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Female Involvement in U.S. Nonfatal Crashes Under a Three-Level Hierarchical Crash Model

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Abstract

Men have long held the lead in motor-vehicle crashes; however, research indicates that women are closing the gap. To further investigate this problem, we applied a hierarchical model to investigate female involvement in fatal crashes in the United States. The hierarchical model recognizes that decisions at higher levels affect the decisions at lower levels. At the top level, the model assumes that the driver's condition (e.g., inattention, fatigue, impairment) affects the next level (e.g., speeding or other failures to obey traffic laws), which subsequently affects the basic maneuvering skills (i.e., the lowest level) were either non-existent, or largely explained by gender differences in alcohol consumption. We found that although female involvement in skill-related crashes was not different from that of males, females were more likely than males to apply wrong maneuvers when speeding was involved. We also found that the most important contributing factor to gender differences in nonfatal crashes can be traced back to gender-based differences in alcohol consumption.

Keywords

female drivers; nonfatal crashes; hierarchical model

1 INTRODUCTION

Despite significant progress in traffic safety during the past decades, motor-vehicle crashes (MVCs) remain a major source of injury. U.S. males account for most of the traffic fatalities—three times that of females—and thus, have received most of the resources and focus (e.g., Cerrelli, 1998). Current data show, however, that the prevalence of women in fatal MVCs is rising. The National Highway Traffic Safety Administration (NHTSA) reported that the number of male drivers killed in fatal crashes dropped from 45 084 in 1975 to 39 739 in 1994. Yet, during the same period, the number of female drivers in fatal crashes increased from 9356 to 13 430 (NHTSA, 1995). Interestingly, the estimated involvement rate in fatal crashes per 100 000 licensed male drivers has constantly declined over the last 30 years (from 62 in 1975 to 42 in 2003), whereas it has remained unchanged for female drivers for about 15 years (National Center for Statistics and Analysis, 2005). Focusing on fatal

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crashes, Romano and colleagues (2008) reported that relative female involvement in fatal crashes has indeed increased in the United States, albeit mostly due to an increase in traffic exposure. As mentioned, reasons for this increase in crash fatalities is often cited as related to the different and richer roles modern women are playing in the society. Some explanations focus on household roles and their associated stresses, travel patterns, and driving skills. Other explanations go beyond exposure and argue that the development of changes in normative behaviors among women that occur over time translate into new, riskier driving behaviors (e.g., Pisarski, 1992; Voas et al., 1998). Romano and colleagues (2008) found some evidence suggesting that the latter could be a factor in explaining the relative increase in female crashes, but only for young female drivers. Understanding these changes would require data simultaneously containing both behavioral and crash data, as well as models able to properly fit the data.

Keskinen (1996) suggested the use of hierarchical models to systematize the contribution of behavioral factors to crash risk. Keskinen hierarchical levels of driving behavior (HLDB) model (described in English by Keskinen et al., 2004) postulates that behavioral factors contributing to the likelihood of crashes respond to a hierarchy, with decisions drivers' made at higher levels affecting the decisions at lower levels. At the top level, the HLDB model assumes that the drivers' goals of life affect the reason they drive, which subsequently affect the drivers' ability to master traffic situation and vehicle maneuvering. Because of its focus on behavior, the HLDB model has been applied in Europe to study the risks that novice drivers face (Laapotti et al., 2001) and the development of driver training programs for young drivers (Hatakka et al., 1999, 2002; Berg, 2006).

Although building a hierarchical model containing both behavioral and driving contextual data could become a valid and useful tool for investigating gender-based differences in crash involvement, building such a model is not straightforward. The main reason for this limitation is that simultaneous information on behavioral and contextual driving is rarely available. To deal with this limitation, we adopted a simplified three-level hierarchical model. The three levels we used are (from top to bottom) driving context (e.g., inattention, fatigue, impairment), which we assume has an effect on the next level (e.g., speeding or other failures to obey traffic laws), which subsequently affects the basic maneuvering skills (i.e., the lowest level). The goal of this effort is twofold. First, we want to investigate if the application of hierarchical models is useful to the study of gender-based differences in nonfatal crashes; and second, if there are gender-based differences across the different contributing crash factors.

2 METHOD

2.1.1 Conceptual Model—Drinking-and-driving contexts can be viewed as decision-making situations requiring individuals to choose between riskier and safer courses of action (Labouvie and Pinsky, 2001). Like the HLDB, our model recognizes that decisions at higher levels affect the decisions (and skills) at lower levels. At the top level, our model assumes that the person's driving context (e.g., drinking and driving) impacts the decisions at the second level (e.g., speeding or other failures to obey traffic laws), and subsequently, affect the basic maneuvering skills (e.g., controlling the vehicle direction).

Hierarchies in our model are broadly defined, with the sole requirement that factors within one level are dependent upon factors in superior levels, but without specifying how the factors are interconnected. Although such a lack of specification precludes a detailed study of the different mechanisms by which the different factors interact, it simplifies the analyses and makes them tractable.

2.1.2 Data—Crash data for this study were obtained from the 1997–2007 General Estimates System (GES). In 1988, the GES began to provide data about all types of crashes involving all types of vehicles. Data in GES come from a nationally representative probability sample of about 6.4 million police-reported crashes, from which about 50,000 are sampled each year. Crashes included are those that result in a fatality or injury that involves major property damage. GES is a valuable database that provides excellent information about the vehicle, the road characteristics, and the road conditions at the time of the crash; the basic sociodemographic characteristics of the driver; and the drivers' alcohol consumption, maneuvering skills, and sources of distraction. Variables in the GES database appear as listed in police crash reports. Thus, for instance, if the police officer at the crash scene believed that bad weather, alcohol, or an improper driving maneuver were factors contributing to the crash, the officer would have included that information in her/his report. Please notice that contributing factors, such as those just mentioned, are not mutually exclusive (i.e., they may all be present in the same crash).

There were 2,747,480 observations read from the 1997–2007 GES data set. About 13% of these records involved single-vehicle crashes ($n=341,467$). From these datasets, we eliminated drivers with missing gender information; drivers of non-passenger vehicles (buses, farm and construction vehicles, snowmobiles, etc.), ambulances, military or police vehicles, and nonmoving vehicles (e.g., parked). Also, to increase the likelihood of a correct identification of crash responsibility, only single-vehicle crashes were considered. After these manipulations, 277,672 drivers remained.

2.2 Measures

2.2.1 The Three Crash-Factor Levels—Table 1 shows the GES variables we used and the criteria we applied to build the condition variables at each of the three crash-factor levels. On top of our model is level-3 (driving context: alcohol consumption, fatigue/inattention), followed by level-2 (failing to obey a traffic signal, speeding, other aggressive driving) and level-1 (loss of vehicle control associated with improper vehicle maneuvering or bad weather or surface conditions).

2.3 Analyses

2.3.1 Analytical Models—To investigate the gender contribution to each level and crash factor, we applied descriptive analyses (chi-square) as well as multinomial (polytomous) logistic regression. Two types of descriptive analyses were applied. First we evaluated the association between gender and crash-factor level within the two crash-severity levels under consideration (nonfatal injuries and property damage only [PDO]). Then we reversed these comparisons and evaluated the association between gender and crash severity within crash-factor level. To expand these bivariate analyses and adjust by other covariables of interest, we then applied multinomial logistic regressions. Two sets of regressions were applied: one modeling the identification of a level-1 crash-factor as a function of level-2 crash-factors and covariables, and another modeling the identification of a level-2 crash-factor as a function of level-3 crash-factors and covariables. Covariables considered were gender (male, female), age (<21 – the reference level, 21–34, 35–64, and 65 and older), and presence of passengers (none – the reference level, 1, and 2 or more). Although the analysis of main effect models was of interest to us, we were particularly interested in the interaction between gender and all relevant factors and covariables. For instance, in modeling level-1 crash-factors, we were especially interested in the interactions between gender and level-2 crash-factors. If such interaction were significant, it would mean that compared to males, the contribution of females to the likelihood of a level-1 crash-factor would partially depend on the occurrence of a level-2 crash-factor. To evaluate these interactions, we run separate models, including only main effect and models including the interactions of interest.

Because of the multiple comparisons performed, we accepted statistical tests to be significant only at a 1% alpha value. STATA 11, which has the ability to accommodate weights and survey designs, such as those used to collect the GES database (“svy” estimation commands), was used for analyses.

3 RESULTS

3.1 Bivariate Comparisons of Gender and Crash-Factor Level Within Crash Severity

Table 2 shows the number of drivers in the file, by gender and severity (first row). It also shows the percentage of those drivers who appear in the different crash-factor levels. The female/male (F/M) ratios for cases in which no specific crash-factor level was identified are also included to serve as control for comparisons against crashes with an identified crash-factor. Also shown in Table 2 is the F/M ratio corresponding to each combination of crash-factor level and crash severity. Overall, for each male driver in the file, there are .57 females. Compared to males, female involvement was significantly smaller in level-3 crash-factors ($F/M = .51$) than in other types of crashes—when level 3 crash-factors were absent ($F/M = .63$)—with such a gender difference also taking place in both types of crash severity ($F/M = .49$ and $F/M = .58$ within PDO crashes, and $F/M = .53$ and $F/M = .74$ among nonfatal injury crashes). The relatively lower involvement of female drivers in level-3 crash-factors occurred in those in which alcohol was identified. No statistically different gender difference was observed associated to fatigue/inattention.

The role of gender in level-2 crash-factors somewhat mimics that for level-3 crash-factors: compared to males, female involvement was significantly smaller in level-2 crash-factors ($F/M = .50$) than in other types of crash-factors—when level 2 was absent ($F/M = .60$)—with such a gender difference also occurring in both types of crash severity. Among the level-2 crash-factors, the relatively lower involvement of female drivers occurred associated to either speeding or other aggressive driving. No statistically different gender difference was observed regarding failure to obey.

The role of gender in shaping the occurrence of level-1 crash-factors seems less clear than in the other two levels. Overall, no statistically significant gender difference was observed among level-1 crash-factors. When individual conditions within level-1 were tested, however, some differences by crash severity surfaced, with female drivers being less involved than males in maneuver PDO crashes, but female drivers were more involved than their male counterparts in weather/surface nonfatal injury crashes.

3.2 Multinomial Logistic Regressions

Table 3 reproduces the outcome of the multinomial logistic regression models for the occurrence of the level-1 crash-factors (dependent variable) as a function of the level-2 crash-factors, gender, and other covariables (the three leftmost columns in Table 3), and level-2 crash-factors (dependent variable) as a function of the level-3 crash-factors, gender, and other covariables (the three rightmost columns in Table 3). Main effects and full models for both regressions are also shown. The Pseudo R^2 measure shown in Table 3 indicates that although the models we applied were not bad, they left an important fraction of the variance unexplained. The inclusion of the interaction terms (our full model) increases the goodness of fit of the main effect models only marginally.

3.2.1 Main effects model—Regression of the level-1 crash-factors on the level-2 crash-factors and covariables (main effects only) shows that the likelihood of a maneuver crash-factor increases significantly ($p < .01$) with speeding ($OR = 5.309$), but not with other aggressive or failure to obey driving situations (). It also tends to decrease as the age of the

driver increases, albeit at lower odds ratios after age 34. A maneuver crash-factor was also less likely to be associated with PDO crashes rather than with nonfatal injury crashes. Speeding also increased the likelihood of a weather/surface crash-factor, although the corresponding odds ratio (1.601) was much lower than the one that links speeding with maneuvering (5.309). Neither age nor gender was significant in the main effect model under the 1% alpha criterion. However, under a less strict criterion (e.g., 2% alpha), females would have been found to be less likely to appear in maneuver situations than males (OR=.835, p value=.019). Presence of passengers does not have a significant impact on maneuver situations under the 1% alpha criterion.

The regression of the level-2 crash-factors on the level-3 crash-factors and covariables (main effects only) shows the important role that alcohol plays in inducing speeding and other aggressive crash-factors. The odds ratio associated with alcohol (either alone or in combination with fatigue/inattention) are among the largest of any factor contributing to speeding (OR=5.392 and OR=5.469, for the main effects and full model, respectively). Alcohol in combination with fatigue/inattention was also among the factors that most contributed to crashes associated to other aggressive driving (OR=2.981 and OR=3.305, for the main effects and full model, respectively). The role of the driver's age differs for speeding, other aggressive, and fail to obey crash-factors. Although the likelihood of speeding decreases with age, the likelihood of fail to obey remains relatively constant over all the age groups except for drivers ages 65 and older, who have higher odds of involvement in fail to obey situations than younger drivers. Speeding was also less likely to be associated to PDO crashes rather than to nonfatal injury crashes. Under the main effects model, gender was significant only to explain other aggressive crashes, with females less likely to be involved in these types of crashes than males (OR=.275).

3.2.2 Full model—As mentioned, the inclusion of the interaction terms does not increase much the goodness of fit of the main effect models. Further, the Akaike's information criterion (AIC) suggests that there is no apparent benefit in considering the full model over the main effects model. Nevertheless, our main interest in running our full models was to investigate the interaction between gender and the different variables under study. For the level-1 on level-2 regression model and although it was not significant in the main effect model, gender tested significant in the full model when it interacted with age and crash severity. Older female drivers (aged 35 and up) were more likely to be involved in maneuver situations than younger female drivers. Females also were more likely to be involved in nonfatal injury crashes than in PDO crashes, a finding that replicates the one obtained from the descriptive bivariate analyses. The interactions that were of particular interest to this level-1 on level-2 model were those involving gender and level-2 crash-factors, for they explore if the role of factors such as speeding, fail to obey, or other aggressive factors on maneuver or weather/surface events differs for males and females. Most interactions in this model were not significant, with the exception of female drivers being more likely to be involved in maneuver and weather/surface crashes than their male counterparts when they were also speeding (OR=1.608). It is interesting to note that although statistically correct, the operational meaning of this finding is not apparent. The production of results statistically significant but difficult to consider for operational purposes may signal one of the limitations of the use of hierarchical models, as we did in this study. On the other hand, the use of the hierarchical model is better justified with findings showing that gender differences in nonfatal crashes at any level are highly associated to gender differences in alcohol consumption.

Like for the level-1 on level-2 model, the interactions in the level-2 on level-3 model were largely nonsignificant. The interactions of particular interest for the level-2 on level-3 model were those involving gender and level-3 crash-factors, as they evaluated whether the role of

factors such as alcohol or fatigue/inattention varied across gender. Table 3 shows that females were less likely to be involved in other aggressive crashes than their male counterparts when they were under the influence of alcohol and fatigue. The latter result should be taken with extreme caution, however, because of the relatively small number of female drivers in that category.

4 DISCUSSION

By looking at different levels of crash-factors, this study allows for some separation of those factors and therefore achieves more detail in studying the role of gender on non-fatal motor vehicle crashes. One of the clearest results coming from this study is that females are less involved in alcohol-related crashes and speeding-related crashes than males. This result is not surprising, however, for it only confirms previous findings in the literature (Liu et al., 2005; Romano et al., 2008). Our lack of finding for gender differences associated to fatigue/inattention or maneuvering suggests that the occurrence of these factors is not circumscribed to a certain gender, but that their occurrence affects the general population. Further, the lack of significance for gender in their association with maneuvering suggests that the skill-levels of males and females may be equivalent.

This study also underscores the implicit complexity of the crash situations, as well as the potentiality of the hierarchical model when applied to crash data. For instance, this study found that female drivers are more prone to be involved in maneuver and weather/surface crash situations than male drivers when speeding, but female drivers were less likely to speed than males. Similar complexity was found by Romano and colleagues (2009) applied a hierarchical model to study the role of gender on fatal crashes. In that study, like in this one, female drivers were less likely to speed or to be involved in alcohol-related crashes than males. Also found in both studies was some evidence suggesting that female drivers were not more prone to skill-related crashes (level-1 crash-factors) than their male counterparts were. Thus, both studies present additional evidence against the popular myth portraying female drivers as more prone to be involved in skill-related crashes than males, particularly when driving occurs under normal traffic conditions. As discussed, however, the evidence coming from this study is not conclusive. We also found that females were more involved in some weather/surface-related crashes (Table 2), and that females might be more prone to maneuver-related crashes when speeding is involved. Unfortunately, reasons for these findings are unclear.

Despite its interesting results, this study is not free of shortcomings. As mentioned, the inclusion of higher-level crash factors in the analytical model seems appropriate because it helped explain some of the variations observed at lower levels. Application of our hierarchical model is not free of problems, however. One such difficulty emanates from the required partition of the database, which resulted in small sample sizes for some categories and forced us to collapse variables into broader categories. Another limitation involves the modeling of crashes as a function of the hierarchically structured factor levels and covariables. An intuitively appealing approach to such modeling would have been the use of path analysis, modeling the role of factors at superior levels (e.g., alcohol) on intermediate levels (e.g., speeding), and lower levels (e.g., maneuvering). Unfortunately, the use of path analysis to the hierarchical model presents several limitations, such as dealing with categorical variables and some paths that are not well defined. Research aiming to find a valid implementation of path analysis to the problem and data under study is already underway by our research team. Unfortunately, this line of research has not yet yielded fruitful results. Finally, due to the unaccounted complexities, some of the results obtained by this study, although statistically significant, are of dubious implications or irrelevant. That is, for instance, the case of our finding that female drivers were more likely to be involved in

maneuver and weather/surface crashes than their male counterparts when they were also speeding. While findings like this are statistically correct, their operational and policy implications are not.

In this study, we proposed an alternative strategy. To understand the role of gender at different crash-factor levels, we separated the analyses into two parts: independently examining the contribution of level-3 to the level-2 crash-factors and the level-2 crash-factors to the level-1 crash-factors. Although this approach did not allow for a full integration of the three-level crash-factors, by focusing on the gender-related interaction terms and going from level-1 crash-factors up to level-3, the model provided some meaningful results.

As mentioned, paths showing the influence of crash-factors as they triggered down from level 3 to level 1 could not be investigated. Also, to maximize the likelihood that drivers included in this study were responsible for the crash, we only included single-vehicle crashes. Not all crashes are reported to law enforcement agencies; therefore, crashes involving very little property damage and no injuries are likely to be underreported and therefore absent from the GES. Finally, another limitation of this study (perhaps the most relevant) involves the possibility of bias by those officers who coded the crashes. Police officers may have been more prone to assign different codes to females than males (e.g., giving a maneuver code to females more frequently than to males). Nevertheless, our study only found an association between female drivers and maneuver in situations in which speeding was involved. If there were gender-related bias in the way these types of crashes were registered, then such an association between speeding and maneuver should be revisited.

In summary, by applying a hierarchical model, this study disentangles some of the factors explaining the role of gender in nonfatal crashes. As such, this effort provides support to the application of these models. As a result, we found that many of the gender-based differences associated to skill-related crashes were either nonexistent, or largely explained by gender differences in alcohol consumption. However, our model was not free of problems and some of the findings seem either irrelevant or difficult to interpret for policy considerations. Thus, further research on the use of hierarchical models to investigate gender-differences in motor-vehicle crashes would be advisable.

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Table 1**GES Variables Used to Create Three Driving Levels and Conditions**

	Variables
Level 3	
Fatigue/Inattention	IMPAIRMT = 1,2; ACTION=24; MDRDSTRD=1-98; DR DSTRD=1-98; PHY COND=1-3;DR IMPMT= 1-3 (If year<1999) MIMPAIR= 1,2 (If year>2001)
Alcohol	ALCHL_I= 1 , VEH_ALCH= 1, V_ALCH_I = 1; VIOLATN = 1,3; VLTN_I = 1,3 PER_ALCH=1,2; DR_IMPMT= 4,5 (If year<1999) MVIOLATN= 1,2 (If year>2001)
Level 2	
Failure to Obey	VIOLATN = 6,7; VLTN_I =6,7
Traffic Signal	MVIOLATN= 6,7; VTRAFCON=1-4,22 (If year>2001) TRAF_CON=1-4,22 (If 2001 <year<1996)
Speeding	VIOLATN = 2-3; VLTN_I =6,7 ; 65<SPEED<999 SPEEDREL = 1 MVIOLATN= 3 (If year>2001) P_CRASH2 = 6 (If year<1999)
Other Aggressive	VIOLATN = 4 MVIOLATN= 4 (If year>2001) ACTION = 6 (If year>1999)
Level 1	
Maneuver	ACC TYPE = 1-3, 6-8, 44-49, 64-85 P_CRASH2 = 300-497 (If year<1999) ACTION = 3-5, 9-10, 21-22 (If year>1999) SURCON_I>1; WEATHR_I>1; V_EVNT_H=7
Weather/Surface	MDRMANAV = 2; VSURCOND=2-8 (If year>2001)
Road Conditions	P_CRASH2 = 5 (If year<1999)

Variables are named as in the NASS-GES Analytical User's Manual, 1988-2008 (2009). For instance, variable "IMPAIRMT" denotes causes of "physical" impairment, with levels 1,2 indicating if the driver was ill, drowsy, sleepy, fatigued, or fell asleep; "DR_IMPMT" identifies driver's "physical or mental" impairment that may have contributed to the cause of the accident, with levels 1,2 indicating the driver was ill, drowsy, sleepy, fatigued or fell asleep; 4 a possible presence of drugs (medication); and 5 the presence of other drugs (marijuana, cocaine, etc.); "MVIOLATN" indicates which violations were charged to drivers, with 1=Alcohol; 2=Drugs; 3=Speeding; 4 = Reckless Driving; 6 = Failure to Yield Right-of-Way; 7 = Running a Traffic Signal or Stop Sign.

Table 2

Distribution of Crash Types Within Gender

	Nonfatal Injuries				PDO ^a				All Nonfatalities			
	Males	Females	F/M ^b		Males	Females	F/M ^b		Males	Females	F/M ^b	
N ^c	87,085	54,231	0.63		76,329	39,235	0.55		163,414	93,466	0.57	
Level 3												
Level 3 absent	53.8%	61.8%	0.74**		62.9%	66.6%	0.58**		60.0%	64.8%	0.63**	
Level 3 present	46.2%	38.2%	0.53**		37.1%	33.4%	0.49**		40.1%	35.2%	0.51**	
Alcohol	25.7%	12.8%	0.32**		14.5%	7.3%	0.29**		18.1%	9.3%	0.30**	
Fatigue/inattention	28.8%	30.3%	0.66		27.9%	29.1%	0.56		28.2%	29.6%	0.44	
Level 2												
Level 2 absent	73.8%	77.4%	0.67**		85.8%	88.6%	0.57**		81.9%	84.6%	0.60**	
Level 2 present	26.2%	22.6%	0.56**		14.2%	11.4%	0.45**		18.1%	15.4%	0.50**	
Speeding	12.1%	9.8%	0.53**		19.7%	15.6%	0.44**		19.5%	16.1%	0.47**	
Fail to obey	12.3%	11.5%	0.60		5.0%	4.4%	0.49**		6.9%	6.6%	0.55	
Other aggressive	2.8%	1.9%	0.43**		1.9%	1.1%	0.34		2.0%	1.3%	0.38**	
Level 1												
Level 1 absent	24.9%	25.2%	0.65		31.8%	34.3%	0.60**		29.6%	31.0%	0.61	
Level 1 present	75.1%	74.8%	0.64		68.2%	65.7%	0.53**		70.4%	69.0%	0.57	
Maneuver	64.7%	65.2%	0.64		53.2%	50.8%	0.52**		53.3%	53.0%	0.57	
Weather/surface	36.8%	39.4%	0.68**		42.7%	43.9%	0.56		37.9%	39.9%	0.60**	

^aPDO stands for property damage only.^bF/M stands for female/male ratio and denotes the ratio of female drivers to male drivers in each category. Percentages indicating presence or absence of a crash level add up to 100% (e.g., 53.8% AND 46.2% in first column). However, percentages within a crash level show prevalence and do not necessarily add to 100% (e.g., 25.7% of males involved in non-fatal injuries recorded a presence of alcohol; 28.8% fatigue/inattention; but 25.7% + 28.8% do not add to 100%).^cN denotes number of drivers in the file.

** denotes an alpha=1% statistically significant within gender comparison (e.g., F/M = .32 – fourth row – is statistically significant from F/M = .63 – first row).

Table 3

Multinomial Regressions

Level 1 on Level 2												
	Main effects			Full model			Main effects			Full model		
	OR	P>z		OR	P>z		OR	P>z		OR	P>z	
	Maneuver			Weather/Surface			Maneuver and Weather/Surface					
Female	0.835	0.019	0.881	0.123	0.927	0.423	1.073	0.629	1.046	0.520	1.089	0.393
Speeding	5.309	0.000	3.847	0.000	1.601	0.004	1.470	0.000	11.125	0.000	6.369	0.000
Fail to obey	0.497	0.021	0.150	0.000	0.897	0.435	0.981	0.820	0.369	0.001	0.167	0.000
Other aggressive	3.370	0.049	2.145	0.002	0.012	0.002	0.371	0.179	1.592	0.546	1.617	0.123
Female & speeding			1.087	0.360			1.145	0.404			1.608	0.000
Female & fail to obey			0.911	0.464			1.092	0.516			0.791	0.255
Female & aggressive			1.777	0.299			0.000	0.980			1.146	0.854
21–34	0.530	0.000	0.663	0.000	0.957	0.559	0.950	0.595	0.627	0.000	0.687	0.000
35–64	0.320	0.000	0.369	0.000	0.935	0.573	0.928	0.418	0.388	0.000	0.434	0.000
65+	0.364	0.000	0.298	0.000	0.686	0.033	0.623	0.001	0.285	0.000	0.306	0.000
Female & 21–34			1.005	0.956			0.804	0.144			0.984	0.872
Female & 35–64			1.274	0.005			0.802	0.120			1.139	0.200
Female & 65+			1.483	0.003			0.836	0.432			0.971	0.872
1 passenger	0.918	0.355	0.992	0.870	0.771	0.064	0.862	0.085	0.874	0.264	1.027	0.667
2+ passengers	0.752	0.012	0.877	0.062	0.871	0.363	1.036	0.755	0.646	0.009	0.785	0.005
Female & 1 pass			1.045	0.586			1.213	0.148			0.830	0.055
Female & 2+ pass			1.016	0.879			0.813	0.241			1.010	0.940
PDO ^a	0.427	0.001	0.684	0.000	1.287	0.111	1.477	0.000	0.805	0.367	1.478	0.000
Female & PDO ^a			0.845	0.008			1.213	0.148			0.800	0.003

Level 2 on Level 3

	Main effects			Full model			Main effects			Full model		
	OR	P>z	OR	P>z	OR	P>z	OR	P>z	OR	P>z	OR	P>z
Speeding												
Fail to Obey												
Female	1.033	0.702	1.005	0.985	0.770	0.040	0.972	0.931	0.275	0.005	0.269	0.285
Alcohol	5.324	0.000	4.975	0.000	0.957	0.892	0.972	0.937	2.192	0.222	1.830	0.402
Fatigue/inattention	0.859	0.228	0.880	0.140	0.961	0.842	0.919	0.639	2.761	0.107	2.588	0.136
Alcohol & fatigue	5.392	0.000	5.469	0.000	1.026	0.939	1.269	0.531	2.981	0.009	3.305	0.002
Female & alcohol			1.268	0.078			0.910	0.819			3.010	0.404
Female & fatigue			0.945	0.733			1.124	0.632			1.431	0.591
Female & both			0.942	0.784			0.356	0.123			NES	NES
21–34	0.681	0.000	0.675	0.000	1.436	0.040	1.539	0.044	0.952	0.816	0.924	0.602
35–64	0.426	0.000	0.408	0.000	1.356	0.053	1.357	0.110	0.232	0.000	0.155	0.000
65+	0.358	0.000	0.362	0.005	1.821	0.003	1.963	0.020	0.081	0.001	0.091	0.001
Female & 21–34			1.021	0.841			0.834	0.592			1.150	0.840
Female & 35–64			1.109	0.244			0.996	0.986			5.195	0.286
Female & 65+			0.991	0.978			0.808	0.499			NES	NES
1 passenger	1.196	0.215	1.123	0.377	0.895	0.452	1.013	0.948	2.174	0.065	2.112	0.154
2+ passengers	1.355	0.029	1.322	0.012	0.655	0.070	0.583	0.144	2.372	0.001	2.338	0.017
Female & 1 pass			1.179	0.327			0.693	0.145			1.149	0.852
Female & 2+ pass			1.056	0.859			1.263	0.526			0.982	0.975
PDO ^d	0.711	0.000	0.740	0.000	0.229	0.000	0.249	0.002	0.604	0.002	0.781	0.053
Female & PDO ^d			0.911	0.475			0.794	0.508			0.246	0.134

Reference dependent level is “No Level 1 crash.”

^dPDO means property damage only. Pseudo R2 for main effect model and full model are .0878 and .0891 (Level2 on Level 3), and .0930 and .0945 (Level1 on Level2), respectively. The AIC indexes for these models are 2.265 and 2.264 (Level2 on Level 3) and 1.778 and 1.779 (Level1 on Level 2), respectively.

Table 4

Multinomial Regressions

	Level 1 on Level 2											
	Main effects			Full model			Main effects			Full model		
	OR	P>z	OR	P>z	OR	P>z	OR	P>z	OR	P>z	OR	P>z
	Maneuver			Weather/Surface			Maneuver and Weather/Surface					
Female	0.835	0.019	0.881	0.123	0.927	0.423	1.073	0.629	1.046	0.520	1.089	0.393
Speeding	5.309	0.000	3.847	0.000	1.601	0.004	1.470	0.000	11.125	0.000	6.369	0.000
Fail to obey	0.497	0.021	0.150	0.000	0.897	0.435	0.981	0.820	0.369	0.001	0.167	0.000
Other aggressive	3.370	0.049	2.145	0.002	0.012	0.002	0.371	0.179	1.592	0.546	1.617	0.123
Female & speeding			1.087	0.360			1.145	0.404			1.608	0.000
Female & fail to obey			0.911	0.464			1.092	0.516			0.791	0.255
Female & aggressive			1.777	0.299			0.000	0.980			1.146	0.854
21–34	0.530	0.000	0.663	0.000	0.957	0.559	0.950	0.595	0.627	0.000	0.687	0.000
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65+	0.364	0.000	0.298	0.000	0.686	0.033	0.623	0.001	0.285	0.000	0.306	0.000
Female & 21–34			1.005	0.956			0.804	0.144			0.984	0.872
Female & 35–64			1.274	0.005			0.802	0.120			1.139	0.200
Female & 65+			1.483	0.003			0.836	0.432			0.971	0.872
1 passenger	0.918	0.355	0.992	0.870	0.771	0.064	0.862	0.085	0.874	0.264	1.027	0.667
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Female & 1 pass			1.045	0.586			1.213	0.148			0.830	0.055
Female & 2+ pass			1.016	0.879			0.813	0.241			1.010	0.940
PDO ^d	0.427	0.001	0.684	0.000	1.287	0.111	1.477	0.000	0.805	0.367	1.478	0.000
Female & PDO ^d			0.845	0.008			1.213	0.148			0.800	0.003

Level 2 on Level 3

	Main effects			Full model			Main effects			Full model		
	OR	P>z	OR	P>z	OR	P>z	OR	P>z	OR	P>z	OR	P>z
Speeding												
Fail to obey												
Other aggressive												
Female	1.033	0.702	1.005	0.985	0.770	0.040	0.972	0.931	0.275	0.005	0.269	0.285
Alcohol	5.324	0.000	4.975	0.000	0.957	0.892	0.972	0.937	2.192	0.222	1.830	0.402
Fatigue/inattention	0.859	0.228	0.880	0.140	0.961	0.842	0.919	0.639	2.761	0.107	2.588	0.136
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Female & PDO ^a	0.911	0.475					0.794	0.508			0.246	0.134

Reference dependent level is “No Level 1 crash.”

^aPDO means property damage only. Pseudo R2 for main effect model and full model are .0878 and .0891 (Level 2 on Level 3), and .0930 and .0945 (Level 1 on Level 2), respectively. The AIC indexes for these models are 2.265 and 2.264 (Level 2 on Level 3) and 1.778 and 1.779 (Level 1 on Level 2), respectively. NES denotes that there was not enough sample size in these cells to be included in the analysis.