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Evaluating the impact of passengers on the safety of older drivers

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Abstract

Problem: This study involved a quasi-induced exposure analysis of 4 years of crashes involving older drivers in the state of Kentucky. *Method:* Single- and multivehicle crashes were disaggregated according to the number of passengers: (a) no passenger, (b) one passenger, and (c) two or more passengers. *Results:* Overall, the presence of two or more passengers was found to negatively impact the probability that drivers 75 years of age or older were at fault in crashes. Several potential factors were studied for interactive effects with passengers: vehicle occupant gender mix, time of the day, road curvature, grade, and number of lanes. The negative impact of passengers increased for some geometric road conditions. However, older drivers were found to be safer at night when carrying two or more passengers. The presence or absence of passengers was not found to affect the 65- to 74-year-old driver group. Groups of male vehicle occupants with a 75+ male driver were found to have high single-vehicle crash rates. *Impact:* These results are among the first to directly consider the effect of passengers on the crash-causing propensity of older drivers and the findings suggest more work is warranted to consider causes for the crash rate differences.
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1. Introduction

Mobility needs are very important for senior citizens and increasingly the primary means to fulfill these needs is the automobile. It was estimated in 1988 that more than 80% of trips by *older drivers* (defined as drivers who are 65 years and above) were made in automobiles and this percentage was increasing (Deacon, 1988). The National Personal Transportation Survey in 1995 confirms the increasing trend with over 90% of trips by older people aged 65–85 years being made by automobile (Rosenbloom & Waldorf, 2001). Depending on the age group, between 59% and 73% of trips were made with the older person as the driver of the vehicle. While the automobile is the most frequently used mode of transportation for both older men and women, men show higher rates of automobile usage (Jette & Brachs, 1992). Due to the changing demographics in society, the total amount of travel that older drivers undertake is expected to be four to five times greater in 30 years (Burkhardt & McGavock, 1999).

Unfortunately, older drivers are involved in a disproportionate number of traffic crashes and, therefore, given the continued increase in the number of older drivers, there is significant motivation to further understand the many factors causing these high crash rates (Stamatiadis & Deacon, 1995). Safety problems for older drivers have been related to sensory (visual), cognitive, and psychomotor skills (Staplin, Lococo, Stewart, & Decina, 1999). Older drivers do practice some compensatory measures to counter their diminishing skills. This research examines one recent hypothesis that could be related to such compensatory measures. Specifically, the work examines whether the presence of different passenger groups in the vehicle could improve the safety records of older drivers or, more specifically, the probability that the driver is at fault in the crash. One can hypothesize that passengers might represent either a distraction or an advantage (e.g., "extra" helpful eyes on the road and traffic). There is only limited previous research on the effect of passengers for older drivers. Because the number of teenage passengers in a vehicle has shown to negatively impact young driver safety in several research studies, limitations on the number of passengers a young driver can carry have become a key component in many state graduated driver licensing systems. Previous research has shown that adult passengers have a positive effect on young

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driver safety (Aldridge, Himmler, Aultman-Hall, & Stamatiadis, 1999), thus promoting the possibility that passengers could represent either a positive or negative depending on the circumstances.

This study makes use of the same technique that has been used to study young drivers and passengers: the quasi-induced exposure methodology. The effect of the number of passengers on the crash-causing propensity of older drivers was evaluated for men and women in two age groups: those aged 65–74 and those greater than 75 years of age. Disaggregate crash circumstances cannot be studied with the typical aggregate crash rates developed from crash tallies and vehicle miles traveled (VMT) because VMT is difficult to estimate for individual driving in a variety of travel circumstances. The quasi-induced exposure method allows for disaggregate analysis by using the crash database itself to generate a relative exposure measure from the drivers that are not-at-fault in two-vehicle crashes. Using this method, estimates of relative crash rates for older drivers with different passengers groups, including those traveling alone, were quantified. Further disaggregate analysis includes differences by passenger gender, time of day, road curvature, road grade, and number of lanes. Four years of crash data from the state of Kentucky were used.

This article summarizes background information related to factors affecting older driver safety and fatality rates, outlines the quasi-induced exposure methodology, and presents the relative crash involvement ratios for single- and multivehicle crashes for older drivers with and without passengers.

2. Background

In the next 30 years, due to the increased number of older drivers, the number of fatalities involving older drivers is expected to increase three to four times if there is no change in the current crash rates (Burkhardt & McGavock, 1999). One of the factors for higher fatality rates is related to body frailty, which begins to increase at age 60–64 years (Li, Braver, & Chen, 2001). At age 75, older drivers begin to noticeably be overinvolved in fatal crashes and frailty is the predominant factor explaining the elevated deaths per mile among these older drivers. The higher crash propensity of older drivers is often attributed to typical aging-related deterioration, which affects three functions important to safe and carefree driving: sensory (visual), cognitive, and psychomotor (Deacon, 1988). It is estimated that 90% of the input that a driver receives is visual (Bailey & Sheedy, 1988). This makes vision the primary sensory function used for driving. The deterioration of visual ability not only reduces the capability to operate an automobile, but it also causes the driver difficulty in judging distances between vehicles, which in turn can lead to crash involvement. Loss of peripheral vision to observe approaching vehicles from the sides is also critical (Baxter et al., 1990).

Numerous studies have indicated that older drivers have traffic safety problems and higher crash rates, but the exact reasons for these crash rates are unclear. For example, Stamatiadis, Taylor, and McKelvey (1991) point out that drivers older than age 65 and younger than age 25 were more likely than other age groups to be involved in crashes at both signalized and nonsignalized intersections. In another study, McKelvey and Stamatiadis (1989) reported that older driver crash rates were higher than young- or middle-aged drivers, primarily because of angle collisions and crashes at intersections controlled by stop signs rather than by traffic signals. In addition, they revealed that older drivers are fined more often than other drivers for failing to yield the right-of-way. A subsequent study also confirmed that older drivers are more likely to be involved in angle crashes, rear-end crashes, and head-on crashes while turning left (Villalba, Kirk, & Stamatiadis, 2001).

Left-turning maneuvers require a driver to consider two directions of travel and to cross oncoming traffic. This places high demands on the driver's visual recognition and search capabilities. It tests the driver's ability to estimate the speed of vehicles through depth perception, and requires a high cognitive demand to evaluate a situation involving many complex actions. Therefore, increased involvement for the senior citizen in this type of crash may indicate a deficiency in any of these capabilities, and it is not surprising to find these crashes are more common among the older drivers.

The occurrence of rear-end crashes is directly affected by the drivers' abilities. This crash type is related to the depth perception and visual recognition abilities of the driver along with the driver's reaction time. For certain groups of drivers, rear-end crashes have been associated with aggressive driving behavior, but this is not the case for older drivers. This crash type is more common among older drivers due to the physical limitations outlined above (Chandraratna & Stamatiadis, in press). Maneuvers at intersections leading to angle crashes require the use of the same visual and cognitive skills as maneuvers leading to rear-end crashes and left-turning movements leading to head-on crashes. However, these maneuvers are less demanding than left turn head-on crashes and more so than rear-end crashes.

In a study performed for the Federal Highway Administration (Staplin, Lococo, Byington, & Harkey, 2001), certain scenarios were examined and evaluated to determine recommendations for changes to the transportation network to better accommodate older drivers. The study identified several particular circumstances that needed further attention, including at grade intersections, grade-separated interchanges, roadway curvature, passing zones, construction zones, and highway-rail grade crossing. There are several important difficulties that older drivers have when negotiating at grade intersections. It has been found through in-car observations that older drivers have a very difficult time responding to traffic signals and performing left and right turns. The drivers also often failed to signal their turns. Poor

positioning was also a problem when turning left along with a general lack of caution, frequent failure to stop, and jerky or abrupt stops. This was a problem with both traffic signals and stop signs.

In addition to the age effect on driver performance, there are a number of time-related changes that are impacting the overall number of older driver crashes. These temporal effects that influence the crash propensity of drivers include the increase in older licensed drivers, both in numbers and age; the characteristics of each cohort, which carries the generational effects of the traffic environment; changes in vehicle capability; and the roadway types, including increasing congestion. There are also societal temporal changes that affect older drivers, including the increased reliance on the automobile. Older drivers have different attitudes and behaviors that come with age, including a reduction in the use of alcohol, an increased awareness of safety, and value for life. Many of these factors affect the crash experience of all drivers, but they have their largest impact on this special population (Stamatiadis & Deacon, 1995).

Previous research has demonstrated that older female drivers have higher crash rates when compared to males and it was attributed to possible cohort and time effects (Stamatiadis, 1996). This assumption implied that there is likelihood that this difference will be reduced, if not eliminated, in the future, since the data for middle-aged drivers show no differences between genders. It has been hypothesized that the differences noted in previous research were due to the lack of experience by female drivers when they were presented with the need to drive in times where their husband was not capable of continuing driving.

It is accepted in social psychology that people behave differently in the presence or absence of spectators (Baxter et al., 1990). The study of drivers driving with or without an audience, in the form of passengers, is particularly interesting and there is evidence that drivers perform differently in the presence of passengers. Compared to drivers driving alone, drivers with passengers have been found to take precautions to drive slower (Baxter et al., 1990) and are in more compliance with the law on speeding, stopping, and turning signaling (Lawshe, 1940). These precautions can be related to safety and crashes, but suggest other risk-taking behavior might differ with and without passengers as well. Research on the effect of passengers on young drivers has shown that the absence or presence of passenger(s) affected the drivers' crash propensity (Doherty, Andrey, & MacGregor, 1998). Specifically, crash-causing propensity was higher with teenage passengers than when the young person was driving alone, but lower with adult passengers. Another study performed to examine the effects of passengers on younger drivers (age 16–19 years) found that the crash involvement ratios increased considerably when the number of passengers increased (Aldridge et al., 1999). Similar findings, indicating an increased risk associated with the presence of passengers, were also noted in another study that examined the crashes of 16- and 17-year-olds (Chen, Baker, Braver, & Li, 2000). Contrary to the negative impact of passengers on young drivers, some research has suggested that older drivers can and do rely on "copilots" (Foley et al., 2000; Shua-Haim & Gross, 1996). Furthermore, in a study that followed 989 older drivers for 5 years, drivers who were allowed to drive alone had more crashes than those driving with caretakers (Bedard et al., 1998).

The extent of crash hazard also depends on the driving environment, including factors such as facility type and climate conditions. Past research has shown that older drivers experience higher crash involvement rates at night, during inclement weather, and at signalized intersection areas (McKelvey & Stamatiadis, 1989; Stamatiadis & Deacon, 1995; Stamatiadis et al., 1991). The day versus night factor is examined in this analysis because older drivers have difficulties driving at night due to their diminished visual ability at night. Research has shown that glare recovery had a marginally significant relationship with driving performance for those older than 54 (Bailey & Sheedy, 1988). This study accounts for whether some of these confounding effects relate to the impact of passengers.

One final interactive effect, which has not received adequate prior attention, is the differences over time among the types of drivers that use different elements of the roadway system (Mengert, 1982). For example, it is reasonable to assume that older drivers may comprise a larger proportion of the drivers on local streets during weekday off-peak periods than on interstates during rush periods. These kinds of differences are not *accurately* represented by traditional aggregate exposure metrics, such as total VMTs, because of the difficulty in collecting the large amount and variety of needed data. The use of induced exposure provides a means to achieve this stratification of data over location and time and, as a result, can reflect the differences in driver characteristics under each combination of circumstances.

The literature indicates that there have been few studies that have specifically examined the effect that passengers may have on older driver behavior and how it can influence safety. Most of the work focused on the effect of passengers on young drivers. Older drivers have crashes under circumstances where passengers might reasonably help or hinder their performance. Therefore, the objective of this article is to investigate the potential relationship between the presence of passengers and crash fault for older drivers and identify possible trends and contributing factors.

3. Methodology

Typical crash analysis techniques are limited when information regarding a particular group of drivers under particular circumstances is sought. Previous research use of these traditional techniques indicates that, overall, older

drivers are more likely to be involved in crashes than their younger adult counterparts (however, teenagers have higher crash rates than older drivers). But without accurate disaggregated travel exposure[1] data, traditional methodologies are inadequate for identifying specific risk factors for crash involvement under specific circumstances, such as traveling with a certain number of passengers or along a given type of road. In other words, extracting meaningful information from the disaggregation of accidents by different characteristics or circumstances becomes difficult without estimates of the relative travel exposure in those same circumstances. The quasi-induced exposure technique is coming into wider use in traffic safety and was used for this analysis. The method has been successfully used for disaggregate crash safety analysis for older drivers (Stamatiadis & Deacon, 1995), road geometric characteristics (Stamatiadis, Jones, & Aultman-Hall, 1999), and young drivers (Aldridge et al., 1999). The method derives the relative exposure for different groups from the accident database itself. In this study, it allowed for the investigation of the relative correlation of the number of passengers, with the likelihood that the older driver (over 65 years) caused the crash.

The relative accident involvement ratio (RAIR) is the measure of accident causing propensity used in the quasi-induced exposure analysis. It is calculated by taking the ratio of the percentage of at-fault drivers in a specific subgroup to the percentage of not-at-fault drivers from the same subgroup. The assumption is that the distribution of not-at-fault drivers is a representative measure of the travel exposure of all drivers in that group. The issue of assigning fault in a crash was determined from the crash database. Each crash record has a human contributing factor that indicates whether the driver was at-fault. These fault assignments rely heavily on the judgment and experience of the police officer at the scene of crash. A fundamental requirement of the quasi-induced exposure method is the determination of the at-fault driver who was mostly responsible for the crash occurrence. This implies that for every multivehicle crash there can only be one such driver. To address this issue, crashes where this distinction was not possible (i.e., either both or no driver was assigned fault) were eliminated (less than 5%). Moreover, all drivers involved in single-vehicle crashes were considered at-fault drivers. An accident ratio can be formed for both single ($RAIR_s$) and two-vehicle accidents ($RAIR_m$); the denominator in both is the percentage of not-at-fault drivers in the two-vehicle crashes, while the numerator is the corresponding at-fault drivers. Ratio values greater than 1.0 indicate that the specific subgroup of drivers is more likely to cause a crash under the specific circumstances being considered. In a similar way, a ratio of less than 1.0 indicates that the drivers in the specific subcategory are less prone to be at-fault in causing the crash.

A hypothetical calculation is shown in Eq. (1). In this case, the ratio computed is that of older male drivers. The numerator indicates that 80% of the at-fault older drivers were male, and therefore 20% were female. The denominator indicates that when an older driver drove the not-at-fault vehicle in a two-vehicle crash, 50% of the time the driver was male. This percentage is taken to be a measure of the relative travel exposure. Therefore, in this case, the interpretation would be that older males and females drive the same amount. Given this assumption, the RAIR value indicates that the older men are 1.6 times as likely to cause a crash compared to the female drivers.

$$\mathrm{RAIR} = \frac{\%\ \text{males at-fault}}{\%\ \text{males not-at-fault}} = \frac{12,000/15,000}{10,000/20,000} = \frac{0.8}{0.5} = 1.6 \tag{1}$$

Given that 4 years of crash data for the older drivers were used in this study, it was reasonable to attempt several two-dimensional disaggregations of the data. The first matter of interest was to determine if the influence of passengers was the same for males versus females and for younger (age 65–74) and older (over 75 years) senior drivers. Secondly, the interaction between the presence of passengers and the following driving circumstances was investigated: differences by passenger gender, time of day, road curvature, road grade, and number of lanes. Note that it was the difference in the impact of passengers between these circumstances that was of interest, not the impact of these variables directly. These relationships have been reported elsewhere.

Once the total number of at-fault and not-at-fault older drivers in each circumstance had been used to calculate the RAIRs for both one- and two-dimensional cases, statistical significance was tested using binary logistic regression. Logistic regression is similar to linear regression, except that the dependent variable is discrete, not continuous. So in this case, one predicts whether or not a given driver was at-fault in a crash (0 or 1) as a function of the driver's age or the type of passengers in the vehicle. Binary logistic regression (as opposed to ordinal or nominal logistic regression) is used in this case when the dependent variable can only take on two values: at-fault or not-at-fault. The model has the form shown in Eq. (2), and the parameters or model coefficients are estimated using maximum likelihood techniques. The overall quality of the model is measured using the log-likelihood function (G parameter). However, of more interest in this case, was the z statistics that were used to determine if a particular factor had a statistically significant impact on the probability that the driver was at-fault in the crash (significance level .05 was used). While these explanatory factors can be either discrete or continuous

[1] Travel exposure is often measured in VMT. In this case, exposure refers to any measure of the relative amount of travel undertaken by young drivers in different circumstances; night versus day driving for example. Exposure metrics are used to normalize crash tallies to develop crash rates.

(e.g., freeway vs. nonfreeway or age) all factors tested in this study were discrete.

$$P(\text{driver is at fault}) = 1/(1 + e^{-z}) \quad (2)$$

where $z = B_0 + B_1X_1 + B_2X_2 + Y + B_nX_n$, P is probability, X_i is the explanatory factor, and B_i is model coefficient.

The at-fault probability is related to the RAIR, which forms the basis for the quasi-induced exposure analysis. In fact, the RAIR is analogous to the ratio shown in Eq. (3). The ratio on the left can be rearranged to the ratio on the right due to the binary nature of the problem (the driver is either at fault or not at fault). As a result, the RAIR can be calculated from the calibrated logistic regression model, which estimates the parameters of the probability function in Eq. (2). By using logistic regression analysis, the statistical significance of whether each variable of interest affects the probability of being at fault can be obtained. When a variable is measured to affect the probability of fault, the ratio in Eq. (3) is therefore statistically not equal to 1.0 and, thus, the RAIR is not equal to 1.0. All testing is performed at the .05 significance level.

$$P(\text{at-fault driver})/P(\text{not-at-fault driver}) = P(\text{at-fault driver})/[1 - P(\text{at-fault driver})] \quad (3)$$

4. Data

The crash data were obtained from the Kentucky State Police reports for the 1995–1998 period. The number of crashes involving drivers age 65 and above is shown in Table 1. For the analysis, the crash data are broken down into two large groups: (a) single- and (b) multivehicle crashes. The multivehicle category includes only crashes involving two vehicles because the assignment of fault is less clear in crashes involving three or more vehicles. Studies have shown that drivers 75 years and older are twice as likely to be involved in a crash per mile driven (National Research Council, 1988). At the same time, the effect of these crashes on them is more serious because of the susceptibility of older persons to injury and fatality. To distinguish drivers above 75 years from the rest of the older drivers in general, drivers were further disaggregated into two age groups: "65–74" years old and "75+." The gender and age of all passengers in the vehicle was extracted as well as the number of lanes on the road, the time of the crash, the road curvature, and road grade. To maintain sufficient data in each subcategory, as disaggregation is undertaken, the crash environmental variables had to be divided into only two categories each. Daytime is considered the period between 6 a.m. and 6 p.m., since this period is daylight in Kentucky for most of the year. Road curvature is divided into straight and curvy (curve sections are those with a degree of curvature greater than 1°) and road grade is defined as level or grade (sections on grade were those with grades greater than 2.0%). The number of lanes is considered as either two or four or more.

Table 1
Number of crashes involving drivers 65 and above

Crash type	Driver's age	Number of crashes
At-fault (single-vehicle crashes)	65–74	4815
	75+	2892
At-fault (multivehicle crashes)	65–74	17,704
	75+	13,594
Not-at-fault	65–74	15,304
	75+	6007

Table 2
The effect of age and gender on crash-causing propensity

	Single-vehicle crashes		Multivehicle crashes	
	Cases	RAIR	Cases	RAIR
Male	18,141	**1.0**	32,147	1.0
Female	10,584	**1.0**	20,430	1.1
65–74	20,107	0.9	32,810	0.8
75+	8887	1.3	19,767	1.6

Bold indicates that the result is not statistically significant (.05).

5. Results

The age and gender of a driver has an impact on crash-causing propensity. These underlying factors are illustrated in Table 2 for the data set used here for both single- and multivehicle crashes. It should be noted that the number of cases shown in all tables for both single- and multivehicle crashes are the total number of both at-fault and not-at-fault drivers. These patterns are reflected throughout the passenger-related results. Men and women show no difference in their propensity to cause a single-vehicle crash, but women are more likely to cause a multivehicle crash. The drivers over the age of 75 years are much more likely to cause a crash than those between the age of 65 and 74 years. This is in agreement with the results of previous research that shows drivers 75+ experience diminishing driving skills and thus are more likely to be involved in crashes (National Research Council, 1988).

To illustrate the use of the logistic regression in modeling the RAIR, the case of multivehicle crashes for the age variable will be examined. The model predicted is $Z = 0.830 - 0.695 \times \text{AGE}$, where AGE is 1 for the 65–74 group and 0 for the 75+ group. It should be noted that the

Table 3
Single-vehicle crashes according to driver's age

Driver's age	No passengers		One passenger		Two or more passengers	
	Cases	RAIR	Cases	RAIR	Cases	RAIR
65–74	14,763	0.9	4323	0.9	979	0.9
75+	6818	1.3	1795	1.3	276	1.6

Table 4
Single-vehicle crashes according to driver's gender

Driver's age	No passengers		One passenger		Two or more passengers	
	Cases	RAIR	Cases	RAIR	Cases	RAIR
Male	13,907	1.0	4439	1.0	875	1.0
Female	8484	1.0	1721	1.0	378	1.0

Table 6
Multivehicle crashes according to driver's age

Driver's age	No passengers		One passenger		Two or more passengers	
	Cases	RAIR	Cases	RAIR	Cases	RAIR
65–74	25,041	0.8	6433	0.8	1336	0.8
75+	15,654	1.5	3647	1.6	466	1.8

logistic regression uses a "reference" category, which is used in defining the relative odds ratios (i.e., age group 75+ here). Using Eqs. (2) and (3), the probabilities for a driver being at-fault and the RAIRs are calculated. The modeled RAIR for the 65–74 group is 1.15 and for the 75+ group 2.30. Although the absolute value of these ratios are not equal to the ones observed in Table 2, it is their relative ratio that is being tested (i.e., 0.8/1.6 and 1.15/2.30 are equivalent). The analysis in this case indicates that relative values of these RAIRs hold and that the assumption of age-related differences holds (P=.00000).

5.1. Single-vehicle crashes

Tables 3 and 4 show the results of the basic analysis of the effect of the number of passengers with driver's age and gender, respectively. The number of passengers does not affect the likelihood that the drivers in the younger group are at fault in a crash, however, the presence of two or more passengers does increase the likelihood that the drivers in the older group are at fault in a crash. This finding is statistically significant. No meaningful difference between the effect of passengers and the gender of the driver was found for single-vehicle crashes, although all differences in this table are statistically significant (rounding to one decimal place makes all the ratios appear exactly equal to 1.0).

The first part of Table 5 shows the crash ratios subdivided by age and gender of the older driver. The number of passengers does not affect the likelihood that the younger group for both males and females are at fault in a crash, however, two or more passengers does increase the likelihood that the older drivers are at fault in a crash for both genders. The second part of Table 5 indicates the results for passenger gender, showing that when all occupants of the vehicle are male and the driver is over 75 years of age, the crash involvement ratio is even higher. There were no sufficient data to consider the age of passengers. The only difference of notable magnitude in the environmental vari-

Table 5
Single-vehicle crash involvement ratio

Factors	Categories	Age group	No passenger		One passenger		Two or more passengers	
			Cases	RAIR	Cases	RAIR	Cases	RAIR
Driver's gender	Male	65–74	9061	0.9	3155	0.9	678	0.9
		75+	4036	1.3	1284	1.2	197	1.7
	Female	65–74	5702	0.8	1210	0.9	301	0.9
		75+	2782	1.4	511	1.3	77	1.6
Occupant gender mix	All male	65–74		–	1054	0.9	65	0.8
		75+		–	374	1.5	22	2.0
	All female	65–74		–	3290	0.9	227	0.9
		75+		–	1410	1.2	102	1.2
	Mixed	65–74		–		–	689	0.9
		75+		–		–	150	1.5
Time of crash	Daytime	65–74	12,518	0.8	3633	0.9	651	0.8
		75+	6023	1.4	1564	1.3	200	1.8
	Nighttime	65–74	2117	0.9	704	0.9	170	1.0
		75+	739	**1.3**	215	**1.3**	43	**1.1**
Road curvature	Straight	65–74	12,873	0.9	3740	0.9	831	0.9
		75+	6007	1.4	1539	1.3	238	1.5
	Curvy	65–74	1962	**0.9**	613	**1.0**	148	**0.8**
		75+	797	1.4	255	1.1	37	2.7
Road grade	Level	65–74	10,774	0.9	3029	0.9	622	0.8
		75+	5056	1.4	1238	1.3	197	1.7
	Grade	65–74	3971	0.9	1324	0.9	357	0.9
		75+	1746	1.3	556	1.2	78	1.6
Number of lanes	Two	65–74	8905	0.9	2537	0.9	605	0.8
		75+	4485	1.4	1132	1.3	176	1.9
	Four	65–74	5173	1.0	1722	1.0	359	0.9
	or more	75+	2058	1.1	616	1.1	96	1.2

Bold indicates that the results are not significant.

Table 7
Multivehicle crashes according to driver's gender

Driver's age	No passengers		One passenger		Two or more passengers	
	Cases	RAIR	Cases	RAIR	Cases	RAIR
Male	24,874	1.0	7034	0.9	1212	0.9
Female	17,514	1.1	3046	1.2	639	1.2

ables in the second half of Table 5 also applies to drivers over the age of 75 years. These drivers have increased crash-causing propensity on curvy sections and on two-lane roads. Interestingly, this group has a lower crash-causing propensity at night. While all ratios not shown in bold in this table represent statistically significant findings, the small magnitude of most of the differences make them of less interest, especially for countermeasure development.

5.2. Multivehicle crashes

Tables 6 and 7 show the basic analysis for multivehicle crashes between driver's age and the number of passengers; and driver's gender and the number of passengers. All ratios are statistically different. The analyses show an interaction between driver's age and the number of passengers similar to single-vehicle crashes: two or more passengers is the most risky for drivers over 75 years of age. The crash-causing propensity for these drivers is increased with passengers over the crash likelihood for when they are driving alone. Table 7 reillustrates the higher RAIR for females, but note that the presence of passengers does not have a meaningfully different effect for men versus women for multivehicle crashes.

Table 8 illustrates the ratios for the disaggregate environmental conditions. The results are statistically significant, except where shown in bold, although the magnitude of the differences is not always seen when RAIR values are reported to one decimal place. The data for the age and gender of the driver indicate that the number of passengers does not affect the likelihood of either age group to cause a crash for both genders. The increased risk for groups of male occupants with a 75+ male driver is not present in the multivehicle crashes. However, the mixed groups have a very high ratio. The driving environment results mirror those of the single-vehicle crashes in that the drivers over the age of 75 years are even more likely to cause a crash with two or more passengers when they are traveling on curves, grades, and two-lane roads. However, once again these results suggest drivers have a reduced risk with two passengers versus with zero or one passenger at night.

6. Concluding comments

The analysis presented here indicates that passengers can have an impact on the safety of older drivers under some of

Table 8
Multivehicle crash involvement ratio

Factors	Categories	Age group	No passenger		One passenger		Two or more passengers	
			Cases	RAIR	Cases	RAIR	Cases	RAIR
Driver's gender	Male	65–74	15,465	0.8	4448	0.8	887	0.8
		75+	9409	1.6	2586	1.7	325	1.9
	Female	65–74	10,710	0.8	1985	0.8	482	0.9
		75+	6807	1.5	1061	1.5	157	1.7
Occupant gender mix	All male	65–74		–	1609	0.8	122	0.9
		75+		–	692	**1.6**	35	**1.5**
	All female	65–74		–	4824	0.8	407	0.9
		75+		–	2951	1.6	191	1.2
	Mixed	65–74		–		–	808	0.8
		75+		–		–	239	2.1
Time of crash	Daytime	65–74	22,120	0.8	5538	0.8	820	0.9
		75+	14,291	1.5	3282	1.6	223	1.3
	Nighttime	65–74	2751	0.8	853	0.8	164	0.9
		75+	1256	1.6	336	1.7	48	1.4
Road curvature	Straight	65–74	22,658	0.8	5740	0.8	1149	0.8
		75+	14,370	1.5	3251	1.6	423	1.8
	Curvy	65–74	2445	0.8	687	0.8	168	0.8
		75+	1270	1.7	391	1.6	42	2.5
Road grade	Level	65–74	18,685	0.8	4598	0.8	901	0.9
		75+	11,814	1.5	2571	1.6	315	1.6
	Grade	65–74	6328	0.8	1829	0.8	436	0.8
		75+	3824	1.6	1071	1.6	150	2.4
Number of lanes	Two	65–74	13,732	0.8	3460	0.8	745	0.8
		75+	8993	1.5	1995	1.6	252	1.9
	Four or more	65–74	10,225	0.8	2772	0.8	558	0.9
		75+	6083	1.5	1539	1.7	202	1.6

Bold numbers indicate that the results are not significant.

the various driving conditions examined here. While the number of passengers had a statistically significant effect on the majority of the factors tested, the actual magnitude of this impact was only large for a small subset of factors. Older drivers, drivers 75+, generally show a higher probability of being at fault in crashes when compared to drivers 65–74 for both single- and multivehicle crashes and this study found they also experience a more negative impact on this probability when two or more passengers are in the vehicle. This negative impact was greater on less-than-ideal road conditions, such as curves or grades. Although the exact cause of the crash and any exact mechanisms involving the passenger cannot be extracted, one can suggest that passengers represent a distraction to the older driver and that there is a level of distraction or nonideal driving environment that older drivers can work with, but beyond a certain point, the distractions lead to higher crash rates.

Groups of male vehicle occupants (driver over 65 years with male passengers of any age) are particularly prone to be at fault in single-vehicle crashes, suggesting the possibility that their risk-taking behavior is greater due to peer pressure. Although overall 75+ drivers traveling with two or more passengers showed a relatively higher crash causing ratio than the other passenger combinations, one subgroup shows the opposite of this trend: travel during night conditions. There is no information in the literature that could explain this finding. It could be hypothesized though that passengers may be more active during adverse conditions and thus they may assist more during such conditions. Therefore, the passengers with the over 75+ drivers may be more consciously trying to assist with the driving task at night, a time that is perceived as risky by many people.

This study has provided further credence for the pursuit of a more comprehensive study of the impact of passengers on older drivers. Future research should consider not only the factors studied here, but also other driving conditions and the impact of passenger age. To demonstrate the effect of passengers on the safety of older drivers it is also necessary to compare their crash rates to those of middle-aged drivers and determine whether the observed trends are indeed specific to older drivers or all drivers in general. Because older drivers have shown a willingness to practice compensatory measures, it is possible that educating older people to provide knowledge of these risks will change behaviors enough to impact safety without the need for restrictive measures such as those applied to young drivers. The benefits of having a passenger in the vehicle could be included in the educational programs available to older drivers and could be presented as an additional compensatory measure.

References

Aldridge, B., Himmler, M., Aultman-Hall, L., & Stamatiadis, N. (1999). Impact of passengers on young driver safety. *Transportation Research Records*, *1693*, 25–30.

Bailey, I., & Sheedy, J. (1988). Vision screening for driver licensure. *Transportation in an ageing society: Improving mobility and safety for older persons, Special Report 218, vol. 2* (pp. 294–324). Washington, DC: Transportation Research Board, National Research Council.

Baxter, J. S., Manstead, S. R., Stradling, S. G., Campbell, K. A., Reason, J. T., & Parker, D. (1990). Social facilitation and driver behavior. *British Journal of Psychology*, *81*, 351–360.

Bedard, M., Molloy, D. W., & Luel, J. A. (1998). Factors associated with motor vehicle crashes in cognitively impaired older adults. *Alzheimer Disease and Associated Disorders*, *12*(3), 135–139.

Burkhardt, J., & McGavock, A. (1999). Tomorrow's older drivers: Who? How many? What impacts? *Transportation Research Records*, *1693*, 62–70.

Chandraratna, S., & Stamatiadsi, N. (2003). Problem driving maneuvers of elderly. TRB Paper 03-2193. *Journal of the Transportation Research Board.* (Washington, DC).

Chen, L., Baker, S., Braver, E., & Li, G. (2000). Carrying passengers as a risk factor for crashes fatal to 16- and 17-year old drivers. *JAMA*, *283*(12), 1578–1582.

Deacon, J. (1988). Potential improvement in roadway delineation for older driver. *Transportation in an ageing society: Improving mobility and safety for older persons, Special Report 218, vol. 2* (pp. 253–269). Washington, DC: Transportation Research Board, National Research Council.

Doherty, S. T., Andrey, J. C., & MacGregor, C. (1998). The situational risks of young drivers: The influence of passengers, time of day and day of the week on crash rates. *Accident Analysis and Prevention*, *30*(1), 45–52.

Jette, A. M., & Brachs, L. G. (1992). A ten year follow-up of driving patterns among the community-dwelling elderly. *Human Factors*, *34*(1), 25–31.

Foley, D. J., Masaki, K. H., Ross, G. W., & White, L. R. (2000). Driving cessation in older men with incident dementia. *Journal of the American Geriatrics Society*, *48*(8), 928–930.

Lawshe, C. H. (1940). Studies in automobile speed on highway. *Journal of Applied Psychology*, *24*(24), 297–307.

Li, G., Braver, E. R., & Chen, L. H. (2001). *Exploring the high death rates per vehicle-mile of travel in older drivers: Fragility versus excessive crash involvement*. Arlington, VA: Insurance Institute of Highway Safety.

McKelvey, F. X., & Stamatiadis, N. (1989). Highway accident patterns in Michigan related to older drivers. *Transportation Research Record*, *1210*, 53–57.

Mengert, P. (1982). *Project memorandum: Literature review on induced exposure models*. (Task 2. HS-270 PM-223-US-4A). Cambridge, MA: U.S. DOT, TSC.

National Research Council (1988). *Transportation in an ageing society: Improving mobility and safety for older persons, Special Report 218,* vol. 1. Washington, DC: Transportation Research Board.

Rosenbloom, S., & Waldorf, B. (2001). *Older travelers: Does place or race make a difference?* (E-circular E-C026). Washington, DC: Transportation Research Board.

Shua-Haim, J. R., & Gross, J. S. (1996). The "co-pilot" syndrome. *Journal of the American Geriatrics Society*, *44*(7), 815–817.

Stamatiadis, N. (1996). Gender effects on the accident patterns of elderly drivers. *Journal of Applied Gerontology*, *15*(1), 8–22.

Stamatiadis, N., & Deacon, J. (1995). Trends in highway safety: Effects of an aging population on accident propensity. *Accident Analysis and Prevention*, *27*(4), 443–459.

Stamatiadis, N., Jones, S., & Aultman-Hall, L. (1999). Causal factors for accidents on southeast low-volume roads. *Transportation Research Record*, *1652*, 111–117.

Stamatiadis, N., Taylor, W. C., & McKelvey, F. X. (1991). Older drivers and intersection traffic control devices. *Journal of Transportation Engineering*, *117*(3), 311–319.

Staplin, L., Lococo, K., Byington, S., & Harkey, D. (2001). *Guidelines and recommendations to accommodate older drivers and pedestrians* (Report No. FHWA-RD-01-051). Washington, DC: United States Department of Transportation, Federal Highway Administration.

Staplin, L., Lococo, K. H., Stewart, J., & Decina, L. E. (1999). *Safety mobility for older drivers handbook* (Report DOT-HS-808-853) Washington, DC: National Highway Transportation Safety Administration.

Villalba, J., Kirk, A., & Stamatiadis, N. (2001). Effects of age and cohort on older drivers. *Proceedings of the 2001 ATT Conference and Exhibition, Oct. 1-3, Barcelona, Spain*, *1*, 113–118.

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