fatal crashes. Whereas older adults' past involvement in fatal crashes has been low, it is fair to examine whether this trend will continue in the future.

An earlier examination of traffic fatality trends confirmed that older adults do not represent a substantial problem regarding fatalities. In their examination of traffic fatality rates between 1940 and 1980, Whitfield and Fife (Whitfield & Fife. 1987) reported that death rates per 100,000 persons increased for the U.S. population aged 15-39, whereas it remained constant or decreased for older groups. The authors stated that "...countermeasures to reduce motor vehicle crash mortality among teenagers and young adults are of increasing importance to the public health. (p. 268) The authors also remarked that the decline in older adult fatalities were "...due entirely to declining pedestrian death rates" (p. 268) but did not expand on the significance of this finding.

Williams and Carsten, in 1989, reported that if predictions based on their 1987 data and census predictions were accurate there would still be more than twice as many younger drivers (less than 30) involved in crashes than older drivers (65+) by year 2030 (Williams & Carsten. 1989). This led them to conclude that crash issues related to older drivers "...will remain relatively small well into the next century." (p. 327) Although they conceded that older drivers may drive more miles then, they did not factor in this possibility and remained convinced that younger drivers will "...continue to be the predominant group in terms of numbers involved".

It is still true in year 2000 that older adults do not represent a sizable problem regarding traffic fatalities. But a focus on the current situation may engender a state of complacency and inertia. We have to evaluate the merits of available projections and determine if we need to worry about the future involvement of older adults in fatal crashes. Other more cautious researchers aptly pointed out that: "Older drivers…warrant increasing attention…" (p. 458)(Stamatiadis & Deacon. 1995).

Revisiting future fatality trends

One would be less concerned with older adults if older driver fatalities were following overall trends; overall fatalities are on the decline. Between 1980 and 1989, overall driving fatalities fell 20% from 19.8 per 100,000 drivers to 15.9. Despite this overall decrease, 65+ fatalities increased 19% from 9.0 per 100,000 to 10.7. Whereas 2,323 drivers aged 65+ died in 1980, accounting for only 8% of all 28,816 fatalities, 3,319 (13%) of all 26,389 drivers killed in 1989 were aged 65+ (Barr. 1991).

What may explain the rise in older adult fatalities compared to other adults is a crucial issue. One possibility is that of cyclical and irregular fluctuations. Unfortunately, the statistics reported above were based on data for the years 1980 and 1989 only. The data for years 1981 to 1988 were not reported. It is possible that the trends presented were the results of cyclical or irregular variations, as is often observed with market based data. Only a thorough estimation of trends over several years can confirm or refute these trends.

Another possibility is an increase in mobility among older drivers. It was noted earlier that fewer older adults were licensed to drive; this is changing. Data from North Carolina for the period from 1974 to 1988 illustrate this point (Stutts & Martell. 1992). Whereas the proportion of residents aged 75+ increased by 39%, the proportion of licensed drivers aged 75+ increased by 129%, and the proportion of crashes involving this age group increased by 75%. Furthermore, increases in licensing rates among the 65+ have been more than four times larger for women than men (Stutts & Martell. 1992).

Overall, in the U.S., the proportion of licensed adults aged 65+ passed from 62% in 1980 to 70% in 1989 (Barr. 1991). Other researchers reported increases from 61% in 1983 to 75% in 1990 (Massie, Campbell, & Williams. 1995). In the U.S., the proportion of adults aged 70+ with valid driver's license is expected to more than double by 2020 (Eberhard. 1996). In Australia, the number of license holders among the elderly is expected to double within the next 20 years (Darzins & Hull. 1999).

Distance traveled is also changing. From 1980 to 1989 the 65+ increased their yearly distance traveled by 31% (Barr. 1991). Comparing data for 1983 and 1990, drivers aged 75+ increased their distance traveled by 90%, the largest percentage increase in travel by any age group (Massie, Campbell, & Williams. 1995). And women, who accounted for 33% of the distance traveled in the U.S. in 1983, accounted for 37% of the distance traveled in 1990 (Massie, Campbell, & Williams. 1995).

These data raise new concerns. While the demographic changes alone will create pressures on driving and crash issues for the older adults, these changes will be compounded by the increased independence and mobility of coming older generations, compared to older generations of a few decades ago. Today's older adults are more likely to retire earlier, with more disposable income, and are more likely to maintain an active lifestyle (Fildes. 1997). The coming generation of "baby-boomers" will be more mobile than the current generation of older adults (Weinand. 1996). And women will likely travel more in future years, especially for older groups, than they did in the past (Stutts & Martell. 1992).

These reasons suggest that fatality projections based only on demographic changes are inappropriate. Demographic changes are not the only force shaping the future of traffic crashes and fatalities; available predictions of older adults' involvement in fatal accidents likely represent underestimates. A greater number of older adults, and women, will be involved in fatal crashes than anticipated. Accurate predictions of the role older adults will play in future fatalities are required. Better knowledge of changes in the driving population will allow for better planning of safety initiatives (Stutts & Martell. 1992).

Chapter 2. Crash initiation

Reductions in the incidence of crashes and fatalities among older adults depend on useful and valid information relevant to older adults. One increasingly critical type of information is the demonstration that drivers are a heterogeneous group of individuals. Despite similar crash and fatality rates for young and older adults, the underlying reasons for the disparities between these groups and the middle-age group are different (McGwin & Brown. 1999). Compared to older drivers, younger ones are more likely to drive above the speed limit, lose control of their vehicle, and get involved in single-vehicle crashes (Clarke, Ward, & Jones. 1998; McGwin & Brown. 1999; Zhang, Fraser, Clarke, & Mao. 1998). Younger drivers are more likely to drive and be involved in fatal crashes while under the influence of alcohol or illicit drugs (Kennedy, Isaac, & Graham. 1996; McGwin & Brown. 1999; Mortimer & Fell. 1989; Solnick & Hemenway. 1997; Zhang, Fraser, Clarke, & Mao. 1998; Zobeck, Grant, Stinson, & Bertolucci. 1994). Ejection of passengers riding in pick-up truck beds operated by young drivers is common (Hamar, King, Bolton, & Fine. 1991; Malliaris, DeBlois, & Digges. 1996), and results in the death of a disproportionately large number of young passengers (Hamar, King, Bolton, & Fine. 1991). These characteristics hardly apply to older drivers.

With reason, past safety initiatives have focused heavily on younger drivers. However, the demographic and societal changes highlighted earlier point to the need for interventions targeting older drivers. Unfortunately, the situations in which older drivers are more likely to initiate crashes are not as well understood as those applying to younger drivers.

To obtain this information, crashes can be dissected into a combination of several variables unique to each crash situation and each driver. Situational crash variables include driver maneuvers and errors, and environmental variables specific to the physical setting. Driver variables include attributes such as age, gender, and alcohol use. If drivers were a homogeneous group, variability across crashes would be random. On the other hand, if variability across crash types is systematic, we may gain information pertinent to safety initiatives for specific groups of drivers (McGwin & Brown. 1999).

Situational crash variables

Recently, considerable attention has been paid to crash situations where older drivers may be over-involved. Two types of studies document systematic variability in variables associated with crashes. The first type is based purely on crash incidence/rates irrespective of responsibility. Necessarily, it only documents the involvement of older drivers and confounds responsibility with exposure. These studies are informative because they identify situations where older drivers are more likely to be involved in crashes, whether they caused them or not. The second type of studies relies on the assessment of responsibility. These studies, although few of them are available, provide estimates of associations between older drivers' initiation of crashes and situational variables. These studies allow stronger causal inferences between aging and crash responsibility. Previous researchers have focused on single versus multi-vehicle crashes, road configuration, weather, day of week, and time of day.

Multi-vehicle crashes

Single vehicle crashes are more likely among younger drivers than among older drivers, and multi-vehicle crashes are more likely among older drivers. The authors of a large study of police-reported crashes found that 16% of crashes involving drivers less than 25 were single-vehicle crashes. Comparatively, that proportion stood at 7% for drivers aged 55+ (McGwin & Brown. 1999). Canadian data showed that vehicle-vehicle collisions accounted for 67% of crashes for drivers aged 65+ compared to 50% for drivers 16-24 (Zhang, Fraser, Clarke, & Mao. 1998).

Viano and colleagues (Viano, Culver, Evans, Frick, & Scott. 1990), using 1982-86 data on serious to fatal injuries from the National Accident Sampling System (NASS), showed that 63% of crashes involving drivers aged 19 and less were single vehicle, compared to 39% for drivers aged 65 to 79 and 49% for those aged 80+. The authors showed considerable discrepancies in the rates of single-vehicle crashes involving a side impact with a fixed object. These types of crashes, believed to be associated with aggressive driving, decreased from 17% of all crashes for younger adults (19 and less) to 2% for drivers aged 80+. However, the authors found that adults aged 80+ were involved in frontal single vehicle crashes with fixed objects in equal proportions (47%) to that of drivers aged 19 or less (46%) or aged 20 to 39 (46%). Drivers aged 40 to 59 (37%) and 60 to 79 (38%) were involved less often in single vehicle crashes with fixed objects.

Applying the induced exposure methodology to 1994-95 FARS data, others reported that older drivers are more likely to cause multiple-vehicle crashes at intersections compared to drivers aged 40-49; comparisons with younger drivers are not provided (Pruesser, Williams, Ferguson, Ulmer, & Weinstein. 1998). The authors provided a fine grain analysis of drivers' age and showed a dose-response relationship between age and risk of multi-vehicle crash initiation at intersections. Specifically, compared to drivers aged 40-49 the risk increased form 2.26 (age 65-69) to 2.94 (70-74), 4.58 (75-79), 7.07 (80-84), and 10.62 (85+). Interestingly, the pattern of crash initiation, although consistently higher for older drivers, was much more elevated in situations where no traffic signals or signs were present. These data provide the strongest evidence that older drivers are more likely to cause crashes at intersection and point to the need for intervention as the population ages (Pruesser, Williams, Ferguson, Ulmer, & Weinstein. 1998).

Crash angle

In multi-vehicle crashes, the angle of the collision differs according to age group. Compared to middle age drivers, older drivers were more likely to be involved in angled crashes, and less likely to be involved in same direction crashes (e.g., head-on); the reverse was true for younger adults (Ryan, Legge, & Rosman. 1998; Stamatiadis & Deacon. 1995; Zhang, Fraser, Clarke, & Mao. 1998). In a large sample of police-reported crashes, 21% of responsible drivers aged 55+ were involved in intersection crashes compared to 17% for drivers less than 25; among drivers non-responsible, the proportion was 22% for both age groups (McGwin & Brown. 1999). The difference between age groups was more salient in a Finnish study where angled crashes represented 55% of the crashes involving drivers aged 65+ compared to 17% of drivers aged 26 to 40 (Hakamies-Blomqvist. 1993). Conversely, head-on crashes accounted for 38% of older drivers' crashes, but 78% of younger drivers'.

The typical side impact, angled crash in which older adults are involved requires the examination of the maneuvers drivers were engaged in. Three teams of investigators recently documented these maneuvers (McGwin & Brown. 1999; Ryan, Legge, & Rosman. 1998; Zhang, Fraser, Clarke, & Mao. 1998). They reported that compared to younger drivers, older drivers were more likely to be turning, merging into traffic, changing lanes, leaving a parking position, or backing.

Road characteristics

One study examining crashes according to road grade and curvature did not report age differences (McGwin & Brown. 1999). Although there was a trend suggesting that older drivers are more likely to be involved in crashes on straight roads compared to younger drivers, this difference did not appear statistically significant (in fact a statistical analysis was not presented). However, the age trichotomization may have been too gross to capture age differences; drivers were classified as 16-34, 35-54, or 55+. Age differences are evident in Canadian data. Zhang and colleagues reported that older drivers

(65+) are less likely to be involved in crashes occurring on curved roads than younger drivers (16-24), and more likely to be involved in straight road crashes (Zhang, Fraser, Clarke, & Mao. 1998). These data, unfortunately, do not account for responsibility and thus, may simply be a reflection of the greater exposure of older drivers to urban environments and their grid-like road patterns.

Weather conditions

Older adults are more likely to be involved in crashes during good weather than younger drivers. In a recent study, 62.3% of drivers aged 55+ were involved in crashes during good weather compared to 60.1% of drivers aged 16-34 (McGwin & Brown. 1999). Slightly larger but consistent proportions were obtained in Canada (Zhang, Fraser, Clarke, & Mao. 1998). Both young drivers (16-24; 72%) and older drivers (65+; 73%) were more likely to be involved in good weather crashes compared to the middle group (25-64; 70%).

Day of week

In their analysis of all police-reported crashes in Alabama for the year 1996, McGwin and Brown (McGwin & Brown. 1999) found that more crashes occur on Friday, and less on Sunday than any other days, while the number of crashes is consistent from Monday to Thursday. Compared to younger drivers (16-34), drivers aged 55+ are less involved in crashes occurring on weekends. The age difference is greatest on Saturday, when 14.2% of crashes for the 16 to

34 group are recorded, compared to 11.9% for the 55+ group. Canadian crashes were categorized as Monday to Thursday, or Friday to Sunday, and whereas 54% of crashes involving older drivers occurred during weekdays, this proportion was only 40% for drivers aged 16-24 (Zhang, Fraser, Clarke, & Mao. 1998).

Time of day

In general, the rate of involvement in fatal crashes at night is five times that of during the day, roughly 0.064 per million kilometers at night versus 0.0136 during daytime (Massie, Campbell, & Williams. 1995). However, older drivers are less likely to be involved in nighttime crashes compared to younger drivers (Massie, Green, & Campbell. 1997; Mortimer & Fell. 1989; Sjogren, Bjornstig, Eriksson, Sonntag-Ostrom, & Ostrom. 1993; Stutts & Martell. 1992). Australian data showed 91% of crashes for drivers age 80+ occurred during daylight, while this proportion was only 64% for drivers aged 17-19 (Ryan, Legge, & Rosman. 1998). Alabama data showed that only 12% of drivers aged 55+ were involved in nighttime crashes, compared to 22% of drivers aged 16 to 34 (McGwin & Brown. 1999). Canadian data confirm the predominance of daylight crashes in older drivers yet the proportions are quite different, ranging from 70% in drivers aged 65+, to 55% in drivers aged 25-64, and 42% in drivers aged 16-24 (Zhang, Fraser, Clarke, & Mao. 1998). At this point it is unclear if differences between Australia, Alabama and Canada are related to their latitude or any other variable.

Nonetheless, these data are consistent with exposure. There is an inverse relationship between age and percentage of distance traveled at night (Williams. 1985), and drivers aged 65+ account for less than 5% of all nighttime vehicle trips (Mortimer & Fell. 1989). Overall, drivers' involvement in nighttime crashes decreases with age. However, when exposure is controlled with distance traveled, 1990 FARS data showed that involvement in daytime crashes by age groups followed the traditional "U"-shaped curve (Massie, Green, & Campbell. 1997). Nonetheless, nighttime driving may not be a special problem for older drivers, the ratio of the nighttime crash rate to daytime crash rate was 1.1 for drivers 75+ while it reached 6.1 for drivers aged 16 to 19 (Massie, Campbell, & Williams. 1995). This suggests that older drivers may impose self-limitations on their nighttime driving because of the perceived risk of the situation; Canadian older drivers are also less frequently involved in crashes during inclement weather and during winter (Zhang, Fraser, Clarke, & Mao. 1998).

There are several possibilities to explain the higher crash rates observed during nighttime. Alcohol use and reduced visibility are two main reasons. The involvement of alcohol is supported by the predominance of young driver involvement. Reduced visibility is supported by evidence of reductions in crashes in months with longer daylight and with the increased crash rate observed during nighttime in conditions of reduced visibility such as fog (Owens & Sivak. 1996).

Urban and Rural environments

Crashes occurring in urban settings differ from those recorded in rural regions. Data from four mid-western U.S. states showed a fatality rate of 0.88 per one million kilometers in urban areas, compared to 1.28 in rural regions, a 44% higher rate of fatalities for the latter (Muelleman & Mueller. 1996). This higher rate of fatality was associated with single-vehicle crashes, fewer younger drivers, higher frequency of gravel surface roads, and longer notification of crashes to emergency services and longer intervals between crash and arrival at the hospital (Muelleman & Mueller. 1996).

Driver maneuvers

The type of driving errors committed by older and younger drivers differs (Graca. 1986). The authors of a large study based on police-reported crashes found that 16% of responsible drivers aged 16 to 24 had lost control of their vehicle, and another 16% failed to yield the right of way. These proportions were respectively 8% and 29% in responsible drivers aged over 54 (McGwin & Brown. 1999). In a large Canadian study, 4% of crashes involving young drivers (16-34) resulted from failure of right of way compared to 14% for drivers 65+ (Zhang, Fraser, Clarke, & Mao. 1998). Similarly, an analysis of overtaking crashes revealed that compared to older drivers, younger drivers were more likely to be involved in crashes resulting from head on collisions and loss of control (Clarke, Ward, & Jones. 1998; Zhang, Fraser, Clarke, & Mao. 1998), and young drivers were more involved in crashes involving speeding (McGwin & Brown. 1999).

Crash initiation by older drivers is more likely to involve turning than for younger drivers, this difference is especially salient for left turn crashes. In the Alabama study (McGwin & Brown. 1999), 19.5% of responsible drivers 55+ were involved in left turn crashes, compared to 11.5% for drivers 16-34. Australian data show similar proportions (Ryan, Legge, & Rosman. 1998). Another study based on Canadian police-reported crashes revealed a similar two-fold ratio between older and younger drivers, but lower overall involvement in left turn crashes, respectively 10% for drivers aged 65+ compared to 4% for those aged 16-24 (Zhang, Fraser, Clarke, & Mao. 1998).

In a sample of 353 drivers responsible for fatal crashes, 58% of drivers aged 65+ had committed an observation error compared to 31% of drivers aged 26 to 40 (Hakamies-Blomqvist. 1993). On the other hand, only 17% of older drivers committed vehicle handling errors compared to 41% for the younger group. In the same study, the authors found that 74% of the younger group was aware of the danger preceding the crash and 55% of younger drivers tried to avoid the crash. For older drivers, these proportions fell to 56% and 27% respectively (Hakamies-Blomqvist. 1993).

Circumstances under which older drivers are more likely to initiate crashes

The studies reviewed above point specific patterns of crash initiation by older drivers. Older drivers are more likely to be involved in crashes at intersections but this may be a reflection of exposure, responsibility has not been clearly scrutinized. It is therefore important to undertake this exercise to identify situations where improvement may lead to lower rates of crash initiation by older drivers.

Furthermore, relatively little data are available regarding the specific types of errors drivers of different age groups make. Such information would be crucial to devise interventions to reduce crashes. Ultimately, we need to identify the situations where older adults are more likely to initiate crashes and what types of errors led to these crashes.

Driver variables associated with crash initiation

The evidence pointing to a higher crash initiation risk among older adults compared to middle-aged adults is convincing. Furthermore, the differences according to age groups in situational variables suggest that the reasons behind the types of errors committed and situations in which crashes occur also differ according to age. Lack of experience, aggressive driving, and driving while impaired are related to crash initiation in younger drivers (Lilley, Arie, & Chilvers. 1995). For older drivers, on the other hand, reduced driving abilities and health-related impairments are more likely agents behind the increased risk of crashes (Lilley, Arie, & Chilvers. 1995; Retchin & Anapolle. 1993; Reuben, Stilliman, & Traines. 1988).

For both younger and older drivers, using age as a label to identify drivers at risk is inappropriate because risk should be based on driving ability, not one's age category. Consequently, we must identify variables associated with increases in crash risk. And whereas alcohol use is the main predictor of crashes among young drivers (Perneger & Smith. 1991), predictors of crash initiation in older drivers are less clear. The identification of variables related to crash initiation may permit the development of preventive strategies to curb crashes among older drivers.

Previous driving record

Data on previous driving record may support a relationship between previous crashes and convictions and future crash involvement. Two studies based on "demerit" points showed this measure was associated with future crash involvement irrespective of age and gender (Chipman & Morgan. 1975). A recent survey of Dutch drivers revealed that drivers with fines in the past year were twice as likely to have been involved in a crash, irrespective of the mileage driven (Lourens, Vissers, & Jessurun. 1999). Unfortunately, it is impossible to determine if the fines reported were in relation to crash reported or anterior to it. Furthermore, these data did not contain information on the party at-fault, the definition of a crash was left to survey respondents, and were based solely on self-reports of 22% of all possible respondents.

In two case-control studies limited to drivers involved in two-vehicle crashes, drivers with any of the following prior driving violations: driving while impaired (DWI), license suspension/revocation, or any crash in the preceding 12 months, were more likely to have initiated the crash (DeYoung, Peck, & Helander. 1997; Perneger & Smith. 1991). However, because the studies did not include single-vehicle crashes the exact contribution of the driving record to crash risk cannot be ascertained. In a recent prospective study of drivers aged 55 and over and followed for five years, drivers with a crash prior to the prospective study had a relative risk of a crash of 2.1 (95% CI = 1.2, 3.7) after adjustment for number of days driven weekly (Sims, McGwin, Allman, Ball, & Owsley. 2000). Unfortunately responsibility for the crash was not considered in the analyses.

Health

It is readily assumed that health problems may have adverse consequences on driving abilities, irrespective of age. Associations between various health indices and driving have been confirmed and are discussed below.

Vision

General indices of vision such as acuity are not related to crashes and are inappropriate to test driving ability (Ball. 1997; Duchek, Hunt, Ball, Buckles, & Morris. 1997; Gresset & Meyer. 1994; Johansson, Bronge, Lundberg, Persson, Seideman, & Viitnen. 1996; Marottoli, Cooney, Wagner, Douchette, & Tinetti. 1994; McCloskey, Koepsell, Wolf, & Buchner. 1994; Panek, Barrett, Sterns, & Alexander. 1977). No relationships between vision impairments and crash rates were found in a prospective study of older drivers (Foley, Wallace, & Eberhard. 1995). Similarly, in their study of drivers with dementia, Hunt and colleagues found no relationship between passing a road test and standard measurements of vision (Hunt, Morris, Edwards, & Wilson. 1993). The most likely explanation for these findings is that standard perimetric vision testing does not mimic the complex driving situation, which requires detection at both the fovea and periphery levels, and processing of information (Ball, Owsley, & Beard. 1990).

However, one's ability to detect visual stimuli under a variety of circumstances, the concept of "field of view" (Panek, Barrett, Sterns, & Alexander. 1977), is correlated with crash rates (Owsley, McGwin, & Ball. 1998; Sims, McGwin, Allman, Ball, & Owsley. 2000). The useful field of view (UFOV) measurement "incorporates stimulus and task features that seem critical for driving" (p. 3112) (Ball, Owsley, Sloane, Roenker, & Bruni. 1993). The UFOV was the best predictor of crash involvement (Owsley, Ball, Sloane, Roenker, & Bruni. 1991) and at-fault crashes in drivers aged 55 and over (Ball, Owsley, Sloane, Roenker, & Bruni. 1993). In a case-control study a reduction of 40% or more of the UFOV in drivers aged 55 to 90 was associated with a six-fold increase (95% CI = 2.9, 12.7) in the risk of initiating a crash (Sims, Owsley, Allman, Ball, & Smoot. 1998). A three-year prospective cohort study of similarly aged participants, found that a 40% reduction in the UFOV was associated with a 2.2-fold increase (95% CI = 1.2, 4.1) in the risk of initiating a crash (Owsley, Ball, McGwin, et al. 1998).

Hearing

Although older adults suffer hearing loss over time (Panek, Barrett, Sterns, & Alexander. 1977), there are few indications that these losses are related to driving problems. In a prospective study of drivers aged 65+ hearing loss was not associated with crash rates (Foley, Wallace, & Eberhard. 1995). However, in another study, drivers who owned and wore hearing aids were more likely to have been involved in crashes (McCloskey, Koepsell, Wolf, & Buchner. 1994). Further studies are required to quantify the independent contribution of hearing loss to crash initiation.

Medical conditions

The importance of medical conditions with respect to driving and crashes rest with the number of older adults who continue to drive despite health problems, and the contribution of these health problems to the risk of crashes. Although older drivers with many chronic illnesses are less likely to continue driving than those with fewer conditions (Chipman, Payne, & McDonough. 1998), more than two thirds of men aged 70 and more with any major health problems (e.g, difficulties with activities of daily living, cardiovascular disease, diabetes), and roughly 40% of women in the same situation, continue to drive (Wallace. 1997). Among patients of five acute geriatric wards in U.K., 19% were still driving (Morgan, Turnbull, & King. 1995).

The maintenance of driving in older adults with health problems would not be an issue if it were not for potential associations between health problems and driving difficulties. In his seminal paper published in 1967, Waller (Waller. 1967) showed that drivers aged 60 and over who were, in Waller's words, "senile" (cognitively impaired-demented), had twice the crash risk of drivers aged 30-59. More importantly, the crash risk was four-fold when a cardiovascular condition was superimposed on the "senility", and the driving violations rate doubled (the impact of "senility" will be examined below in a special section on dementia; dementia is directly related to crash risk).

Among 123 drivers aged 65+ held responsible for crashes, 11% had medical conditions that were "believed" to be related to crashes (Hakamies-Blomqvist. 1993). The comparison sample of drivers aged 26 to 40 had a rate of less than one percent (1 in 235). In a study of 84 consecutive drivers presenting to a trauma center following a crash, 62 (74%) had an underlying medical condition (Rehm, Ross, & Steven. 1995). Fifty-three of all 67 drivers at fault (79%) had a medical condition, compared to 9 of 17 drivers not at fault (53%). In a study of deceased drivers, a larger proportion of drivers with pre-crash medical conditions were found at-fault compared to drivers without medical conditions (Sjogren, Eriksson, & Ostrom. 1996). However, data were not adjusted for the age of the drivers.

In a study of 136,465 police-reported crashes in Alabama during 1996, officers reported that drivers may have been impaired in some way, other than through alcohol or illicit drugs, in roughly 10% of all drivers in each age group (McGwin & Brown. 1999). And, whereas a medical condition was suspected to have affected 1.4% of young drivers, this proportion was 8.4% for drivers aged 55+.

Marottoli and colleagues (Marottoli, Cooney, Wagner, Douchette, & Tinetti. 1994) found that individuals with four or more chronic medical conditions, or those with worse physical ability, were more likely to be involved in crashes or commit driving violations. Consistently with the latter observation, drivers aged 55 and over who reported difficulties with yard work or house work were twice as likely to have been involved in crashes (Sims, McGwin, Allman, Ball, & Owsley. 2000), and older drivers with a history of falls were four times more likely (95% CI = 1.2, 15.0) to be responsible for a crash than drivers without a history of falls (Sims, Owsley, Allman, Ball, & Smoot. 1998).

Epidemiological data on specific medical conditions and crashes are available but inconsistent. In a prospective study of drivers aged 65+ and living in rural Iowa, depression symptoms, memory problems and chronic back pains were associated with higher crash rates (but not necessarily responsibility), but not a history of chest pain, respiratory symptoms, or urinary symptoms (Foley, Wallace, & Eberhard. 1995). In a five-year prospective study, the only medical condition associated with higher crash involvement was depression (Gresset & Meyer. 1994). Johansson and colleagues (Johansson, Bronge, Lundberg, Persson, Seideman, & Viitnen. 1996) did not report an association between cardiovascular diseases and crashes (p = .067) but their study was low-powered (N = 52). The results of two large case-control studies (N > 4,000) of drivers aged 45 to 70 found no associations between crashes and medical conditions after adjustment for age and mileage (Gresset & Meyer. 1994; Guibert, Duarte-Franco, Ciampi, Potvin, Loiselle, & Philibert. 1998; Guibert, Potvin, Ciampi, Loiselle, Philibert, & Franco. 1998).

In a large cohort study, individuals with diabetes had a higher incidence of crashes, but not traffic violations, compared to non-diabetics (Hansotia & Broste. 1991). In a study limited to drivers 65 and over, diabetes was not associated with crash initiation (McGwin, Sims, Pulley, & Roseman. 1999). In a small case-control study of insulin-dependent diabetes mellitus (IDDM) individuals, IDDM was associated with crash risk in women but not men (Songer, LaPorte, Dorman, et al. 1988). Also, based on the self-reports of 39 patients with IDDM who experienced crashes during an eight-year period, nine of the crashes (16%) were attributed to hypoglycemia (Eadington & Frier. 1989). In a rather ambiguous study, coronary heart disease, and diabetes, were associated with a higher risk of motor vehicle injury (Koepsell, Wolf, McCloskey, & et al. 1994). Yet, roughly 50% of the injured drivers committed the driving error leading to the crash. Therefore, it is impossible to determine if these health conditions increased the likelihood of initiating a crash or are indicators of frailty.

Epilepsy is one medical condition anecdotally associated with an increased crash risk. A large cohort study revealed a 33% excess risk for crashes among epileptics compared to controls, but no differences regarding traffic violations (Hansotia & Broste. 1991). A further study confirmed the increased risk for crashes but also supported an increased risk of traffic violations (Hansotia & Broste. 1993). In a different study, epilepsy was not associated with an increased overall crash risk, but was associated with more severe crashes (Oborne, Batty, Maskrey, Swift, & Jackson. 1997).

Other serious medical conditions have seldom been examined because they are less prevalent, or because comparatively fewer individuals with these conditions drive. However, individuals with schizophrenia are at higher risk of crash involvement than age-matched controls after adjustment for mileage

(Edlund, Conrad, & Morris. 1989). Similarly, patients with Huntington's disease performed worse on a driving simulator and experienced more crashes than controls (Rebok, Bylsma, Keyl, Brandt, & Folstein. 1995).

The special case of dementia

There are reasons to believe that drivers with dementia may pose a safety threat to themselves and others, and continue to drive despite significant impairment (Cooper, Tallman, Tuokko, & Beattie. 1993; Dubinsky, Williamson, Gray, & Glatt. 1992; Logsdon, Teri, & Larson. 1992; Lucas-Blaustein, Filipp, Dungan, & Tune. 1988). In a study of 182 consecutive patients presenting at a geriatric clinic (Carr, Jackson, & Alquire. 1990), 42 were still driving. Although drivers were generally more cognitively intact than non-drivers, the mean Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh. 1975) score of these individuals was 23.7, indicating that many drivers had mild dementia. Furthermore, 26% of drivers needed help with some basics activities of daily living (ADL). In a different study, ADL problems were associated with more driving difficulties (O'Neill, Neubauer, Boyle, Gerrard, Surmon, & Wilcock. 1992). In yet another study, more than 80% of drivers with dementia continued driving after a crash (for which 92% of dementia drivers were responsible) for a period of up to three years (Cooper, Tallman, Tuokko, & Beattie. 1993).

In a retrospective comparison of 30 drivers with Alzheimer's disease (AD) and 20 age-matched healthy controls, 47% of AD drivers experienced crashes during the preceding five-year period compared to 10% for controls

(Friedland, Koss, Kumar, et al. 1988). Eleven of the 30 AD drivers were still driving at the end of the study; the average SMMSE score at the time of driving cessation for the remaining participants was 18.5 (Friedland, Koss, Kumar, et al. 1988). A larger retrospective study found a crash rate in individuals with dementia roughly 250% that of healthy controls (Tuokko, Tallman, Beatie, Cooper, & Weir. 1995). A Swedish study found a larger proportion of drivers with cognitive impairment among those who experienced crashes than among those who did not (Johansson, Bronge, Lundberg, Persson, Seideman, & Viitnen. 1996).

Nonetheless, many drivers in the early stages of dementia may remain able to drive safely. In a study of 12 individuals with very mild dementia, 13 individuals with mild dementia and 13 healthy age-matched controls, only five of the individuals with mild dementia did not pass a one-hour road test (Hunt, Morris, Edwards, & Wilson. 1993). Crash rates for individuals with AD were not appreciably higher than rates for healthy controls during the first two years of the condition, but increased steadily thereafter (Drachman & Swearer. 1993).

Road test scores in individuals with dementia were lower than in age-matched diabetic controls (Fitten, Perryman, Wilkinson, Little, Burns, & et al. 1995), and were positively correlated ($r = .63$ to $.72$) to MMSE scores (Fitten, Perryman, Wilkinson, Little, Burns, & et al. 1995; Fox, Bowden, Bashford, & Smith. 1997; Odenheimer, Beaudet, Jett, Albert, Grande, & Minaker. 1994). The rate of collisions and moving violations per 1,000 miles was inversely related to the road test scores (Fitten, Perryman, Wilkinson, Little, Burns, & et al. 1995). Failing road tests was strongly associated ($r > .75$) with inability to follow instructions, interpret road signs, and displaying poor judgment (Hunt, Morris, Edwards, & Wilson. 1993).

Determining who may continue driving and who should not is a difficult task without road tests. Screening tests for cognition (e.g., SMMSE) are correlated, but only moderately ($r \approx .5$), with driving simulation tests (Rebok, Keyl, Bylsma, Blaustein, & Tune. 1994). Furthermore, MMSE scores are not related to crashes (Gilley, Wilson, Bennett, Stebbins, & et al. 1991). Furthermore, traditional vision tests have not identified important deficits among older drivers. However, individuals with AD have more serious visual field limitations than controls, resulting in a tunnel-like vision correlated to the stage of the condition (Steffes & Thralow. 1987). Individuals with AD also have limitations in their ability to detect coarse and fine patterns (Nissen, Corkin, Buonanno, Growdon, & et al. 1995). Visual tracking is also impaired in individuals with AD, resulting in a saccadic tracking compared to the smooth regular tracking observed in healthy controls (Hutton. 1985).

Many errors committed by drivers with dementia are analogous to that of older drivers in general, involving intersections, traffic signals, and lane changes (Friedland, Koss, Kumar, et al. 1988; Odenheimer, Beaudet, Jett, Albert, Grande, & Minaker. 1994). However, other types of errors may be limited to drivers with dementia. These include driving the wrong way, driving below the speed limit, and getting lost (Lucas-Blaustein, Filipp, Dungan, & Tune. 1988; O'Neill, Neubauer, Boyle, Gerrard, Surmon, & Wilcock. 1992).

Alcohol and illicit drugs

Considerable evidence points to a serious problem of drinking and driving among younger drivers (Centers for Disease Control and Prevention. 1990; Centers for Disease Control and Prevention. 1991; Centers for Disease Control and Prevention. 1992a; Centers for Disease Control and Prevention. 1992b; Centers for Disease Control and Prevention. 1993; Centers for Disease Control and Prevention. 1995; Zador. 1991; Zhang, Fraser, Clarke, & Mao. 1998). Although traditionally 85% of this problem was attributed to young male drivers (Isaac, Kennedy, & Graham. 1995), driving while impaired is also emerging as a problem for young female drivers (Dobson, Brown, Ball, Powers, & McFadden. 1999; Popkin. 1991). Contrary to younger drivers, however, older drivers are very unlikely to drink and drive (Centers for Disease Control and Prevention. 1993). Less than one percent of alcohol-related fatalities are accounted by drivers and passengers aged 65+ (Zobeck, Grant, Stinson, & Bertolucci. 1994).

Reductions in alcohol use are associated with reductions in fatalities (Robertson. 1996). Yet more could be achieved, rate decreases in alcohol-related crashes are equivalent to those on non-alcohol-related crashes (Zobeck, Grant, Stinson, & Bertolucci. 1994). It is thus possible that other variables account for this difference. Some estimated that traffic fatalities could be reduced by nearly 50% if driving with any level of alcohol was eliminated (Evans. 1990b).

Few data on the relationship between illicit drugs and crashes are available. However, a recent large scale Canadian study substantiated that the use of illicit drugs among young drivers (16 to 24) is associated with a higher rate of fatal crashes (not necessarily initiation) compared to drivers aged 25 to 64 (Zhang, Fraser, Clarke, & Mao. 1998).

Medications

Whereas the problem underlying crashes among older drivers is not alcohol related, several researchers have documented an association between medication use and driving issues. In a study of 194 fatally injured drivers aged 65 and over, 27 (14%) were found to have used tricyclic antidepressants and/or sedatives (Johansson & Bryding. 1997). In seven (4%) the drug concentration was above therapeutic levels, and it was considered above toxic levels in four drivers (2%).

An early report found a five-fold risk of crash-related hospitalizations and deaths for those using minor tranquilizers such as diazepam (Skegg, Richards, & Doll. 1979). However, this study did not establish if the increased risk was related to a higher crash risk or to a higher susceptibility of those taking the medication to the traumatic effect of the crashes. Among older drivers (65+) of a prospective study (Foley, Wallace, & Eberhard. 1995), more than 10% were using non-steroidal anti-inflammatory medications (NSAID's). The relative risk (RR) of a crash among users of NSAID's was nearly twice that of drivers not using these medications (RR = 1.9, 95% CI = 1.3, 2.7). However, none of the other 12 categories of medications tested were associated with crash risk. A spurious association for NSAID's cannot be discounted.

An elegant study linking computerized data from prescribing and crash records revealed that older drivers ($\geq$ 67 years) who used long-acting benzodiazepines were more likely to be involved in a crash than those who did not (Hemmelgarn, Suissa, Huang, Boivin, & Pinard. 1997). The adjusted crash rate ratio was 1.45 (95% CI = 1.04, 2.03) during the first week of medication use, and remained statistically significant for continuous use up to one year (1.26, 95% CI = 1.09, 1.45). Short-acting benzodiazepines were not related to crashes, a finding also confirmed by a systematic review (Thomas. 1998). A separate study confirmed that larger proportions of drivers with AD who were taking medications with sedative effects experienced crashes (Gilley, Wilson, Bennett, Stebbins, & et al. 1991).

In a study of different classes of psychoactive medications, benzodiazepines and antidepressants were associated with more crashes (Ray, Fought, & Decker. 1992). However, two other classes of psychoactive medications, opioid analgesics and sedating antihistamines, were not associated with a higher crash rate. In a similar case-control study of the same psychoactive medications, anti-depressant medications and opioid analgesics, but not benzodiazepines and sedating antihistamines, were associated with crashes (Leveille, Buchner, Koepsell, McCloskey, Wolf, & Wagner. 1994).

Unfortunately, in all these studies the drivers' responsibility for the crashes could not be determined. In one study of benzodiazepines use where data on responsibility for crashes was obtained, no relationship between benzodiazepines and crash responsibility was found after adjustment for alcohol use (Benzodiazepine/Driving Collaborative Group. 1993). In a second study benzodiazepines were related to crash initiation but data were not adjusted for alcohol use (Arditti, Bourdon, David, Lanze, Thirion, & Jouglard. 1993).

The potential role of benzodiazepines and other medications in crashes remains unclear but biologically plausible. The underlying mechanism is possibly related to the impact of medications on attention/perception mechanisms and other cognitive functions. Benzodiazepines may adversely affect memory (Kruse. 1990) and cognition (Foy, O'Connell, Henry, Kelly, Cocking, & Halliday. 1995), and they have the potential to cause cognitive impairment and aggravate existing cognitive impairment (Larson, Kukull, Buchner, & Reifler. 1987). Furthermore, age-related pharmacokinetics changes in older adults may aggravate the problems experienced with benzodiazepines (Kruse. 1990).

Presence of passengers

Recent data suggest that younger drivers may be adversely affected by the presence of passengers. Doherty and colleagues found a higher rate of crashes among young drivers (16 to 19) in the presence of passengers than in their absence (Doherty, Andrey, & MacGregor. 1998). The effect of passengers on the risk of crashes was compounded by the effect of weekends and nighttime driving. On the other hand, no associations between passenger presence and crash rates were found for the other age groups studied (20 to 24, 25 to 59).

Similarly, using FARS data for 16- and 17-year old drivers, the risk of death increased, independently of gender of the driver and time of day, with the presence of passengers (Chen, Baker, Braver, & Li. 2000). In comparison to a 16-year old driving alone, driving with one passenger yielded a relative risk of death of 1.39 (95% CI = 1.24, 1.55), with two passengers the relative risk was 1.86 (95% CI = 1.56, 2.20), and with 3 passengers it climbed to 2.82 (95% CI = 2.27, 3.50). Relative risks for 17-year olds were similar.

Data on younger drivers show that their errors most often result from aggressive driving, and driving while impaired. These conditions may be correlated with or aggravated by the presence of passengers. It is likely that the presence of young passengers and not older passengers may be of importance. High school students (aged 17 to 18) drove faster when alone and with friends than in the presence of their parents (Arnett, Offer, & Fine. 1997). And the risk of death for drivers aged 16 and 17 increased only when passengers were aged less than 30 (Chen, Baker, Braver, & Li. 2000). Furthermore, the impact of passengers may be magnified if the driver himself/herself is impaired. However, the specific conditions under which passengers are associated with the crash risk have not been fully explored.

Older drivers, on the other hand, may be positively affected by the presence of passengers. The most plausible explanation for this suggestion may lie with the type of errors committed by older drivers. Because crashes involving older drivers most often occur at intersections and involve an attention/perception error (Hakamies-Blomqvist. 1993; McGwin & Brown.

1999; Ryan, Legge, & Rosman. 1998; Zhang, Fraser, Clarke, & Mao. 1998), it is conceivable that a passenger, by alerting the driver, may have the potential to prevent a crash (Wallace & Retchin. 1992). Passengers, in situations where they provide assistance to drivers, are referred to as "co-pilots" (Shua-Haim & Gross. 1996). Some data support the possible benefits of co-pilots, but they are limited to cases of AD.

One study reported four case studies of drivers with AD who drove regularly, always with the presence of the same passenger who provided direction and assistance as required (Shua-Haim & Gross. 1996). Over a one year follow-up period, no crashes or incidents were reported. These results prompted the investigators to suggest that when competency to drive is questioned, transportation agencies should test the driver/co-pilot team. In a second study using a case-control design, the driving records of all individuals who presented to a geriatric clinic were examined (Bédard, Molloy, & Lever. 1998). Those who drove alone were five years younger than those who did not, and their cognition scores on the MMSE were five points higher. However, their crash rate was twice as high (OR = 2.23, 95% CI = 1.20, 4.15).

Although both studies supported an association between a reduced crash risk and the presence of a co-pilot, neither allowed a strong level of inference. In both cases the study design did not rule out potential confounders and in the second study, responsibility for the crashes, exposure, and the competency of the co-pilots to provide assistance was not determined. Furthermore, neither study could be generalized to healthy, or at least non-AD populations.

Nonetheless, the utility of a co-pilot is conceivable. The type of errors committed by older drivers, and especially minor ones, may be avoided by the presence of a competent passenger (Bédard, Molloy, & Lever. 1998; Shua-Haim & Gross. 1996; Wallace & Retchin. 1992). Just as young drivers are believed to be safer with the presence of an adult at their side, older drivers may also be safer with someone to provide assistance.

Next steps

Much of the evidence presented in this chapter points to considerable variability in crash responsibility according to crash situations and driver characteristics. However, many discrepancies were found in the literature. Furthermore, most results were based on crash involvement, not crash responsibility. Few studies estimated the effect of situation and driver variables on crash responsibility, and the studies set up to examine crash responsibility generally had low sample sizes, and lacked adequate control for potential confounders.

For proper planning, more detailed information on crash responsibility is crucial. The identification of who may be at risk of making driving errors, and under what situations, is required, and will provide directions for future research and the development of interventions aimed at reducing driving errors and their consequences.

Chapter 3. Protective variables

A traffic fatality can be decomposed into two distinct components. First, a number of events and circumstances lead to a crash. Second, the passenger is unable to withstand the physical trauma imposed upon him/her. Hence, reducing traffic fatalities is best accomplished by working simultaneously on two fronts. First, it is desirable to reduce fatalities by reducing the number of crashes. However, crashes will not be eliminated in the foreseeable future. Therefore, a second set of strategies involves the provision of additional protection to passengers in the event of crashes. In the previous chapter, the variables related to crash initiation were examined. The present chapter will be devoted to variables associated with a reduction in the probability of fatal injuries when crashes occur.

The physical trauma associated with a crash results from the sudden deceleration and consequent impact of the body against the vehicle restraint system and interior, and the impact of the body organs against the body cavity. The impact of crashes may be mitigated by vehicle occupant characteristics (e.g., age), and/or vehicle characteristics (e.g., weight). These are discussed in the following sections.

Vehicle occupant characteristics

Age and gender

Data for years 1980 and 1989 showed an overall increase in fatalities among adults aged 65+ but a reduction among younger adults over the 10-year period (Barr. 1991). This increase in fatalities among older adults occurred despite an overall decrease in crashes, leading the authors to suggest that the increase in fatalities is partly accounted by older adults susceptibility to the traumatic effects of crashes (Barr. 1991).

However, this suggestion is difficult to support with epidemiological data. As for crash rates, fatality rates follow a "U"-shaped curve with age (Graca. 1986). Data from year 1983 in the U.S. confirm that older drivers composed a small proportion of fatalities compared to younger drivers (Evans. 1988a). However, on a distance traveled basis, fatality rates for the oldest drivers resemble those of 20-year old drivers, and there are no differences between the rates of men and women (Evans. 1988a). Data from 1996 showed a fatality rate of 0.05 per million kilometers for adults aged less than 25, a rate of 0.02 for those aged 45 to 54, and a rate of 0.06 for those 75+ (McGwin & Brown. 1999).

These data cannot be used as indicators of frailty because they do not account for differences in driving patterns. Whereas young drivers, especially males, have a higher tendency to take risks while driving (e.g., consuming alcohol, speeding), older adults do not drink and drive in an equivalent proportion, and typically drive at lower speeds than younger drivers (Bradbury & Robertson. 1993; McGwin & Brown. 1999). More sophisticated analyses using Wisconsin data for 1991 revealed an hospitalization rate of 3.58 per one million kilometers for adults aged 16 to 64 but a rate of 12.42 for those aged 85+, a 347% difference (Dulisse. 1997). Consistently, the same data set revealed death rates of 0.60 per million kilometers for adults aged 16 to 64 but 2.22 for adults aged 85+, 370% that of the younger group (Dulisse. 1997). Others showed that given a similar injury severity, passengers aged 70 and over were 11% more likely to die than a 20 year old (McCoy, Johnston, & Duthie. 1989).

Although these data do not imply a causal mechanism, Evans, using the double-pair comparison method (Evans. 1986a), supported these findings. By comparing individuals involved in crashes in the same vehicles, Evans calculated ratios of fatality, and showed that adults aged 70 and over were three times more likely to die in a crash than a 20-year old adult (Evans. 1988c). In a different study, drivers aged 80+ were 2.3 times more likely to be fatally injured than younger drivers after controlling for age and gender (Zhang, Lindsay, Clarke, Robbins, & Mao. 2000).

Gender differences are less certain. In one study, women up to age 45 were 25% more likely to die in crashes than men of comparable age; however, the relationship between gender and fatalities became unclear for older age groups (Evans. 1988c). In a study based on traveling speed, women were fatally injured at lower speeds than men (Levine, Bédard, Molloy, & Basilevsky. 1999). However, a different study found men were 40% more likely to die than women, after controlling for age and other situational variables (Zhang, Lindsay, Clarke, Robbins, & Mao. 2000). The relationship between gender and fatality risk remains to be elucidated.

Unfortunately age and gender are immutable (generally speaking). Other characteristics, however, may be modified to reduce fatalities. Possibly perceived as the most important is seat belt use.

Seat belt use

Driver behavior, and especially restraint use (manual and automatic seat belts), has been touted as important to prevent fatalities (Robertson. 1996). Some data suggest that 43% of fatalities among unrestrained passengers could be avoided with seat belt use (Evans. 1986b; Evans. 1987). Rear seat occupants, who are typically less at risk of a fatal injury than front passengers, may be 18% less likely to be fatally injured if using a belt (Evans. 1988b). Data based on two similar Japanese car models (Toyota Cressida and Nissan Maxima), one equipped with automatic shoulder and manual lap seat belts, the other with shoulder and lap manual systems, showed a 40% reduction in fatalities among occupants of the vehicles equipped with automatic systems (Nash. 1989). To avoid the potential pitfalls associated with different vehicles, Streff used only crashes involving Ford Escorts from 1981 to 1991 (Streff. 1995). During those years, the Escort model did not change appreciably, but automatic belts were introduced in 1988. After controlling for passengers' age and car deformity, automatic belts were associated with 15% to 25% fewer severe injuries and fatalities according to the jurisdiction examined.

There may be differences in the effectiveness of different seat belt types. For example, it is possible that a three-point belt (shoulder and lap belt), may be more efficient at preventing injuries and fatalities than a two-point belt (shoulder only or lap only). Data from the National Accident Sampling System (NASS) and from research on cadavers show a higher incidence of injuries, and especially liver injuries, with two-point restraint system compared to three-points (Crandall, Pilkey, Klopp, et al. 1994). However, FARS data from four U.S. states, but limited to automatic belts, did not support this contention (Padmanaban & Ray. 1994).

The exact mechanism through which belts protect passengers is unclear. Belts are probably better suited at minimizing injuries likely to happen in frontal crashes, whereas they afford little protection for passengers struck on the near side. Consistently, belt effectiveness at preventing injuries varied from 44% in striking vehicles to 27% in struck vehicles (Evans & Frick. 1986). However, these results do not control for potential confounders.

Prevention of ejection is another proposed reason for reductions in fatalities attributed to belts. Using Evans' double-pair methodology and FARS data, Esterlitz showed that un-belted passengers were twice as likely to be ejected from a vehicle than belted drivers (Esterlitz. 1989). And, Evans and Frick showed that eliminating ejections would reduce fatalities to unrestrained passengers by approximately 18%, irrespective of car seating position (Evans & Frick. 1989a).

Alcohol use

Although higher fatality rates have been reported for intoxicated drivers, alcohol is often believed to protect passengers against the trauma associated with crashes (Waller, Stewart, Hansen, Stutts, Popkin, & Rodgman. 1986). The higher fatality rates have been attributed by some to a lower use of restraints by drunk drivers, and to the reckless driving behavior of drunk drivers (Waller. 1994). However, what is seldom recognized is that alcohol may also lead to higher fatalities for those injured in crashes. Contrary to widely-held beliefs, data suggest that drivers who used alcohol may be at higher risk of being fatally injured in crashes compared to sober drivers, after controlling for passenger age, restraint use, car weight and vehicle deformity (Evans. 1992a; Evans. 1993b; Waller, Stewart, Hansen, Stutts, Popkin, & Rodgman. 1986).

Crash and vehicle characteristics

Point of impact

One possible interpretation of the higher fatality rate of older adults is related to the point of impact. Specifically, side impacts may be more traumatic than other types of impact because there is little protection, especially in driver side impact situations. Analyses based on FARS data showed drivers were five times more likely to be fatally injured, when struck on the right side of their vehicle, compared to drivers in the striking vehicles of the same mass. When hit on the driver side, the risk of a fatal injury was ten times greater (Evans. 1993b). However, these analyses did not control for the age of the drivers. Older drivers responsible for crash initiation are less likely to incur front impact than younger drivers. They are, however, more likely to be hit on the side (McGwin & Brown. 1999).

Model year

Some evidence shows that more recent vehicles are associated with fewer fatalities after controlling restraint use and other passenger characteristics (Levine, Bédard, Molloy, & Basilevsky. 1999; Robertson. 1996). This suggests that vehicle manufacturers have increased the "crash worthiness" of more recent car models (Robertson. 1996). However, it is unclear whether this really is a cohort effect as opposed to an effect of the age of a vehicle fleet. Specifically, is the effect explained by better designs for recent models, or simply because these vehicles are younger and possibly in better condition. The potential confounding effect of vehicle age needs to be examined before causal inferences are offered.

Weight

Car mass has been shown to protect passengers in crashes. Specifically, everything else being equal, the passenger of the heaviest vehicle in a two-vehicle crash is more likely to survive (Evans. 1985; Evans. 1992b; Evans. 1993b; Evans & Frick. 1994). Maybe more importantly, overall mass may protect occupants, irrespective of the mass of other vehicles, by absorbing greater amounts of energy and affecting the sudden deceleration experienced in crashes. Evans and Wasielewski (Evans & Wasielewski. 1987) studied serious injuries and fatalities in crashes involving vehicles of the same mass. They found that the likelihood of a serious or fatal injury increased with lower vehicle mass, such that the driver of a 900kg car colliding with another 900kg car was twice as likely to be seriously or fatally injured as the driver of a 1,800kg car colliding with another 1,800kg car. Unfortunately, the authors did not examine the contribution of other key variables such as drivers age.

Air bags

Air bags may be beneficial, especially in front impacts (Evans. 1990a; Evans. 1991), for which they are especially well suited. Comparisons of frontal crashes to all crashes yielded a 23% reduction in fatalities for frontal crashes compared to 16% for all crashes (Lund & Ferguson. 1995). In a study based on early models with air bags, cars with air bags had 28% fewer fatalities compared to cars equipped with manual restraint systems only (Zador & Ciccone. 1993). However, the investigators of these studies did not control adequately for age (dichotomized age at the 30 year old cut-off), ignored vehicle weights, and classified impacts at 10 and 2 o'clock as frontal, when clearly these are lateral impacts. The present study will provide further information on the utility of air bags by controlling for potential confounders.

Next steps

There are sufficient theoretical reasons and data to conclude that older adults are more susceptible to fatal injuries than younger adults, as are individuals who drank alcohol. Passengers who use seat belts are less likely to be fatally injured. Other individual characteristics that may be related to a higher risk of fatality have not been clearly identified. One important variable is the overall health of passengers. It is likely that less robust individuals would be more susceptible to the trauma resulting from crashes. Important vehicular characteristics associated with fatalities include side impact, older vehicles, lighter vehicles, and the absence of air bags.

However, many of the results available to date have been derived from aggregate data, and/or are based on univariate statistics, lacking control for potential confounders. Identifying the independent contribution of individual and vehicle characteristics to the risk of fatal injuries is a required objective that has yet to be met. It represents, however, a first step to reducing fatalities. Although many passenger characteristics may not be modifiable (e.g., age, gender, health) others may be (e.g., alcohol and seat belt use). Similarly, vehicle attributes may also be ameliorated to prevent fatalities. Because older adults are more likely to suffer fatal injuries than younger adults, they may derive considerable benefit from any information leading to new fatality prevention interventions.

Driving fatalities and public health

The above review of the literature aptly points to driving fatalities as a major public health issue. Fatalities involving older adults are on the rise and will continue to do so for many years to come. It is thus essential that we determine the future involvement of older adults in fatalities to allocate resources in consequence. Furthermore, to reduce crashes and fatalities in older adults, we must first identify the specific variables that may be associated with crash initiation in this select group of drivers, and second, identify protective factors to reduce the incidence of fatalities when crashes occur.

Past research has demonstrated that we need to develop new estimates of future traffic fatalities. Better estimation of the future involvement of older adults in traffic fatalities is desirable. Although it is difficult to predict future demographic changes, licensing rates, and exposure and their relationship to fatalities, it is reasonable to assume that all these trends are contained in FARS data from the past 24 years (the FARS database will be described in details in Chapter 4). Thus, predicting future fatalities from these data should include estimates of increased number of licensed older adults, and increased exposure, and should represent a more accurate picture than estimating fatalities from predicted census data alone. This is the preferred approach that will be used in Chapter 5.

Past research also demonstrated that older drivers' behaviors are not similar to younger ones. The situation and type of crashes in which they are involved differ and may provide directions regarding interventions. Similarly, the personal characteristics of drivers affect their probability of making a driving error and causing a crash. Current data, however, offers only a limited window into the variables that may be related to driving errors and crashes. Extending this work to provide a more comprehensive profile of drivers who make driving errors is the goal of Chapters 6 and 7.

Chapter 8 is reserved for the examination of protective variables in the event of a crash. The literature demonstrates substantial protective value to some driver and vehicle characteristics. However, confounding variables need to be controlled with more rigor than exercised so far to strengthen causal inferences.

Past research on driving and fatalities includes small and large sample designs, studies considering responsibility, others not, and studies limited to a few variables compared to more extensive studies. Although much progress has been realized in the past two decades, "The nature of the subtle interactions among roadway, vehicle, and driver characteristics that either cause or avoid a crash is almost totally unknown." (p. 7)(Waller. 1992). Furthermore, what strategies should be pursued to minimize the trauma associated with crashes is not clear. A comprehensive study of traffic fatalities is required. Sufficient data has been collected in FARS to allow this study, and, hopefully, to answer, at least in part, some of these pressing questions.

Chapter 4. General methods

Research design considerations

Possibly the most important consideration in the selection of a research design is the level of causal inferences desired. Ultimately, it is desirable, given logistical constraints, to use experimental designs to test research hypotheses. However, one major problem with experimental designs for traffic research is their ethical ramifications. As an example, it is clearly ethically indefensible to test the efficacy of seat belts using human participants with an experimental design.

Therefore, researchers are left with observational designs to test their hypotheses. Yet a second difficulty is readily evident to seasoned researchers: fatal crashes are rare events. Hence, prospective studies are generally impractical, leading researchers to rely on case-control designs (Waller. 1992).

A further consideration regarding the selection of a research design is the nature and complexity of the problem examined. Traffic crashes and fatalities are complex, multi-factorial events. One common criticism of past research is the inadequate control of potential confounders. To alleviate this problem a large sample size with information on these potential confounders is required. And a large sample can only be acquired over a number of years through government, mandated programs.

The Fatal Accident Reporting System

Few government databases contain sufficient information to perform meaningful analyses and are readily available to most researchers. One such database is the Fatal Accident Reporting System (FARS) database collected under the U.S. Department of Transportation. For every traffic fatality, anywhere in the U.S., information about crash situations, drivers and passengers, and about the vehicles involved is added to the database. The FARS database contains data from 1975 onward. Considerable information is collected under FARS. Many variables contained in FARS are not available in other national databases (Fife. 1989), making this database the most comprehensive tool to study fatal crashes. Although there are some biases in the reporting of the information (these will be discussed later), the quantity of information coded in the database, and number of crashes recorded allows for the control of numerous potential confounders, and calculation of crash estimates more easily generalizable to the general population (Barr, Foley, Dubinsky, & Glatt. 1993).

Rationale for using FARS data

Several considerations pointed to the FARS as the best tools available to study traffic crashes and fatalities. Possibly the most important is that the FARS database contains information on crash initiation. Therefore, it will allow the identification of risk factors pertinent to crash initiation and not only crash involvement. The database contains information on the crash setting, driver and passenger characteristics. Among driver characteristics, it contains information on past traffic violations and crashes, and alcohol and drug/medications use. These data may allow us to depict a profile of adults more likely to initiate crashes.

An additional reason for using FARS is that the database is limited to crashes involving at least one fatality. Although it represents a subset of all crashes occurring in the U.S. for the study years, several advantages are derived from the inclusion of fatal crashes only. Maybe most importantly is the consistency of crash reporting. Because of the severity of the incidents, reporting, and thus inclusion in FARS must be very close to 100%. On the other hand, administrative databases containing less severe crashes may be of variable completeness according to the jurisdiction (Carr. 1997; Marottoli. 1997; Marottoli, Cooney, & Tinetti. 1997; McGwin, Owsley, & Ball. 1998). A comparison of self-reported crashes with state reported crashes in Alabama yielded a correlation of .11 (Owsley, Ball, Sloane, Roenker, & Bruni. 1991).

One possible explanation for this discrepancy is that older drivers may be more likely to report minor crashes limited to property damages, compared to younger drivers (Brorsson. 1989; Ryan, Legge, & Rosman. 1998). Furthermore, the threshold for reporting crashes varies from one jurisdiction to another. Whereas in some jurisdiction all crashes resulting in damages of more than $300US may be recorded, this threshold may be $500US for some other jurisdiction. This amount is also raised periodically to account for inflation and demands on the authority cumulating these data. Hence biased associations are possible using less reliable administrative databases or self-reports (McGwin, Owsley, & Ball. 1998). The involvement of the police in fatality-related crashes minimizes these biases. Using FARS reduces any selection bias to its minimum.

An additional advantage of FARS is the built-in quality control mechanisms. First, all data analysts are formally trained. Second, for every data field several value checks are performed to ensure valid data are entered. For example, if the time of a crash is 2:00 AM, a value of "daylight" for the "light condition" variable would be rejected. Through standardized training and quality control FARS has achieved a high level of consistency.

One obvious question is why use a U.S. dataset for a Canadian thesis? The goals of this thesis require a database that has been in existence for a considerable number of years to provide the substantial number of observations necessary to elaborate analyses. Furthermore, the types of analyses depend on detailed information regarding crashes including driver errors. These conditions are met with the FARS database.

On the other hand, Canadian datasets are more recent and less comprehensive. Trauma registry databases such as those available with the Canadian Institute for Health Information do not contain data on all Canadian fatalities and have fewer data elements regarding the crash situations than FARS. Possibly the closest dataset to FARS is the Canadian Traffic Accident Information Databank (TRAID). However, with an inception date of 1984, the TRAID contains much fewer data than FARS. Furthermore, and perhaps more relevant to the current endeavor, the TRAID database contains only sketchy details regarding driver errors. Therefore, the analyses planned for the current thesis require the FARS database.

Given the required use of a U.S. dataset, it is reasonable to question how generalizable these data are to the Canadian context. As for many other societal aspects, there are similarities and dissimilarities between the two countries. For example, seat belt use rates are much higher in Canada than in the U.S. Weather patterns are also quite different between certain regions of the two countries. And possibly, licensing requirements vary according to the jurisdictions of Canada and the U.S. Furthermore, the baby-boom phenomenon may have differed between the two countries. On the other hand, the road systems, cars, and general attributes of vehicle occupants share many similarities.

The intent of this study is to identify trends in fatalities and predictors of driving errors and fatal injuries, the patterns of data, though not their absolute magnitude may hold in the Canadian context. For example, it is likely that changes in the number of fatalities in Canada will parallel those observed in the U.S., but that the numbers per 100,000 residents may be quite different because of the higher use of seat belts in Canada. Ideally, the results obtained with FARS data should be replicated with Canadian data. Unfortunately, these data are not yet available. FARS biases

Although it is likely that most crashes resulting in fatalities are included in the database, other biases may plague it. Maybe the most important is the assessment of responsibility for the crash. It is believed that at times, police officers called to the scene may not cite the responsible driver for a traffic violation if considerable personal suffering resulted from the crash (Ray. 1997). It is impossible to evaluate the extent of this potential problem with the current dataset. However, such a bias would result in fewer responsible drivers identified, and a thus an underestimation of associations between situational and personal variables, and traffic violations. To minimize this potential bias, assessment of responsibility for crashes will be based on driver-related factors coded in FARS and not based on the driver citation for a violation. Driver-related factors described the types of errors or actions drivers committed, and will be discussed in more details in Chapter 6.

Driver-related factors, despite their advantages over traffic violations, have limitations that need to be taken into consideration when interpreting the results. Most importantly, the report of these errors may vary with the individual officer investigating the crash. Some driving errors may be reported more frequently depending on the characteristics of the drivers. For example, officers may be more prone to report "driving too fast" when young drivers are involved than older drivers. There are not mechanisms to verify the validity of the driving errors reported. Second, more than one driver, in a multiple-vehicle crash, may have committed errors according to investigating officers. Hence, if both drivers in a two-vehicle crash committed errors, the assignment of responsibility is not feasible. The assignment of responsibility for the crash can only be accomplished through careful crash reconstruction. Accordingly, the results presented must be interpreted in terms of driving errors and not crash initiation.

As this thesis is focused on older drivers, it is important to point some limitations pertinent to this age group. Data on alcohol use, and driving under the influence and speeding have limited relevance to older drivers. Similarly, the drugs/medications tested for do not necessarily reflect the types of medications used mostly by older drivers. Therefore, medication data, though informative, will likely represent an underestimate of the problem linked to medications. Data acquisition

Data from FARS are available to the public via a Department of Transportation web site (www-fars.nhtsa.dot.gov/). Compressed data files in American Standard Code for Information Interchange (ASCII) or Statistical Analysis Software (SAS) format, and SAS library files can be downloaded directly from the web site into a personal computer. Every year (around July), data from the past year become available. A resource manual explaining the data variables is also available for downloading.

Data management

The first data management task accomplished for this dissertation was the downloading and decompressing of the required data and library files. Data files for years 1975 to 1998 were available at the time. These data consume approximately 700 megabytes (MB) of hard drive space.

To convert the ASCII data files into useful SPSS data files, the SAS library files were translated into SPSS syntax. The SAS library files give the exact location of the data within the ASCII files and the translation process is easily done. Examples of the SAS library file and equivalent SPSS file are presented in Appendix I. The process was repeated for every data file. Note that the uploading process produced four files for each year. These were for data at the accident level, vehicle level, driver level, and person level. Data from these four files were combined through unique identifiers to produce one file for every year. Subsequently, all files were joined to produce one massive data file containing information on all crashes resulting in at least one fatal injury in the U.S. from 1975 to 1998. Smaller data files were created, as dictated by the specific analyses required, to reduce computing time. Data files were backed on compact disks (CD).

Limited analyses

One potential problem with FARS is the heterogeneity of the cases it contains. A fatality may have been caused by any of a multitude of events. While most fatalities were car passengers, some fatalities were pedestrians, others were driving off-road vehicles. The inclusion of truck data also leads to increased heterogeneity. Orr showed that excluding truck data improves the fit of regression bases on FARS data and greatly reduces collinearity (Orr. 1984). To avoid Type II errors (failure to reject the null hypothesis when it is false) caused by heterogeneity, most analyses will be based on passenger car and light trucks/utility vehicles only. The case selection process will be described in more details in Chapter 5.

Data analysis

An interesting aspect of the work to be conducted for this dissertation regards the distinction between "populations" and "samples". When considering research with humans, a population refers to all possible individuals with a specific characteristic. for example all Canadian residents. A sample, on the other hand, and whether it is representative or not, refers to a sub-set of the whole population. Sampling is desirable because it is often impractical to obtain data on the whole population, and requires the estimation of the population parameters through inferential statistics. A parameter estimate is usually accompanied with a confidence interval (e.g., 95% confidence limits), to delineate the range within which the true value of the population parameters lies. Because the data used for this thesis are that of the whole population of fatal crashes, one may doubt the need for confidence intervals as the actual population parameters may be obtained. However, these data can be considered a sample in time, of all fatal crashes. Furthermore, data points are often missing for many observations (e.g., drug use) and the resulting analyses are based on a sub-set of the population for which the information was available. Hence, confidence intervals will be used throughout the thesis.

Most data analyses presented in this thesis were based on regression models. Linear regression (using the least-square method) was used for projections presented in Chapter 5. Logistic regressions were used for Chapters 6, 7, and 8. Relevant details are presented in the Method section of each Chapter.

Chapter 5. Crash-related fatality projections

Introduction

Fatalities involving older drivers compared to other age groups

In their examination of fatal crash rates between 1940 and 1980, Whitfield and Fife (Whitfield & Fife. 1987) reported that death rates increased for the U.S. population aged 15-39, whereas it remained constant or decreased for older groups. They stated that "...countermeasures to reduce motor vehicle crash mortality among teenagers and young adults are of increasing importance to the public health. (p. 268) In 1989, another researcher (Brorsson. 1989) concluded that, compared to older drivers, drivers aged 18-19 represent "...a much greater safety problem." (p. 256) In a journal article published in 1999 (McGwin & Brown. 1999), the authors claimed that "...older drivers do not contribute significantly to the problem of traffic crashes in the United States." (p. 188)

These conclusions represent the common observation that the magnitude of the problem posed by older drivers is relatively small compared to that of younger drivers, because there are fewer older drivers, and their exposure level is less (Ryan, Legge, & Rosman. 1998). However, despite these assurances, safety analysts and planners are increasingly concerned by the demographic changes facing our society and the potential crash risk posed by older drivers (Janke. 1991).

Although fewer older drivers are involved in fatal crashes compared to other age groups, older drivers represent a crash risk equivalent to that of younger drivers when exposure is taken into account. Crash risk, when accounted for exposure, usually follows a "U"-shaped curve, starting high for young drivers, declining and remaining steady for experienced drivers, and then rising with drivers aged 65+ (Brorsson. 1989; McGwin & Brown. 1999; Ryan, Legge, & Rosman. 1998; Stutts & Martell. 1992; Williams & Carsten. 1989; Zhang, Fraser, Clarke, & Mao. 1998).

Yet, the observation that older adults contribute to fatal crashes in a smaller proportion than younger adults may give the impression that we do not need to worry about older adults' involvement in crashes in the years to come. The answer to this question lies in the prediction of the future involvement of older adults in crashes.

Williams and Carsten ventured a prediction (Williams & Carsten. 1989). Based on their 1987 data, and census predictions, they reported that there would still be more than twice as many younger drivers (less than 30) involved in fatal crashes than older drivers (65+) by year 2030. This led them to conclude that crash issues related to older drivers "...will remain relatively small well into the next century." (p. 327)

A contentious issue with their methodology is the generation of the predictions based on demographic changes alone. Demographic changes are not the only force shaping the future of traffic crashes and fatalities. Increases in licensing rates and mobility among older adults need to be taken into account.

Although Williams and Carsten conceded that older drivers may drive more miles in the future, they did not factor in this possibility and remained convinced that younger drivers will "…continue to be the predominant group in terms of numbers involved." (p. 327)

The results of Williams and Carsten likely underestimate the contribution of older drivers to crashes because they ignored changes in licensing rates and mobility among older drivers. Data from North Carolina illustrate this point and are probably generalizable to other jurisdictions (Stutts & Martell. 1992). Between 1974 and 1988, the proportion of residents aged 75+ increased by 39%, while the proportion of licensed drivers aged 75+ increased by 129%, and the proportion of crashes involving this same age group increased by 75%. In the U.S. in general, the proportion of adults aged 70+ with valid driver's license is expected to double by 2020 (Eberhard. 1996). Furthermore, it is expected that coming generations of "baby-boomers" will be more mobile than the current generation of older adults (Weinand. 1996).

Fatalities involving men and women

Similar issues apply to comparisons of men and women's involvement in fatal crashes. Men consistently comprise a large proportion of individuals involved in and fatally injured in crashes (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993; Evans. 1988a; Li, Baker, Langlois, & Kelen. 1998; Massie, Campbell, & Williams. 1995; Massie, Green, & Campbell. 1997; Stutts & Martell. 1992; Whitfield & Fife. 1987). Researchers have explained this observation by men's risk-taking behavior and women's lower exposure

(Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993; Evans. 1988a; Li, Baker, Langlois, & Kelen. 1998; Massie, Campbell, & Williams. 1995; Massie, Green, & Campbell. 1997; Stutts & Martell. 1992).

However, women's exposure is changing. North Carolina data showed that increases in licensing rates were four times higher among women aged 65+ than among men of the same age (Stutts & Martell. 1992). Similarly, whereas less than seven percent of all women and men aged 70 or more today hold a driver's license, this proportion will climb to 18% for women but only 13% for men by year 2020 (Eberhard. 1996). The influence of future demographic and mobility changes on traffic fatalities, for both men and women, remains unknown.

Future trends

Given the potential biases introduced by reliance on demographic statistics alone, available predictions of older adults', and women's, involvement in fatal accidents likely represent underestimates. More accurate predictions of the role older adults will play in future fatalities are required to allow for better planning of safety initiatives (Stutts & Martell. 1992). Accordingly, the aim of the analyses presented in this chapter was to predict the future involvement of older adults, in comparison to younger and middle-aged adults, in fatal crashes, and that of women in comparison to men.

Although it is difficult to predict future demographic changes, licensing rates, and exposure and their relationship to fatalities, it is reasonable to assume that all these trends are contained in motor vehicle fatality data from past years.

Thus, predicting future fatalities from these data incorporates estimates of changes in the number of licensed older adults, and changes in exposure. Such fatality estimates should represent a more accurate picture than that predicted from census data alone. This is the approach used in this chapter. The future involvement of older adults and women in fatal motor vehicle crashes is predicted based on data contained in FARS. It was hypothesized that older adults, and women, would comprise an increasing proportion of all fatalities.

Methods

Data

Data from years 1975 to 1998 (inclusive) were included in the analyses. Initially, for each year, the total number of individuals, along with injury severity was calculated. This number included all individuals involved, including pedestrians. Subsequent analyses and predictions focused on vehicle drivers and passengers only, a more homogeneous group facilitating interpretation of the findings. Further analyses were conducted with age and gender stratified. Age was categorized as < 30, 30 to 64, > 64.

Statistical analyses

Statistical analyses included descriptives (counts and percentages), measures of association (chi-square), and time-series predictions based on de-seasonalized data (full year) using a least-square regression model (Hamburg. 1977). De-seasonalized data were used to avoid the cyclical variations observed with seasonality, and least-square methods are routinely used to make predictions.

Briefly, a least-square regression method was used to fit the actual number of fatalities, and generate a regression equation to predict the number of fatalities for every year (Snedecor & Cochran. 1989; Spiegel. 1992). The regression equations then were used to predict future fatalities to year 2015 (trend), a period of 17 years in addition to the available 24 years of data. It was elected to predict to 2015 to have a clear index of long-term trends.

Because the relationship between the dependent variable (number of fatalities and independent variables (age and gender) was possibly non-linear, different curve estimations were used to determine the best fitting model. For each prediction the model best fitting the data was determined through a combination of the highest multiple correlation coefficient (r-value) and visual fit of the data (George & Mallery. 2000). Plotting the actual data against the predicted values of several models provides an initial judgment of the validity of the models tested (Snedecor & Cochran. 1989). Furthermore, an additional criterion to select the best model was its parsimony as determined by its degrees of freedom. Specifically, in the presence of two similar r-values and visual fit, the model with the most degrees of freedom was selected (Dowdy & Wearden. 1991).

The validity of the final model chosen was also verified with the percentage of trend values, good trend models should have a close approximation of actual data (Hamburg. 1977). Percentage of trend is calculated as:

$$\% \text{ trend} = (\text{actual value}/\text{predicted value}) * 100$$

For each data year, the percentage of trend was calculated and depicted. With a perfect model, the predicted values would be exactly 100% of the actual data. However, a perfect model was not expected because of irregular variations not taken into account by the calculations. In years where these variations lead to lower fatalities, the predicted values will overestimate the actual values.

Conversely, in years where these variations lead to higher numbers of fatalities, the predicted values will underestimate the actual numbers of fatalities.

Probably the most important irregular variations affecting fatalities are linked to the economy. Economic variations, especially for younger drivers, are linked to crash frequency and fatalities (Mercer. 1987). For example, years with lower economic prosperity (e.g., higher unemployment in the early 80's) should lead to lower fatalities, and should have percentage of trend values below 100. On the other hand, years of economic prosperity (e.g., lower unemployment in late 80's) should have percentage of trend values above 100. Therefore, if the calculated trend represents a good fit to the data, the percentage of the trend should be clustered around 100%, albeit not perfectly.

Results

Fatalities from 1975 to 1998

Data for every individual involved in a fatal crash are collected by FARS, and for each individual the severity of the injuries is reported and coded as: "no injury", "possible", "evident", "incapacitating", or "fatal". For all but one year (1992) between 1975 and 1998, more than 40,000 individuals suffered fatal injuries in accidents involving vehicles each year. Over the 24-year period covered by these data, more than one million individuals lost their lives in the U.S. (Table 1). This number is roughly equivalent to the whole population of the Province of Saskatchewan. When only drivers and passengers are considered, more than 35,000 persons died each year (Table 2).

The number of fatalities remained relatively constant across the years examined. However, the characteristics of individuals accounting for these fatalities changed considerably over time. Specifically, older adults and women composed a larger proportion of fatalities in 1998 than they did in 1975, and this trend is expected to continue.

Table 1. Total number of injuries (with row percentage; column percentage for "Total" column) related to motor vehicle crashes by year and type of injury.

Year	No injury	Possible	Evident	Incapacitating	Fatal	Total
75	20863	5674	12722	20809	44522	104886
	(19.9)	(5.4)	(12.1)	(19.8)	(42.4)	(4.1)
76	19937	6074	12924	20985	45523	105609
	(18.9)	(5.8)	(12.2)	(19.9)	(43.1)	(4.2)
77	20233	6451	14395	21984	47877	111107
	(18.2)	(5.8)	(13.0)	(19.8)	(43.1)	(4.4)
78	20679	6910	14970	21960	50331	115161
	(18.0)	(6.0)	(13.0)	(19.1)	(43.7)	(4.5)
79	20526	6780	14936	21260	51093	114885
	(17.9)	(5.9)	(13.0)	(18.5)	(44.5)	(4.5)
80	20100	6523	14470	20681	51091	113289
	(17.7)	(5.8)	(12.8)	(18.3)	(45.1)	(4.5)
81	21147	6787	14701	19599	49301	112460
	(18.8)	(6.0)	(13.1)	(17.4)	(43.8)	(4.4)
82	20992	5512	12873	17719	43945	102120
	(20.6)	(5.4)	(12.6)	(17.4)	(43.0)	(4.0)
83	20675	5195	13091	16963	42589	99316
	(20.8)	(5.2)	(13.2)	(17.1)	(42.9)	(3.9)
84	21678	5628	13412	17523	44257	103348
	(21.0)	(5.4)	(13.0)	(17.0)	(42.8)	(4.1)
85	22336	5631	12774	17994	43825	104045
	(21.5)	(5.4)	(12.3)	(17.3)	(42.1)	(4.1)
86	22717	6369	12872	19492	46087	109073
	(20.8)	(5.8)	(11.8)	(17.9)	(42.3)	(4.3)
87	23362	6917	13316	20073	46390	111457
	(21.0)	(6.2)	(11.9)	(18.0)	(41.6)	(4.4)
88	23226	7232	14048	19774	47087	112958
	(20.6)	(6.4)	(12.4)	(17.5)	(41.7)	(4.5)
89	21722	7787	14183	19356	45582	109866
	(19.8)	(7.1)	(12.9)	(17.6)	(41.5)	(4.3)
90	21757	8118	13885	18333	44599	107777
	(20.2)	(7.5)	(12.9)	(17.0)	(41.4)	(4.2)
91	19545	7484	12745	17032	41462	99255
	(19.7)	(7.5)	(12.8)	(17.2)	(41.8)	(3.9)
92	18818	7407	12337	16826	39250	95691
	(19.7)	(7.7)	(12.9)	(17.6)	(41.0)	(3.8)
93	19238	7482	12751	17013	40150	97589
	(19.7)	(7.7)	(13.1)	(17.4)	(41.1)	(3.8)
94	19575	7635	13053	17065	40716	98945
	(19.8)	(7.7)	(13.2)	(17.2)	(41.2)	(3.9)
95	19800	7907	13742	17620	41798	101931
	(19.4)	(7.8)	(13.5)	(17.3)	(41.0)	(4.0)
96	20425	8246	13765	17535	41907	102955
	(19.8)	(8.0)	(13.4)	(17.0)	(40.7)	(4.1)
97	19992	8016	13853	17426	42013	102197
	(19.6)	(7.8)	(13.6)	(17.1)	(41.1)	(4.0)
98	20012	8177	13882	16403	41471	100978
	(19.8)	(8.1)	(13.7)	(16.2)	(41.1)	(4.0)
Total	499355	165942	325700	451425	1072866	2536898
	(19.7)	(6.5)	(12.8)	(17.8)	(42.3)	(100)

Table 2. Total number of injuries (with row percentage; column percentage for "Total" column) related to motor vehicle crashes by year and type of injury for drivers and passengers of motor vehicles only.

Year	No injury	Possible	Evident	Incapacitating	Fatal	Total
75	20817	5532	12446	20271	35818	94884
	(21.9)	(5.8)	(13.1)	(21.4)	(37.7)	(4.1)
76	19889	5902	12648	20484	36997	95920
	(20.7)	(6.2)	(13.2)	(21.4)	(38.6)	(4.2)
77	20205	6286	14051	21449	39042	101033
	(20.0)	(6.2)	(13.9)	(21.2)	(38.6)	(4.4)
78	20618	6760	14642	21428	41391	104839
	(19.7)	(6.4)	(14.0)	(20.4)	(39.5)	(4.5)
79	20475	6637	14647	20703	41827	104289
	(19.6)	(6.4)	(14.0)	(19.9)	(40.1)	(4.5)
80	20018	6364	14160	20101	41788	102431
	(19.5)	(6.2)	(13.8)	(19.6)	(40.8)	(4.4)
81	21050	6599	14367	18998	40255	101269
	(20.8)	(6.5)	(14.2)	(18.8)	(39.8)	(4.4)
82	20881	5378	12603	17238	35557	91657
	(22.8)	(5.9)	(13.8)	(18.8)	(38.8)	(4.0)
83	20590	5067	12799	16525	34733	89714
	(23.0)	(5.6)	(14.3)	(18.4)	(38.7)	(3.9)
84	21531	5495	13049	17053	36175	93303
	(23.1)	(5.9)	(14.0)	(18.3)	(38.8)	(4.0)
85	22240	5525	12545	17629	35956	93895
	(23.7)	(5.9)	(13.4)	(18.8)	(38.3)	(4.1)
86	22603	6228	12590	19050	38128	98599
	(22.9)	(6.3)	(12.8)	(19.3)	(38.7)	(4.3)
87	23221	6776	13047	19574	38456	101074
	(23.0)	(6.7)	(12.9)	(19.4)	(38.0)	(4.4)
88	23097	7100	13775	19311	39058	102341
	(22.6)	(6.9)	(13.5)	(18.9)	(38.2)	(4.4)
89	21581	7584	13918	18940	38013	100036
	(21.6)	(7.6)	(13.9)	(18.9)	(38.0)	(4.3)
90	21605	7947	13611	17881	37026	98070
	(22.0)	(8.1)	(13.9)	(18.2)	(37.8)	(4.3)
91	19429	7316	12487	16618	34578	90428
	(21.5)	(8.1)	(13.8)	(18.4)	(38.2)	(3.9)
92	18703	7224	12114	16356	32795	87192
	(21.5)	(8.3)	(13.9)	(18.8)	(37.6)	(3.8)
93	19137	7316	12481	16626	33503	89063
	(21.5)	(8.2)	(14.0)	(18.7)	(37.6)	(3.9)
94	19436	7451	12784	16686	34209	90566
	(21.5)	(8.2)	(14.1)	(18.4)	(37.8)	(3.9)
95	19675	7755	13447	17189	35157	93223
	(21.1)	(8.3)	(14.4)	(18.4)	(37.7)	(4.0)
96	20229	8104	13532	17182	35477	94524
	(21.4)	(8.6)	(14.3)	(18.2)	(37.5)	(4.1)
97	19846	7890	13601	17056	35611	94004
	(21.1)	(8.4)	(14.5)	(18.1)	(37.9)	(4.1)
98	19872	8051	13637	16110	35248	92918
	(21.4)	(8.7)	(14.7)	(17.3)	(37.9)	(4.0)
Total	496748	162287	318981	440458	886798	2305272
	(21.5)	(7.0)	(13.8)	(19.1)	(38.5)	(100)

Age and fatalities

Historically, young drivers and passengers made up the bulk of fatalities. However, this pattern is changing (see Table 3), with older adults representing an increasing proportion of all fatalities among all age groups. In 1975, 20,214 (57%) of all fatalities were accounted by those less than 30. In 1985 it was 18,897 (53%), and in 1998, this number had shrunk to 14,176 (40%). In contrast, the 65+ group accounted for 3,536 (10%) fatalities in 1975, 4,062 (11%) in 1985, and 6,022 (17%) fatally injured drivers and passengers in 1998 (χ^2 (2) = 1653.02, $p = .001$).

Projections for fatalities across age groups are presented in Figure 1. Based on these data, it is expected that the number of young adult fatalities will decrease to 9,701 (27%) by 2015. The number of older adult fatalities is expected to rise to 9,569 (27%) by 2015. Trend data best approximated actual data with a logistic model defined as:

$$y = 1 / (b0 * b1^t)$$

Where y is the predicted number of yearly fatalities, b0 and b1 are regression coefficients, and t is the year, ranging from 1 (1975) to 41 (2015). Regression coefficients, r and probability values, and mean percentage of trend, are presented in Table 4. Percentage of trend from years 1975 to 1998 is presented in Figure 2. Fluctuations are consistent across all age groups, and with economic cycles.

Table 3. Fatal injuries by year and age (age was not available for some fatalities). Cell numbers are fatalities (percent of all fatalities for year in question).

Year	< 30	30 - 64	> 64	Total
75	20214	11951	3536	35701
	(56.6)	(33.5)	(9.9)	
76	21087	12119	3682	36888
	(57.2)	(32.9)	(10.0)	
77	22687	12653	3545	38885
	(58.3)	(32.5)	(9.1)	
78	24042	13426	3765	41233
	(58.3)	(32.6)	(9.1)	
79	24172	13908	3603	41683
	(58.0)	(33.4)	(8.6)	
80	23914	14160	3563	41637
	(57.4)	(34.0)	(8.6)	
81	22266	14080	3629	39975
	(55.7)	(35.2)	(9.1)	
82	19551	12408	3495	35454
	(55.1)	(35.0)	(9.9)	
83	18659	12344	3649	34652
	(53.8)	(35.6)	(10.5)	
84	19287	12814	3976	36077
	(53.5)	(35.5)	(11.0)	
85	18897	12881	4062	35840
	(52.7)	(35.9)	(11.3)	
86	20263	13321	4405	37989
	(53.3)	(35.1)	(11.6)	
87	19861	13946	4587	38394
	(51.7)	(36.3)	(11.9)	
88	19799	14314	4892	39005
	(50.8)	(36.7)	(12.5)	
89	18479	14447	5030	37956
	(48.7)	(38.1)	(13.3)	
90	17789	14347	4844	36980
	(48.1)	(38.8)	(13.1)	
91	16170	13356	4990	34516
	(46.8)	(38.7)	(14.5)	
92	14585	13081	5047	32713
	(44.6)	(40.0)	(15.4)	
93	14709	13421	5318	33448
	(44.0)	(40.1)	(15.9)	
94	14914	13630	5619	34163
	(43.7)	(39.9)	(16.4)	
95	15051	14392	5659	35102
	(42.9)	(41.0)	(16.1)	
96	15070	14528	5812	35410
	(42.6)	(41.0)	(16.4)	
97	14562	14848	6135	35545
	(41.0)	(41.8)	(17.3)	
98	14176	14999	6022	35197
	(40.3)	(42.6)	(17.1)	
Total	450204	325374	108865	884443

Figure 1. Number of fatalities (data) for years 1975 to 1998, and projected trends to year 2015 by age group (with 95% lower and upper confidence limits).

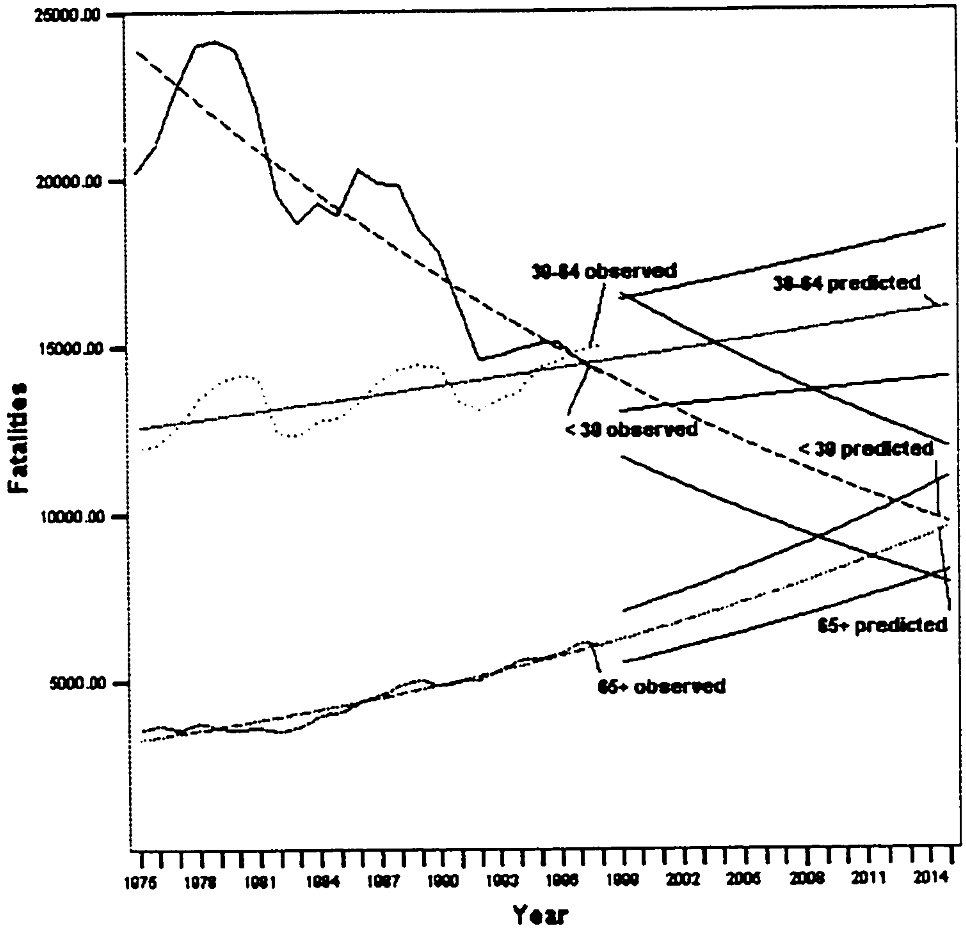
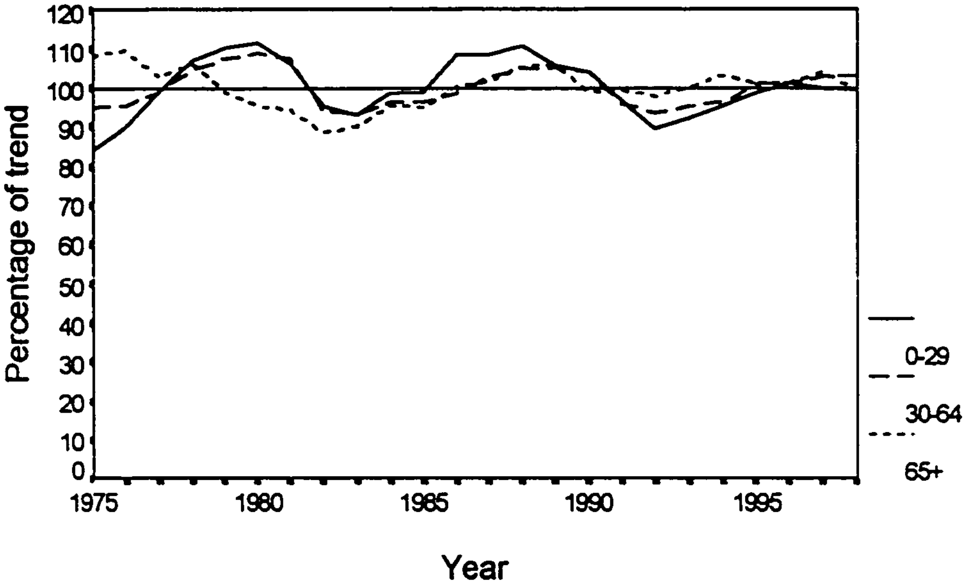


Table 4. Regression coefficients, r and probability values, and mean percentage of trend for fatalities by age group.

	0 – 29	30 – 64	65+
b0 coefficient*	4.1 E-5	8.0 E-5	3.0 E-4
b1 coefficient*	1.02	0.99	0.97
r-value	.82	.44	.93
F-value	99.67	17.19	281.48
Degrees of freedom	22	22	22
p-value	.001	.001	.001
Mean % trend	100.3	100.1	100.1

*Regression coefficients were rounded up for the table but not calculation of projections

Figure 2. Percentage of trend for year 1975 to year 1999 per age group.



Gender and fatalities

Whereas the number of men suffering fatal injuries decreased by 13%, from 26,522 to 23,193 between 1975 and 1998, the number of women fatally injured increased by 30% from 9,291 to 12,043 (Table 5). Men accounted for 74% of all fatalities in 1975. This proportion had been reduced to 71% by 1985, and 66% by 1998 (χ^2 (2) = 582.36, p = .001). Proportionally, men are expected to experience a continued decrease in fatalities, whereas women will experience an increase. It is predicted that by year 2015, men will account for 18,569 (58%) fatalities compared to 13,699 (42%) for women.

Projections for fatalities across gender are presented in Figure 3. Trend data best approximated actual data with a logistic model as defined earlier. Regression coefficients, r and probability values, and mean percentage of trend, are presented in Table 6. Percentage of trend from years 1975 to 1998 is presented in Figure 4. Fluctuations are consistent across gender, and with economic cycles.

Table 5. Fatal injuries by year and gender (gender was not available for 405 fatalities over the 24 years). Cell numbers are fatalities (percent of all fatalities for year in question).

Year	Males	Females	Total
75	26522	9291	35813
	(74.1)	(25.9)	
76	27027	9966	36993
	(73.1)	(26.9)	
77	28443	10597	39040
	(72.9)	(27.1)	
78	30340	11047	41387
	(73.3)	(26.7)	
79	30968	10856	41824
	(74.0)	(26.0)	
80	30798	10984	41782
	(73.7)	(26.3)	
81	29536	10565	40101
	(73.7)	(26.3)	
82	25876	9680	35556
	(72.8)	(27.2)	
83	24864	9864	34728
	(71.6)	(28.4)	
84	25680	10493	36173
	(71.0)	(29.0)	
85	25423	10527	35950
	(70.7)	(29.3)	
86	27105	10987	38092
	(71.2)	(28.8)	
87	26845	11600	38445
	(69.8)	(30.2)	
88	27227	11817	39044
	(69.7)	(30.3)	
89	25905	12099	38004
	(68.2)	(31.8)	
90	25524	11490	37014
	(69.0)	(31.0)	
91	23611	10955	34566
	(68.3)	(31.7)	
92	22140	10624	32764
	(67.6)	(32.4)	
93	22551	10940	33491
	(67.3)	(32.7)	
94	22804	11393	34197
	(66.7)	(33.3)	
95	23388	11744	35132
	(66.6)	(33.4)	
96	23386	12081	35467
	(65.9)	(34.1)	
97	23295	12299	35594
	(65.4)	(34.6)	
98	23193	12043	35236
	(65.8)	(34.2)	
Total	622451	263942	886393

Figure 3. Number of fatalities (data) for years 1975 to 1998, and projected trends to year 2015 by gender (with 95% lower and upper confidence limits).

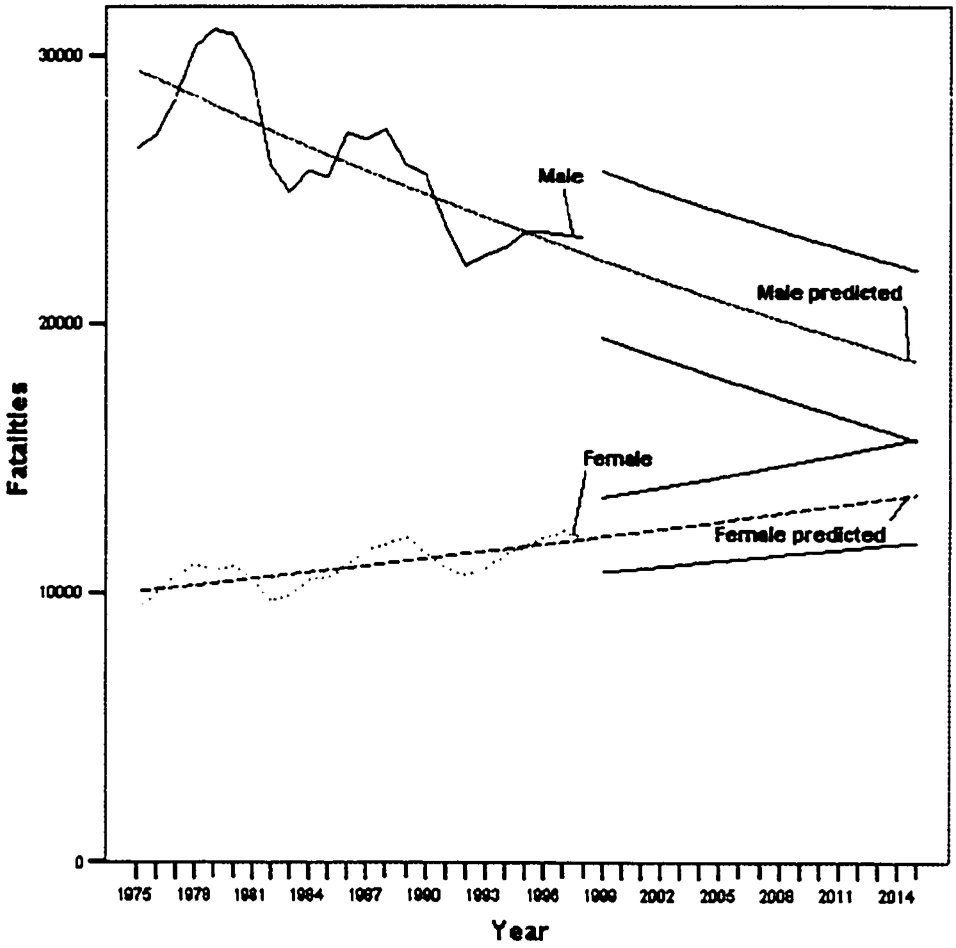
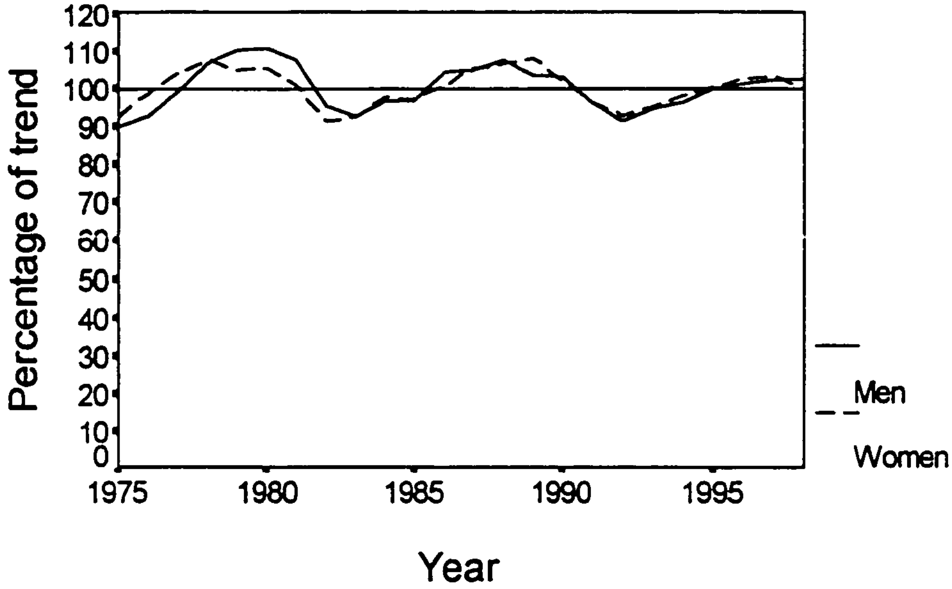


Table 6. Regression coefficients, r and probability values, and mean percentage of trend for fatalities by gender.

	Men	Women
b0 coefficient*	3.4 E-5	1.0 E-4
b1 coefficient*	1.01	0.99
r-value	.65	.54
F-value	40.84	26.18
Degrees of freedom	22	22
p-value	.001	.001
Mean % trend	100.2	100.1

*Regression coefficients were rounded up for the table but not calculation of projections .

Figure 4. Percentage of trend for year 1975 to year 1999 across gender groups.



Older women and men

Data for men and women aged 65+ paint an alarming picture. Total fatalities have risen by 70% from 1975 to 1998 (Table 7). Women accounted for only 37% of driver and passenger fatalities in 1975, this proportion rose to 44% by 1985, and reached 46% in 1998 (χ^2 (2) = 60.87, p = .001). Projections suggest that this gender difference should remain stable thereafter. When one considers the combined effect of the gender and age trends, we can expect that the number of 65+ female fatalities will rise 373%, from 1,324 in 1975 to 4,941 by year 2015, and 271% for males, from 2,212 in 1975 to 5,988 in 2015.

Projections for fatalities among adults aged 65+ by gender are presented in Figure 5. Trend data best approximated actual data with a quadratic model defined as

$$y = b0 + (b1 * t) + (b2 * t^2)$$

Where y is the predicted number of yearly fatalities, b0, b1 and b2 are regression coefficients, and t is the year, ranging from 1 (1975) to 41 (2015). Regression coefficients, r and probability values, and mean percentage of trend, are presented in Table 8. Percentage of trend from years 1975 to 1998 is presented in Figure 6. Fluctuations are consistent across gender, and with economic cycles.

Table 7. Fatal injuries by year and gender for drivers and passengers aged 65+. Cell numbers are fatalities (percent of all fatalities for year in question).

Year	Males	Females	Total
75	2212	1324	3536
	(62.6)	(37.4)	
76	2202	1472	3674
	(59.9)	(40.1)	
77	2150	1395	3545
	(60.6)	(39.4)	
78	2300	1465	3865
	(61.1)	(38.9)	
79	2214	1389	3603
	(61.4)	(38.6)	
80	2166	1390	3556
	(60.9)	(39.1)	
81	2210	1419	3629
	(60.9)	(39.1)	
82	2006	1489	3495
	(57.4)	(42.6)	
83	2147	1502	3649
	(58.8)	(41.2)	
84	2253	1713	3966
	(56.8)	(43.2)	
85	2287	1775	4062
	(56.3)	(43.7)	
86	2481	1924	4405
	(56.3)	(43.7)	
87	2546	2041	4587
	(55.5)	(44.5)	
88	2787	2094	4881
	(57.1)	(42.9)	
89	2737	2293	5030
	(54.4)	(45.6)	
90	2668	2176	4844
	(55.1)	(44.9)	
91	2768	2222	4990
	(55.5)	(44.5)	
92	2814	2222	5036
	(55.9)	(44.1)	
93	2899	2419	5318
	(54.5)	(45.5)	
94	3082	2537	5619
	(54.8)	(45.2)	
95	3041	2618	5659
	(53.7)	(46.3)	
96	3187	2611	5798
	(55.0)	(45.0)	
97	3330	2805	6135
	(54.3)	(45.7)	
98	3281	2741	6022
	(54.5)	(45.5)	
Total	61768	47036	108804

Figure 5. Number of fatalities (data) for years 1975 to 1998, and projected trends to year 2015 by gender for individuals aged 65+ (with 95% lower and upper confidence limits).

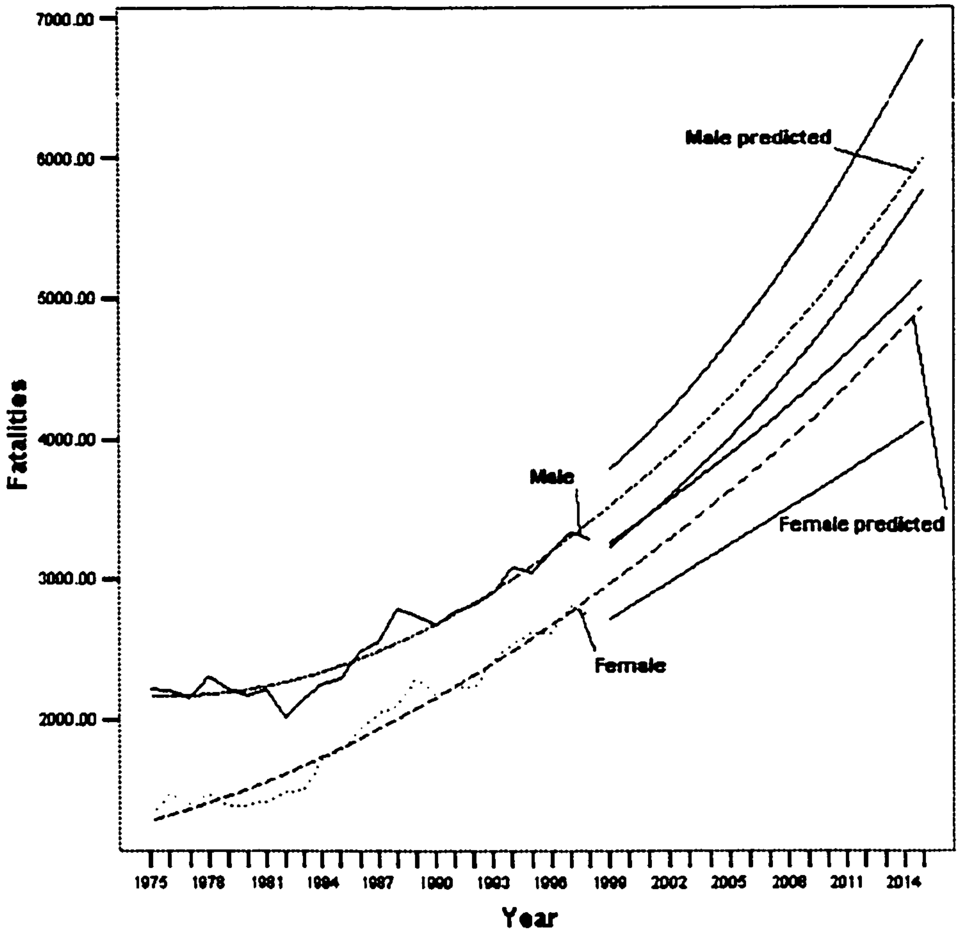
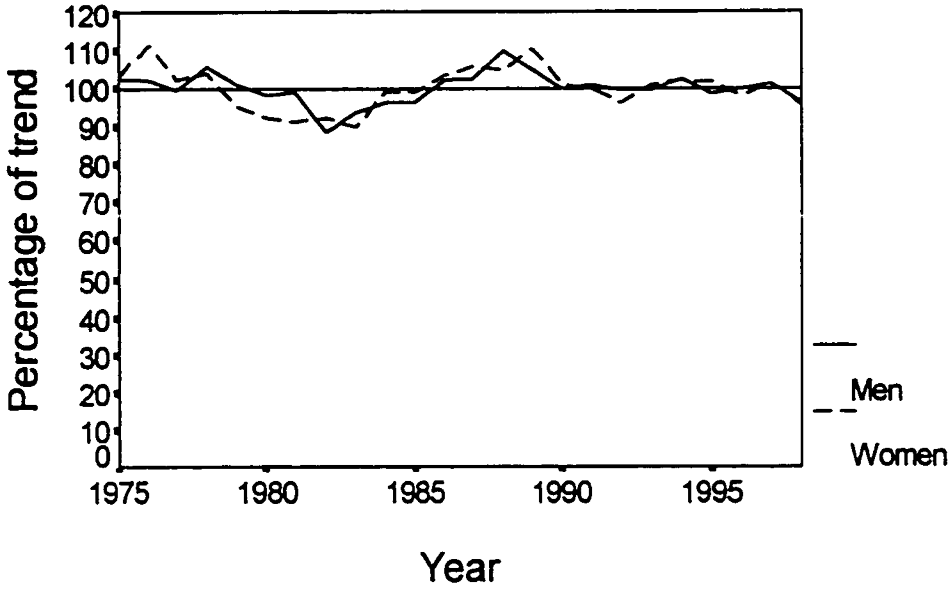


Table 8. Regression coefficients, r and probability values, and mean percentage of trend for fatalities by gender for adults aged 65+.

	Men	Women
b0 coefficient*	2163.92	1246.06
b1 coefficient*	-7.28	35.24
b2 coefficient*	2.45	1.34
r-value	.94	.96
F-value	160.40	267.23
Degrees of freedom	21	21
p-value	.001	.001
Mean % trend	100.0	100.0

*Regression coefficients were rounded up for the table but not calculation of projections

Figure 6. Percentage of trend for year 1975 to year 1998 across gender for adults aged 65+.



Discussion

Crash risk and age groups

The results are consistent with other findings that crash and fatality risks are higher in young drivers and passengers. However, contrary to the predictions of others (e.g., Williams & Carsten. 1989), the results presented here predict an equal involvement of young and older adults in future fatal crashes. Together, and equally, drivers and passengers aged less than 30 and those aged 65+ will represent the bulk of fatalities by year 2015.

These predictions, however, assume that few changes will occur in coming years to affect their accuracy. Future events could affect these predictions in two major ways. First, the actual number of fatalities among sub-groups may be higher or lower depending on intervening events. This may happen, however, without affecting the proportions of fatalities accounted by the sub-groups. For example, if an engineering advance introduced were to save lives, while being equally efficacious for the various sub-groups of drivers and passengers, then the overall number of fatalities would decrease, but the proportion accounted by the various subgroups would remain unchanged. Second, if an event were to affect a sub-group specifically, then the absolute number of fatalities and proportion accounted by that sub-group would change. For example, if further reductions in drinking and driving were achieved among young drivers, their absolute number of fatalities and proportion of the overall fatalities would be decreased. Consequently, the proportion of fatalities accounted by other groups would increase.

It is easy to imagine that several events may result in higher or lesser fatalities than expected. A number of these possibilities are presented in Table 9; many others are possible.

Reducing crash risk and consequences among older adults

The predicted involvement of older adults in fatal crashes requires the immediate attention of authorities to safety initiatives that may reduce fatalities. To determine what these initiatives should be is problematic. Ryan and colleagues (Ryan, Legge, & Rosman. 1998), based on their findings that drivers 70+ accounted for 3% of all crashes in Western Australia, concluded that "...the absolute numbers are small, so that imposing restrictions on their driving would have a very small effect on the total number of crashes occurring." (p. 386) The authors were concerned with achieving a balance between public safety and the mobility needs of older adults. Restrictions may be a solution to this problem in some circumstances, but are unlikely to achieve the result we are seeking, that is, maximizing the independence of older adults while ensuring public safety and their own.

One researcher (Dulisse. 1997) argued that the critical issue is "... the degree to which older drivers impose a higher level of risk on other road users." (p. 573) Based on an analysis that compared drivers aged 65+ to all other drivers, and did not consider "at fault" drivers, he concluded that older drivers do not impose an excess risk to other road users.

Table 9. Events that may lower or increase the traffic fatality projections.

Event (compared to expectations)	Lower fatalities	Higher fatalities
Higher mobility		✓
More driver re-training	✓	
Engineering advances	✓	
Increased speed limits		✓
Increased longevity		✓
Graduated licenses	✓	
Co-pilots	✓	

His argument is problematic on several points. First, by comparing older drivers to all other drivers, he artificially increased the risk imposed by the comparison group through the inclusion of the youngest drivers. A better approach would have compared older drivers to the best drivers (those aged 40-49). Second, by not considering drivers at-fault, it is impossible to really calculate excess risk. The author' rationale was that a collision would not have been possible without two drivers, implying that by being on the road one is partially responsible for the collision. Finally, his position suggests that we need not worry about the safety of older drivers and passengers because they do not represent an excess risk to others! Older drivers and passengers' safety should be a primary concern, whether they represent an excess risk to other road users or not. The projections based on FARS data attest that the needs of adults aged 65+ cannot be ignored.

The main goal of traffic planners should be to achieve a balance between public safety, and older adults' own safety and independence. This cannot be achieved by blanket restrictions imposed on older adults, but rather by understanding why crashes and fatalities happen. Three main sources of information must be harvested

First is the identification of situations where older drivers may be more likely to initiate fatal crashes. Compared to young adults, older adults are over-involved in crashes during daytime (Mortimer & Fell. 1989; Ryan, Legge, & Rosman. 1998; Zhang, Fraser, Clarke, & Mao. 1998), on weekdays (Zhang, Fraser, Clarke, & Mao. 1998), at intersections and merging situations (McGwin

& Brown. 1999; Pruesser, Williams, Ferguson, Ulmer, & Weinstein. 1998; Ryan, Legge, & Rosman. 1998; Viano, Culver, Evans, Frick, & Scott. 1990; Zhang, Fraser, Clarke, & Mao. 1998), and during good weather (Zhang, Fraser, Clarke, & Mao. 1998). Although informative, this information fails short of providing clear recommendations because crash rates may be the results of higher exposure, higher crash initiation, or a combination of both. For example, even though older adults are involved in daytime crashes in larger proportion than younger adults it is not clear if their responsibility for daytime crashes is more elevated. If we are to reduce crash risks in older adults, the crucial information we need is whether older adults are more likely to initiate crashes during daytime or nighttime.

Knowing under what situations older adults are more likely to initiate crashes may also allow us to devise age-specific strategies to reduce older adult involvement in crashes (Zhang, Fraser, Clarke, & Mao. 1998). These strategies, which may involve re-engineering or re-training, may yield substantial benefit given the projected increase in older adult involvement in fatal crashes. The ultimate cost of these strategies could potentially be offset by reductions in fatal crashes.

Second, is the identification of older drivers who may be at increased risk of initiating crashes. Perneger and Smith (Perneger & Smith. 1991), in their landmark study, reported that alcohol use and older age were strongly associated with crash initiation. Whereas the abilities of some older adults will decline below acceptable thresholds, that of others will remain above for their entire lives (Bédard, Molloy, Guyatt, Stones, & Strang. 1997). The identification of older drivers at risk of crash initiation may lead to new safety strategies. Strategies such as graduated licenses and co-pilots (Bédard, Molloy, & Lever. 1998; Shua-Haim & Gross. 1996) may reduce the likelihood of crash initiation in subgroups of drivers. Larger scale testing of these options is desirable.

Third, we need to address the greater susceptibility of older adults to fatal injuries (Evans. 1988c) by identifying protective variables. Their susceptibility may be related to physiological variables. Specifically, the aging human body may be less able to sustain trauma than younger bodies (Brorsson. 1989; Evans. 1988c; Viano, Culver, Evans, Frick, & Scott. 1990). Alternatively, it is possible that vehicle characteristics (e.g., car design, seat belts, air bags) provide a differential protective benefit to young and older adults (Levine, Bédard, Molloy, & Basilevsky. 1999; Viano, Culver, Evans, Frick, & Scott. 1990). A combination of both sets of variables may be at work.

It would be difficult to alter physiological variables in order to protect older adults in the event of a serious crash. However, a better understanding of the relationship between vehicle characteristics and fatal injuries may allow the development of strategies enhancing the probability of survival of older adults involved in crashes. Data from FARS suggest that drivers of recent model years cars can survive more serious crashes than drivers of older model years (Levine, Bédard, Molloy, & Basilevsky. 1999). Drivers of heavy cars are more likely to survive impacts than drivers of lighter cars (Evans. 1992b; Evans. 1993b; Evans

& Frick. 1994; Evans & Wasielewski. 1987; Levine, Bédard, Molloy, & Basilevsky. 1999). Engineering advances targeted specifically to older adults may provide additional protection (Viano, Culver, Evans, Frick, & Scott. 1990).

The data presented in this Chapter attest to the growing problem presented by an aging and mobile society. Older adults will represent a sizable proportion of future traffic fatalities, and this warrants special attention to their needs. Our best strategy to minimize future fatalities among older adults must focus on the driving environment and driver behavior.

Chapter 6. Associations between crash situations and driver errors

Introduction

The predicted involvement of older drivers in fatal crashes warrants a detailed examination of the driving errors they are more likely to commit and the situations in which they are more likely to commit them. Information pertinent to older drivers represents a gateway to safety initiatives with maximum benefits for this category of drivers.

Most frequent types of errors

It is inappropriate to assume that younger and older drivers, because they have similar crash rates, commit similar driving errors (Graca. 1986; McGwin & Brown. 1999). Younger drivers commit errors related to drinking and driving, and the aggressive nature of their driving (Clarke, Ward, & Jones. 1998; Kennedy, Isaac, & Graham. 1996; McGwin & Brown. 1999; Mortimer & Fell. 1989; Solnick & Hemenway. 1997; Zhang, Fraser, Clarke, & Mao. 1998; Zobeck, Grant, Stinson, & Bertolucci. 1994). In a study of 353 drivers who initiated fatal crashes, 41% of drivers aged 26 to 40 committed an handling/operation error, compared to only 17% of drivers aged 65+ (Hakamies-Blomqvist. 1993). In another study, based on fatal and non-fatal police reported crashes, 16% drivers aged 16 to 24 lost control of their vehicles but this proportion was halved (8%) among drivers aged more than 54 (McGwin & Brown. 1999).

However, problems at intersections show a predominant involvement of older drivers. McGwin and Brown found that failure to yield was the driving error reported by police officers in 29% of crashes initiated by drivers aged 55 or more (McGwin & Brown. 1999). Among drivers aged 16 to 24 this proportion was 16%. Similarly, the crash involvement of older drivers in left-turn crashes was roughly twice that of younger drivers according to an Australian study and a Canadian study (Ryan, Legge, & Rosman. 1998; Zhang, Fraser, Clarke, & Mao. 1998). However, these studies did not control for crash initiation.

Most frequent crash situations

Differences in types of errors are consistent with the predominant situations where younger and older drivers crash. For older drivers the majority of crashes involved other vehicles (Hakamies-Blomqvist. 1993; McGwin & Brown. 1999; Viano, Culver, Evans, Frick, & Scott. 1990; Zhang, Fraser, Clarke, & Mao. 1998). A study based on Alabama crash data found that 93% of drivers aged 55+ had multi-vehicle crashes, compared to 84% of drivers aged less than 25 (McGwin & Brown. 1999). Data from the U.S. NASS for 1982 to 1986 showed that 37% of drivers aged 19 or less were involved in multi-vehicle crashes, compared to 61% of drivers aged 65 to 79 (Viano, Culver, Evans, Frick, & Scott. 1990). In Canada, from 1984 to 1993, 67% of crashes involving drivers aged 65+ involved another vehicle, compared to 50% for drivers aged 16 to 24 (Zhang, Fraser, Clarke, & Mao. 1998). The differences in the proportion of multi-vehicle crashes across these datasets may be explained by geographical, demographic, and analytical disparities. Nonetheless, the pattern across age groups is consistent.

The type of vehicle-vehicle crashes also vary according to age. A small Finnish study (N = 330) reported 78% vehicle-vehicle crashes involving drivers aged 26 to 40 were "head-on" compared to 38% of crashes involving drivers aged 65+ (Hakamies-Blomqvist. 1993). Also, increasing age is positively associated with the risk of initiating a crash at an intersection; 85 year old drivers are 10 times more likely to initiate a crash at an intersection than drivers aged 40 to 49 (Pruesser, Williams, Ferguson, Ulmer, & Weinstein. 1998).

About 70% of crashes involving older drivers occurred during good weather (McGwin & Brown. 1999; Zhang, Fraser, Clarke, & Mao. 1998). And at least as many occurred during daylight (McGwin & Brown. 1999; Ryan, Legge, & Rosman. 1998; Zhang, Fraser, Clarke, & Mao. 1998). However, whereas there appeared to be no difference between younger and older drivers in the likelihood of a crash in good or bad weather (McGwin & Brown. 1999; Zhang, Fraser, Clarke, & Mao. 1998), younger drivers were more likely to be involved in a nighttime crash than older drivers (Massie, Green, & Campbell. 1997; McGwin & Brown. 1999; Mortimer & Fell. 1989; Ryan, Legge, & Rosman. 1998; Sjogren, Bjornstig, Eriksson, Sonntag-Ostrom, & Ostrom. 1993; Stutts & Martell. 1992; Zhang, Fraser, Clarke, & Mao. 1998). Older drivers were also less likely to be involved in crashes in curved sections (Zhang, Fraser, Clarke, & Mao. 1998). Although these differences were likely attributable to driving behavior (e.g., drinking and driving) it is important to rule out exposure as a confounder and identify if some driving situations represent more salient problems for older drivers than for other age groups.

Next steps

Available data suggest that driving errors committed by older drivers may result from attention/perception errors as opposed to operation/handling errors (Hakamies-Blomqvist. 1993). However, the quantification of the crash initiation risk posed by older drivers under various driving situations remains to be undertaken comprehensively. It is critical to identify the types of driving errors older drivers commit, and the situations where older drivers are more likely to commit these errors. Safety initiatives for older drivers could be directed towards situations where both a high frequency of driver involvement and a high error risk are present.

However, this undertaking requires the control of several confounders. For example, the higher involvement of older drivers in daytime crashes likely represent a higher exposure. Older drivers may have an increased crash risk during nighttime after controlling for exposure. This information would be critical for the development of safety initiatives. There is at present not data on crash risk after control for potential confounders.

Therefore, the primary goal of the work reported in this Chapter was to identify the type of driving errors committed by older drivers and the situations where older drivers were especially at risk of causing fatal crashes, after controlling for potential confounders. It was hypothesized that driving errors would reflect aggressive driving among younger drivers and attention/perception errors among older drivers. Furthermore, it was expected that crashes occurring at intersections would represent a major problem for older drivers because of the rate of their involvement and because of their responsibility for a disproportion of these crashes.

Methods

Data

Data from years 1975 to 1998 were included in the analyses. The first task identified drivers who committed errors, and the type of errors with data contained in "driver-related factors", as done by others (Perneger & Smith. 1991; Pruesser, Williams, Ferguson, Ulmer, & Weinstein. 1998). Briefly, for every driver, up to three (four since 1997) driver-related factors were coded according to police reports (more than one factor may be coded for the same driver). Driver-related codes greater or equal to 20 and less than or equal to 59 were considered driving errors (these codes are presented in Appendix II). A driver who had any one of these codes was considered to have committed an error leading to the crash. A driver who did not have any of these codes was considered not responsible for the crash.

Situational variables examined were extracted from the FARS files and classified arbitrarily into one of three categories for presentation purposes: driving conditions, road characteristics, and traffic flow. Driving conditions referred to changing conditions that may have affected driving (weather, light conditions, surface condition, road construction/maintenance). Road characteristics included stable engineering aspects of the roadways (number of lanes, road alignment, road profile, pavement type, and rail crossing). Finally, the traffic flow category referred to variables describing the traffic flow and the collision (collision manner, junction type, urban/rural, limited/unlimited road access, presence of school bus, speed limit, traffic direction).

A note of caution is required regarding the interpretation of data on driving errors and situational variables. First, data on some but not all variables were collected for the entire study period (1975-1998). For example, data on the driving error "overcorrecting" is reported only since 1995. Data on the presence of a construction/maintenance zone was not collected between 1975 and 1979. Therefore, meaningful comparisons across years are limited to general observations. However, it is appropriate to make comparisons across age categories within years.

Second, coding has changed over time. For example, during the period 1975-1981, road profile consisted of three codes: "level", "grade", or "unknown". From 1982 onward, "hill crest" and "sag" were added. Therefore, to maximize the number of data points available for the analyses, data were re-coded to achieve consistency across years. Using the road profile example, data from 1982-1998 were re-coded such that grade, hill crest and sag were classified as "not level".

Statistical analyses

Data on the frequency of driving errors and situations are presented with percentages. Differences across age groups on driving errors leading to crashes were examined with odds ratios (OR). For all analyses, drivers in the 40-49 age category were used as the reference group (their OR is thus 1.0). Subsequently, the OR of committing any one driving error were examined for specific weather, road characteristics, and traffic flow situations. Because of the number of OR calculated, 99% confidence intervals (99% CI) were calculated instead of the traditional 95% confidence intervals. The difference between groups was considered significant at the $p < .01$ level for every OR where the 99% CI did not include 1.0.

Results

Frequency of driving errors

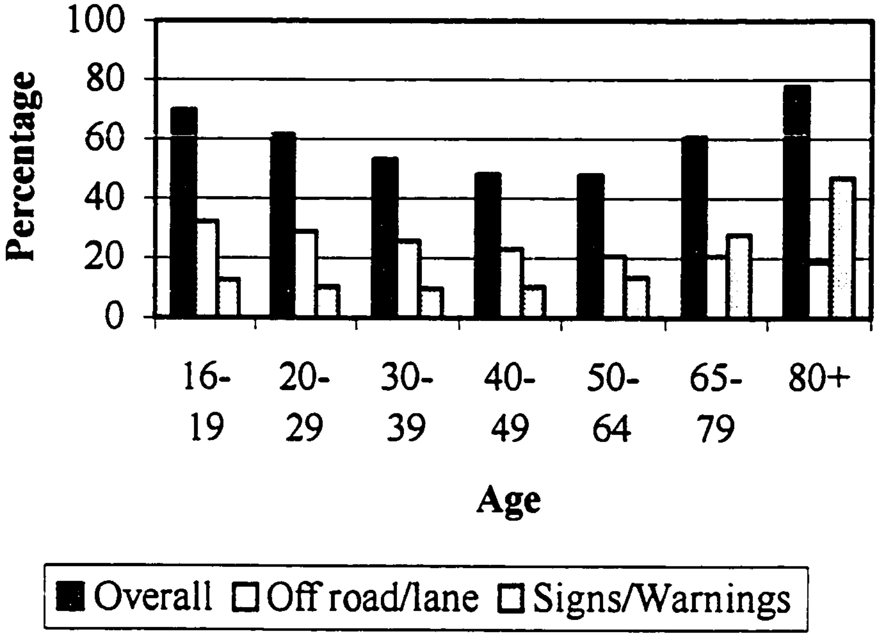
The total number of driving errors was highest among drivers aged 20-29 (Table 10), but proportionally it was highest among the youngest (< 20) and oldest (80+) drivers. Overall, 70% of the youngest drivers committed a driving error. The percentage of drivers who committed errors bottomed out at 48% among drivers aged 40-64, and climbed to 78% for drivers aged 80+.

The most frequent driving error among the youngest drivers was driving too fast for the conditions (36.2%). Only 6.1% of drivers aged 80+ drove too fast for the conditions. Conversely, 46.9% of the oldest drivers ignored signs or warnings, while only 12.5% of the youngest drivers did. Figure 7 displays the overall error rate and the two most predominant error types observed for older drivers (ignoring signs/warnings, traveling off one's lane or off the road).

Table 10. Number and percentage of driving errors, by error type and age category.

Error Type	< 20	20-29	30-39	40-49	50-64	65-79	80+
Overall	120247	225240	116719	65160	64010	54164	19492
	69.6	61.4	53.1	48.0	47.8	60.9	77.8
Operation	1941	3805	2043	1082	820	405	83
	1.1	1.0	0.9	0.8	0.6	0.5	0.3
Following	994	2442	1461	887	891	718	244
	0.6	0.7	0.7	0.7	0.7	0.8	1.0
Lane changing	1147	2552	1385	793	815	551	150
	0.7	0.7	0.6	0.6	0.6	0.6	0.6
Travel off lane/road	55140	105772	56030	31016	27441	18303	4611
	31.9	28.8	25.5	22.9	20.5	20.6	18.4
Traffic entry/exit	243	451	303	208	281	399	244
	0.1	0.1	0.1	0.2	0.2	0.4	1.0
Passing	4206	6646	2860	1393	1199	748	209
	2.4	1.8	1.3	1.0	0.9	0.8	0.8
Other careless	20063	36741	17079	8406	7740	4947	1462
	11.6	10.0	7.8	6.2	5.8	5.6	5.8
Signs/	21595	37641	21543	13967	18048	24856	11756
warnings	12.5	10.3	9.8	10.3	13.5	27.9	46.9
Signaling	118	237	126	101	140	160	42
	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Too fast	62582	111189	49254	23096	16424	7150	1534
	36.2	30.3	22.4	17.0	12.3	8.0	6.1
Changing speeds	271	504	338	183	191	136	43
	0.2	0.1	0.2	0.1	0.1	0.2	0.2
Turning	3005	6560	3895	2461	2617	2858	1086
	1.7	1.8	1.8	1.8	2.0	3.2	4.3
Wrong way/side	430	1500	929	572	640	497	257
	0.2	0.4	0.4	0.4	0.5	0.6	1.0
Inexperience	8394	16864	8475	4557	4579	2820	787
	4.9	4.6	3.9	3.4	3.4	3.2	3.1
Unfamiliar with	3233	567	165	98	83	56	10
road	1.9	0.2	0.1	0.1	0.1	0.1	0.0
Stopped in roadway	455	741	295	182	159	174	47
	0.3	0.2	0.1	0.1	0.1	0.2	0.2
Underriding parked	303	842	670	422	387	252	63
truck	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Getting in/out	58	193	101	46	49	24	4
	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Improper tire press	96	194	119	96	61	26	9
	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Locked wheel/	3742	6050	3754	2200	1579	916	186
overcorrecting	2.2	1.6	1.7	1.6	1.2	1.0	0.7

Figure 7. Percentage of drivers committing at least one driving errors (overall), and two most frequent error types (driving off lane or road, and failing to heed signs or warnings) by age group.



Risk of driving errors

The frequency of driving errors may be related to exposure. Accordingly, OR of committing errors were calculated using drivers aged 40-49 as the reference group. Odds ratios for committing any one error (overall) confirmed the "U"-shaped pattern found by others. The OR of a driving error for drivers aged 80+ was nearly four times that of drivers aged 40 to 49. These OR are shown in the top row of Table 11.

Odds ratios for specific driving error by age groups are also presented in Table 11. Examination of the results substantiated differences across the life span. For example, younger drivers were more at risk to make errors related to passing, and driving too fast, but were less at risk to drive in the wrong way or on the wrong side of the road. Older drivers, on the other hand, were six times more at risk to make errors while entering or exiting traffic (OR = 6.40, 99% CI = 5.02, 8.17), and eight times more at risk to ignore signs or warnings (OR = 7.69, 99% CI = 7.39, 8.01) compared to reference drivers. Seldom did older drivers drive too fast for the conditions (OR = 0.32, 99% CI = 0.30, 0.34).

Table 11. Odds ratios of committing errors compared to 40-49 age group with 99% confidence intervals.

Error Type	< 20	20-29	30-39	50-64	65-79	80+
Overall	2.47	1.72	1.22	0.99	1.68	3.78
	2.42, 2.52	1.69, 1.75	1.20, 1.24	0.97, 1.01	1.64, 1.72	3.63, 3.94
Operation	1.41	1.30	1.17	0.77	0.57	0.41
	1.29, 1.55	1.19, 1.42	1.06, 1.28	0.68, 0.86	0.49, 0.66	0.31, 0.55
Following	0.88	1.02	1.02	1.02	1.24	1.49
	0.78, 0.99	0.92, 1.13	0.91, 1.13	0.90, 1.15	1.09, 1.41	1.24, 1.80
Lane changing	1.14	1.19	1.08	1.04	1.06	1.02
	1.01, 1.28	1.07, 1.32	0.96, 1.21	0.91, 1.18	0.92, 1.22	0.81, 1.29
Travel off lane/road	1.58	1.37	1.15	0.87	0.87	0.76
	1.55, 1.61	1.34, 1.39	1.13, 1.18	0.85, 0.89	0.85, 0.90	0.73, 0.80
Traffic entry/exit	0.92	0.80	0.90	1.37	2.93	6.40
	0.72, 1.17	0.65, 1.00	0.71, 1.13	1.08, 1.73	2.35, 3.66	5.02, 8.17
Passing	2.40	1.78	1.27	0.87	0.82	0.81
	2.22, 2.60	1.65, 1.92	1.17, 1.38	0.79, 0.96	0.73, 0.92	0.67, 0.98
Other careless	1.99	1.68	1.27	0.93	0.89	0.94
	1.92, 2.06	1.63, 1.74	1.23, 1.32	0.89, 0.97	0.85, 0.93	0.87, 1.01
Signs/ warnings	1.24	1.00	0.95	1.36	3.38	7.69
	1.21, 1.28	0.97, 1.02	0.92, 0.97	1.31, 1.40	3.28, 3.48	7.39, 8.01
Signaling	0.92	0.87	0.77	1.40	2.42	2.25
	0.65, 1.30	0.64, 1.18	0.55, 1.08	1.00, 1.97	1.74, 3.35	1.40, 3.62
Too fast	2.76	2.12	1.41	0.68	0.43	0.32
	2.70, 2.83	2.08, 2.16	1.37, 1.44	0.66, 0.70	0.41, 0.44	0.30, 0.34
Changing speeds	1.16	1.02	1.14	1.06	1.13	1.27
	0.91, 1.49	0.82, 1.27	0.90, 1.44	0.81, 1.38	0.85, 1.52	0.82, 1.97
Turning	0.96	0.99	0.98	1.08	1.80	2.45
	0.89, 1.03	0.93, 1.05	0.91, 1.04	1.00, 1.16	1.67, 1.93	2.23, 2.70
Wrong way/side	0.59	0.97	1.00	1.13	1.33	2.45
	0.50, 0.70	0.85, 1.10	0.87, 1.15	0.98, 1.31	1.13, 1.55	2.01, 2.97
Inexperience	1.47	1.39	1.15	1.02	0.94	0.93
	1.40, 1.54	1.33, 1.45	1.10, 1.21	0.96, 1.08	0.88, 1.00	0.84, 1.03
Unfamiliar with road	26.36	2.14	1.04	0.86	0.87	0.55
	20.22, 34.36	1.62, 2.84	0.75, 1.44	0.58, 1.26	0.57, 1.34	0.23, 1.30
Stopped in roadway	1.96	1.51	1.00	0.88	1.46	1.40
	1.57, 2.46	1.22, 1.86	0.78, 1.27	0.67, 1.17	1.11, 1.92	0.92, 2.13
Underriding parked truck	0.56	0.74	0.98	0.93	0.91	0.81
	0.46, 0.68	0.63, 0.86	0.83, 1.15	0.77, 1.11	0.74, 1.12	0.57, 1.14
Getting in/out	0.99	1.55	1.35	1.08	0.80	0.47
	0.59, 1.65	1.02, 2.37	0.86, 2.14	0.64, 1.83	0.42, 1.52	0.12, 1.80
Improper tire press	0.78	0.75	0.76	0.64	0.41	0.51
	0.54, 1.14	0.54, 1.03	0.54, 1.09	0.42, 0.98	0.23, 0.73	0.21, 1.25
Locked wheel /overcorrecting	1.34	1.02	1.05	0.72	0.63	0.45
	1.25, 1.44	0.95, 1.08	0.98, 1.13	0.66, 0.79	0.57, 0.70	0.37, 0.55

Driving errors and situations

The impact of older drivers on the roads will remain a combination of their likelihood to commit errors and the situations they engage in; this requires the examination of the situations in which older drivers are involved. Overall, most crashes occurred during light conditions in fair weather, and crashes involving older drivers were no exception. Furthermore, most crashes happened on straight, level sections of smaller roads (1-2 lanes). These patterns fit drivers of all age categories (see Tables 12 and 13).

Traffic flow and collision variables revealed considerable differences across age groups. Single-vehicle crashes were most predominant among younger drivers, accounting for more than 50% of crashes in the < 20 age category. Proportionally, about half as many drivers aged 80+ had single-vehicle crashes. This situation was reversed for angled crashes, the predominant type of crash for older drivers (see Table 14). These numbers were reflected in the larger number of crashes occurring at intersections for older drivers (47% for 80+ vs. 27% for 16-19).

Although, the overall OR of committing an error was "U"-shaped, the magnitude of the OR varied according to the situations examined (Tables 15, 16, and 17). For example, the OR of a driving error for an 80+ driver in clear weather was 3.67 (99% CI = 3.51, 3.84), while it was 4.53 (99% CI = 4.01, 5.11) in adverse conditions. The risk of an error was 4.61 (99% CI = 4.40, 4.83) during daylight for the older drivers but it was only 2.16 (99% CI = 1.86, 2.50) in dark situations. And, whereas the risk of a crash on dry pavement was close to the overall risk, at 3.68 (99% CI = 3.51, 3.85), it stood at 4.27 (99% CI = 3.86, 4.72) when adverse pavement conditions were present (e.g., wet).

Driving error OR also varied within age groups according to road characteristics. In comparison to the reference group older drivers were 3.50 times (99% CI = 3.33, 3.67) at risk to commit errors on small roads (1-2 lanes), but 5.58 times at risk (99% CI = 4.33, 7.19) on larger roads (5+ lanes). Older drivers had higher error OR on straight and level road sections (where intersections are typically located). Importantly, pavement type revealed OR of 3.81 (99% CI = 3.64, 3.99) for bituminous surfaces, 4.67 (99% CI = 4.08, 5.34) for other hard surfaces, and 1.04 (99% CI = 0.73, 1.48) for loose surfaces.

The results confirmed those of others regarding older drivers and angled crashes (OR = 8.62, 99% CI = 8.05, 9.24) and non-interchange intersections (OR = 7.09, 99% CI = 6.65, 7.56). Interestingly, errors rates were lower at intersections located within interchanges (OR = 4.00, 99% CI = 2.89, 5.55). Problems related to intersections are reflected in OR pertinent to the rural/urban dichotomy. The risk of committing errors was 3.42 (99% CI = 3.22, 3.63) on rural roads, but it stood at 4.39 (99% CI = 4.13, 4.67) on urban roads. The data suggested that problems in situations involving school buses may be worse for older drivers with an OR of 5.32 (99% CI = 2.39, 11.87). And roads with speed limits in the 40 to 50 range may be related to a higher risk of error (OR = 4.83, 99% CI = 4.44, 5.25).

Odds ratios obtained from univariate analyses are susceptible to confounding and produced some puzzling results. For example, the OR for errors among the 80+ drivers on straight road sections was 4.21 (99% CI = 4.03, 4.41) while it was 2.60 (99% CI = 2.31, 2.92) on curved sections. One possible explanation for this discrepancy is that intersections are found mostly on straight sections. Therefore, to examine the independent contributions of the various situations, a multiple logistic regression was conducted for drivers aged 65+.

Table 12. Number and percentage of drivers involved in situations according to driving conditions and age group.

Situation	16-19	20-29	30-39	40-49	50-64	65-79	80+
Weather							
Clear	149423	313006	185697	1134478	111826	76142	22038
	86.9	85.7	84.8	84.1	83.9	85.9	88.3
Adverse	22597	52032	33303	21501	21518	12486	2929
	13.1	14.3	15.2	15.9	16.1	14.1	11.7
Light							
Day	70365	137205	98918	69149	80417	67746	21712
	40.8	37.5	45.1	51.2	60.2	76.3	86.7
Dawn/dusk	6507	15059	9437	6109	5988	3040	641
	3.8	4.1	4.3	4.5	4.5	3.4	2.6
Dark	66031	140238	74045	40352	31141	11289	1569
	38.3	38.4	33.8	29.9	23.3	12.7	6.3
Dark/lighted	29363	72962	36853	19570	16020	6709	1110
	17.0	20.0	16.8	14.5	12.0	7.6	4.4
Surface							
Dry	140421	295166	174305	106413	104848	71822	20823
	81.5	80.7	79.5	78.7	78.5	80.9	83.3
Adverse	31884	70432	44991	28829	28739	16931	4172
	18.5	19.3	20.5	21.3	21.5	19.1	16.7
Construction/maintenance							
No	126094	277473	177767	108391	102566	72251	21637
	98.8	98.5	98.4	98.3	98.3	98.3	98.4
Yes	1478	4261	2892	1925	1765	1295	360
	1.2	1.5	1.6	1.7	1.7	1.8	1.6

Table 13. Number and percentage of drivers involved in situations according to road characteristics and age group.

Situation	16-19	20-29	30-39	40-49	50-64	65-79	80+
Number lanes							
1-2	143061	283439	168598	104136	102947	68870	19195
	84.1	78.6	77.9	78.0	78.1	78.6	77.8
3-4	24549	69212	42778	26155	25851	16777	4812
	14.4	19.2	19.8	19.6	19.6	19.1	19.5
5+	2551	8080	5095	3181	3088	1995	653
	1.5	2.2	2.4	2.4	2.3	2.3	2.6
Road alignment							
Straight	124274	270829	167648	105726	107145	74194	21677
	73.1	74.9	77.0	78.8	81.0	84.2	87.2
Curved	45698	90787	49972	28380	25112	13904	3193
	26.9	25.1	23.0	21.2	19.0	15.8	12.8
Road profile							
Level	116529	257295	154980	95299	94731	64519	18846
	70.4	73.0	72.8	72.7	73.3	74.8	77.4
Not level	49030	95182	57792	35813	34503	21784	5515
	29.6	27.0	27.2	27.3	26.7	25.2	22.6
Pavement type							
Bituminous	141706	299509	180243	111156	109614	74195	21120
	86.9	86.2	85.9	85.8	86.0	87.4	88.1
Concrete/ brick/block	15479	41520	25651	16075	15699	9533	2551
	9.5	11.9	12.2	12.4	12.3	11.2	10.6
Loose	5844	6496	3877	2258	2077	1178	310
	3.6	1.9	1.8	1.7	1.6	1.4	1.3
Rail crossing							
No	171560	364268	218357	134565	132825	88164	24801
	99.3	99.4	99.3	99.3	99.2	99.1	99.0
Yes	1209	2310	1490	953	1070	762	245
	0.7	0.6	0.7	0.7	0.8	0.9	1.0

Table 14. Number and percentage of drivers involved in traffic flow situations and age group.

Situation	16-19	20-29	30-39	40-49	50-64	65-79	80+
Collision manner							
Single vehicle	90074	179372	96474	54669	49357	27877	6334
	52.2	49.0	43.9	40.4	36.9	31.4	25.3
Rear end	7208	21994	15104	9995	10194	6097	1427
	4.2	6.0	6.9	7.4	7.6	6.9	5.7
Head on	33101	76765	50341	32748	31922	17468	3615
	19.2	21.0	22.9	24.2	23.9	19.7	14.4
Rear/rear	70	178	124	67	87	40	13
	0.0	0.0	0.1	0.0	0.1	0.0	0.1
Angle	37982	78186	51211	33702	38059	35277	13261
	22.0	21.3	23.3	24.9	28.5	39.7	53.0
Sideswipe	4244	9802	6375	4148	4128	2130	389
	2.5	2.7	2.9	3.1	3.1	2.4	1.6
Junction							
No	125733	265845	155785	94340	88701	49405	10643
	73.3	73.0	71.3	70.1	66.8	56.0	42.9
Non Interchange	43896	92519	58684	37815	41855	37343	10734
	25.6	25.4	26.9	28.1	31.5	42.4	55.4
Interchange	1946	5949	3920	2441	2288	1428	430
	1.1	1.6	1.8	1.8	1.7	1.6	1.7
Land use							
Rural	93415	183124	113890	71198	70016	47298	12800
	60.2	54.8	55.6	56.9	57.5	57.3	53.9
Urban	61717	150984	91058	53865	51710	35253	10927
	39.8	45.2	44.4	43.1	42.5	42.7	46.1
Access							
Unlimited	98669	204064	130255	77768	72961	53210	16733
	84.0	78.2	76.6	74.7	74.9	76.3	79.2
Limited	18772	56722	39734	26377	24489	16546	4395
	16.0	21.8	23.4	25.3	25.1	23.7	20.8
School bus							
No	155488	334915	205486	125350	122019	82735	23766
	99.8	99.8	99.8	99.8	99.8	99.7	99.6
Yes	379	599	368	291	298	241	99
	0.2	0.2	0.2	0.2	0.2	0.3	0.2
Speed limit							
< 40	39976	82752	46271	26962	27272	19728	6671
	24.8	24.0	22.2	21.0	21.6	23.4	27.9
40-54	39839	84657	51859	31511	29982	21357	6490
	24.7	24.6	24.8	24.5	23.8	25.3	27.1
55-64	80612	175372	109158	68927	67756	42474	10623
	50.0	50.9	52.3	53.6	53.7	50.4	44.4
65+	828	1841	1525	1249	1189	790	158
	0.5	0.5	0.7	1.0	0.9	0.9	0.7
Traffic direction							
One-way	52345	96520	45478	27812	32278	17222	3627
	30.7	26.7	20.9	20.7	24.4	19.6	14.7
Divided	29333	84635	55169	34926	33140	23000	6593
	17.2	23.4	25.4	26.0	25.0	26.1	26.6
Not divided	89087	180949	116702	71360	66930	47733	14525
	52.2	50.0	53.7	53.2	50.6	54.3	58.7

Table 15. Odds ratios and 99% confidence intervals of committing a driving error according to driving conditions and age group.

Situation	16-19	20-29	30-39	50-64	65-79	80+
Weather						
Clear	2.43	1.72	1.22	0.98	1.67	3.67
	2.38, 2.48	1.69, 1.75	1.20, 1.25	0.96, 1.00	1.63, 1.71	3.51, 3.84
Adverse	2.73	1.73	1.22	1.05	1.76	4.53
	2.59, 2.87	1.66, 1.81	1.17, 1.28	1.00, 1.10	1.66, 1.86	4.01, 5.11
Light						
Day	2.58	1.51	1.09	1.15	2.09	4.61
	2.51, 2.66	1.47, 1.54	1.06, 1.12	1.12, 1.18	2.03, 2.15	4.40, 4.83
Dawn/dusk	2.62	1.80	1.27	1.01	1.59	2.90
	2.38, 2.88	1.66, 1.94	1.17, 1.38	0.92, 1.11	1.42, 1.79	2.29, 3.67
Dark	2.28	1.80	1.33	0.80	1.01	2.16
	2.20, 2.36	1.75, 1.86	1.29,1.37	0.77, 0.83	0.96, 1.07	1.86, 2.50
Dark/lighted	2.24	1.76	1.30	0.88	1.18	2.19
	2.14, 2.36	1.68, 1.83	1.24, 1.36	0.83, 0.93	1.10, 1.27	1.85, 2.59
Surface						
Dry	2.42	1.72	1.23	0.98	1.66	3.68
	2.37, 2.47	1.69, 1.76	1.21, 1.25	0.96, 1.00	1.62, 1.70	3.51, 3.85
Adverse	2.69	1.69	1.21	1.03	1.75	4.27
	2.58, 2.81	1.63, 1.76	1.16, 1.26	0.99, 1.07	1.67, 1.84	3.86, 4.72
Construction/maintenance						
No	2.55	1.75	1.24	0.99	1.70	3.80
	2.49, 2.60	1.72, 1.78	1.22, 1.27	0.97, 1.01	1.66, 1.74	3.63, 3.98
Yes	2.52	1.82	1.32	0.98	1.63	4.65
	2.09, 3.03	1.58, 2.10	1.14, 1.54	0.83, 1.16	1.35, 1.96	3.23, 6.69

Table 16. Odds ratios and 99% confidence intervals of committing a driving error according to road characteristics and age group.

Situation	16-19	20-29	30-39	50-64	65-79	80+
Number of lanes						
1-2	2.52	1.77	1.23	0.97	1.59	3.50
	2.46, 2.57	1.74, 1.81	1.21, 1.26	0.95, 0.99	1.55, 1.63	3.33, 3.67
3-4	2.06	1.60	1.20	1.07	2.06	5.10
	1.97, 2.16	1.54, 1.66	1.15, 1.25	1.02, 1.12	1.95, 2.16	4.64, 5.61
5+	1.94	1.47	1.19	1.15	2.11	5.58
	1.69, 2.23	1.32, 1.65	1.06, 1.35	1.00, 1.31	1.81, 2.45	4.33, 7.19
Road alignment						
Straight	2.24	1.57	1.16	1.05	1.87	4.21
	2.19, 2.29	1.54, 1.60	1.14, 1.19	1.03, 1.08	1.83, 1.92	4.03, 4.41
Curved	3.28	2.23	1.42	0.81	1.15	2.60
	3.14, 3.43	2.15, 2.32	1.36, 1.47	0.77, 0.84	1.09, 1.22	2.31, 2.92
Road profile						
Level	2.36	1.68	1.21	1.01	1.78	4.01
	2.31, 2.42	1.65, 1.71	1.19, 1.24	0.99, 1.04	1.73, 1.82	3.82, 4.21
Not level	2.77	1.84	1.25	0.93	1.47	3.18
	2.66, 2.87	1.78, 1.90	1.21, 1.30	0.90, 0.97	1.41, 1.54	2.92, 3.47
Pavement type						
Bituminous	2.48	1.74	1.23	0.99	1.68	3.81
	2.43, 2.53	1.71, 1.78	1.20, 1.25	0.97, 1.01	1.64, 1.73	3.64, 3.99
Concrete/	2.27	1.64	1.22	1.05	1.84	4.67
brick/block	2.14, 2.41	1.56, 1.72	1.16, 1.28	0.99, 1.12	1.72, 1.97	4.08, 5.34
Loose	2.07	1.14	1.11	0.78	0.88	1.04
	1.78, 2.42	1.22, 1.63	0.96, 1.30	0.65, 0.92	0.72, 1.08	0.73, 1.48
Rail crossing						
No	2.48	1.73	1.22	0.99	1.68	3.79
	2.43, 2.53	1.70, 1.75	1.20, 1.25	0.97, 1.01	1.65, 1.72	3.64, 3.96
Yes	1.50	1.42	1.12	1.15	1.11	1.60
	1.06, 2.13	1.05, 1.92	0.82, 1.54	0.82, 1.62	0.76, 1.61	0.86, 2.99

Table 17. Odds ratios and 99% confidence intervals of committing a driving error according to traffic flow situations and age group.

Situation	16-19	20-29	30-39	50-64	65-79	80+
Collision						
Single	2.06	1.52	1.17	0.89	1.07	1.51
vehicle	2.00, 2.13	1.48, 1.56	1.13, 1.20	0.86, 0.92	1.03, 1.12	1.40, 1.63
Rear end	2.06	1.85	1.27	0.99	1.35	2.72
	1.90, 2.24	1.74, 1.98	1.19, 1.37	0.91, 1.07	1.24, 1.48	2.34, 3.15
Head on	2.83	1.96	1.34	0.96	1.46	3.88
	2.72, 2.95	1.89, 2.03	1.29, 1.39	0.92, 1.00	1.39, 1.53	3.51, 4.28
Rear/rear	2.70	1.43	1.63	0.82	1.28	3.06
	1.09, 6.73	0.66, 3.08	0.72, 3.66	0.33, 2.00	0.44, 3.69	0.61, 15.33
Angle	2.29	1.45	1.08	1.29, 1.24,	3.35	8.62
	2.20, 2.38	1.40, 1.50	1.04, 1.12	1.34	3.22, 3.50	8.05, 9.24
Sideswipe	2.87	1.95	1.26	1.04	1.69	3.44
	2.55, 3.22	1.77, 2.15	1.13, 1.40	0.92, 1.17	1.47, 1.95	2.59, 4.57
Junction						
No	2.62	1.81	1.27	0.91	1.24	2.35
	2.55, 2.68	1.77, 1.85	1.24, 1.30	0.89, 0.93	1.20, 1.28	2.22, 2.49
Non	2.16	1.48	1.09	1.22	2.91	7.09
Interchange	2.08, 2.24	1.43, 1.53	1.05, 1.13	1.17, 1.26	2.80, 3.02	6.65, 7.56
Interchange	2.29	1.83	1.26	1.15	2.03	4.00
	1.94, 2.70	1.61, 2.08	1.11, 1.44	0.99, 1.34	1.69, 2.42	2.89, 5.55
Land use						
Rural	2.60	1.83	1.26	0.94	1.51	3.42
	2.53, 2.68	1.79, 1.87	1.23, 1.29	0.91, 0.97	1.46, 1.55	3.22, 3.63
Urban	2.35	1.70	1.22	1.05	1.96	4.39
	2.28, 2.42	1.65, 1.74	1.18, 1.25	1.02, 1.09	1.89, 2.03	4.13, 4.67
Access						
Unlimited	2.57	1.75	1.25	0.98	1.66	3.72
	2.50, 2.64	1.71, 1.79	1.22, 1.28	0.95, 1.01	1.61, 1.71	3.53, 3.92
Limited	2.49	1.75	1.24	1.02	1.87	4.42
	2.36, 2.62	1.68, 1.82	1.19, 1.29	0.98, 1.07	1.78, 1.97	3.99, 4.90
School bus						
No	2.50	1.74	1.23	0.99	1.68	3.78
	2.45, 2.55	1.71, 1.77	1.21, 1.25	0.97, 1.01	1.65, 1.72	3.62, 3.95
Yes	2.70	1.33	0.96	1.21	2.06	5.32
	1.75, 4.15	0.92, 1.93	0.64, 1.43	0.79, 1.86	1.28, 3.30	2.39, 11.87
Speed limit						
< 40	2.49	1.71	1.21	1.02	1.72	3.31
	2.39, 2.60	1.65, 1.78	1.16, 1.26	0.97, 1.06	1.64, 1.80	3.07, 3.58
40-54	2.42	1.69	1.20	1.00	1.94	4.83
	2.32, 2.52	1.63, 1.75	1.15, 1.24	0.95, 1.04	1.85, 2.03	4.44, 5.25
55-64	2.60	1.80	1.27	0.97	1.59	3.84
	2.53, 2.68	1.76, 1.84	1.23, 1.30	0.95, 1.00	1.54, 1.64	3.60, 4.11
65+	3.22	1.76	1.19	1.04	1.58	3.88
	2.45, 4.21	1.45, 2.14	0.98, 1.45	0.84, 1.29	1.24, 2.02	2.19, 6.87
Traffic direction						
One-way	2.40	1.72	1.16	0.97	1.51	3.25
	2.31, 2.50	1.66, 1.78	1.12, 1.21	0.93, 1.01	1.43, 1.59	2.93, 3.61
Divided	2.06	1.56	1.18	1.07	2.05	5.17
	1.98, 2.15	1.51, 1.62	1.14, 1.22	1.02, 1.11	1.96, 2.14	4.74, 5.63
Not	2.63	1.80	1.27	0.96	1.59	3.46
divided	2.56, 2.70	1.76, 1.84	1.24, 1.30	0.93, 0.99	1.54, 1.64	3.28, 3.66

Driving errors, situations, and drivers aged 65+

All variables discussed above were included in a multiple logistic regression with any driving error as the dependent variable. Data for 19,374 drivers aged 65+ with complete data were entered in the analysis. The data confirmed that some situations, after controlling for others, are related to lower or higher risk of error (Table 18). Notably, nighttime conditions and higher numbers of lanes were associated with lower OR. However, curved sections, concrete/brick/block pavement surfaces, intersections, and roads with higher speed limits were associated with higher OR.

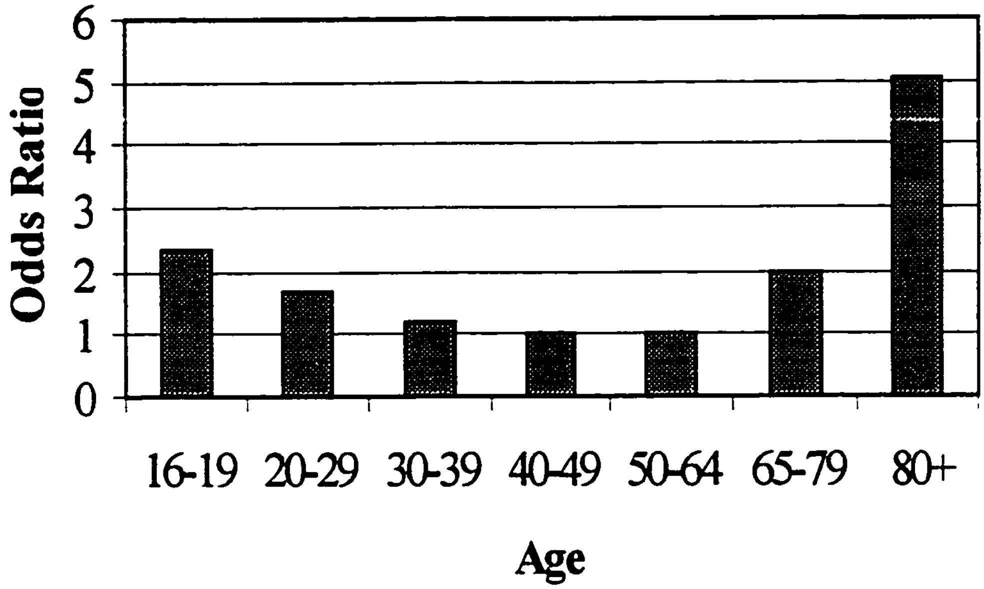
Table 18. Odds ratios of committing a driving error and 99% CI based on multiple regression analysis. The reference category is in brackets.

Situation	OR	99% CI
Weather (clear)		
Adverse	1.15	0.91, 1.44
Light (day)		
Dawn/dusk	0.72	0.55, 0.95
Dark	0.79	0.66, 0.94
Dark/lighted	0.63	0.51, 0.78
Surface (dry)		
Adverse	1.05	0.87, 1.28
Construction/maintenance (no)		
Yes	1.45	0.99, 2.14
Number of lanes (1-2)		
3-4	0.92	0.82, 1.05
5+	0.75	0.57, 0.98
Road alignment (straight)		
Curved	1.32	1.14, 1.53
Road profile (level)		
Not level	0.94	0.84, 1.05
Pavement type (bituminous)		
Concrete/brick/block	1.22	1.04, 1.44
Loose	0.80	0.53, 1.20
Collision manner (none)		
Rear end	0.42	0.35, 0.51
Head on	0.75	0.65, 0.86
Rear/rear	1.53	0.09, 26.20
Angle	1.69	1.46, 1.95
Sideswipe	0.59	0.42, 0.82
Junction (none)		
Non-Interchange	1.39	1.23, 1.58
Interchange	1.03	0.73, 1.45
Land use (rural)		
Urban	0.92	0.81, 1.04
Access (unlimited)		
Limited	1.06	0.93, 1.22
School bus (none)		
Yes	1.64	0.73, 3.65
Speed limit (< 40)		
40-54	1.26	1.11, 1.44
55-64	1.54	1.33, 1.77
65+	2.04	1.11, 3.75
Traffic direction (one-way)		
Divided	1.32	1.00, 1.73
Not divided	1.07	0.82, 1.38

Driving errors and age

The last analysis showed that committing errors is dependent on the situations older drivers are involved in. Ignoring the situation confounds driving error and exposure. Consequently, the overall odds of committing driving errors across age groups were calculated taking these situations into consideration. A multivariate logistic regression with situational variables and age categories was conducted to examine the independent contribution of age after removal of the effect of situations. The odds ratios paralleled those found earlier with the typical "U"-shaped curve. However, after controlling for situations, drivers aged 80+ were five-times more at risk to commit errors than drivers in the reference category (OR = 5.05, 99% CI = 4.80, 5.30). In comparison, the OR for the other age categories were, for drivers aged 16-19 2.34 (99% CI = 2.28, 2.40), 1.68 (99% CI = 1.65, 1.72) for the 20-29, 1.23 (99% CI = 1.20, 1.25) for the 30-39, 1.03 (99% CI = 1.01, 1.06) for those 50-64, and 1.96 (99% CI = 1.91, 2.02) for drivers aged 65-79. These OR are depicted in Figure 8.

Figure 8. Adjusted odds ratio of committing a driving error by age. The reference age category is 40-49 (OR = 1.0).



Discussion

The findings reported in this chapter are important for several reasons. First, they supported others' findings. Second, they provided a higher level of detail regarding the type of errors committed by older drivers. And third, they supported a relationship between situational variables and driving errors.

The type of errors committed by drivers supported the belief that younger drivers operate their vehicles in an aggressive fashion whereas older drivers commit errors of attention/perception (Clarke, Ward, & Jones. 1998; Kennedy, Isaac, & Graham. 1996; McGwin & Brown. 1999; Mortimer & Fell. 1989; Solnick & Hemenway. 1997; Zhang, Fraser, Clarke, & Mao. 1998; Zobeck, Grant, Stinson, & Bertolucci. 1994). The most predominant type of error committed by younger drivers, driving too fast for the conditions (36%), was infrequent among the oldest drivers (6%). However, nearly half of drivers 80+ (47%) ignored road signs/warnings, compared to 13% for the youngest drivers. Other researchers, albeit with a small sample, reported that a higher proportion of older drivers, compared to younger drivers, committed errors of observation (Hakamies-Blomqvist. 1993). The results presented here confirmed those findings and point to road signs/warnings as an important issue.

The data analyzed herein confirmed that older drivers (and other drivers alike) are more likely to be involved in daylight crashes, under good driving conditions. However, contrary to younger drivers who are more likely to be involved in single-vehicle crashes, older drivers are more likely to be involved in multiple-vehicle crashes at intersections. The results confirmed wellestablished patterns reported by others (Hakamies-Blomqvist. 1993; McGwin & Brown. 1999; Pruesser, Williams, Ferguson, Ulmer, & Weinstein. 1998; Ryan, Legge, & Rosman. 1998; Viano, Culver, Evans, Frick, & Scott. 1990; Zhang, Fraser, Clarke, & Mao. 1998).

The results of the multivariate regression suggest that drivers 65+ are not more at risk to commit driving errors under poor driving conditions than under good conditions. However, older drivers were less at risk to commit errors under nighttime conditions than daytime conditions. This observation is new, and suggests that either, older drivers adjust to changing driving conditions, or only better drivers engage in driving under less than ideal conditions. This remains to be elucidated.

Road characteristics affected the risk of errors in older drivers. Compared to small roads, drivers aged 65+ were 25% less at risk to commit driving errors on roads with five or more lanes. However, older drivers were more at risk to make errors on curved road sections compared to straight ones, and on concrete/brick/block types of pavements compared to bituminous surfaces.

The results regarding curved road sections highlight that controlling for exposure is crucial. Results based on univariate OR suggested that older drivers may be at increased risk of committing driving errors on straight road sections compared to curved ones. However, after controlling for urban/rural settings and junction types, and comparing straight road sections directly against curved sections, the risk of a driving error was higher for curved sections.

Data on collision manner and junctions showed that intersections are a likely source of driving errors compared to non-intersection situations. The driving error OR at intersections was 3 for drivers aged 65 to 79, and 7 for drivers 80+. Consistently, Retting and colleagues found that drivers aged 70 to 79 were three times more at risk to run red lights than drivers aged 40-49, and drivers aged 80+ were 4.5 times more at risk (Retting, Ulmer, & Williams. 1999). The exact problem with intersections is unclear. Some data suggest that older drivers fail to notice incoming traffic, or notice incoming traffic too late to make successful avoidance maneuvers (Hakamies-Blomqvist. 1993). Others have shown that older drivers take longer to merge into traffic (Keskinen, Ota, & Katila. 1998). And, whereas some report that older drivers may underestimate the speed of incoming vehicles (Keskinen, Ota, & Katila. 1998) others do not report such an effect (Scialfa, Guzy, Leibowitz, Garvey, & Tyrrell. 1991). Further dissection of intersection crashes is highly desirable.

The analyses presented in this chapter also demonstrated that the risk of driving errors is aggravated with increased speed limits but is unaffected by rural or urban conditions when other variables are controlled for. This finding has important policy implications. A study based on 40 U.S. states where speed limits were increased in the late 1980's showed increased fatalities by as much as 15% on some interstate highways (Garber & Graham. 1990). Whereas other data suggested that increasing speed limits had overall beneficial effects by channeling more drivers from regional roads towards the safer highways (Houston. 1999), the data presented here suggest that increasing speed limits may have an adverse effect on older drivers. Clearly, an understanding of the impact of speed limits on driving errors and fatalities is required.

It is reasonable to assume that changes to road characteristics may reduce the risk of fatal errors (Marottoli. 1997). For example curved sections may be better indicated, and possibly, the curvature of future roads adapted to an aging population. Although some evidence suggests that rain itself, and not wet pavements may be problematic (Andrey & Yagar. 1993), the use of concrete may be eliminated in areas where wet pavement is a frequent occurrence. Intersections may be improved, and clearly, a lowering of speed limits may result in fewer driving errors by older drivers.

Few studies have been designed to study safety initiatives aimed at the driving environment. Nonetheless, some support for reduced crash rates following driver training (Gregersen, Brehmer, & Moren. 1996) and engineering changes (Elvik. 1993; Kulmala. 1994) has been obtained. Work to make intersections safer is important to reduce fatalities because 50% of crashes involving older adults occurred at intersections, and because older drivers were 39% more likely to initiate crashes at intersections compared to non-intersection settings. A Finnish study reported crash reductions following engineering changes to improve signaling and lighting and reduce speed at intersections (Kulmala. 1994). These results are consistent with findings regarding road signs/warnings reported in this chapter. Together, these results support potential causal links between these situational variables and crashes, and confirm that lives may be saved, by targeting situations where older drivers are most likely to commit driving errors.

Little work has been conducted to determine the impact of better road signs on drivers, yet it is reasonable to assume that they would reduce the risk of crashes (Marottoli. 1997). The results presented in this chapter showed that about 50% of errors committed by drivers aged 80+ were related to signs and warnings, and that the OR of such errors was eight times that of drivers aged 40 to 49. Road signs and warning may hold an important safety potential, and may also affect mobility if older drivers feel uncomfortable driving because of the inadequacy of road signs and warnings.

This hypothesis has not been tested. One study aimed at identifying determinants of mileage reduction and driving cessation focused only on drivers characteristics (Marottoli, Ostfeld, Merrill, & et al. 1993). However, another study found that older drivers who experienced difficulties finding their way around drove less (Burns. 1999). Although this relationship between "wayfinding" and mobility may not be causally linked to road signs and warnings it remains a worthy possibility to explore. Furthermore, driving cessation is related to depression symptoms independently of age, gender and health (Marottoli, Mendes de Leon, Glass, et al. 1997). Better road signs and warnings may improve the safety and independence of older adults, and possibly improve other health outcomes indirectly.

Chapter 7. Associations between driver characteristics and driving errors

Introduction

The importance of age regarding driving errors has been demonstrated at earlier. However, age on its own is often just a marker for other characteristics. For example, young drivers may be healthy but inexperienced. Older drivers may be unhealthy but experienced. Middle age drivers may be both healthy and experienced. These other driver characteristics may be related to crash initiation, and require a detailed examination. Specifically, gender, previous driving record, alcohol and drug/medication use, and the number of passengers in the vehicle at the time of the crash may have a relationship with driving errors.

Gender of drivers involved in, and responsible for crashes

On a per driver basis, men may be as much as three times more likely to be involved in crashes than women (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993; Li, Baker, Langlois, & Kelen. 1998). However, after adjustment for distance traveled, serious discrepancies between investigative teams were found. One research team found roughly equivalent crash rates between men and women (Li, Baker, Langlois, & Kelen. 1998). However, this equivalence may be misleading because another group reported equivalent crash rates across gender but also a gender by age interaction, with young men crashing more often than young women, and the reverse for older drivers (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993). Yet others found a higher rate of fatal crashes for men but higher non-fatal crash rates for women (Massie, Campbell, & Williams. 1995). Others found no differences between men and women for police-reported (Massie, Green, & Campbell. 1997) and self-reported crashes (Lourens, Vissers, & Jessurun. 1999). The divergence highlighted by these studies may stem for the selection of different data sources.

Previous driving record

A driver's previous driving record is, potentially, predictive of future incidents. In three studies, the risk of crash involvement was doubled among drivers who had previous convictions, irrespective of age, gender, and distance traveled (Chipman & Morgan. 1975; Lourens, Vissers, & Jessurun. 1999; Sims, McGwin, Allman, Ball, & Owsley. 2000).

Responsibility for crashes was doubled in drivers with a prior license suspension but not affected by prior speeding convictions (Perneger & Smith. 1991). Drivers with currently suspended/revoked licenses were almost four times more likely to be responsible for crashes (DeYoung, Peck, & Helander. 1997). Unfortunately, the findings of these two studies were not adjusted for age, gender, and alcohol use, and were limited to crashes including two vehicles.

Alcohol and drug/medications

Alcohol use is by far the best predictor of crash involvement and crash responsibility (Perneger & Smith. 1991). It is, however, a problem mostly limited, but not exclusively, to young male drivers (Dobson, Brown, Ball, Powers, & McFadden. 1999; Isaac, Kennedy, & Graham. 1995; Popkin. 1991; Zador. 1991; Zhang, Fraser, Clarke, & Mao. 1998). Historically, 85% of the drinking and driving problem has been attributed to young male drivers (Isaac, Kennedy, & Graham. 1995) and less than one percent to drivers aged 65 and over (Zobeck, Grant, Stinson, & Bertolucci. 1994).

The causal link between alcohol use and fatal crashes is overwhelming. The OR of committing a driving error leading to a fatal crash was 11.53 (95% CI = 9.57, 13.89) among drivers who reportedly used alcohol, according to the investigating officer, compared to drivers who did not (Perneger & Smith. 1991). In a subset of drivers for whom BAC had been tested, there was a positive relationship between BAC and the OR for driving errors, reaching 36.24 (95% CI = 18.88, 69.60) for drivers with a BAC of .25 or more (Perneger & Smith. 1991).

Data on drug and medication use, and their relationships to crashes are more nebulous. Although the potential association between psychoactive drugs and crashes is biologically plausible, convincing evidence is not available. The most studied class of medications is the benzodiazepines. Benzodiazepines can adversely affect memory and cognition (Foy, O'Connell, Henry, Kelly, Cocking, & Halliday. 1995; Kruse. 1990; Larson, Kukull, Buchner, & Reifler. 1987;

Nelson & Chouinard. 1999). Associations between benzodiazepines (especially long-acting) and crash involvement (Gilley, Wilson, Bennett, Stebbins, & et al. 1991; Hemmelgarn, Suissa, Huang, Boivin, & Pinard. 1997; Leveille, Buchner, Koepsell, McCloskey, Wolf, & Wagner. 1994), and crash initiation (Arditti, Bourdon, David, Lanze, Thirion, & Jouglard. 1993), were found. However, these studies did not control for alcohol use. In a study of 495 injurious crashes, benzodiazepines were associated with a 50% increased risk in crash involvement regardless of alcohol use (Ray, Fought, & Decker. 1992). However, in a study of crash initiation with nearly 3,000 cases where alcohol and benzodiazepine use were examined simultaneously, benzodiazepine use was not significantly related to crash initiation but alcohol use was (Benzodiazepine/Driving Collaborative Group. 1993).

Data regarding other medication classes are equally clashing. Opioid analgesics were associated with crash involvement in one study (Leveille, Buchner, Koepsell, McCloskey, Wolf, & Wagner. 1994) but not another (Ray, Fought, & Decker. 1992). Non-steroidal anti-inflammatory analgesics were statistically associated with crash involvement at the $p < .05$ level, but the association may have been spurious given that 13 classes of medications were compared (Foley, Wallace, & Eberhard. 1995). Finally, in two studies antidepressants were associated with crash involvement (Leveille, Buchner, Koepsell, McCloskey, Wolf, & Wagner. 1994; Ray, Fought, & Decker. 1992), but not according to the results of another one (Foley, Wallace, & Eberhard. 1995).

To resolve these discrepancies future studies require the distinction between crash involvement and crash initiation. Furthermore, to derive precise estimates of the association between drug/medication use and crashes, large sample sizes are required.

Presence of passengers

The presence of passengers was associated with a doubling of crash rates among male and female drivers aged 16 to 19, but not among drivers aged 20 to 59 (Doherty, Andrey, & MacGregor. 1998). Similarly, among drivers aged 16 and 17, the risk of death in a crash, increased with the number of passengers, independently of gender and time of day, reaching 2.82 (95% CI = 2.27, 3.50) for a 16 year old driver with three passengers (Chen, Baker, Braver, & Li. 2000).

On the other hand, the crash rates of female drivers aged 25 to 59 were half that of drivers without passengers (Doherty, Andrey, & MacGregor. 1998). However, no beneficial effect of passengers was found for men. Associations between the presence of passengers and lower crash involvement rates were reported for older adults with cognitive impairment (Bédard, Molloy, & Lever. 1998; Shua-Haim & Gross. 1996). The crash involvement among cognitively impaired older adults was twice as high for those who drove alone compared to those who did not drive alone (Bédard, Molloy, & Lever. 1998). However, the investigators did not control for exposure and did not have data on crash initiation.

The methodological limitations outlined in this section highlight the need for a more comprehensive study of driver variables that may predict crash initiation. However, crashes are rare events, and collection of data on the multiple variables that may affect their rates is essential to a better comprehension of the relationship between drivers and crashes. For these reasons, the FARS database will become a crucial tool to study these issues.

Methods

Data on previous driving record, alcohol and drug/medication use, and number of passengers were extracted from the FARS database for each driver. All data have been collected since 1975, with the exception of alcohol use, which were mostly missing for 1975 and 1976, and drug use, which have been collected with sufficient details since 1991.

The driving record included information for the three-year period immediately prior to the current crash. The number of prior crashes (irrespective of responsibility), license suspensions, and convictions (not violations) for driving while impaired (DWI), speeding (including driving too slowly), and other harmful convictions (e.g., running a red light) were recorded. The actual blood alcohol concentration (BAC) was reported if tested. Drug use was categorized into one of the following categories: not tested/unknown, no drugs, narcotics (e.g., codeine, heroin, morphine), depressants (e.g., barbiturates, benzodiazepines, chloral hydrate), stimulants (e.g., amphetamine, cocaine), hallucinogens (e.g., amphetamine variants, lysergic acid, mescaline), cannabinoids (e.g., hashish, marijuana), phencyclidines (PCP, ethylamine), anabolic steroids (e.g., methandranone, testosterone), inhalants (paint removers, nitrous oxide, chloroform), and others. Drug results excluded the use of nicotine, aspirin, alcohol, and all drugs administered for life-saving purposes.

The analytical plan mirrored that used for chapter 5. Briefly, descriptive data were obtained by age category. The OR of committing a driving error were calculated using drivers in the age 40-49 category as reference unless specified.

For each variable based on the record of the past three years, drivers aged 40 to 49 with no recorded instances of the variables examined were used as reference. For example, in calculating the OR of making driving errors according to age category and number of crashes in the past three years, drivers aged 40 to 49 with no recorded crashes were used as the reference category. Statistical significance was set at $p \leq .01$.

Results

Age, gender, and crash initiation

The proportion of male and female drivers who committed errors differed according to age groups. The distributions for both groups of drivers follow a "U"-shaped pattern (Table 19). However, proportionally fewer young women committed driving errors than young men. This difference was especially salient for drivers aged less than 30. From the 50-64 age category onward, a higher proportion of women committed errors.

The higher risk of younger male drivers to commit errors was also evidenced with the OR compared to male drivers aged 40 to 49. These statistics, presented in Table 20, showed that among male drivers, those aged 50 to 64 had the lowest risk to commit driving errors. However, female drivers aged 30 to 64 had an equivalent or reduced risk of committing errors compared to the better male drivers.

Table 19. Number of drivers (percentage) who committed errors by age category and gender.

Gender	< 20	20-29	30-39	40-49	50-64	65-79	80+
Male	92907	181642	89308	48258	46082	36767	14261
	(71.7)	(64.1)	(55.1)	(49.3)	(47.5)	(59.0)	(77.5)
Female	27334	43585	27404	16898	17927	17397	5230
	(63.1)	(52.2)	(47.2)	(44.8)	(48.5)	(65.1)	(78.5)

Table 20. Odds ratios and 99% CI of committing a driver error with reference to male drivers aged 40-49.

Gender	< 20	20-29	30-39	40-49	50-64	65-79	80+
Male	2.61	1.84	1.27	1.00	0.93	1.48	3.55
	2.55, 2.67	1.80, 1.88	1.24, 1.29	1.00, 1.00	0.91, 0.95	1.44, 1.52	3.38, 3.72
Female	1.76	1.12	0.92	0.84	0.97	1.92	3.76
	1.71, 1.81	1.10, 1.15	0.90, 0.95	0.81, 0.86	0.94, 1.00	1.85, 1.99	3.47, 4.06

Driving record

The majority of drivers involved in crashes had not been previously involved in another crash during the preceding three year period. Data on drivers aged less than 20 are difficult to compare to that of other age groups because many of these drivers have not had the opportunity to drive for long enough to accumulate crashes, license suspensions and violations during the preceding three years. Nonetheless, there appears to be a "U"-shaped relationship between age category and crashes, with a higher proportion of drivers at the extreme age categories with reported crashes during the previous three years (Table 21). Among the oldest drivers, 17.1% experienced a crash in the previous three year period, compared to 23.1% of drivers aged 20 to 29.

This type of relationship does not apply to license suspensions, and convictions. Decreasing proportions of drivers with license suspensions and convictions were found (Table 21 and 22). These data substantiate differences in the driving style of younger and older drivers. For example, only 0.2% of drivers aged 80+ had previous DWI convictions compared to 6.6% of drivers aged 20 to 29, a 33-fold difference. Similarly, only 4.1% of the older drivers had speeding-related convictions (which may include driving too slowly). This proportion was 26.9% for drivers aged 20 to 29, a seven-fold difference.

Table 21. Number of driving incidents recorded for past three years (percentage within age group).

Variable	< 20	20-29	30-39	40-49	50-64	65-79	80+
Previous crash							
0	135329	272721	176068	111489	111237	74860	20410
	(81.5)	(76.9)	(82.4)	(84.4)	(85.1)	(86.0)	(82.9)
1	23692	61239	29902	16683	15873	10050	3468
	(14.3)	(17.3)	(14.0)	(12.6)	(12.1)	(11.5)	(14.1)
2	5449	15316	5999	3045	2754	1674	592
	(3.3)	(4.3)	(2.8)	(2.3)	(2.1)	(1.9)	(2.4)
3+	1598	5313	1810	893	861	509	145
	(1.0)	(1.5)	(0.8)	(0.7)	(0.7)	(0.6)	(0.6)
Previous suspension							
0	155267	296083	187181	121193	124651	85755	24430
	(93.1)	(83.2)	(87.1)	(91.2)	(94.9)	(97.9)	(98.6)
1	8015	34978	16314	7048	4390	1300	269
	(4.8)	(9.8)	(7.6)	(5.3)	(3.3)	(1.5)	(1.1)
2	1997	12552	5872	2516	1391	322	58
	(1.2)	(3.5)	(2.7)	(1.9)	(1.1)	(0.4)	(0.2)
3+	1472	12354	5534	2072	935	177	16
	(0.9)	(3.5)	(2.6)	(1.6)	(0.7)	(0.2)	(0.1)

Table 22. Number of convictions reported for past three years (percentage within age group).

Conviction	< 20	20-29	30-39	40-49	50-64	65-79	80+
DWI							
0	164011	332652	201521	126134	126913	86511	24733
	(98.4)	(93.4)	(93.8)	(95.0)	(96.6)	(98.8)	(99.8)
1	2417	19160	10720	5289	3496	855	39
	(1.4)	(5.4)	(5.0)	(4.0)	(2.7)	(1.0)	(0.2)
2	277	3345	2047	1066	713	145	0
	(0.2)	(0.9)	(1.0)	(0.8)	(0.5)	(0.2)	(0.0)
3+	50	821	620	352	250	45	1
	(0.0)	(0.2)	(0.3)	(0.3)	(0.2)	(0.1)	(0.0)
Speeding							
0	126983	224769	156732	104675	110586	80563	23750
	(76.1)	(63.1)	(72.9)	(78.8)	(84.2)	(92.0)	(95.9)
1	25956	75779	38287	19644	154453	5737	891
	(15.6)	(21.3)	(17.8)	(14.8)	(11.8)	(6.6)	(3.6)
2	8730	31720	12290	5532	3637	934	101
	(5.2)	(8.9)	(5.7)	(4.2)	(2.8)	(1.1)	(0.4)
3+	5086	23712	7599	2987	1696	322	31
	(3.0)	(6.7)	(3.5)	(2.2)	(1.3)	(0.4)	(0.1)
Other harmful							
0	133008	253076	174033	113305	114897	78932	22088
	(79.8)	(71.1)	(81.0)	(85.3)	(87.5)	(90.1)	(89.2)
1	22639	64557	28943	14499	12732	6941	2222
	(13.6)	(18.1)	(13.5)	(10.9)	(9.7)	(7.9)	(9.0)
2	6833	22125	7380	3294	2488	1207	361
	(4.1)	(6.2)	(3.4)	(2.5)	(1.9)	(1.4)	(1.5)
3+	4275	16214	4553	1743	1256	477	102
	(2.6)	(4.6)	(2.1)	(1.3)	(1.0)	(0.5)	(0.4)

To determine the relationship between driving record and driving errors, data on driving record were re-coded to have sufficient numbers of observations for each cell. Previous crashes, suspensions, speeding convictions and other harmful convictions were categorized as none, one, and two or more. Previous DWI convictions were dichotomized as none versus any. The OR were computed using drivers aged 40 to 49 with a clean record as reference.

The OR of committing driving errors according to previous crash history and age category were consistent with the "U"-shaped curves found earlier. Higher risks of errors were found for the youngest and oldest drivers. Overall, the OR increased with the number of previous incidents, irrespective of the nature of the incident and the age category. The OR of committing errors are presented in tables 23 and 24.

Table 23. Odds ratios (top row) and 99% CI (bottom row) of committing driving error according to age group and previous crashes and license suspensions.

	< 20	20-29	30-39	40-49	50-64	65-79	80+
Crash							
0	2.54	1.71	1.22	1.00	0.99	1.70	3.87
	2.49, 2.60	1.68, 1.75	1.20, 1.25	1.00, 1.00	0.97, 1.02	1.66, 1.74	3.70, 4.06
1	2.39	1.90	1.41	1.19	1.16	2.00	4.01
	2.30, 2.49	1.85, 1.95	1.36, 1.46	1.14, 1.24	1.11, 1.21	1.89, 2.11	3.61, 4.47
2+	2.70	2.18	1.64	1.37	1.41	2.39	5.02
	2.52, 2.90	2.09, 2.28	1.54, 1.74	1.26, 1.49	1.29, 1.54	2.10, 2.71	3.93, 6.43
Suspension							
0	2.60	1.69	1.19	1.00	1.03	1.81	4.12
	2.55, 2.65	1.66, 1.72	1.17, 1.22	1.00, 1.00	1.01, 1.05	1.77, 1.86	3.94, 4.29
1	3.58	2.86	2.59	2.34	2.26	3.05	5.62
	3.35, 3.84	2.76, 2.96	2.47, 2.71	2.19, 2.51	2.08, 2.46	2.60, 3.58	3.71, 8.51
2+	4.16	3.56	3.23	3.26	3.21	4.07	7.99
	3.74, 4.63	3.42, 3.71	3.05, 3.42	2.99, 3.56	2.85, 3.63	3.12, 5.30	3.27, 19.54

Table 24. Odds ratios (top row) and 99% CI (bottom row) of committing driving error according to age group and previous convictions.

	< 20	20-29	30-39	40-49	50-64	65-79	80+
DWI							
0	2.57	1.72	1.21	1.00	1.01	1.78	4.03
	2.52, 2.62	1.69, 1.75	1.19, 1.23	1.00, 1.00	0.99, 1.03	1.74, 1.82	3.87, 4.21
1+	5.10	4.37	3.87	3.44	3.22	3.39	4.57
	4.49, 5.80	4.19, 4.57	3.66, 4.09	3.20, 3.71	2.94, 3.51	2.82, 4.07	1.66, 12.62
Speeding							
0	2.53	1.68	1.21	1.00	1.01	1.76	3.97
	2.48, 2.59	1.65, 1.72	1.18, 1.23	1.00, 1.00	0.99, 1.03	1.72, 1.80	3.80, 4.14
1	2.49	1.86	1.37	1.14	1.10	1.63	3.35
	2.40, 2.59	1.82, 1.91	1.33, 1.41	1.09, 1.18	1.05, 1.15	1.51, 1.75	2.75, 4.09
2+	2.72	2.09	1.59	1.31	1.20	1.82	5.81
	2.58, 2.86	2.03, 2.15	1.52, 1.65	1.23, 1.39	1.12, 1.29	1.56, 2.11	3.16, 10.67
Other harmful							
0	2.53	1.66	1.20	1.00	1.01	1.75	3.96
	2.48, 2.59	1.63, 1.69	1.18, 1.22	1.00, 1.00	0.99, 1.03	1.71, 1.80	3.79, 4.14
1	2.70	2.10	1.67	1.40	1.32	2.12	4.62
	2.60, 2.82	2.05, 2.16	1.61, 1.73	1.34, 1.47	1.26, 1.39	1.98, 2.26	4.03, 5.31
2+	3.26	2.61	2.09	1.72	1.61	2.43	4.73
	3.08, 3.45	2.53, 2.70	1.98, 2.20	1.60, 1.86	1.48, 1.76	2.12, 2.78	3.50, 6.39

It is possible that some drivers' records contained past crashes, license suspensions, and convictions. Theoretically, drivers with multiple incidents in all categories may be the worst drivers imaginable. Accordingly, a "driver record" index was developed to capture the worst possible drivers. The index was computed by summing the values of the five driver record variables. Hence, the best possible score was 0, and the worst possible score was 14. A driver with a score of 0 had no crash, license suspension or conviction in the past three years. A driver with a score of 14 had three or more crashes, three or more license suspensions, two or more DWI conviction, three or more speeding convictions, and three or more other convictions. The numbers and proportions of drivers with all possible scores on this index are presented in Table 25.

The maximum score on the driving index was nine. Only 40% of all drivers aged 20 to 29 had a clean record for the past three years. This proportion increased with drivers' age, reaching 75% for drivers aged 80+. Conversely, a majority of young drivers had at least one incident in the three-year period prior to the current crash. The majority of drivers who did not have a clean record had one or two incidents.

It was shown previously that the OR of committing errors increased with a higher number of reported incidents in the three years preceding the current crash for all age categories. This suggested that driving records, may be directly related to the risk of making a driving error, independently of age. To test this possibility a logistic regression was conducted with the driving record index and age category as independent variables. Because few drivers had more than five prior incidents, drivers with five or more incidents were classified as one group.

Results of the logistic regression are presented in Table 26. There was a regular progression in the OR of driving errors for every incident recorded in the previous three years. After one incident (OR = 1.07, 99% CI = 1.06, 1.09), each additional incident was associated with an approximate increase of 25% in the risk of a driving error. The OR of an error exceeded that of drivers with a clean record by 50% after three or more incidents (OR = 1.56, 99% CI = 1.52, 1.59).

Table 25. Driving record index. Number of drivers at specific levels (percentage).

Incidents	< 20	20-29	30-39	40-49	50-64	65-79	80+
0	96243	140748	107605	76612	84976	64734	18393
	(58.0)	(39.7)	(50.3)	(58.0)	(65.0)	(74.3)	(74.7)
1	29766	72436	45641	27214	24966	13703	3851
	(17.9)	(20.4)	(21.3)	(20.6)	(19.1)	(15.7)	(15.6)
2	18140	56126	29070	14932	11750	5465	1643
	(10.9)	(15.8)	(13.6)	(11.3)	(9.0)	(6.3)	(6.7)
3	10031	35644	15182	6961	4955	1897	463
	(6.0)	(10.1)	(7.1)	(5.3)	(3.8)	(2.2)	(1.9)
4	6034	23330	8384	3540	2251	811	193
	(3.6)	(6.6)	(3.9)	(2.7)	(1.7)	(0.9)	(0.8)
5	3182	13306	4355	1635	1058	310	53
	(1.9)	(3.8)	(2.0)	(1.2)	(0.8)	(0.4)	(0.2)
6	1675	7807	2170	743	450	112	10
	(1.0)	(2.2)	(1.0)	(0.6)	(0.3)	(0.1)	(0.0)
7	690	3453	886	313	211	43	7
	(0.4)	(1.0)	(0.4)	(0.2)	(0.2)	(0.0)	(0.0)
8	263	1442	376	110	77	12	2
	(0.2)	(0.4)	(0.2)	(0.1)	(0.1)	(0.0)	(0.0)
9	39	289	107	47	29	4	0
	(0.0)	(0.1)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)

Table 26. Results of the logistic regression with driving error as dependent variable and driving record index and age as independent variables. Drivers with a perfect driving record (driving record index = 0) are the reference group.

Driving record index	OR	99% CI
0	1.00	1.00, 1.00
1	1.07	1.06, 1.09
2	1.30	1.28, 1.32
3	1.56	1.52, 1.59
4	1.79	1.75, 1.84
5+	2.09	2.03, 2.15

Alcohol use

Alcohol use data are presented in Table 27. Most data from years 1975 and 1976 were missing, thus the total number of cases is roughly 10% less than reported for other variables. For approximately half of all drivers BAC was not tested. This proportion increased with age. Despite the number of drivers not tested for alcohol use, some overall trends are clear.

First, less than one percent of drivers refused the test, and this proportion decreased with age. Second, alcohol use generally decreased with age. The highest proportion of alcohol users (64%) was found among those aged 20 to 29. This proportion decreased steadily to 7% for drivers aged 80+. The proportion of drivers aged less than 20 who used alcohol was 48%, a proportion more in line with drivers aged 40 to 49 than other groups.

Table 27. Alcohol use. Data availability and number of drivers at specific blood alcohol levels (percentage) if data available.

Blood alcohol level	< 20	20-29	30-39	40-49	50-64	65-79	80+
Refused test	456	1617	1042	467	254	44	3
	(0.3)	(0.5)	(0.5)	(0.4)	(0.2)	(0.1)	(0.0)
Not tested	83222	162314	103310	67878	70645	49366	14394
	(55.7)	(51.5)	(53.6)	(56.6)	(59.5)	(61.3)	(62.8)
BAC							
0	34242	51154	33700	24693	29358	25066	7897
	(52.1)	(33.8)	(38.1)	(47.9)	(61.3)	(80.7)	(92.8)
.01 - .04	4027	7227	3417	1835	1702	1132	249
	(6.1)	(4.8)	(3.9)	(3.6)	(3.6)	(3.6)	(2.9)
.05 - .09	6452	12974	5122	2388	1841	790	131
	(9.8)	(8.6)	(5.8)	(4.6)	(3.8)	(2.5)	(1.5)
.10 - .14	8525	21589	8854	3891	2610	987	98
	(13.0)	(14.3)	(10.0)	(7.5)	(5.5)	(3.2)	(1.2)
.15 - .19	7152	26030	12987	5771	3698	1196	59
	(10.9)	(17.2)	(14.7)	(11.2)	(7.7)	(3.9)	(0.7)
.20 - .29	4877	28603	19939	10195	6743	1574	62
	(7.4)	(18.9)	(22.6)	(19.8)	(14.1)	(5.1)	(0.7)
≥ .30	460	3723	4395	2767	1925	319	14
	(0.7)	(2.5)	(5.0)	(5.4)	(4.0)	(1.0)	(0.2)

The impact of alcohol use on driving errors was examined with a logistic regression, using the group with a confirmed BAC of zero as the reference group. The OR of drivers who were not tested and those who refused the tests were also calculated. It was hypothesized that drivers who were not tested were likely presumed to have not made a driving error. Conversely, it was hypothesized that drivers who refused the test were attempting to avoid incriminating themselves, and likely committed a driving error. Similarly, it was hypothesized that the OR of a driving error would increase with BAC among drivers testing positive for alcohol use.

The results confirmed the hypotheses. Drivers who refused to take the test were three times more at risk to have committed a driving error than drivers who had a BAC of zero (OR = 3.21, 99% CI = 2.87, 3.59). Drivers not tested had half the risk to have committed a driving error compared to drivers with a BAC of zero (OR = 0.48, 99% CI = 0.47, 0.49). All levels of alcohol use were associated with higher risk of driving errors. Drivers with a reported BAC of less than .05 were 40% at higher risk to have committed a driving error (OR = 1.39, 99% CI = 1.33, 1.45). Drivers with a BAC equal to or higher than .30 were nearly seven times more at risk to have commited a driving error than the sober group (OR = 6.88, 99% CI = 6.35, 7.45).

Table 28. Alcohol use. Odds ratios and 99% CI of committing a driving error at specific blood alcohol levels.

Blood alcohol level	OR	99% CI
Refused	3.21	2.87, 3.59
Not tested	0.48	0.47, 0.49
BAC		
0	1.00	1.00, 1.00
.01 - .04	1.39	1.33, 1.45
.05 - .09	2.37	2.28, 2.46
.10 - .14	3.91	3.78, 4.06
.15 - .19	5.20	5.01, 5.39
.20 - .29	6.24	6.03, 6.46
≥ .30	6.88	6.35, 7.45

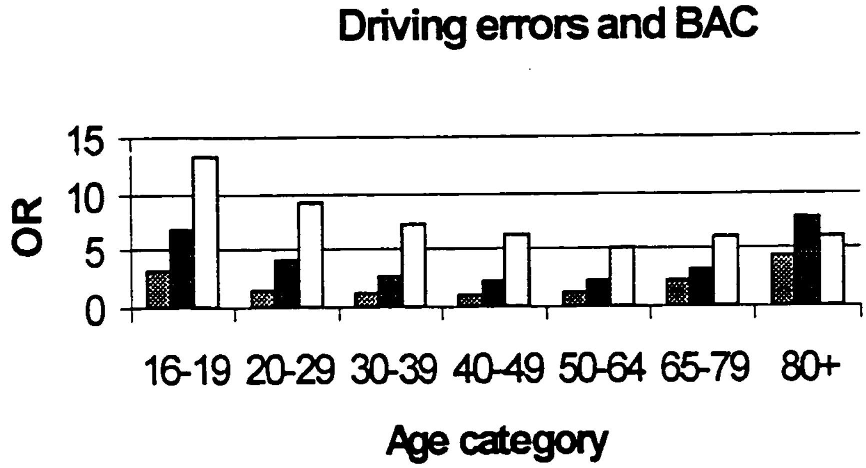
The risk of committing a driving error under the influence of alcohol may be altered by the age of the driver, such that an inebriated young driver may be at an even higher risk than other drivers. To test this possibility age and BAC were stratified, and OR comparing drivers with a BAC greater than zero to sober drivers aged 40 to 49 were computed. These results are presented in table 29.

Perhaps be the most fascinating aspect of this analysis was that all levels of BAC were associated with increased error risk. Even drivers aged 40 to 49 with a BAC of less than .05 had an excess error risk of 33% (99% CI = 18%, 51%) The results also showed the compounding effect of age and alcohol use on driving errors. The OR for a driving error among drivers less than 20 with a BAC of .20 to .29 exceeded 14, four times the OR of a sober driver of the same age. On the other hand, the effect of alcohol on driving errors was less dramatic for older age groups, yet remained serious. Differences between age categories are depicted for three BAC levels (0, .05 to .09, and .15 to .19) in Figure 9.

Table 29. Alcohol use. Odds ratios (99% CI) of committing a driving error based on drivers age and blood alcohol concentration (BAC) level. Drivers aged 40-49 with a confirmed BAC of 0 were used as the comparison group for all other groups.

BAC	< 20	20-29	30-39	40-49	50-64	65-79	80+
0	3.07	1.52	1.10	1.00	1.16	2.12	4.45
	2.93, 3.21	1.46, 1.58	1.05, 1.15	1.00, 1.00	1.11, 1.21	2.02, 2.22	4.10, 4.83
.01-.04	4.47	2.38	1.46	1.33	1.31	2.32	4.52
	4.01, 4.99	2.21, 2.56	1.33, 1.61	1.18, 1.51	1.15, 1.49	1.96, 2.75	2.96, 6.91
.05-.09	6.77	4.07	2.73	2.28	2.07	3.04	7.82
	6.12, 7.49	3.81, 4.35	2.50, 2.98	2.02, 2.57	1.81, 2.36	2.46, 3.77	3.86, 15.86
.10-.14	10.55	6.66	5.03	4.14	3.64	4.98	8.88
	9.51, 11.71	6.27, 7.08	4.64, 5.45	3.71, 4.62	3.21, 4.14	3.99, 6.21	3.76, 20.96
.15-.19	13.37	9.30	7.16	6.22	5.05	5.99	6.16
	11.82, 15.12	8.74, 9.91	6.63, 7.72	5.61, 6.90	4.49, 5.69	4.83, 7.42	2.35, 16.16
.20-.29	14.38	11.41	9.56	8.14	7.05	6.99	7.34
	12.35, 16.75	10.69, 12.17	8.91, 10.25	7.46, 8.88	6.37, 7.79	5.74, 8.53	2.69, 20.01
≥ .30	11.77	13.07	11.75	10.43	8.08	5.45	5.85
	7.54, 18.39	11.06, 15.44	10.14, 13.62	8.75, 12.43	6.69, 9.77	3.66, 8.12	0.84, 40.69

Figure 9. Odds ratios for committing a driving error according to age and BAC. For each age category the left column represents a BAC of 0, the middle column a BAC of .05 to .09, and the right column a BAC of .15 to .19.



Drug/medication use

Drug/medication use was less prevalent than alcohol use among drivers tested. Although drug/medication use was tested in less than 25% of all drivers involved in crashes for the years 1991 onward, actual drug/medication use was found for less than 25% of those tested. Drug/medication use was most prevalent among drivers aged 30 to 39 (24%) and least prevalent among the oldest drivers (9%).

The most frequently used drug/medication types varied with age. For the younger drivers, stimulants and cannabinoids were most frequently used. Middle-aged drivers used narcotics and depressants more than other age groups. Older drivers were more likely to have been using other, non-specified, drugs. Traces of hallucinogens, phencyclidines, anabolic steroids, and inhalants were rarely found in drivers. Anabolic steroids and inhalants were not studied further.

Odds ratios comparing drivers with drug/medication traces to those who did not were obtained with a logistic regression, and are presented in Table 31. The results suggest that all types of compounds were associated with increased driving error risk. Drivers who used phencyclidines were especially at risk of committing a driving error (OR = 3.51), but the confidence interval was wide (99% CI = 1.56, 7.87).

Table 30. Drug use (1991-1998). Number of drivers not tested, with negative results and positive results for drug use (percentage).

Drug/medication	< 20	20-29	30-39	40-49	50-64	65-79	80+
Not tested	29236	57866	45935	32731	27891	21735	7824
	(76.0)	(74.7)	(76.4)	(77.5)	(78.2)	(78.4)	(79.7)
No drugs	7900	15837	10739	7655	6776	5317	1825
	(85.5)	(80.9)	(75.7)	(80.3)	(87.1)	(88.7)	(91.3)
Tested positive							
Narcotics	94	284	411	346	187	140	35
	(1.0)	(1.5)	(2.9)	(3.6)	(2.4)	(2.3)	(1.8)
Depressants	117	475	726	470	294	188	40
	(1.3)	(2.4)	(5.1)	(4.9)	(3.8)	(3.1)	(2.0)
Stimulants	321	1489	1398	643	163	24	11
	(3.5)	(7.6)	(9.8)	(6.7)	(2.1)	(0.4)	(0.6)
Hallucinogens	7	20	13	6	1	3	2
	(0.1)	(0.1)	(0.1)	(0.1)	(0.0)	(0.1)	(0.1)
Cannabinoids	731	1414	953	349	65	10	2
	(7.9)	(7.2)	(6.7)	(3.7)	(0.8)	(0.2)	(0.1)
Phencyclidines	24	43	41	17	4	1	1
	(0.3)	(0.2)	(0.3)	(0.2)	(0.1)	(0.0)	(0.1)
Anabolic steroids	0	2	2	1	3	0	0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Inhalants	7	3	7	1	3	0	0
	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Others	243	679	707	510	469	424	106
	(2.6)	(3.5)	(5.0)	(5.4)	(6.0)	(7.1)	(5.3)

Table 31. Drug/medication use. Odds ratios and 99% CI of committing a driving error when using drugs/medications.

Drug/medication	OR	99% CI
Narcotics	1.43	1.20, 1.69
Depressants	2.08	1.78, 2.43
Stimulants	2.35	2.08, 2.66
Cannabinoids	1.62	1.44, 1.83
Phencyclidines	3.51	1.56, 7.87
Others	1.33	1.18, 1.49

Presence of passengers

With the exception of drivers aged less than 20, the majority of fatal crashes involved vehicles occupied by drivers only (Table 32). Younger drivers drove with more passengers than older drivers. There were five vehicle occupants or more, including the driver, in five percent of fatal crashes involving drivers aged less than 20.

To confirm the associations between age and the presence of passengers, and crash risk reported by others, OR for driving errors were calculated within age groups. That is, for each age group, the reference group was those driving alone at the time of the crash (OR = 1.00).

The results confirmed an association between the number of passengers and the risk of a driving error (Table 33). However, the nature of the association was dependent of the age of the driver. Among drivers aged less than 20, the presence of any passenger was associated with an increased risk in driving errors. With four or more passengers, drivers aged less than 20 were more than twice at risk (99% CI = 2.00, 2.31) to commit an error than a driver of the same age driving alone. The strength of this association weakened for drivers of the next age category (20-29), and passengers provide a protective effect thereafter. The OR did not reach statistical significance for more than 1 passenger among drivers aged 80+. However, all OR were in the hypothesized direction, and the lack of statistical significance can be attributed to decreasing sample sizes (as shown in Table 32).

Table 32. Number of passengers accompanying drivers by age group (percentage within age category).

Passengers	< 20	20-29	30-39	40-49	50-64	65-79	80+
0	69710	194906	130242	84747	84987	50945	15933
	(40.8)	(53.8)	(59.9)	(63.2)	(64.1)	(57.8)	(64.1)
1	54101	98007	47127	28990	32547	29139	7783
	(31.7)	(27.0)	(21.7)	(21.6)	(24.6)	(33.1)	(31.3)
2	24479	37928	19052	10102	8201	4786	761
	(14.3)	(10.5)	(8.8)	(7.5)	(6.2)	(5.4)	(3.1)
3	13949	19316	11576	5613	4161	2270	305
	(8.2)	(5.3)	(5.3)	(4.2)	(3.1)	(2.6)	(1.2)
4+	8660	12236	9384	4684	2592	970	78
	(5.1)	(3.4)	(4.3)	(3.5)	(2.0)	(1.1)	(0.3)

Table 33. Odds ratios and 99% CI of committing a driving error according to number of passengers and age category. Drivers of the same age with passengers are the reference categories.

Passengers	< 20	20-29	30-39	40-49	50-64	65-79	80+
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.00, 1.00	1.00, 1.00	1.00, 1.00	1.00, 1.00	1.00, 1.00	1.00, 1.00	1.00, 1.00
1	1.32	1.14	0.89	0.71	0.67	0.76	0.91
	1.28, 1.36	1.12, 1.16	0.86, 0.91	0.69, 0.74	0.64, 0.69	0.73, 0.79	0.83, 0.99
2	1.70	1.18	0.77	0.66	0.68	0.74	0.82
	1.63, 1.77	1.15, 1.22	0.74, 0.80	0.63, 0.70	0.64, 0.72	0.69, 0.80	0.66, 1.02
3	1.90	1.16	0.62	0.59	0.60	0.66	0.78
	1.80, 2.01	1.11, 1.21	0.59, 0.65	0.55, 0.64	0.55, 0.66	0.59, 0.74	0.56, 1.10
4+	2.15	1.08	0.66	0.67	0.68	0.73	0.74
	2.00, 2.31	1.03, 1.14	0.62, 0.69	0.62, 0.72	0.61, 0.76	0.61, 0.86	0.38, 1.44

Independent contribution of driver variables to driving errors

The risk of making a driving error is likely the complex interplay of several driver variables. To better quantify the independent contribution of these variables, two multivariate logistic regressions were conducted with personal variables associated with driving errors. The first regression included all personal variables described in this chapter: age, gender, driver record, BAC, drug/medication use, and presence of passenger. Presence of passengers was dichotomized as "no passenger" versus "any". The second regression focused exclusively on adults aged 65 and over. Furthermore, because drug/medication data were available in less than 25% of all cases this second regression excluded drug/medication data to verify the stability of the first regression.

Results of the first regression are presented in Table 34. The OR of a driving error was "U"-shaped. The youngest and oldest drivers were at higher risk to commit driving errors with OR approaching four. There was no difference across gender, but the driving record was positively associated with the OR of a driving error in a dose-related fashion. Similarly, BAC was associated with driving errors in a dose-related fashion, the OR exceeded 8 with a BAC greater than or equal to .20. The lowest BAC category (.01 to .04) was associated with a 45% increase in the OR of driving errors. All drug/medication variables were statistically associated with driving errors after adjustment for other variables. Drug/medications with depressant or stimulant effects, and phencyclidines had OR greater than 2. Finally, the presence of passengers was associated with an overall reduction in the risk of driving errors.

Results of the second regression analysis showed women at higher risk of driving errors compared to men. This finding was consistent with those presented with the univariate analyses. The results confirmed the dose-related associations between driving errors and driving record, and BAC. However, the magnitude of the associations was less than found in the first regression. Few drivers had high scores on the driving record index and BAC, hence the wider confidence intervals for high values of these independent variables. The presence of passengers was strongly associated with reduced risk of driving errors (OR = 0.69; 99% CI = 0.65, 0.74).

Table 34. Results of the multivariate logistic regression with driving error as dependent variable. Drivers used as the reference group have an OR of 1.00.

Variable	OR	99% CI
Age		
<20	3.71	3.34, 4.11
20-29	1.53	1.41, 1.66
30-39	1.08	0.99, 1.18
40-49	1.00	1.00, 1.00
50-64	1.07	0.98, 1.18
65-79	1.89	1.70, 2.09
80+	3.85	3.24, 4.57
Gender		
Male	1.00	1.00, 1.00
Female	0.99	0.93, 1.04
Driving record index		
0	1.00	1.00, 1.00
1	1.10	1.03, 1.18
2	1.14	1.05, 1.24
3	1.28	1.14, 1.43
4	1.54	1.32, 1.79
5+	1.46	1.24, 1.72
BAC		
0	1.00	1.00, 1.00
.01 - .04	1.45	1.27, 1.65
.05 - .09	2.83	2.47, 3.24
.10 - .14	4.68	4.07, 5.37
.15 - .19	6.32	5.52, 7.23
.20 - .29	8.17	6.53, 8.38
≥ .30	8.20	6.34, 10.62
Drug/medication use		
None	1.00	1.00, 1.00
Narcotics	1.51	1.25, 1.83
Depressants	2.16	1.82, 2.57
Stimulants	2.14	1.86, 2.46
Cannabinoids	1.25	1.10, 1.44
Phencyclidines	3.93	1.50, 10.33
Others	1.35	1.18, 1.54
Passengers		
0	1.00	1.00, 1.00
1+	0.83	0.79, 0.88

Table 35. Results of the multivariate logistic regression with driving error as dependent variable, for drivers aged 65+ only.

Variable	OR	99% CI
Gender		
Male	1.00	1.00, 1.00
Female	1.21	1.13, 1.30
Driving record index		
0	1.00	1.00, 1.00
1	1.02	0.94, 1.11
2	1.27	1.11, 1.44
3	1.37	1.09, 1.72
4	1.35	0.97, 1.88
5+	1.33	0.84, 2.10
BAC		
0	1.00	1.00, 1.00
.01 - .04	1.05	0.89, 1.23
.05 - .09	1.35	1.10, 1.66
.10 - .14	2.09	1.68, 2.61
.15 - .19	2.34	1.88, 2.90
.20 - .29	2.70	2.21, 3.30
≥ .30	2.24	1.49, 3.36
Passengers		
0	1.00	1.00, 1.00
1+	0.69	0.65, 0.74

Discussion

The results of this chapter illustrate once more that young male drivers have been the predominant group involved in fatal driving errors. Compared to young female drivers, young male drivers committed a disproportion of driving errors leading to fatal crashes. The gender effect, however, is reversed among older drivers. The multivariate regression focusing on drivers aged 65+ showed a 21% increased odds of a driving error among women than men. Others reported an age by gender interaction using crash involvement (Chipman, MacGregor, Smiley, & Lee-Gosselin. 1993). This study expands on the previous one by examining driving errors and controlling for other potential confounders.

Whereas the reasons for the higher involvement of young male drivers are rooted in their behavior (e.g., drinking and driving), the reasons for the higher error rates of older women are less clear. Possibly, these results are caused by a cohort effect. Specifically, because older generations of women may not have driven much in their lives until older age, their higher rate of errors may be in part explained by their relative inexperience. Hence, it is possible that the young female drivers of today will retain their safety edge over men in the long run.

Evans showed a cohort effect by comparing fatalities of drivers of specific ages for cohorts born at different time (Evans. 1993a). He found that cohorts of drivers born recently suffered fewer fatalities per million population compared to cohorts of drivers born earlier. For example, drivers born between

1937 and 1941 had a fatality rate of approximately 200 drivers per one million population when they were aged 25, whereas drivers born between 1947 and 1951 had a fatality rate of approximately 150 when they were 25 years of age. The results were consistent irrespective of the cohort examined. However, these data did not control for exposure and may have been influenced by several variables in addition to driver ability.

One possible index of driver ability is past driving record. The results showed the predictive value of one's past driving record. The number of incidents recorded in the past three years is linearly related to the OR of committing a driving error. Each past incident was associated with an increased risk of approximately 10%, even after controlling for age and BAC. Previous studies reported a doubling of the crash involvement rate among drivers who were convicted of driving related offenses (Chipman & Morgan. 1975; Lourens, Vissers, & Jessurun. 1999; Sims, McGwin, Allman, Ball, & Owsley. 2000). Whereas the results of these studies were possibly confounded by exposure, the results presented here attest with confidence that driving records can be used to predict driving errors.

Possibly the best predictor of a driving error is alcohol use. Consistently with the claims of others (Isaac, Kennedy, & Graham. 1995; Zobeck, Grant, Stinson, & Bertolucci. 1994) the drinking and driving problem is one of young male drivers, and barely affects older drivers. Yet, without considering the age of the driver, any concentration of blood alcohol is associated with excess driving errors. Even at its lowest concentration, alcohol consumption resulted in a 40% increase in the risk of the driver making an error. At its worst, alcohol increased the overall risk of a driving error by nearly 700%. When age was considered the data showed the compounding effect of driver age and alcohol use. Compared to sober drivers aged 40 to 49, drivers aged less than 20 had driving error OR in excess of 10 even at a BAC of .10 to .14.

The generalizibility of the findings based on BAC is limited because more than 50% of all drivers were not tested for alcohol. Testing likely resulted from the presumption that drivers were responsible for crashes. The results showed a 50% reduction in the risk of an error in drivers not tested compared to those tested. On the other hand, drivers who refused to be tested were three times more at risk to have committed an error. Given that the majority of drivers who were not tested did not commit an error, their exclusion of the analyses on BAC may underestimate the contribution of alcohol use to driving errors. It is plausible that, had alcohol data been available for all drivers, the OR for driving errors would be substantially higher.

Although few drivers were tested for drugs/medications, all drug/medication categories examined were associated with higher driving error risks, even after control for age and alcohol consumption. Drug/medications with depressant or stimulant effects, and phencyclidines had OR exceeding 2. The associations were not as strong as those found with alcohol. However, dosage or blood concentration information was not available. Thus, very small concentrations of the drug/medication may lead to underestimates of their adverse effect on driving. Furthermore, results on drug/medications may represent an underestimate because a maximum of three drug/medications could be listed (the hierarchy if more than three were present followed the order of Table 30). Thus, if one had more than three reported types of drug/medications only the first three were coded. Such situations would have led to some drug/medication being misclassified as not present, and may have weakened statistical associations. However, this would not apply to narcotics, depressants and stimulants because they were coded first, second and third respectively.

Another explanation for the smaller associations between drug/medications and driving errors is a lesser effect on driving compared to alcohol. Studies comparing different drug/medications and alcohol dosages are required to solve this question.

An additional limitation to drug data is case selection. Data were available for few drivers. And although the proportion of drivers tested was similar across age groups, it is unclear if a selection bias was operating, limiting the scope of possible generalizations. More importantly, it is impossible to dissociate the potential effect of the active compounds from an underlying medical condition. Future research must dissociate them.

The presence of passengers had an adverse effect on drivers aged less than 30, but a protective effect on those 30 and older. The problem for the youngest drivers was aggravated by the frequency of crashes including at least two occupants. Drivers aged less than 20 were the only age group for which a majority (59%) of crashes occurred with at least two vehicle occupants.

Others have shown that the presence of passengers with drivers aged less than 20 is associated with a doubling of the crash involvement and fatality (Chen, Baker, Braver, & Li. 2000; Doherty, Andrey, & MacGregor. 1998). The results presented here were consistent, while expanding on these results by focusing on driving errors. Furthermore, the results also substantiated the dose-related response curve reported by others (Chen, Baker, Braver, & Li. 2000). For drivers aged less than 20, the risk of a driving error increased with the number of passengers. A weaker yet statistically significant adverse effect of passengers was found for drivers age 20 to 29. However, there was no dose-related response; any number of passengers was equally associated with the risk of a driving error.

Drivers aged 30 and over had a lower risk to commit a driving error in the presence of passengers, regardless of age. It is, however, impossible to determine if the underlying mechanism leading to lower driving error risk is the same across all age groups. Middle-age drivers committed fewer errors because they drove more carefully with passengers. However, an alternate suggestion is that older drivers were better drivers because passengers acted as "co-pilots".

The results presented in this Chapter suggest that modification of some variables examined may prevent fatalities. A driver's prior record is closely linked to the risk of a driving error and may serve as a marker for targeted intervention. As the number of previous incidents increases so does the need for attention to the driver. Alcohol, even at the lowest level, was associated with an increased driving error risk. Drinking and driving must remain a main priority for transportation authorities. Finally, the impact of passengers, especially among the youngest drivers, must be examined further. It remains unclear if age or lack of driving experience is critical here. The answer to this question has policy implications.

Chapter 8. Associations between driver, crash, and vehicle characteristics and fatal injuries

Introduction

Seeking ways to minimize the impact of crashes is possible and desirable. Researchers have provided much information about factors that may affect the risk of a fatality in the event of a crash. These factors include vehicle occupant characteristics such as age, gender and behavior (alcohol and seat belt use), crash characteristics (direction of impact and vehicle speed at impact), and vehicles characteristics such as weight, length, model year, and safety devices (air bags).

Age and gender

Although older adults account for few fatalities compared to other age groups (Evans. 1988a; Graca. 1986), this involvement will likely increase in coming years. Barr showed an overall increase in fatalities among adults aged 65+ between the years 1980 and 1989, but a reduction among younger adults over the same 10-year period (Barr. 1991). He suggested these changes were a reflection of increasing frailty with age.

Although demographic changes may also explain the increasing number of fatalities among older age groups, the issue of increased frailty remains at the forefront. This possibility was substantiated with data from Wisconsin showing that adults aged 85 and over were three times more at risk to be hospitalized or fatally injured in a crash compared to adults aged 16 to 64 (Dulisse. 1997).

However, these data did not consider driving patterns. Older adults typically drive at lower speeds and are less likely to be inebriated (Bradbury & Robertson. 1993; McGwin & Brown. 1999). A recent study reported that mean vehicle speed immediately before a fatal driver crash was 64 miles per hour for drivers aged less than 30, declining steadily to 46 miles per hour for drivers aged 65 and more (Levine, Bédard, Molloy, & Basilevsky. 1999). After controlling for driver's age and gender, Canadian data showed a 230% increase in the risk of fatal injuries for 80 year-old drivers compared to 65 year old drivers (Zhang, Lindsay, Clarke, Robbins, & Mao. 2000). In a study based on FARS data, adults aged 70 and over were three times more likely to die in a crash than a 20 year old in the same crash (Evans. 1986a). And even in the event of an injury of similar severity, adults aged 70 and over were 11% more at risk to die of their injuries (McCoy, Johnston, & Duthie. 1989).

Age differences are potentially confounded by gender and vice versa. Although, overall, women may be more susceptible to fatal injuries than men (Levine, Bédard, Molloy, & Basilevsky. 1999), age and gender may interact. Some data suggested that young women were more susceptible to be fatally injured than young men (Evans. 1988c), but that the situation was reversed for older adults (Zhang, Lindsay, Clarke, Robbins, & Mao. 2000).

Behavior

Anecdotally, alcohol is believed to exert a protective effect on fatalities (Waller, Stewart, Hansen, Stutts, Popkin, & Rodgman. 1986). Although, fatality data show higher fatality rates among intoxicated drivers compared to sober ones. this effect is typically attributed to the reckless driving behavior of drunk drivers (Waller. 1994). In addition, intoxicated drivers and passengers may be at increased risk of fatal injuries as a result of the physiological effects of alcohol on the body, even after controlling for the confounding effects of age, seat belt use, vehicle weight, and vehicle deformity (Evans. 1992a; Evans. 1993b; Waller, Stewart, Hansen, Stutts, Popkin, & Rodgman. 1986).

Restraint use (manual and automatic seat belts), has been touted as the most important behavior to prevent fatalities (Robertson. 1996). Evans went as far as proposing that more than 40% of all fatalities incurred by non belted drivers and passengers could be avoided with seat belts (Evans. 1986b; Evans. 1987). At the very least, researchers estimated that we could expect a reduction of 15% in all severe and fatal injuries if all drivers, and passengers were belted, even after controlling for age and vehicle deformity (Evans. 1988b; Nash. 1989; Streff. 1995).

Crash characteristics

Drivers in struck vehicles may be more vulnerable than drivers of striking vehicles. The fatality risk of the former is five times that of the latter when struck on the right side, and ten times more when struck on the left (driver's) side (Evans. 1993b). Among Ontario drivers aged 65 and more

(Zhang, Lindsay, Clarke, Robbins, & Mao. 2000), head-on crashes were more likely to result in fatal crashes than minimal injury crashes when compared to rear-end crashes (OR = 55.1, 95% CI = 34.2, 88.9), followed by right-turn collisions (OR = 8.7, 95% CI = 5.2, 14.7).

Speed may also be a risk factor according to data from the same study (Zhang, Lindsay, Clarke, Robbins, & Mao. 2000). Crashes which occurred in 70 to 90 kilometer per hour zones were almost six times more likely to result in fatal injuries compared to crashes occurring in zones with slower posted speed limits. Although these data did not rely on the speed of vehicles it is unlikely that this limitation would have biased the effect considerably.

Dischinger and colleagues examined the impact of deceleration on the development of post-injury medical complications (Dischinger, Siegel, Ho, & Kufera. 1998). They found that larger deceleration was associated with more complications, independently of age and injury severity. Because the impact of speed may be related to trauma sustained with the sudden deceleration experienced (Viano. 1988), future work should include indices of traveling speed.

Vehicle characteristics

Both driver behavior and vehicle characteristics may be modified, and therefore hold some promise to mitigate fatal injuries. Possibly the vehicle attribute most closely related to injury severity is size. Although weight and length are highly correlated, weight is the most studied characteristic.

Evans reported that in any two-vehicle crash, the passengers of the heavier vehicle fared better than those of the lighter (Evans. 1985; Evans. 1992b; Evans. 1993b; Evans & Frick. 1994). Yet, drivers of two 900 kilogram vehicles were twice at risk to be fatally injured compared to drivers of two 1,800 kilogram vehicles (Evans & Wasielewski. 1987). And, Levine and colleagues reported that every 1,000 pound increases in vehicle weight were equivalent to the driver's ability to withstand front impact crashes of six more miles per hour before being fatally injured (Levine, Bédard, Molloy, & Basilevsky. 1999).

Data suggest that recent model year vehicles allowed drivers to survive crashes at higher speeds after controlling for drivers' age and gender (Levine, Bédard, Molloy, & Basilevsky. 1999). However, these analyses did not consider the age of the vehicle. In a different study, vehicle age was positively related to fatal injuries but model year was not (Robertson. 1996). But, these analyses were limited to fatalities from 1975 to 1977, and did not control for driver characteristics beyond seat belt use and alcohol consumption.

Air bags represent a recent engineering advance that may prevent fatalities, especially in frontal impacts for which they appear well-suited (Evans. 1990a; Evans. 1991). Lund and Ferguson reported that fatalities were reduced by 23% in front impacts, and 16% overall (Lund & Ferguson. 1995). An early report attributed 28% fewer fatalities to cars with air bags compared to cars with manual belt systems (Zador & Ciccone. 1993). Yet the real impact of air bags remains to be confirmed. Previous studies have failed to control adequately for driver, crash, and other vehicle characteristics.

Aims of this chapter

The main purpose of this chapter is to identify the independent contribution of driver, crash, and vehicle characteristics to fatal injuries. It is imperative to identify what characteristics may yield additional protection to drivers. Furthermore, because older drivers will populate the roads in increasing proportions, and because they may be more vulnerable to crash trauma, it is essential that we consider avenues to prevent fatalities in this group in particular.

Methods

Data

The analyses presented in this chapter were based on driver fatalities only, to factor out the effect of seating position. Seating position has been shown to affect the risk of a fatal injury, with rear center seats as the safest location in a vehicle (Evans & Frick. 1988; Evans & Frick. 1989b). Also, in multiple vehicle crashes, the risk of fatality is dependent on the characteristics of the other vehicle(s) (Evans. 1985; Evans. 1992b; Evans. 1993b; Evans & Frick. 1994). Therefore, to maximize the interpretability of findings, a model focusing on driver fatalities involving single vehicle crashes with fixed objects was chosen. Focusing on drivers removes the confounding impact of seating position, and focusing on single vehicle crashes removes the effect of other vehicle characteristics.

One difficulty emerged at this point. Because crashes are included in FARS only if a fatality ensued, all drivers of single-vehicle crashes in which they were the sole occupants were killed, effectively removing any variability, and possibly biasing the results of the analyses. This led to a sample in which 85% of drivers were killed. To alleviate this difficulty, analyses were performed on crashes where at least two vehicle occupants were present. In all cases the crash was sufficiently serious to kill at least one occupant, but not necessarily the driver. A total of 110,813 cases were available for the analyses with this subset, and drivers represented approximately 50% of all fatalities.

Statistical analyses

To determine if driver, crash, and vehicle characteristics were associated with fatalities, injury severity was dichotomized as "fatal" or "non-fatal". Descriptive data were obtained by age category for driver and crash characteristics. The OR of suffering a fatal injury in a crash were calculated for each variable with a multivariate logistic regression to control for individual, crash, and vehicle characteristics.

Individual characteristics include age category, gender, BAC, seat belt use, and air bag use. Crash characteristics included impact direction, vehicle deformity, and vehicle speed before or at impact. Vehicle characteristics included weight, wheel base length, model year, and vehicle age. Statistical significance was set at $p \leq .01$.

Results

Age and gender

The majority of the fatalities reported were among male drivers aged less than 30. However, older adults were, proportionally, more likely to be fatally injured than younger adults. And although there appeared to be no difference across gender for young drivers, a larger proportion of older male drivers were fatally injured compared to older female drivers (Table 36).

Table 36. Fatalities by age category and gender.

Gender	< 20	20-29	30-39	40-49	50-64	65-79	80+
Men							
Non-fatal	13801	18994	5845	2427	1903	1549	377
	(54.9)	(51.5)	(49.0)	(47.4)	(46.3)	(47.5)	(46.6)
Fatal	11318	17878	6091	2689	2211	1713	432
	(45.1)	(48.5)	(51.0)	(52.6)	(53.7)	(52.5)	(53.4)
Women							
Non-fatal	3311	3779	1945	994	966	749	130
	(54.4)	(52.7)	(50.9)	(49.5)	(52.0)	(53.4)	(49.4)
Fatal	2774	3386	1877	1016	892	653	133
	(45.6)	(47.3)	(49.1)	(50.5)	(48.0)	(46.6)	(50.6)
Total*							
Non-fatal	17112	22773	7791	3422	2869	2298	507
	(54.8)	(51.7)	(49.4)	(48.0)	(48.0)	(49.3)	(47.3)
Fatal	14092	21265	7969	3705	3103	2366	565
	(45.2)	(48.3)	(50.6)	(52.0)	(52.0)	(50.7)	(52.7)

*Total number of cases are slightly higher than men and women data together as gender data were missing for approximately 200 cases.

Alcohol use and fatal injuries

The number of fatalities by age and blood alcohol concentration are show in Table 37. The proportion of sober drivers fatally injured increased from 64.2% for drivers aged less than 20 to 88.5% for drivers aged 80 and more. However, the relationship between BAC and fatality risk was "U"-shaped. Fatality risk initially decreased with increasing BAC, reaching the lowest point at a BAC of .10 to .14. It then increased with BAC to reach its maximum at a BAC of .30 or greater. Using the age category 40 to 49 as an example, the ratio of fatally injured drivers to non-fatally injured drivers was 2.79 at a BAC of zero. At a BAC of .10 to .14, the same ratio was 1.38. Yet, at a BAC of .30 or more, the ratio was 7.06. This pattern was consistent for the other age groups, though little data were available for older drivers.

Table 37. Fatalities by blood alcohol concentration (BAC) and age group.

BAC	< 20	20-29	30-39	40-49	50-64	65-79	80+
0							
Non-fatal	1882 (35.8)	1308 (34.6)	456 (27.6)	279 (26.4)	248 (19.9)	218 (16.9)	31 (11.5)
Fatal	3381 (64.2)	2469 (65.4)	1194 (72.4)	778 (73.6)	996 (80.1)	1071 (83.1)	238 (88.5)
.01 - .04							
Non-fatal	544 (50.0)	607 (52.7)	122 (42.1)	40 (32.8)	20 (22.5)	16 (27.6)	3 (25.0)
Fatal	543 (50.0)	544 (47.3)	168 (57.9)	82 (67.2)	69 (77.5)	42 (72.4)	9 (75.0)
.05 - .09							
Non-fatal	1016 (50.1)	1506 (53.6)	353 (54.3)	81 (39.7)	36 (36.0)	5 (13.9)	2 (28.6)
Fatal	1012 (49.9)	1302 (46.4)	297 (45.7)	123 (60.3)	64 (64.0)	31 (86.1)	5 (71.4)
.10 - .14							
Non-fatal	1301 (45.6)	2345 (46.9)	590 (47.0)	178 (42.0)	70 (34.0)	13 (27.7)	0 (0.0)
Fatal	1553 (54.4)	2654 (53.1)	665 (53.0)	246 (58.0)	136 (66.0)	34 (72.3)	4 (100)
.15 - .19							
Non-fatal	813 (35.8)	2154 (39.0)	701 (37.6)	213 (36.0)	85 (32.1)	17 (27.9)	1 (25.0)
Fatal	1460 (64.2)	3371 (61.0)	1162 (62.4)	378 (64.0)	180 (67.9)	44 (72.1)	3 (75.0)
.20 - .29							
Non-fatal	301 (23.0)	1303 (26.0)	626 (27.2)	196 (21.6)	92 (22.4)	19 (23.5)	0 (0.0)
Fatal	1005 (77.0)	3717 (74.0)	1678 (72.8)	710 (78.4)	319 (77.6)	62 (76.5)	1 (100)
.30+							
Non-fatal	15 (12.2)	83 (15.3)	59 (13.9)	28 (12.4)	10 (9.4)	4 (28.6)	0 (0.0)
Fatal	108 (87.8)	458 (84.7)	365 (86.1)	197 (87.6)	96 (90.6)	10 (71.4)	2 (100)

Direction of impact

Roughly 65% of all crashes where data were available involved front impacts. Right side impacts were the next most frequent occurrence at 17.5%, followed by left side (driver side) impacts at 13.5%, and finally rear side impacts in 3.5% of all cases.

Data on direction of impact show the lethal consequences associated with impacts of the driver side (Table 38). At best one third of drivers survived left side impacts, irrespective of age. Rear end and right side impacts were fatal for fewer drivers. However, whereas the proportion of fatalities following rear impacts was not dependent on age, it progressed with age for right side impacts. Similarly, the proportion of fatally injured drivers following front impacts increases with age. Front impacts were most likely to result in fatalities after left side impacts.

Table 38. Fatalities by direction of impact and age group.

Impact	< 20	20-29	30-39	40-49	50-64	65-79	80+
Front impact							
Non-fatal	8371	11883	4428	2118	1903	1683	418
	(54.8)	(51.9)	(49.8)	(48.9)	(48.9)	(49.2)	(48.1)
Fatal	6893	10992	4464	2214	1990	1736	451
	(45.2)	(48.1)	(50.2)	(51.1)	(51.1)	(50.8)	(51.9)
Right side impact							
Non-fatal	3813	4669	1319	488	365	234	35
	(72.2)	(69.3)	(63.8)	(62.1)	(61.0)	(64.3)	(57.4)
Fatal	1471	2064	749	298	233	130	26
	(27.8)	(30.7)	(36.2)	(37.9)	(39.0)	(35.7)	(42.6)
Rear impact							
Non-fatal	623	754	284	146	97	65	4
	(63.8)	(58.7)	(61.1)	(67.6)	(64.2)	(65.0)	(33.3)
Fatal	354	530	181	70	54	35	8
	(36.2)	(41.3)	(38.9)	(32.4)	(35.8)	(35.0)	(66.7)
Left side impact							
Non-fatal	1316	1565	555	212	155	92	14
	(33.1)	(30.7)	(32.3)	(29.8)	(32.4)	(32.2)	(27.5)
Fatal	2665	3535	1164	499	323	194	37
	(66.9)	(69.3)	(67.7)	(70.2)	(67.6)	(67.8)	(72.5)

Restraint use

Approximately 84% of drivers with restraint data were not wearing a seat belt at the time of the crash. Of the remaining 16% drivers, most were wearing a three-point belt (shoulder and lap). Data for restraint use is presented in Table 39, the following emphasizes three-point belt use versus no belts.

Seat belt use was associated with fewer fatalities. The proportion of fatally injured drivers not wearing seat belts ranged from a low of 47.8% for drivers aged less than 20 to a high of 59.1% for drivers aged 50 to 64. On the other hand, the proportion of fatally injured drivers wearing belts ranged from a low of 30.5% for drivers aged 40 to 49 to a high of 44.6% for drivers aged 80 and over.

The difference between proportions of fatally injured without belts and with three-points belts varied with age according to an inverted "U"-shaped curve. Thirty-five percent fewer drivers aged less than 30 died wearing belts compared to those not wearing belts. This proportion increased to 42% for drivers aged 30 to 39 and to 48% for drivers aged 40 to 49. From then onward the belt advantage decreased to 40% for drivers aged 50 to 64, and 29% and 22% for drivers aged 65 to 74 and 80+ respectively. These differences across age groups may represent discrepancies in driving behavior (e.g., speeding) and overall frailty. Multivariate regressions will provide control for these other variables.

Table 39. Fatalities by restraint use and age group.

Restraint	< 20	20-29	30-39	40-49	50-64	65-79	80+
No seat belt							
Non-fatal	11766	15431	4925	1923	1531	1054	240
	(52.2)	(48.7)	(44.8)	(41.1)	(40.9)	(43.4)	(42.5)
Fatal	10771	16277	6057	2754	2212	1373	325
	(47.8)	(51.3)	(55.2)	(58.9)	(59.1)	(56.6)	(57.5)
Shoulder only							
Non-fatal	76	94	25	10	13	16	3
	(55.5)	(54.3)	(48.1)	(35.7)	(46.4)	(57.1)	(42.9)
Fatal	61	79	27	18	15	12	4
	(44.5)	(45.7)	(51.9)	(64.3)	(53.6)	(42.9)	(57.1)
Lap only							
Non-fatal	201	253	122	55	69	52	11
	(63.4)	(65.2)	(62.6)	(63.9)	(63.9)	(51.5)	(64.7)
Fatal	116	135	73	26	39	49	6
	(36.6)	(34.8)	(37.4)	(32.1)	(36.1)	(48.5)	(35.3)
Shoulder and lap							
Non-fatal	2092	2661	1318	799	732	760	160
	(68.7)	(66.6)	(67.9)	(69.5)	(64.7)	(59.6)	(55.4)
Fatal	954	1336	624	351	400	515	129
	(31.3)	(33.4)	(32.1)	(30.5)	(35.3)	(40.4)	(44.6)

Air bags

Although air bag data were missing for 65% of the cases available, these data are equivocal in comparison to seat belt data. As shown in Table 40, air bags did not appear to have a protective effect on drivers aged less than 40, appeared beneficial to drivers aged 40 to 64, but may have been detrimental to older drivers. Although these data also suggested an inverted "U"-shaped curve as found with seat belts, the overall benefit of air bags without controlling for other variables appears dubious.

Table 40. Fatalities by air bag deployment and age group.

Air bag status	< 20	20-29	30-39	40-49	50-64	65-79	80+
Bag not deployed							
Non-fatal	5263	7067	3043	1435	975	899	242
	(55.9)	(52.1)	(50.4)	(49.1)	(48.9)	(50.6)	(48.8)
Fatal	4160	6490	2998	1485	1020	879	254
	(44.1)	(47.9)	(49.6)	(50.9)	(51.1)	(49.4)	(51.2)
Bag deployed							
Non-fatal	355	489	211	118	110	115	22
	(56.3)	(53.7)	(49.9)	(51.5)	(55.6)	(47.3)	(44.9)
Fatal	276	422	212	111	88	128	27
	(43.7)	(46.3)	(50.1)	(48.5)	(44.4)	(52.7)	(55.1)

Vehicle deformity

Data on vehicle deformity attested to the violence of the impacts. Vehicle deformity was ranked by investigating officers on a four-point scale, severe deformity was one extreme. Data were dichotomized as severe deformity or less severe. Approximately 94% of all vehicles were severely deformed following the crash. Consistently, proportionally more fatalities were found among drivers of severely deformed vehicles (Table 41). Among drivers of severely deformed vehicles, drivers aged less than 30 were less likely to be fatally injured than other drivers.

The proportion of severely deformed vehicles also varied according to age. The ratio of severely deformed vehicles to less deformed vehicles decreased steadily with age. Specifically, among drivers aged less than 20, the number of crashes resulting in severe deformity was 15.22 times that of crashes resulting in less severe deformity. This ratio plummeted to 10.57 for drivers aged 30 to 39, and 7.09 for those aged 80+.

Table 41. Fatalities by vehicle deformity and age group.

Vehicle deformity	< 20	20-29	30-39	40-49	50-64	65-79	80+
Severe							
Non-fatal	15723	20674	6818	2927	2445	1996	431
	(54.2)	(50.9)	(47.8)	(46.1)	(46.1)	(48.4)	(46.4)
Fatal	13281	19962	7434	3423	2862	2127	498
	(45.8)	(49.1)	(52.2)	(53.9)	(53.9)	(51.6)	(53.6)
Less severe							
Non-fatal	1205	1885	884	458	401	271	72
	(63.2)	(62.7)	(65.6)	(64.2)	(65.4)	(56.9)	(55.0)
Fatal	701	1122	464	255	212	205	59
	(36.8)	(37.3)	(34.4)	(35.8)	(34.6)	(43.1)	(45.0)

Vehicle speed

Higher speeds were associated with more fatalities irrespective of age group (Table 42). The youngest drivers fared better than other drivers, and the oldest fared worst. Whereas only 25% of drivers aged less than 20 were fatally injured in crashes at speeds of less than 35 miles per hour, 49% of drivers aged 80 and over were. The differential across age groups continued for other speed categories.

As shown with vehicle deformity, the proportion of crashes at different speed categories varied by age groups. For drivers aged less than 30, the largest proportion of crashes occurred at speeds of 70 miles per hour or more. However, for all other age categories the largest number of crashes occurred at speeds of 35 to 59 miles per hour.

Table 42. Fatalities by vehicle speed and age group.

Vehicle speed	< 20	20-29	30-39	40-49	50-64	65-79	80+
< 35							
Non-fatal	207	279	183	124	114	129	34
	(75.5)	(72.3)	(71.8)	(71.3)	(62.0)	(62.0)	(50.7)
Fatal	67	107	72	50	70	79	33
	(24.5)	(27.7)	(28.2)	(28.7)	(38.0)	(38.0)	(49.3)
35-59							
Non-fatal	2734	3659	1587	805	781	650	121
	(62.4)	(59.9)	(56.5)	(55.0)	(53.4)	(51.6)	(49.2)
Fatal	1648	2451	1222	658	682	610	125
	(37.6)	(40.1)	(43.5)	(45.0)	(46.6)	(48.4)	(50.8)
60-69							
Non-fatal	1582	2094	814	338	248	201	24
	(57.7)	(54.2)	(52.5)	(50.2)	(46.4)	(51.8)	(39.3)
Fatal	1162	1772	736	335	286	187	37
	(42.3)	(45.8)	(47.5)	(49.8)	(53.6)	(48.2)	(60.7)
70+							
Non-fatal	2431	3115	799	257	111	52	2
	(47.6)	(44.2)	(38.1)	(33.6)	(32.8)	(37.1)	(13.3)
Fatal	2674	3925	1299	508	227	88	13
	(52.4)	(55.8)	(61.9)	(66.4)	(67.2)	(62.9)	(86.7)

Vehicle attributes

Vehicle attributes that may impact on fatality risk included weight, wheel base, model year, and age. Weight, wheel base and model year were extracted directly from the FARS database. Vehicle age was obtained by subtracting the vehicle model year from the crash year. Descriptive statistics for these variables are presented in Table 43.

The distribution of these variables was examined to ensure normality. All variables were considered normally distributed with the exception of vehicle age, which was positively skewed (Figures 10 to 13). Although normality of the independent variables is not a strong requirement for logistic regression, the model was tested with both the untransformed and transformed data. Given the practice of auto makers to release new model year vehicles midway in the previous year a number of vehicles had an age of −1. Therefore, vehicle age was transformed using the natural logarithm (Howell. 1987) of vehicle age + 2 (it is impossible to obtain a natural logarithm for a value of zero or less) and plotted. The distribution of the transformed variable approached normality (Figure 14).

Table 43. Descriptive statistics for vehicle attributes

Variable	Mean	SD	Minimum	Maximum
Weight	3000.78	684.97	1085	5863
Wheel base	106.34	9.81	78.70	168.50
Model year	1979.07	8.45	1900	1999
Age	7.17	5.56	-1	84

Figure 10. Distribution of vehicle weight in pounds. Normal curve is superimposed for inspection of normality.

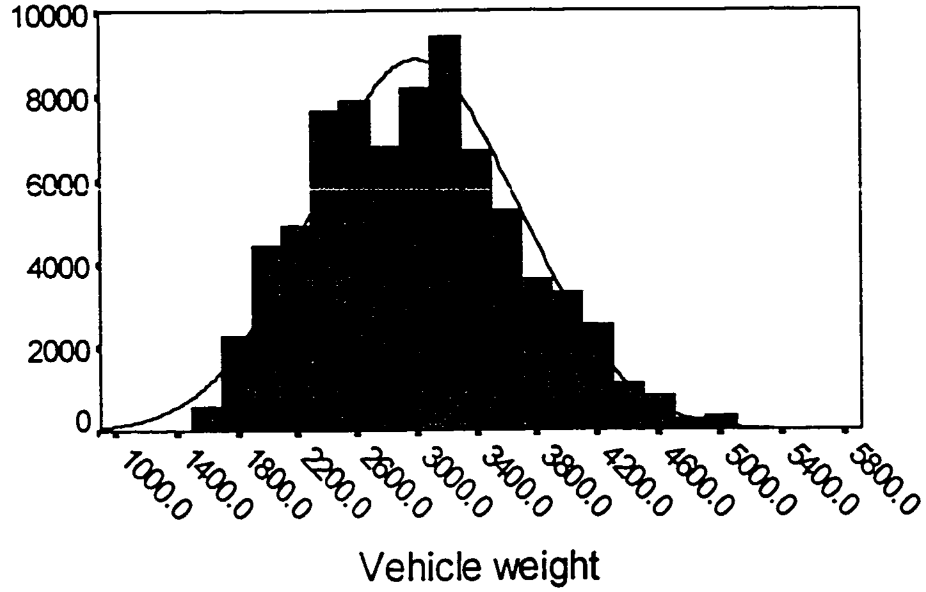


Figure 11. Distribution of vehicle wheel base in inches. Normal curve is superimposed for inspection of normality.

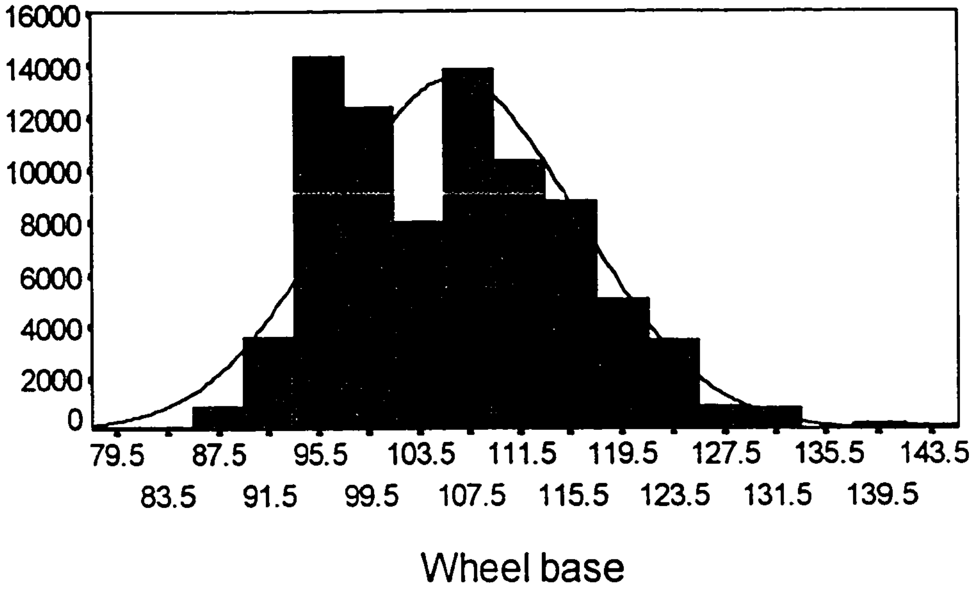


Figure 12. Distribution of vehicle model year. Normal curve is superimposed for inspection of normality.

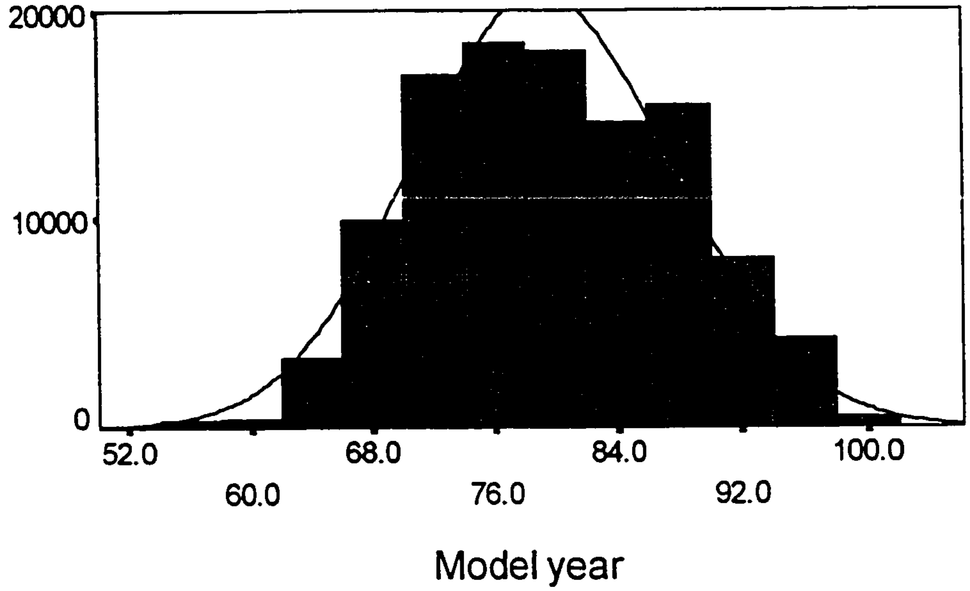


Figure 13. Distribution of vehicle age. Normal curve is superimposed for inspection of normality.

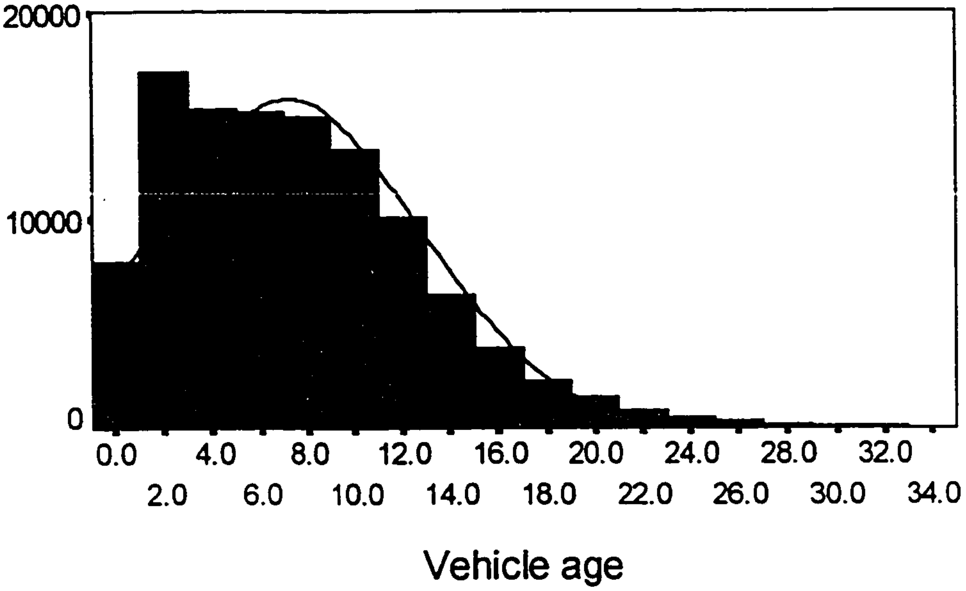
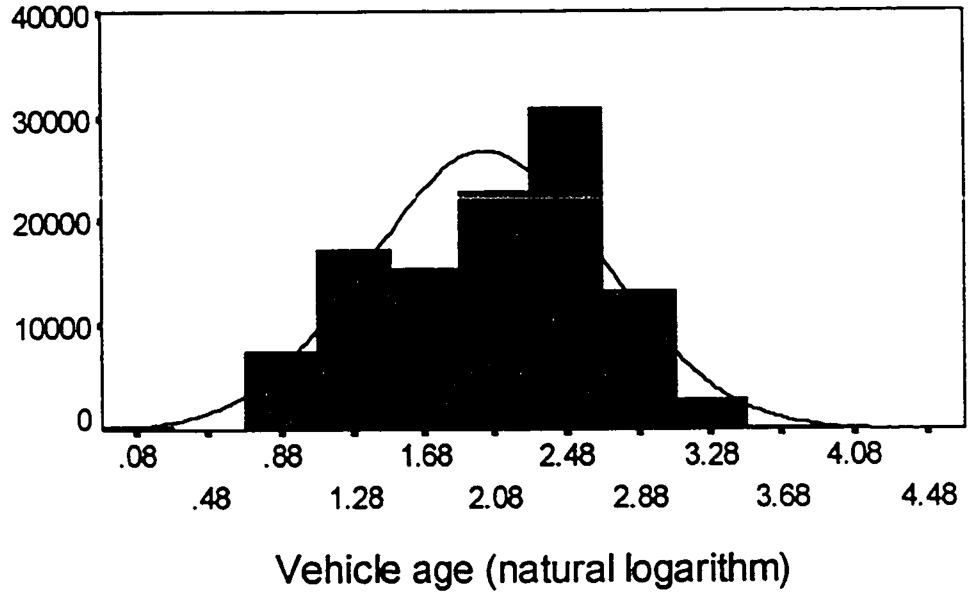


Figure 14. Distribution of vehicle age natural logarithm. Normal curve is superimposed for inspection of normality.



Independent predictors of fatal injuries

A multivariate logistic regression was conducted to examine the independent contribution of driver, crash, and vehicle characteristics to fatal injuries. Age category, gender, BAC, impact direction, restraint use, air bag deployment, traveling speed, vehicle model year, vehicle wheel base, and the natural logarithm of the vehicle age (repeated with the untransformed data) were entered and sequentially removed with a backward procedure if not statistically significantly associated with fatal injuries at the $p < .05$ level. To index the severity of the impact vehicle speed was chosen because it provided more detailed information compared to deformity, which was severe in 94% of all cases. Vehicle wheel base and weight were highly correlated ($r = 0.82$), hence only wheel base was entered. Wheel base was chosen because information was available for about 1,000 additional cases (a further regression with weight yielded a similar model but less precise estimates).

In the initial regression ($n = 6,811$) the air bag variable was not statistically associated with fatal injuries ($p = .72$). Because air bag data were missing for 65% of all cases, a final regression was run to obtain more precise estimates by excluding the air bag variable, thus increasing the sample size to 12,325. Results of the regression are presented in Table 44. Vehicle age (transformed or not) was not statistically significant and was removed from the model. Increasing driver age was associated with fatal injuries. Younger drivers were less at risk to be fatally injured than drivers aged 40 to 49. These drivers, in turn, were less at risk to be injured than older drivers. Drivers aged

80+ were five times more at risk to be fatally injured than drivers aged 40 to 49. Overall, women were 54% more at risk to be fatally injured in a crash than men.

Data on BAC painted an interesting picture. A protective effect of alcohol was found at lower levels of BAC, but an injurious effect was found at higher concentrations. Drivers with little alcohol were 50% less at risk to be fatally injured. Conversely, heavily inebriated drivers were more than three times more at risk to be fatally injured than sober drivers.

In comparison to head on crashes, crashes on the right side and rear were associated with a lower risk of fatal injuries. However, crashes on the drivers' side had more than twice the risk to result in fatalities than head on crashes. Only three-point seat belts (shoulder and lap combined) offered protection in the event of a crash. Drivers wearing shoulder and lap seat belts were 54% less at risk to be fatally injured. Increasing traveling speed was associated with increased risk of fatal injuries. Drivers traveling at speeds of 70 miles per hour or more were nearly three times more at risk to be fatally injured than those traveling at speeds of less than 35 miles per hour.

The size of the vehicle (indexed either with wheel base or weight) provided protection against fatalities. A 10 inch increase in wheel base translated into a 10% reduction in the fatality risk. Surprisingly, recent model year vehicles were associated with a higher fatality risk. A five-year increase in model year translated into a 5% increase risk of fatality.

Table 44. Results of the multivariate logistic regression with driver fatality as dependent variable (OR and 99% CI).

Variable	OR	99% CI
Age		
<20	0.78	0.62, 0.99
20-29	0.76	0.60, 0.95
30-39	0.84	0.66, 1.07
40-49	1.00	1.00, 1.00
50-64	1.73	1.23, 2.44
65-79	2.33	1.58, 3.43
80+	4.98	2.01, 12.37
Gender		
Male	1.00	1.00, 1.00
Female	1.54	1.35, 1.76
BAC		
0	1.00	1.00, 1.00
.01 - .04	0.49	0.39, 0.62
.05 - .09	0.49	0.41, 0.58
.10 - .14	0.54	0.46, 0.64
.15 - .19	0.80	0.68, 0.94
.20 - .29	1.37	1.14, 1.64
≥ .30	3.16	1.96, 5.09
Impact		
Head on	1.00	1.00, 1.00
Right side	0.48	0.42, 0.55
Rear end	0.72	0.56, 0.93
Left side	2.26	1.92, 2.65
Restraint use		
None	1.00	1.00, 1.00
Shoulder belt	0.66	0.36, 1.21
Lap belt	0.82	0.50, 1.36
Shoulder and lap belt	0.46	0.39, 0.53
Travelling speed		
< 30	1.00	1.00, 1.00
30 – 59	1.36	0.94, 1.96
60 – 69	1.68	1.15, 2.45
70+	2.64	1.82, 3.83
Model year		
5 year increment	1.05	1.01, 1.09
Wheel base		
10 inch increment	0.90	0.85, 0.95

Seat belt use and fatality estimates

Several researchers have reported that seat belt use is over-reported because of the legal implication of not wearing seat belts in several U.S. jurisdictions (Levine, Bédard, Molloy, & Basilevsky. 1999; Li, Kim, & Nitz. 1999; Malliaris, DeBlois, & Digges. 1996; Stewart. 1993; Streff & Wagenaar. 1989). The net effect of this over-reporting is to misclassify survivors as belt wearers, and overestimate the effectiveness of belts in preventing fatalities. American researchers proposed that seat belt use should be discounted by 12% to reflect actual use (Streff & Wagenaar. 1989). Recently, Australian data showed that police reported belt use in crashes resulting in injuries overestimated actual use by 9% (Li, Kim, & Nitz. 1999). Therefore, the regression model was re-examined by discounting belt use by 10%. To model the effect of a 10% seat belt over-reporting, 10% of all cases were selected randomly, and all selected cases for whom a shoulder and lap belt was reportedly used were recoded as non-belt wearer. These data were re-analyzed as above. Verification of the re-coding procedure revealed that 9.8% fewer cases were coded as shoulder and lap belt wearer, and all cases were effectively added to the no belt category. Despite this change the model obtained was virtually identical to the one presented in Table 44. The effect of shoulder and lap belt was slightly less (OR = 0.48) but remained statistically significant and convincing (99% CI = 0.41, 0.56).

Older drivers

A regression analysis was completed to focus on drivers aged 65+. However, to maximize the number of observations available for the analysis only gender, direction of impact, restraint use, and travelling speed were used. This left 1,839 cases; results are presented in Table 45. The model obtained was similar to that obtained with all age categories (although the estimates were less precise) except for gender. Using drivers aged 65 and over only revealed that women were less at risk to be fatally injured than men.

Table 45. Results of the multivariate logistic regression with driver fatality (65+ only) as dependent variable (OR and 99% CI).

Variable		OR	99% CI
Gender			
	Male	1.00	1.00, 1.00
	Female	0.75	0.57, 0.98
Impact			
	Head on	1.00	1.00, 1.00
	Right side	0.68	0.44, 1.05
	Rear end	0.49	0.20, 1.17
	Left side	1.61	0.97, 2.67
Restraint use			
	None	1.00	1.00, 1.00
	Shoulder belt	0.48	0.11, 2.07
	Lap belt	0.71	0.31, 1.63
	Shoulder and lap belt	0.46	0.35, 0.60
Travelling speed			
	< 30	1.00	1.00, 1.00
	30 – 59	1.43	0.95, 2.14
	60 – 69	1.67	1.03, 2.69
	70+	3.00	1.57, 5.70

Discussion

The data presented here confirmed the assumption that older drivers are more vulnerable to the traumatic effects of crashes. A positive relationship was found between age and fatal injuries, after controlling for gender, BAC, restraint use, crash direction, traveling speed, and vehicle wheel base and model year. Whereas the risk of a fatal injury among young drivers (< 30) was less than 80% that of reference drivers aged 40 to 49, the risk of a fatal injury for an 80 year old or more driver was five times that of drivers aged 40 to 49. These results confirmed and expanded on the findings of others (Evans. 1986a; Levine, Bédard, Molloy, & Basilevsky. 1999; McCoy, Johnston, & Duthie. 1989; Zhang, Lindsay, Clarke, Robbins, & Mao. 2000) by controlling for driver, crash, and vehicle characteristics.

Consistently with others (Levine, Bédard, Molloy, & Basilevsky. 1999), data on gender showed an overall 50% in increased risk for fatal injuries in women compared to men. However, in both this study and that of Evans (Evans. 1988c) this effect appears mostly limited to younger women. Women aged 65 and over in this study were 25% less at risk to be fatally injured than men of the same age, results once again consistent with the literature (Zhang, Lindsay, Clarke, Robbins, & Mao. 2000). The reasons for this age by gender interaction are not clear. These findings were obtained after controlling for driver behavior and important crash and vehicle characteristics. Possibly, overall health, which cannot be determined with the present database, may explain gender differences.

Data on BAC and fatalities revealed a "U"-shaped relationship. The risk of a fatal injury was 50% less among drivers with alcohol concentrations at or below the typical legal limits (< .10), than among sober drivers. This suggests that anecdotal support for a protective effect of alcohol may be real (Waller, Stewart, Hansen, Stutts, Popkin, & Rodgman. 1986). However, at higher BAC (> .19) alcohol had a detrimental effect on survival risk. At a BAC of .30 or greater, drivers were three times more at risk to be fatally injured than sober drivers. Because the analyses controlled for driver behavior, the lethal effect of high alcohol concentrations likely represented a weakened physiological response to the crash trauma as suggested earlier (Evans. 1992a; Evans. 1993b; Waller, Stewart, Hansen, Stutts, Popkin, & Rodgman. 1986)

When driver and vehicle characteristics were maintained constant, driver side impacts were the most lethal. Drivers hit on the left side were more than twice at risk to be fatally injured than drivers who experienced front impacts. On the other hand, right side and rear impacts, which accounted for only 21% of all crashes, were associated with proportionally fewer fatalities. The problem associated with driver side crashes may be especially relevant for older drivers because they are more likely to be struck by incoming vehicles at intersections than other age groups (Hakamies-Blomqvist. 1993).

Consistently with others (Evans. 1986b; Evans. 1987; Evans. 1988b; Nash. 1989; Robertson. 1996; Streff. 1995), analyses on restraint data showed an unequivocal protective effect of three-point belts. Two-point belts had OR in the expected direction but sample sizes were too small to provide precise estimates. However, most vehicles on the roads at the present time are equipped with three-point belts.

Given the strength of the association between restraint use and non-fatal injuries it appeared unlikely that the effect was due to over-reporting of belt use. This possibility was substantiated by the random recoding of 9.8% of all three-point belted cases into non-belt wearers. Furthermore, there was a gradient (dose-related response) between restraint use and fatal injuries, such that the risk of a fatal injury decreased from no restraint to two-point restraints to three-point restraints. These facts reinforce the belief that seat belts saved lives. Wearing a seat belt halved the risk of a fatal injuries in the dataset analyzed.

The protective effect of belts may not generalize well to crash conditions outside those studied here. The majority of the crashes studied involved front impacts, for which belts are best suited (Levine, Bédard, Molloy, & Basilevsky. 1999); seat belts are reportedly less effective in struck vehicles than striking vehicles (Evans & Frick. 1986). Thus, increasing the proportion of angled crashes such as those resulting from multi-vehicle intersection crashes may reduce the overall protective effect of belts. On the other hand, belts are beneficial in preventing ejections in roll-over situations (Esterlitz. 1989), which are also associated with considerable excess mortality (Evans & Frick. 1989a; Zhang, Lindsay, Clarke, Robbins, & Mao. 2000). Roll-over crashes were not included in the dataset analyzed, the safety impact of belts may be increased with the inclusion of these cases.

Air bag data failed to show a protective effect. This result is surprising given that air bags are expected to perform well in front impacts (Evans. 1990a; Evans. 1991; Zador & Ciccone. 1993). Other researchers reported reductions in fatalities ranging between 16 and 28% (Lund & Ferguson. 1995; Zador & Ciccone. 1993). However, their analyses did not control adequately for driver, crash, and vehicle characteristics. Also, early models equipped with air bags may have been luxurious, large vehicles. It is also unclear what additional benefit, if any, air bags provided to seat belts, and, if specific groups of drivers may have been adversely affected by air bags.

Both vehicle deformity and traveling speed provided evidence supporting a relationship between the extent of the damage sustained by a vehicle and injury severity. Severe vehicle deformity and faster vehicle speed prior to the crash were associated with more fatalities, corroborating the results of others (Dischinger, Siegel, Ho, & Kufera. 1998; Kulmala. 1994; Zhang, Lindsay, Clarke, Robbins, & Mao. 2000), while controlling for potential confounders. In the regression analysis, traveling at a speed of 70 miles per hour or more was independently associated with a 264% increase in the risk of a fatality compared to speeds of less than 30 miles per hour.

Larger vehicle were safer after controlling for other variables. A 10 inch increase in wheel base translated into a 10% reduction in the fatality risk. Similarly, others have reported benefits for longer/heavier vehicles (Evans. 1985; Evans. 1992b; Evans. 1993b; Evans & Frick. 1994; Evans & Wasielewski. 1987; Levine, Bédard, Molloy, & Basilevsky. 1999). On the other hand, earlier model year vehicles were associated with an increased risk of fatalities of five percent for each five years. Others reported that recent models were safer (Levine, Bédard, Molloy, & Basilevsky. 1999) and others that there was no relationship (Robertson. 1996). And whereas the present analyses did not find an association between vehicle age and fatalities, others reported such findings (Robertson. 1996). Discrepancies between these studies are likely explained by crucial methodological differences and samples. This study controlled for more potential confounders, but focusing analyses on single-vehicle impacts with fixed objects limited the generalizibility of the findings.

The findings of this chapter illustrate that older adults are at increased risk of fatal injuries in crashes younger adults may survive. Although drivers with low BAC may be more likely to survive a crash, they are even more likely to commit driving errors leading to fatal crashes (see Table 28). A high BAC is doubly lethal because both the risk of a driving error and fatal injury are highly elevated compared to sober drivers.

Possibly the best safety provision for older adults is to wear seat belts, avoid traveling at high speeds, and avoid driver side crashes. Side air bags are now available with many new vehicles. However, their efficacy, as well as that of front air bags, remains to be elucidated fully. Finally, larger vehicles continue to afford more protection to their occupants than smaller vehicles. Their public health benefits need to be weighted against the societal benefits of smaller cars.

Chapter 9. General discussion

Projections

If current trends continue, the number of traffic fatalities involving older drivers and passengers will rise dramatically in coming years. In 1975, 3,536 drivers and passengers aged 65 and over lost their lives. This number is expected to rise to 9,569 by year 2015. In 1975, drivers and passengers aged less than 30 accounted for nearly six times more fatalities than those aged 65 and over. In 1998, this ratio was down to three to one. By 2015 it is expected that the number of fatalities attributed to driver and passengers aged 65 or more will be equivalent to that of drivers aged less than 30.

Swift action is required to address this expected increase in traffic fatalities and other injuries. However, effective new prevention strategies require a re-evaluation of the driving environment, and driver characteristics. It is insufficient to continue or step-up existing strategies, new ones will need to be devised to address new problems related to changes in the typical driver's profile. In the past years, traffic crashes were rightly seen as a young male driver problem. In coming years crashes will involve an heterogeneous group of drivers; prevention strategies will have to reflect this changing reality.

Driving errors

Data from FARS showed that older drivers committed proportionally more errors than middle-aged drivers. In this study, 61% of drivers aged 65 to 79, and 78% of drivers aged 80 and over, committed a driving error, compared to 48% of drivers aged 40 to 49. Young drivers committed errors related to their aggressive driving behavior. Older drivers, on the other hand, made attention/perception errors. Among the sample studied the most frequent driving error involved a road sign or warning. Twenty-eight percent of drivers aged 65 to 79, and 47% of drivers aged 80 and more, made a driving error involving a road sign or warning. In comparison, only 10% of drivers aged 40 to 49 made such errors.

After controlling for exposure, drivers age 65 to 79 were more than three times more at risk to commit errors related to road signs and warnings than drivers aged 40 to 49, drivers aged 80 and more were nearly eight times more at risk. Errors involving traffic entering/exiting, and turning were also more likely among drivers aged 65+ compared to those aged 40 to 49. These types of errors are not consistent with those recorded for younger drivers and attest to the special needs of older drivers.

Upon examination of the situations in which older drivers are more likely to commit driving errors, several prevention avenues present themselves. Older drivers were at higher risk to commit errors on small roads, on curved sections, when the pavement surface was concrete, at intersections, and on roads with higher speed limits. In these situations, re-engineering to make roads friendlier to older adults may reduce the number of fatalities.

Altogether, the type of errors older drivers committed, and the situations in which they were most at risk to commit these errors point to difficulties with attention and perception. Even among healthy older adults, attention and perceptual abilities are not as good as that of younger adults (Nestor, Parasuraman, & Haxby. 1989; Rabbit. 1965). Selective attention and perceptual measures were related to driving errors and crashes in older commercial drivers (Barret, Mihal, Panek, & et al. 1977; Kahneman & Ben-Ishai. 1973; Mihal & Barrett. 1976). Furthermore, potentially distracting devices such as cellular phones are related to crashes (Redelmeier & Tibshirani. 1997; Violanti & Marshall. 1996).

Overall, the results presented here showed that drivers aged 65 to 79 were twice at risk to commit a driving error compared to drivers aged 40 to 49, and drivers aged 80 or more were five times more at risk, after controlling for the crash situations in which drivers were involved. The data on drivers aged 80 or more suggest that some may be cognitively impaired at the time of the crash. The implications of this possibility will be discussed further in the section on "driving assessment and cessation".

Driver characteristics related to driving errors

Driver characteristics may be used to identify drivers who may be at increased risk of committing driving errors. A driver's prior record of crashes and convictions was related to driving errors in a linear fashion. More incidents in the three-year period preceding the crash increased the risk that the driver made a driving error in the current crash. Interestingly, this relationship was not dependent on age, once four or more incidents have been recorded, the risk of a driving error increased by 50%. This shows that considerable variability in driver ability exists even within the so-called "safest" driver age groups.

Data on driver characteristics once again highlighted the importance of alcohol consumption in crashes, and also supported the notion that it is a problem especially pertinent to young drivers (Isaac, Kennedy, & Graham. 1995; Zobeck, Grant, Stinson, & Bertolucci. 1994). Alcohol represents a social problem because different types of accident-related injuries. not just crash-related injuries, are linked to alcohol consumption (Chipman. 1995). More worrisome, the analyses presented showed that driving errors increased significantly even at very modest alcohol levels. No levels of alcohol were found to be safe.

However, these results can only be extended so far because approximately 50% of all drivers were not tested. Although, it is likely that drivers who were not tested were not impaired, the results can only be generalized to drivers who were tested. If many drivers with a BAC greater than zero were not tested because they did not commit an error, then the overall effect of alcohol was overestimated in this study. On the other hand, if drivers who were not tested had a BAC of zero, then the overall effect of alcohol was underestimated. Future work should clearly determine if there is a safe BAC in relation to driving.

In a related fashion, drug/medication use (both licit and illicit categories) was associated with driving errors. The data confirmed that narcotics and medications with depressant effects were associated with driving errors as suggested by others (Arditti, Bourdon, David, Lanze, Thirion, & Jouglard. 1993). These medications (Gilley, Wilson, Bennett, Stebbins, & et al. 1991;

Hemmelgarn, Suissa, Huang, Boivin, & Pinard. 1997; Leveille, Buchner, Koepsell, McCloskey, Wolf, & Wagner. 1994; Ray, Fought, & Decker. 1992) may require monitoring, especially for older adults. This study expanded on previous work by using driving errors as the dependent variable as opposed to crash involvement, and controlling for potential confounders, including alcohol use. Furthermore, the data were not obtained via self-report, which sometimes results in under-reporting of medication use (Ray, Gurwitz, Decker, & Kennedy. 1992).

Unfortunately, several limitations were noted with the FARS dataset. Drug/medication use was obtained for a very small subset of all drivers, limiting the generalizibility of the findings as well as the extent to which specific classes of drug/medications can be investigated. However, the collection of these data is continuing. More detailed analyses could be conducted in a few years. Furthermore, it was impossible to distinguish the effect of the medications used from that of an underlying illness (Ray, Gurwitz, Decker, & Kennedy. 1992). Several studies point to relationships between illnesses and increased crash risk (Lilley, Arie, & Chilvers. 1995; Waller. 1992), but controlling for these conditions was not possible because the information was not available. Ideally, information on medical diagnoses should be made available for future work.

The presence of passengers was related to fewer driving errors among older adults. However, the mechanism of this effect has not been ascertained. Some have suggested that older adults, and especially those who may be cognitively impaired, may benefit from the presence of a "co-pilot" (Bédard, Molloy, & Lever. 1998; Donnelly & Karlinsky. 1990; Shua-Haim & Gross. 1996; Wallace & Retchin. 1992). One cynical alternative is that older drivers who are unable, but continue to drive, do not find willing souls to drive along with them. Alexander (Alexander. 1995) reported the case of a 90 year old driver with whom "...accepting a lift...was a fate to be avoided at all costs." (p. 269)

Protection against fatal injuries

In the event of a crash, some individuals will fare better than others. The reasons for this differential lie in the characteristics of the individual, as well as in those of the crash and the vehicle in which the occupants were. Older adults are more susceptible to injuries than younger adults. After controlling for confounders, an 80 year old driver was five times more at risk to be fatally injured than a 40 year old driver. Interestingly, older women did better than men. These data are consistent with others (Evans. 1988c; Zhang, Lindsay, Clarke, Robbins, & Mao. 2000).

Impacts on the driver's side were the deadliest, followed by head-on impacts. Impacts on the right side and rear were the least fatal. These data highlight the lack of protection in driver side impacts. There is little to prevent the intrusion of traumatic objects into the occupant cage (Dischinger, Siegel, Ho, & Kufera. 1998; Shkrum, McClafferty, Green, Nowak, & Young. 1999). And furthermore, seat belts are engineered to work best in front impact situations (Evans & Frick. 1986; Levine, Bédard, Molloy, & Basilevsky. 1999).

Although seat belts were associated with a 50% reduction in the risk of fatal injuries, speeds of 70 miles per hour or more were associated with a tripling of the fatality·risk compared to speeds of less than 30 miles per hour. Others also have reported an increase in fatality rates with speed (Dischinger, Siegel, Ho, & Kufera. 1998; Zhang, Lindsay, Clarke, Robbins, & Mao. 2000). Compounded with their increased susceptibility to trauma, older adults are even more at risk of fatal injuries in high-speed crashes.

Prevention strategies

Large databases such as the FARS database have considerable potential to answer health questions (Ray. 1997; Rubin. 1997) and may represent a suitable alternative to randomized controlled trials (Hornberger & Wrone. 1997). Ethically, a randomized controlled trial would not be desirable to answer the questions asked here. An observational design is the only possibility. Although causal inferences are limited they are possible. It is for example, clear that alcohol is causally related to driving errors leading to fatal crashes, because of the strength of the association, and its dose-related gradient.

Importantly, this study focused on driving errors leading to fatal crashes. Collectively, we are especially interested in reducing crashes, hence crashes are the most relevant outcome (Marottoli. 1997). Despite the focus on fatal crashes, the size of the database allowed for multivariate analyses. Others have attested to the multi-factorial nature of crashes and other traffic-related events (Ball & Owsley. 1991). The simultaneous evaluation of several variables strengthened the results obtained by other investigators. Based on the results reported here and by others several prevention strategies were identified.

Two mainstream prevention strategies are possible to curb traffic-related fatalities, "high-risk" strategies, and "population-based" strategies (Rose. 1992). High-risk strategies focus on individuals especially at-risk for driving errors and crashes. Population-based strategies focus on society-wide interventions. Both types of strategies have advantages. A combination of both would maximize prevention.

Possibly the most general recommendation is that further research is required to determine with more assurance, what variables are causally linked to driving errors and crashes and what impact current programs may have. However, although we need more detailed information to tackle many of the issues raised so far, the lack of absolute "scientific" knowledge is not a sufficient reason to ignore and postpone action on the problems at hand (Schlesselman. 1987).

Driving record

The association between previous driving mishaps and driving errors is not new (Janke. 1990). The clear relationship between these two variables suggests that the driving record could be used to identify drivers at risk of committing errors. Demerit points systems, such as the one used in Ontario, are also potentially useful to identify drivers at risk of committing errors (Chipman & Morgan. 1975). However, demerit point systems may be too relaxed and too heavily weighted towards incidents perceived as severe. For example, in

Ontario, no automatic suspension is given unless a driver reaches 15 demerit points. The most serious offence according to the system (seven points) is failing to remain on the scene of an accident, and no demerit points are given for speeding violations not exceeding 15 kilometers per hour above the speed limit (Ontario Ministry of Transportation. 2000).

Under its current structure, the Ontario demerit point system may not capture hazardous drivers until it is too late. Furthermore, the system has no built-in re-training strategies. Re-testing may be required, but given that most adults can pass the test, it is not necessarily an indication that the driver has improved his/her driving skills. Hence, mandatory re-training and re-testing following a specific number of driving incidents in a specific time period may lead to fewer crashes by these drivers.

The variability of driving records within all age categories studied illustrates that there are unsafe drivers among all these age groups. This suggests that the sacredness of the driver's license needs to be questioned, the driver's license is a privilege and not a right. The driver's license is awarded after limited training, it then becomes an unquestionable right for 50 or 60 years, and then may be given up or revoked. There are no reasons to assume that all drivers remain safe all along their driving career. Mandatory lifelong testing every five years may be desirable, followed by biannual testing from age 65 to 79, and annual testing thereafter. It is not clear why the Government of Ontario has eliminated its mandatory testing for drivers aged 80 or more. The data provided here point to a five-fold risk of driving errors compared to drivers aged 40 to 49. The irony, as O'Neill pointed out (O'Neill. 1992) is that many jurisdictions "...test vehicles as they age, but do not test elderly drivers." (p.42)

Alcohol use

Alcohol use and driving was infrequently cited among older drivers, yet continues to be a major societal problem. The human cost associated with alcohol exceeds that related to the excess initiation of crashes, and includes the excess mortality related to the injury vulnerability associated with alcohol (Evans. 1992a; Waller, Stewart, Hansen, Stutts, Popkin, & Rodgman. 1986).

Given that a BAC of .30 or greater is associated with an eight-fold increased risk of a driving error, and a three-fold increased in fatality risk, the damaging effects of high alcohol consumption are unquestionable. However, it is often impossible to identify individuals with a high BAC before they "hit the road". Waller suggested that licensed establishments serve a maximum number of drinks by customer, a number in line with legal limits (Waller. 1986). To what extent this proposal remains feasible, or would simply divert drinking behavior to other venues are important unanswered questions.

Data on the impact of raising the legal drinking age attest to this problem. Smith and colleagues compared the effect of raising the legal drinking age from 18 to 20 in Massachusetts, to New York state where it remained at 18 (Smith, Hingson, Morelock, et al. 1984). Little changed in Massachusetts regarding the frequency and amount of alcohol consumed after the legislation, but the frequency of alcohol being purchased by others raised after the legislation. Overall fatal crashes were unaffected by the legislation changes. It is possible that many crash-involved drinkers are "hard core" drinkers not easily deterred from their habit, and potentially in need of medical intervention (Kennedy, Isaac, & Graham. 1996).

Maybe the most contentious issue raised by the results presented in this thesis is whether a "zero-tolerance" policy should be recommended. Increases in driving error rates were found at even the smallest alcohol levels. And Evans projected that 48% of all U.S. fatalities would be eliminated if drinking and driving disappeared (Evans. 1990b). However, fewer fatalities occurred at the lower BAC. Thus, preventing drinking and driving at the lowest BAC would not result in as many lives saved as if driving with moderate to high BAC were eliminated. Pertinent to this issue is that of enforcement. It is unclear how enforceable a "zero-tolerance" policy would be, and at what cost. Nonetheless, it is clear that population-based education strategies for the public, and especially the younger drivers, are desirable. A "zero-tolerance" policy for young drivers may represent a suitable compromise.

Drug/medication use

Illicit drug use is not a concern for older drivers. However, medications they use (e.g., narcotics) were associated with driving errors. One of the most significant physiological changes associated with aging is the reduction in the body's ability to metabolize and excrete medications at the hepatic and renal levels, and following age-associated changes in the fat to lean body mass ratio (Ray, Gurwitz, Decker, & Kennedy. 1992). At the kidney level, aging results in reduced renal blood flow and a reduction in the number of intact nephrons, leading to a progressive loss of glomerular filtration, reaching 35% by age 90 (Lindeman, Tobin, & Shock. 1985). A recent study of long-term care residents revealed that 57% had considerable renal clearance impairment (Campbell & Graham-Robinson. 1999).

The reduced capacity of the aging body to dispose of drugs is in sharp contrast to the increase in medication use associated with aging. Although adults 65+ account for 12% of the population (World Health Organization. 1999), they are the largest consumers of prescription and over the counter medications (Quinn, Baker, & Evans. 1992). The average elderly uses four to five prescription and over the counter medications, and 30% of older adults use six or more medications (Larson, Kukull, Buchner, & Reifler. 1987; Pollow, Stoller, Forster, & Duniho. 1994). The number of medications consumed is associated with the development of adverse drug events (Starr & Whalley. 1994). In older adults using six or more medications the relative odds of an adverse event is 13 (Larson, Kukull, Buchner, & Reifler. 1987).

One contributing variable to the problem of adverse drug events is the discrepancy between the medication dosages older adults take, and their body's ability to dispose of these medications, with the resulting toxicological effects of the medications (Gurwitz & Avorn. 1991; Jick. 1977). Consequently, geriatric pharmacologists have determined optimal dosages under varying conditions of clearance capacity (American Society of Health Systems Pharmacists. 1998; Aronoff, Berns, Brier, et al. 1999; Canadian Pharmacological Association. 1999; Semla, Beizer, & Higbee. 1998).

Physicians should be especially cautious about the dosages they prescribe to older drivers (Ray, Gurwitz, Decker, & Kennedy. 1992). For many medications, medication use should be discontinued, for others dosage should be reduced according to the individual's ability to eliminate medications. Alternatives medications with fewer side effects could be prescribed if available. Also, in some instances, therapeutic efficacy may be achieved independently of side effects. Hence, it would be desirable to foster the development of newer medications with fewer side effects that may impair driving ability (O'Hanlon. 1992).

Restraint use

In a study of 246 consecutive patients who sustained crash-related trauma, belted patients were less likely to have sustained severe injuries than non-belted patients, despite similar proportions of drivers who were exceeding 55 miles per hour (Redelmeier & Blair. 1993). Importantly, 50% of non-belted drivers suffered head injuries compared to 30% of belted drivers. Consistently, the resultant hospital charges were twice as much for the non-belted group ($16,209US vs. $8,580US). Although twice as many non-belted drivers had a BAC of .08 or more, this difference appears unlikely to explain the discrepancy in hospital costs.

These data illustrate the societal implications of not wearing seat belts. Overall, belts reduced the fatality risk by 50% in the analyses conducted for this thesis. However, belts are associated with increases in other injury types. Specifically, belt wearers are 50% more at risk to suffer neck sprains

(Bourbeau, Desjardins, Maag, & Laberge-Nadeau. 1993; Bradbury & Robertson. 1993) and other cervical injuries (Tolonen, Kiviluoto, Santavirta, & Slätis. 1984) in crashes. The proportion of chest injuries also increased with seat belts (Allen, Barnes, & Bodiwala. 1985; Muwanga, Cole, Sloan, Bruce, Dove, & Dave. 1986; Newman. 1984; Newman & Jones. 1984). In severe crashes where heart ruptures are common, seat belts may be ineffective at preventing fatalities (Levine, Bédard, Molloy, & Basilevsky. 1999; Santavirta & Arajärvi. 1992; Shkrum, McClafferty, Green, Nowak, & Young. 1999). Furthermore, seat belts may be better suited to younger vehicle occupants than older ones (Evans. 1991; Levine, Bédard, Molloy, & Basilevsky. 1999; Lilley, Arie, & Chilvers. 1995). Increases in chest injuries may be more predominant among older occupants than younger ones (Lilley, Arie, & Chilvers. 1995).

It would be desirable to target injuries that are associated with belts to maximize the benefits afforded by wearing them. It is not clear how air bags may provide additional safety in addition to belts. Air bags are also best suited to front impacts (Evans. 1991) and afford less protection against ejections than belts (Evans. 1990a). And because of the mechanics of injuries (Viano. 1988), crashes severe enough to fatally injure vehicle occupants wearing seat belts may not result in different outcomes even with the addition of air bags. The data presented in this thesis attested to this possibility. Air bags are possibly more a response of car makers to Americans' reluctance to wear seat belts. Automatic seat belts were also intended to force passengers to wear seat belts.

Additional safety features to seat belts must come from protection against side impacts. The data presented here attested clearly to the danger of being struck on the driver' side. This problem may be partially explained by our perpendicular intersections, and possibly by the height differential between vehicles. This situation may worsen with the increased popularity of four by four vehicles. Side air bags may provide some protection in side impacts, but this possibility will not be tested satisfactorily until more data have been acquired.

Speed limits

Speed had two main consequences for older drivers. First, it increased their risk of making a driving error. Second, it increased their risk of being fatally injured in a crash. Therefore, if we want to reduce the number of crashes older drivers initiate, and the consequences of these crashes, it appears desirable to reduce the speeds at which we drive.

The societal implications of such decisions are varied and beyond the scope of the present thesis. However, reductions in speed limits, or even "zero-tolerance" of existing ones would likely reduce the number of crashes, fatalities, and crash-related health care expenses (Dischinger, Siegel, Ho, & Kufera. 1998; Van Tuinen. 1994).

Engineering

Others have suggested that improved road signs may prevent crashes among older drivers (Marottoli. 1997). The data presented here provide convincing support for this proposition. Road signs/warnings were associated with a driving error risk eight times greater among drivers aged 80 or over compared to drivers aged 40 to 49. Similarly, engineering changes at intersections may provide protection for older drivers (Marottoli. 1997).

Automotive engineering changes beyond restraints and air bags (e.g., crumpling zones, rigid cages) may provide added benefits. However, the data presented here did show a negative effect of newer models. New driver protection standards introduced in the late 1960's (e.g., rearward column displacement) were not found to reduce fatality rates (Evans & Frick. 1989b). Others have reported increased safety with newer models but focused only on front impacts, and did not factor in the vehicle age (Levine, Bédard, Molloy, & Basilevsky. 1999).

Kaszniak suggested that advanced electronic guidance systems may help older drivers (Kasziak, Keyl, & Albert. 1991). The potential usefulness of such devices is dubious for cognitively impaired drivers but may benefit other older drivers and deserves to be tested.

The cognitively impaired driver

The older drivers included in the analyses presented in earlier chapters probably included adults suffering from cognitive impairment. Lundberg and colleagues showed that among a sample of 37 drivers aged 65 or more with suspended licenses, crash-involved drivers were more likely to have a cognitive impairment than those whose were not involved in crashes (Lundberg, Hakamies-Blomqvist, Almkvist, & Johansson. 1998). Others showed an association between prior crash involvement and cognition among 3,238 older drivers (65+) applying for license renewal (Stutts, Stewart, & Martell. 1998). .

The number of cognitively impaired older adults is increasing. Results from the Canadian Study on Health and Aging (McDowell & et al. 1994) revealed that 2.4% of Canadian adults age 65 to 74 have dementia, and this proportion was 11.1% for adults aged 75 to 84, and 34.5% for those aged 85 and over. The number of Canadians with dementia is expected to rise from 252,600 in 1991, to 475,000 by year 2011 (McDowell & et al. 1994). Therefore, the identification of older drivers who may be cognitively impaired is critical.

The identification of cognitively impaired drivers

Attention/perception difficulties in healthy older adults were discussed earlier. In cognitively impaired older adults these difficulties are magnified (Tinklenberg. 1984). Short-term memory loss is often the first sign of cognitive impairment (Baddeley & et al. 1986). This aspect is worrisome because the knowledge required to initiate driving depends on long-term memory, and is therefore intact, whereas the knowledge necessary to maintain safe driving depends heavily on short-term memory, which is impaired early in the course of dementia (Parasuraman & Nestor. 1991).

In individuals with Alzheimer's disease, the first impairment not related to memory is a loss of attention capacity (Grady, Haxaby, & Horowitz. 1988). The ability to divide attention is crucial for driving (Duchek, Hunt, Ball, Buckles, & Morris. 1997), yet it is impaired in individual with Alzheimer's disease (Grady, Grimes, Patronas, Sutherland, Foster, & Rapoport. 1989;

Nestor, Parasuraman, Haxby, & Grady. 1991). Performing simultaneous tasks is more difficult for these individuals than in age-matched healthy controls (Baddeley & et al. 1986). Similarly, an important attention mechanism is selective attention, or the ability to select important information and ignore irrelevant information (Duchek, Hunt, Ball, Buckles, & Morris. 1997). In Alzheimer's disease, the ability to ignore (inhibit) irrelevant information is compromised (Sullivan, Faust, & Batola. 1995), and selective attention is related to driving abilities as determined by an on-road driving test (Duchek, Hunt, Ball, Buckles, & Morris. 1998).

One solution to the problem posed by cognitively impaired older drivers is to discontinue driving for all who have a diagnosis of cognitive impairment. Friedland suggested that all drivers with Alzheimer's disease should stop driving (Friedland, Koss, Kumar, et al. 1988). Lipski claimed that there is no evidence supporting safe driving in those with dementia (Lipski. 1997). Swift editorials in response to these claims aptly pointed out that several individuals with dementia are safe drivers (Drachman. 1988; Fox & Bashford. 1997). Not all individuals with some form of cognitive impairment are unable to drive (Donnelly & Karlinsky. 1990; Fox, Bowden, Bashford, & Smith. 1997). Most individuals with mild impairment will remain capable of safely operating a vehicle if they do not have other functional impairment (Bédard, Molloy, Guyatt, Stones, & Strang. 1997; Johansson & Lundberg. 1997).

On the other hand, many chronic conditions may affect one's ability to drive irrespective of age. The issue is not so much one of the older driver as it is one of the unsafe driver (Wallace & Retchin. 1992). Because of the importance of driving in today's society, each driver's privilege to drive should be decided based on his/her own abilities (O'Neill. 1993). One reason supporting the use of diagnostic labels to identify unsafe drivers is that it is difficult to screen for drivers at risk. It is imperative that we reassure ourselves that unsafe drivers are identified so that the driving privilege is not revoked without reason (O'Neill. 1992).

At present, in the absence of mandatory on-road testing, the responsibility to identify unsafe drivers rests mostly on primary care physicians (Reuben. 1996). Physicians have a moral obligation to report individuals who cannot drive safely (Antrim & Engum. 1989; Capen. 1994; Coopersmith, Korner-Bitensky, & Mayo. 1989; Retchin & Anapolle. 1993; Reuben, Stilliman, & Traines. 1988). However, they do not have the training and tools to detect the attention/perception deficits most likely to affect driving (Bédard, Molloy, Guyatt, Stones, & Strang. 1997; Fitten. 1997), and relatives often fail to identify unsafe drivers reliably (Cooper, Tallman, Tuokko, & Beattie. 1993). Their assessment is thus based on general health and vision, both of which bear little relationship with driving ability (Brouwer & Ponds. 1994). Preferably, a brief screening test to determine who needs more comprehensive testing should be developed and applied (Carr. 1997; Dobbs. 1997; Drickamer & Marottoli. 1993). Such a screening process would be cost-effective (Retchin & Hillner. 1994).

Re-testing

Periodical on-road testing remains the best strategy to identify unsafe older drivers (Bédard, Molloy, Guyatt, Stones, & Strang. 1997; Fox, Bowden, Bashford, & Smith. 1997; Fox, Withaar, & Bashford. 1996). Levy and colleagues reported that states with mandatory vision and road tests for older drivers enjoyed lower fatality rates than other states not requiring testing (Levy, Vernick, & Howard. 1995). However, crash initiation was not ascertained in their analyses. Also, it remains unclear if these data are attributable to older drivers giving up driving because of the testing burden, or if unsafe drivers were identified (Levy, Vernick, & Howard. 1995). A comparison of Finland, where strict re-testing procedures are in place, and Sweden, showed that fewer Finnish adults continued to drive compared to their Swedish counterparts (Hakamies-Blomqvist, Johansson, & Lundberg. 1996).

Yet, with increasing demographic pressure, legislators may be tempted to move away from large-scale screening (Parasuraman & Nestor. 1991). Witness the Province of Ontario. Mandatory yearly testing for drivers aged 80 or more has been replaced with a written test and participation in a seminar every second year (Bédard, Molloy, Guyatt, Stones, & Strang. 1997). Simulators may be used to reduce the screening burden. Although the utility of simulators to test driving abilities has not been demonstrated so far, it is worthy of research (Blysma. 1997; Eberhard. 1997). Simulators also may become useful to decompose crashes into events and errors leading to crashes (Reinach, Rizzo, & McGehee. 1997).

Driving cessation

Most older adults will restrict their driving as they get older, and stop driving when they feel unsafe (Brorsson. 1989; Forrest, Bunker, Songer, Coben, & Cauley. 1997). Driving cessation is inevitable for all adults who will live long enough, and potentially creates considerable lifestyle changes. The personal advantages of the automobile over public transportation are undeniable. They include: easy access, easy baggage transportation, privacy, weather protection, and psychological safety (Brouwer & Ponds. 1994). Driving cessation means losing one or more of these advantages. How this will affect an older adult's quality of life, and potentially that of a spouse, is unclear and needs to be studied (Waller. 1992).

Driving cessation may have a psychological impact. One's sense of self-worth may be related to the ability to go places independently with his/her automobile (Friedland. 1997). Driving cessation is one of the most important predictors of increases in depression symptoms among older adults (Marottoli, Mendes de Leon, Glass, et al. 1997). Ways to alleviate the impact of driving cessation are desirable. However, while focusing on driving cessation, researchers should also examine ways to maintain safe driving for as long as possible.

Re-training/education

Much effort has been devoted to identifying unsafe drivers but much less to enabling older adults to continue driving safely (O'Neill. 1995). Re-training of older adults with attention/perception problems but not cognitive impairment may achieve reduction in crashes (Ball. 1997; Owsley. 1994; Owsley. 1997; Parasuraman & Nestor. 1991). For most current older drivers, formal driver training was not available when they started driving, hence refresher courses may be beneficial (Underwood. 1992). However, the effectiveness of re-training lacks the support of empirical data, rehabilitation and re-training as means to promote safe driving have been virtually ignored by researchers (O'Neill. 1996).

In addition to attention/perception skills, a less discussed yet possibly re-trainable aspect of aging is that of psychomotor abilities (Marottoli & Drickamer. 1993; Marottoli, Ostfeld, Merrill, & et al. 1993). Psychomotor abilities may play a crucial role in safe driving. Reaction time increases may result from motor deficits (Marottoli & Drickamer. 1993). Foot problems and poor mobility have been associated with driving difficulties (Marottoli, Cooney, Wagner, Douchette, & Tinetti. 1994). One other issue that may be addressed through re-training is the older drivers' bias that they are less likely to be involved in crashes than other drivers of the same age (Holland. 1993). In a separate study of 37 patients hospitalized in a geriatric ward who intended to drive following discharge, all considered themselves safe to drive, but medical staff considered 78% of them as unsafe (Pullen, Harlacher, & Fusgen. 1997).

Transportation/societal changes

Maintaining independent living

The number of older adults that will be fatally injured in the coming years is worrisome. If the fatality projections described in this work are accurate, we are facing a considerable public health problem. Traffic-related injuries and fatalities represent an obvious threat to the quality of life and independence of older adults. Interventions based on research are desirable avenues to reduce the number of older adults who may otherwise be injured in crashes.

The results presented in the previous chapters illustrate salient differences between young and older drivers. This information expands on the results presented by several other researchers and points to intersections and signs/warnings as potential areas for interventions. Furthermore, prior driving records point to older drivers who may pose an unusual safety risk. On the positive side, drivers may have a reduced risk of making driving errors when accompanied by passengers. Changes in the driving environment may result in the prolongation of the driving privilege for many older adults.

Yet, driving cessation does not necessarily mean the end of independent living, but in our society, driving is often considered as an important component of successful aging (O'Neill. 1996). However, it is not clear if someone who cannot drive is nonetheless in a position to use other existing forms of transportation (Eberhard. 1997). Bus stops may be too far or bus routes non-existent, cab fares too expensive, and friends and relatives too distant or unavailable to provide transportation. More research should be devoted to the study of transportation alternatives and other mechanisms to maintain autonomy in older adults, and minimize the impact of driving cessation on quality of life (O'Neill. 1997; Owsley. 1997; Ray. 1997).

Societal changes

Possibly, the challenges we face with the aging population point to a need for wider societal changes. The typical sprawling suburbs where many older adults presently live may have promoted dependence on the automobile (Bédard, Molloy, Guyatt, Stones, & Strang. 1997). These suburbs will have to change if older adults are to remain independent, while relying less on their own vehicles for transportation (Stanfield. 1996).

How we allocate resources will also have to change in order to reflect the interdependence of the various sectors of our society. The health care budget is affected by changes in traffic-related injuries. Possibly then, it would be fair to allocate health care resources to reduce traffic-related injuries. Such changes require the de-fragmentation of budgets. At present, every public sector operates without consideration for others, because budget accountability is not based on a society-wide perspective. Meeting the needs of increasing numbers of older adults will require a shift in the budgeting process towards a global perspective.

Appendix I

FATAL ACCIDENT REPORTING SYSTEM
1998 SEQUENTIAL ANALYSIS FILES
RECORDS DESCRIPTIONS

ACCIDENT LEVEL DATA FIELDS	TYPE	START	LENGTH
CASE STATE	N	1	2
CASE NUMBER	N	3	4
SEQUENCE NUMBER	N	7	1
VEHICLE NUMBER (value: blanks)	A	8	2
LEVEL NUMBER (value: 1)	N	10	1
PERSON NUMBER (value: blanks)	A	11	2
CITY	N	13	4
COUNTY	N	17	3
ACCIDENT DATE			
MONTH/DAY mmdd	N	20	4
YEAR yyyy	N	24	4
ACCIDENT TIME hhmm	N	28	4
NUMBER OF VEHICLE FORMS	N	32	2
NUMBER OF PERSON FORMS	N	34	2
NUMBER OF NON-MOTORIST FORMS	N	36	2
NATIONAL HIGHWAY SYSTEM	N	38	1
ROADWAY FUNCTION CLASS	N	39	2
ROUTE SIGNING	N	41	1
TRAFFICWAY IDENTIFIER	A/N	42	20
MILEPOINT	N	62	5
SPECIAL JURISDICTION	N	67	1
FIRST HARMFUL EVENT	N	68	2
MANNER OF COLLISION	N	70	1
RELATION TO JUNCTION	N	71	2
RELATION TO ROADWAY	N	73	2
TRAFFICWAY FLOW	N	75	1
NUMBER OF LANES	N	76	1
SPEED LIMIT	N	77	2
ALIGNMENT	N	79	1
PROFILE	N	80	1
SURFACE TYPE	N	81	1
SURFACE CONDITION	N	82	1
TRAFFIC CONTROL DEVICE	N	83	2
TRAFFIC CONTROL FUNCTIONING	N	85	1
HIT AND RUN	N	86	1
LIGHT CONDITION	N	87	1
ATMOSPHERIC CONDITION	N	88	1
CONSTRUCTION/MAINTENANCE ZONE	N	89	1
NOTIFICATION TIME EMS-hhmm	N	90	4
ARRIVAL TIME EMS hhmm	N	94	4
EMS HOSPITAL hhmm	N	98	4
SCHOOL BUS RELATED	N	102	1
RELATED FACTOR (1)-ACCIDENT LEVEL	N	103	2
RELATED FACTOR (2)-ACCIDENT LEVEL	N	105	2
RELATED FACTOR (3)-ACCIDENT LEVEL	N	107	2
RAIL GRADE CROSSING	A/N	109	7
NUMBER OF FATALITIES	N	116	2
DAY OF WEEK	N	118	1
NUMBER DRINKING DRIVERS	N	119	1

FATAL ACCIDENT REPORTING SYSTEM
1998 SEQUENTIAL ANALYSIS FILES
RECORDS DESCRIPTIONS

VEHICLE LEVEL DATA FIELDS	TYPE	START	LENGTH
CASE STATE	N	1	2
CASE NUMBER	N	3	4
SEQUENCE NUMBER	N	7	1
VEHICLE NUMBER	N	8	2
LEVEL NUMBER (value: 2)	N	10	1
PERSON NUMBER (value: blanks)	A	11	2
NUMBER OF OCCUPANTS	N	13	2
MAKE	N	15	2
MODEL	N	17	3
BODY TYPE	N	20	2
MODEL YEAR	N	22	4
VIN	A/N	26	12
REGISTRATION STATE	N	38	2
REGISTERED VEHICLE OWNER	N	40	1
ROLLOVER	N	41	1
JACKKNIFE	N	42	1
TRAVEL SPEED	N	43	2
HAZARDOUS CARGO	N	45	1
VEHICLE TRAILING	N	46	1
VEHICLE CONFIGURATION	N	47	1
NUMBER OF AXLES	N	48	2
CARGO BODY TYPE	N	50	2
SPECIAL USE	N	52	1
EMERGENCY USE	N	53	1
IMPACT POINT INITIAL	N	54	2
IMPACT POINT PRINCIPAL	N	56	2
UNDERRIDE/OVERRIDE	N	58	1
EXTENT OF DEFORMATION	N	59	1
VEHICLE ROLE	N	60	1
MANNER OF LEAVING SCENE	N	61	1
FIRE OCCURRENCE	N	62	1
RELATED FACTOR (1)-VEHICLE LEVEL	N	63	2
RELATED FACTOR (2)-VEHICLE LEVEL	N	65	2
VEHICLE MANEUVER	N	67	2
CRASH AVOIDANCE MANEUVER	N	69	1
MOST HARMFUL EVENT	N	70	2
MOTOR CARRIER IDENTIFICATION NUMBER	N	72	11
NUMBER OF DEATHS	N	83	2
VINA DECODES			
MODEL	A/N	85	3
BODY TYPE	A/N	88	2
AUTO			
WEIGHT	A/N	90	4
WHEELBASE (SHORT)	A/N	94	4
WHEELBASE (LONG)	A/N	98	4
TRUCK			
FUEL CODE	A	102	1
WEIGHT CODE	A/N	103	1
SERIES	A/N	104	3
MOTORCYCLE			
DISPLACEMENT	A/N	107	4
VIN LENGTH	N	111	2

FATAL ACCIDENT REPORTING SYSTEM
1998 SEQUENTIAL ANALYSIS FILES
RECORDS DESCRIPTIONS

DRIVER LEVEL DATA FIELDS	TYPE	START	LENGTH
CASE STATE	N	1	2
CASE NUMBER	N	3	4
SEQUENCE NUMBER	N	7	1
VEHICLE NUMBER	N	8	2
LEVEL NUMBER (value: 3)	N	10	1
PERSON NUMBER (value: blanks)	A	11	2
DRIVER PRESENCE	N	13	1
DRIVER DRINKING	N	14	1
LICENSE STATE	N	15	2
LICENSE STATUS	N	17	1
CDL STATUS	N	18	1
LICENSE ENDORSEMENTS	N	19	1
LICENSE COMPLIANCE	N	20	1
LICENSE RESTRICTIONS	N	21	1
VIOLATIONS CHARGED (1 of 3)	N	22	2
VIOLATIONS CHARGED (2 of 3)	N	24	2
VIOLATIONS CHARGED (3 of 3)	N	26	2
PREVIOUS RECORDED ACCIDENTS	N	28	2
PREVIOUS RECORDED SUSPENSIONS	N	30	2
PREVIOUS DWI CONVICTIONS	N	32	2
PREVIOUS SPEEDING CONVICTIONS	N	34	2
PREVIOUS OTHER MOTOR VEHICLE CONV	N	36	2
MONTH OF LAST ACCIDENT	N	38	2
YEAR OF LAST ACCIDENT	N	40	4
MONTH OF FIRST ACCIDENT	N	44	2
YEAR OF FIRST ACCIDENT	N	46	4
DRIVER ZIP CODE	N	50	5
RELATED FACTOR (1)-DRIVER LEVEL	N	55	2
RELATED FACTOR (2)-DRIVER LEVEL	N	57	2
RELATED FACTOR (3)-DRIVER LEVEL	N	59	2
RELATED FACTOR (4)-DRIVER LEVEL	N	61	2
DRIVER WEIGHT	N	63	3
DRIVER HEIGHT	N	66	3
filler (value: blanks)	A	69	51

FATAL ACCIDENT REPORTING SYSTEM
1998 SEQUENTIAL ANALYSIS FILES
RECORDS DESCRIPTIONS

PERSON LEVEL DATA FIELDS	TYPE	START	LENGTH
CASE STATE	N	1	2
CASE NUMBER	N	3	4
SEQUENCE NUMBER	N	7	1
VEHICLE NUMBER	N	8	2
LEVEL NUMBER (value: 4)	N	10	1
PERSON NUMBER	N	11	2
NON MOTORIST STRIKING VEHICLE	N	13	2
AGE	N	15	2
SEX	N	17	1
PERSON TYPE	N	18	2
SEATING POSITION	N	20	2
RESTRAINT SYSTEM-USE	N	22	2
AIR BAG AVAILABILITY/DEPLOYMENT	N	24	2
EJECTION	N	26	1
EJECTION PATH	N	27	1
EXTRICATION	N	28	1
NON MOTORIST LOCATION	N	29	2
POLICE REPORTED ALCOHOL INVOLVEMENT	N	31	1
METHOD ALCOHOL DETERMINATION	N	32	1
ALCOHOL TEST TYPE	N	33	1
ALCOHOL TEST RESULT	N	34	2
POLICE-REPORTED DRUG INVOLVEMENT	N	36	1
METHOD OF DRUG DETERMINATION	N	37	1
DRUG TEST TYPE (1 of 3)	N	38	1
DRUG TEST RESULTS (1 of 3)	N	39	3
DRUG TEST TYPE (2 of 3)	N	42	1
DRUG TEST RESULTS (2 of 3)	N	43	3
DRUG TEST TYPE (3 of 3)	N	46	1
DRUG TEST RESULTS (3 of 3)	N	47	3
INJURY SEVERITY	N	50	1
TAKEN TO HOSPITAL	N	51	1
DEATH DATE mmddyyyy	N	52	8
DEATH TIME hhmm	N	60	4
LAG TIME ACCIDENT TO DEATH hhhmm	N	64	5
RELATED FACTOR (1)-PERSON LEVEL	N	69	2
RELATED FACTOR (2)-PERSON LEVEL	N	71	2
RELATED FACTOR (3)-PERSON LEVEL	N	73	2
filler (value: asterisks)	A	75	12
FATAL INJURY AT WORK	N	87	1
filler (value: blanks)	A	88	32

SPSS syntax to extract 1998 FARS data

```
SET
BLANKS=SYSMIS BLANKS=SYSMIS
UNDEFINED=WARN.

DATA LIST
FILE='C:\FARS\DOT_DATA\FARS98\TPLar98.DAT' FIXED RECORDS=1
TABLE /1

 state 1-2              number 3-6
 sequence 7-7           level 10-10
 city 13-16             county 17-19
 month 20-21            day 22-23
 year  26-27            hour 28-29
 minutes 30-31          vehforms 32-33
 performs 34-35         nonforms 36-37
 fed_aid 38-38          road_fun 39-40
 signing 41-41          traff_id 42-61(A)
 mile_p 62-66           spec_jur 67-67
 first_he 68-69         manner_c 70-70
 rel_junc 71-72         rel_road 73-74
 traf_low 75-75         num_lane 76-76
 speed_lm 77-78         road_ali 79-79
 road_pro 80-80         road_sur 81-81
 road_con 82-82         traff_cd 83-84
 tcd_func 85-85         hit_run 86-86
 light 87-87            atmos 88-88
 construc 89-89         notetime 90-93
 arr_time 94-97         ems_hosp 98-101
 school_b 102-102       factor1 103-104
 factor2 105-106        factor3 107-108
 rail_gci 109-115(A)    fatals 116-117
 day_week 118-118       drunk_dr 119-119 .

 FILTER OFF.
 USE ALL.
 SELECT IF(level = 1).

 SAVE OUTFILE='C:\FARS\SPSS\FARS98\FARS98AC.SAV'
 /COMPRESSED.
```

```
SET
BLANKS=SYSMIS BLANKS=SYSMIS
UNDEFINED=WARN.

DATA LIST
FILE='C:\FARS\DOT_DATA\FARS98\TPLar98.DAT' FIXED RECORDS=1
TABLE /1

  state 1-2            number 3-6
  sequence 7-7         vehicle 8-9
  level 10-10          num_occ 13-14
  make 15-16           model 17-19
  bodytype 20-21       mod_year 24-25
  vin 26-37(A)         regstate 38-39
  regowner 40-40       rollover 41-41
  jacknife 42-42       travel_s 43-44
  hazard_c 45-45       trailing 46-46
  config 47-47         axles 48-49
  cargo_bt 50-51       spec_use 52-52
  emer_use 53-53       impactl 54-55
  impact_p 56-57       underide 58-58
  deform 59-59         veh_role 60-60
  man_leav 61-61       fire 62-62
  factorl 63-64        factor2 65-66
  maneuver 67-68       crash_am 69-69
  most_he 70-71
  carr_id 72-82        death_ve 82-83
  vina_mod 85-87(A)    vina_bod 88-89(a)
  weight 90-93(A)      wheel_bs 94-97(A)
  wheel_bl 98-101(A)   vinafuel 102-102(A)
  truck_l 103-103(A)   series 104-106(A)
  motor_cc 107-110(A) length 111-112.

FILTER OFF.
USE ALL.
SELECT IF(level = 2).

SAVE OUTFILE='C:\FARS\SPSS\FARS98\FARS98VE.SAV'
/COMPRESSED.
```

```
SET
BLANKS=SYSMIS BLANKS=SYSMIS
UNDEFINED=WARN.

DATA LIST
FILE='C:\FARS\DOT_DATA\FARS98\TPLar98.DAT' FIXED RECORDS=1
TABLE /1

  state 1-2          number 3-6
  sequence 7-7       vehicle 8-9
  level 10-10        DR_PRES 13-13
  DR_DRINK 14-14
  L_STATE 15-16      L_STATUS 17-17
  CDL_STAT 18-18     L_ENDORS 19-19
  L_COMPL 20-20      L_RESTRI 21-21
  VIOL_CHG 22-23
  VIOL_CH2 24-25     VIOL_CH3 26-27
  PREV_ACC 28-29
  PREV_SUS 30-31     PREV_DWI 32-33
  PREV_SPD 34-35     PREV_OTH 36-37
  LAST_MO 38-39      LAST_YR  42-43
  FIRST_MO 44-45     FIRST_YR 48-49
  DR_ZIP 50-54       DR_CF1 55-56
  DR_CF2 57-58       DR_CF3 59-60
  DR_CF4 61-62
  WEIGHT 63-65
  HEIGHT 66-68 .

FILTER OFF.
USE ALL.
SELECT IF(level = 3).

SAVE OUTFILE='C:\FARS\SPSS\FARS98\FARS98DR.SAV'
/COMPRESSED.
```

```
SET
BLANKS=SYSMIS BLANKS=SYSMIS
UNDEFINED=WARN.

DATA LIST
FILE='C:\FARS\DOT_DATA\FARS98\TPLar98.DAT' FIXED RECORDS=1
TABLE /1

   state     1-2      number    3-6
   sequence  7-7      vehicle   8-9
   level     10-10    PER_NO    11-12
   N_MOT_NO  13-14    AGE       15-16
   SEX       17-17    PER_TYP   18-19
   SEAT_POS  20-21    REST_USE  22-23
   AIR_BAG   24-25    EJECTION  26-26
   EJ_PATH   27-27    EXTRICAT  28-28
   LOCATION  29-30    DRINKING  31-31
   ALC_DET   32-32
   ALC_TEST  33-33
   ALC_RES   34-35
   DRUGS     36-36    DRUG_DET  37-37
   DRUGTST1  38-38    DRUGRES1  39-41
   DRUGTST2  42-42    DRUGRES2  43-45
   DRUGTST3  46-46    DRUGRES3  47-49
   INJ_SEV   50-50    HOSPITAL  51-51
   DEATH_MO  52-53    DEATH_DA  54-55
   DEATH_YR  58-59    DEATH_TM  60-63
   DEATH_HR  60-61    DEATH_MN  62-63
   LAG_HRS   64-66    LAG_MINS  67-68
   P_CF1     69-70    P_CF2     71-72
   P_CF3     73-74
   WORK_INJ  87-87   .

FILTER OFF.
USE ALL.
SELECT IF(level = 4).

SAVE OUTFILE='C:\FARS\SPSS\FARS98\FARS98PE.SAV'
/COMPRESSED.

EXECUTE.
```

Appendix II

Driver Factors Level

Note: There are four driver related factor variables, namely DR_CF1, DR_CF2, DR_CF3 and (DR_CF4 Since 1997).

Note the FARS coder may have used any of the three variables to code a related factor. One must test all three variables to insure that the selected related factor is included.

1982 and later except as noted

DRIVER RELATED FACTORS:

20 Leaving Vehicle Unattended in Roadway
21 Overloading or Improper Loading of Vehicle with Passengers or Cargo
22 Towing or Pushing Vehicle Improperly
23 Failing to [Dim Lights or, Since 1995] Have Lights on When Required
24 Operating without Required Equipment
25 Creating Unlawful Noise or Using Equipment Prohibited by Law
26 Following Improperly
27 Improper or Erratic Lane Changing
28 Failure to Keep in Proper Lane or Running off Road
29 Illegal Driving on Road Shoulder, in Ditch, on Sidewalk, on Median
30 Making Improper Entry to or Exit from Trafficway
33 Passing where Prohibited by Posted Signs, Pavement Markings, Hill or Curve, or School Bus Displaying Warning not to Pass
34 Passing on Wrong Side
35 Passing with Insufficient Distance or Inadequate Visibility or Failing to Yield to Overtaking Vehicle
36 Operating the Vehicle in Other Erratic, Reckless, Careless or Negligent Manner [or Operating at Erratic or Suddenly Changing Speeds, Since 1995]
37 Traveling on Prohibited Trafficway (Since 1995)
38 Failure to Yield Right of Way
39 Failure to Obey Traffic Signs, Traffic Control Devices or Traffic Officers, Failure to Observe Safety Zone Traffic Laws
40 Passing Through or Around Barrier Positioned to Prohibit or Channel Traffic
41 Failure to Observe Warnings or Instructions on Vehicles Displaying Them
42 Failure to Signal Intentions
43 Giving Wrong Signal
44 Driving too Fast for Conditions or in Excess of Posted Speed Limit
45 Driving Less than Posted Maximum
46 Operating at Erratic or Suddenly Changing Speeds
47 Making Right Turn from Left Turn Lane or Making Left Turn from Right Turn Lane
48 Making Improper Turn
49 Driving Wrong Way on One-Way Trafficway
50 Driving on Wrong Side of Road [(Intentionally or Unintentionally) Since 1995]
51 Operator Inexperience
52 Unfamiliar with Roadway
53 Stopping in Roadway (Vehicle not Abandoned)

54 Underriding a Parked Truck
55 Getting Off/Out of or On/In to Moving Transport Vehicle
56 Getting Off/Out of or On/In to Non-Moving Transport Vehicle
57 Improper Tire Pressure (Since 1995)
58 Locked Wheel (Since 1995)
59 Overcorrecting (Since 1995)

1975 to 1981

Note Values 02 to 06 correspond to 01 to 05 for the 1982 and later data. Values of 20 and higher correspond directly the same values for 1982 and later.

DRIVER RELATED FACTORS:

20 Leaving Vehicle Unattended in Roadway
21 Overloading or Improper Loading of Vehicle with Passengers or Cargo
22 Towing or Pushing Vehicle Improperly
23 Failing to Have Lights on When Required
24 Operating without Required Equipment
25 Creating Unlawful Noise or Using Equipment Prohibited by Law
26 Following Improperly
27 Improper or Erratic Lane Changing
28 Failure to Keep in Proper Lane or Running off Road
29 Illegal Driving on Road Shoulder, in Ditch, on Sidewalk, on Median
30 Making Improper Entry to or Exit from Trafficway
33 Passing where Prohibited by Posted Signs, Pavement Markings, Hill or Curve, or School Bus Displaying Warning not to Pass
34 Passing on Wrong Side
35 Passing with Insufficient Distance or Inadequate Visibility or Failing to Yield to Overtaking Vehicle
36 Operating the Vehicle in Other Erratic, Reckless, Careless or Negligent Manner
38 Failure to Yield Right of Way
39 Failure to Obey Traffic Signs, Traffic Control Devices or Traffic Officers, Failure to Observe Safety Zone
40 Passing Through or Around Barrier Positioned to Prohibit or Channel Traffic
41 Failure to Observe Warnings or Instructions on Vehicles Displaying Them
42 Failure to Signal Intentions
43 Giving Wrong Signal
44 Driving too Fast for Conditions or in Excess of Posted Speed Limit
45 Driving Less than Posted Maximum
46 Operating at Erratic or Suddenly Changing Speeds
47 Making Right Turn from Left Turn Lane or Making Left Turn from Right Turn Lane
48 Making Improper Turn
49 Driving Wrong Way on One-Way Roadway
50 Driving on Wrong Side of Road
51 Operator Inexperience
52 Unfamiliar with Roadway

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