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ABSTRACT

Objective: Aggressive driver behavior is one of the major contributing factors to road crashes. However, the relationship between aggressive driver behavior and crash risk is scarcely explored. The present study focused on quantifying the effect of aggressive driver behavior on crash probability.

Method and Data Sources: A sample of 405 Indian drivers were analyzed to model the aggressive driver behavior using self-reported measures. Generalized linear models were developed to quantify the effects of independent variables such as age, gender, personality traits (e.g., driving anger, physical aggression, hostility), and individual predilections to commit violations (e.g., excessive speeding and frequent risky overtaking) on aggressive driver behavior and crash probabilities.

Results: K-means clustering technique was applied to the Aggressive Driving Scale (ADS) scores to cluster the drivers into three groups (aggressive, normal, and cautious). Gender was significantly correlated with aggressive driver behavior. Compared to female drivers, male drivers were 2.57 times more likely to engage in aggressive driving. Driver's age was negatively correlated with aggressive driving. With one-year increment in driver's age, the tendency of a driver to engage in aggressive driving was reduced by 26%. In addition, the likelihood of being engaged in aggressive driving was increased by 2.98 times and 2.15 times for the drivers who engage in excessive speeding and frequent risky overtaking, respectively. Driver's personality traits were significantly correlated with aggressive drivers. The crash involvement model showed that aggressive drivers were 2.79 times more likely to be involved in road crashes than cautious drivers. Further, married drivers were 2.17 times less likely to be involved in crashes, whereas for professional drivers the crash involvement probability was increased by 75%.

Conclusions: The results revealed that in addition to age and gender personality traits were significant predictors of driving aggression. Further, the driver's marital status was negatively correlated with the crash involvement and professional drivers were more likely to be involved in crashes than nonprofessional drivers. The study findings can be used in identifying specific risk-prone drivers to provide safety measures via in-vehicle Advanced Driver Assistance Systems (ADAS).

Introduction

Every year, worldwide, approximately 1.35 million people die due to road crashes (Global Status Report on Road Safety 2018). The National Highway Traffic Safety Administration (2020) reported that 36,096 people were killed, and 2.74 million people were injured on U.S roadways in the year 2019. The National Crime Record Bureau (2019) (NCRB-2019) reported that in India, due to road crashes, 0.44 million people were injured and 0.15 million people were killed in 2019. Aggressive driver behavior is one of the significant contributors to road crashes (Paleti et al. 2010). American Automobile Association Foundation for Traffic Safety (AAA Foundation for Traffic Safety 2009) stated that about 56% of the total crashes that happened during 2003 and 2007 in the United States were due to aggressive driver behavior (speeding and reckless driving).

According to NCRB-2019, in India, 54.9% and 27.7% of road crashes were due to aggressive driver behavior such as excessive speeding and overtaking, respectively.

Due to its positive correlation with road crashes and adverse effects on public safety, aggressive driver behavior has drawn attention in the last decade. According to the National Highway Traffic Safety Administration (2009), aggressive driving "is generally understood to mean driving actions that markedly exceed the norms of safe driving behavior and that directly affect other road users by placing them in unnecessary danger". The present study adopted the definition, of aggressive driver behavior based on intentions and negative personality traits. Tasca (2000) defined aggressive driver behavior as "if the behavior is deliberate, likely to increase the risk of collision and is motivated by impatience, annoyance, hostility, and/or an attempt to save time". It depends on several factors, such as contextual variables

(traffic congestion, aggressive stimuli, etc.), drivers' individual predilections, and driving environment (Tasca 2000). Further, when drivers interact with external stressors (traffic congestion, frustrating events, other aggressive drivers, etc.), that may elicit a state of negative emotions and lead to reckless or aggressive driving. It is often manifested in speeding, risky overtaking, failure to yield right of way, improper following, and racing. This kind of risky behavior is often seen in younger and male drivers. In the previous studies, age was reported to have a negative correlation with aggressive driving (Dahlen and White 2006). Gender was significantly associated with aggressive driver behavior and found that male drivers were more likely to engage in aggressive driving than female drivers (Sârbescu et al. 2014). In addition to demographic characteristics (age and gender), driver's personality traits substantially contributed to aggressive driver behavior (Dahlen and White 2006; Sârbescu et al. 2014). Further, it has a positive correlation with driving anger (Li et al. 2014), hostility (Kovácsová et al. 2014), and physical and verbal aggression (Deffenbacher et al. 2004). Existing studies reported that aggressive drivers tend to be involved in thrill-seeking behavior (Dahlen et al. 2012). Moreover, the drivers with thrill seeking behavior engage in excessive speeding and commit violations (Rowden et al. 2016; Wishart et al. 2017); this behavior is well associated with aggressive driving.

The existing studies investigated the relationship between various influencing factors and aggressive driving, but limited studies quantified the effects of these variables on aggressive driving. Therefore, in addition to driver attributes and personality traits, the present study included moving violations (excessive speeding and frequent and sudden overtaking) as predictors of aggressive driver behavior and quantified the effects of these variables subsequently. Moving violations included in this study were excessive speeding (if drivers exceeding the posted speed limit more than 15 mph) (AAA Foundation for Traffic Safety 2009) and frequent and risky overtaking with critical gaps, aggressive drivers are more prone to engage in overtaking with critical gaps. Though aggressive driver behavior was well explored in the existing studies, the findings may not be well suited for Indian conditions. Further, drivers in various countries may show differences in their aggressive driver behavior, based on the country's legislation, policy, and enforcement in terms of road safety (Ersan et al. 2019). Therefore, due to the differences in culture, law enforcement, demographics, personality traits, and driving conditions (e.g., congested and heterogeneous traffic) past investigations may not be applicable for Indian drivers.

Research gap and objectives

Overall, existing studies only focused on driver attributes or personality traits while investigating aggressive driver behavior. The effect of driver's dispositions to engage in excessive speeding and frequent risky overtaking on aggressive driver behavior was scarcely explored. The effects of various explanatory variables on aggressive driver behavior were investigated separately. But in real world driver behavior is complex and influenced by multidimensional explanatory variables. Further, while investigating aggressive driver behavior or crash involvement probabilities, interaction effects between explanatory variables (simultaneously) were not considered in many existing studies. The quantifiable effect of aggressive driver behavior on crash probability was scarcely explored.

Based on these research gaps, the study aimed to investigate the following aspects:

1. The study analyzed and quantified the effects of various influencing factors such as: driver attributes (age and gender), personality traits, and moving violations on aggressive driver behavior simultaneously.
2. In addition to the driver attributes, personality traits, and demographics the study quantified the effects of individual dispositions to engage in excessive speeding and frequent risky overtaking on aggressive driver behavior.
3. The study focused on quantifying the effects of aggressive driving, marital status, and driver profession (professional versus nonprofessional drivers) on crash involvement probability. In addition, the interaction effect between marital status and aggressive driving was also investigated.

Methodology

Sample

In total, initially, drivers were identified from a database collected from small companies, institutions, and transport agencies in India. The participants were identified as per the requirement with respect to age, gender, and crash involvement. Two inclusion criteria were considered: (1) participants should hold a valid driving license and (2) should have more than two years of driving experience. Initially identified Eight hundred drivers were invited through Email/Facebook/WhatsApp to participate in a telephonic survey, out of which only 419 participants showed a willingness to participate in the survey. Due to inconsistent responses, fourteen participants were omitted, and the remaining 405 driver's responses were considered in the study. In the assessment of psychological construct, self-reported measures may suffer social desirability bias (Af Wåhlberg 2010). However, to countermeasure, the study collected responses anonymously and participants have assured the confidentiality of their information. The final data includes 42% female and 58% of male drivers with a mean age of 37.27 years. (SD = 11.17; aged 22–58) years. The mean driving experience was 6.7 years (SD = 4.06 years). There were 21% professional drivers (working in transport companies with a valid driving license) and 79% nonprofessional drivers. Further, 34% of the drivers reported being involved in at least one crash and the remaining 66% of the data reported that no crash involvement in the last two years. 55% of the participants were reported as married and

the remaining 45% were unmarried. Moving violations committed in the last 6 months were recorded and 41% of the participants were reported to be involved in excessive speeding and 32% of them in frequent and risky overtaking. In addition, the mean driving exposure of professional and nonprofessional drivers was 19,700 km (SD =15,318 km) and 10,276 km (SD =10,140 km), respectively.

Self-reported measures

Demographic measures and driving history
A demographic questionnaire was used to obtain the details of the driver attributes (age, gender, marital status, and occupation), driving exposure (kilometers driven in last one year and the driving license held years), history of violations committed (in the last six months), and crash involvement (in the last two years). Participants were asked whether they were seeking thrill in committing violations (excessive speeding and risky overtaking). Further, to rate their thrill-seeking experience on a 5-point Likert scale ranging from "1 = not at all" to "5 = very much".

Measures of personality traits
In the previous studies personality traits including driving anger, hostility, and physical aggressions reported to have a significant effect on aggressive driving (Buss and Perry 1992; Deffenbacher et al. 1994, 2004; Kovácsová et al. 2014; Li et al. 2014; Chai and Zhao 2016).

Driving anger scale (DAS)
A short version of 14-items DAS was a driving anger scale and a self-reported instrument developed to measure the anger generated by specific anger-provoking situations while driving (Deffenbacher et al. 1994). The respondents were asked to rate their anger experienced by specific situations for all the listed items, on a 5-point Likert scale ranging from "1 = not at all" to "5 = very much". (Deffenbacher et al. 1994; Li et al. 2014).

The Buss-Perry aggression questionnaire (BPAQ)
A 29-items BPAQ was developed to measure four aspects of human aggression including physical aggression, verbal aggression, anger, and hostility (Buss and Perry 1992). Physical and verbal aggression subscales were developed to measure behavioral aspects. The hostility subscale was developed to measure cognitive response and the anger subscale measures emotional aspects. For all the listed items, the responses were recorded on a 5-point Likert scale ranging from 1 (Extremely uncharacteristic) to 5 (Extremely characteristic). (Deffenbacher et al. 2004; Kovácsová et al. 2014).

Aggressive driving scale (ADS)
A 24-items ADS was developed to measure driving aggression (Krahé and Fenske 2002). The respondents were asked to rate the frequency of driving aggression they engage in each listed situation while driving on a 5-point Likert scale,

ranging from "1 = never" to "5 = very often"(Chai and Zhao 2016).

Data analysis and results

Dependent and independent variables
Aggressive driver behavior is one of the major contributing factors of road crashes (Paleti et al. 2010). Identifying aggressive driver behavior helps to evaluate the risk factors involved. Therefore, the study identified the aggressive drivers based on self-reported measures of driving aggression. K-means clustering technique was applied to the ADS scores (Chai and Zhao 2016) to cluster the participants into three groups (aggressive, normal, and cautious) (Guo and Fang 2013). It measures the cluster quality in terms of how similar observations are within a cluster compared to other clusters. The optimal number of clusters obtained were three (k = 3) at which maximum Silhouette Coefficient (SC =0.58) was observed for ADS scores. The attributes of clustered drivers were shown in Table A1 (see Appendix A, online supplement).

Driver behavior (aggressive, normal, and cautious) and crash involvement (yes or no) were considered as dependent variables. The factors influencing driver behavior, including driver characteristics (age, gender, etc.), personality traits (driving anger, hostility, physical and verbal aggression), and dispositions to commit violations (excessive speeding, frequent and risky overtaking, etc.) were considered as independent variables. Similarly, the factors contributing to crash involvement, including driver behavior, marital status, and driving profession were taken as independent variables. The preliminary analysis (mean, standard deviations, and percentages) of these parameters were presented in Table A2 (see Appendix A, online supplement). In order to investigate the effect of the explanatory variables on aggressive driver behavior and crash involvement probability, two generalized linear models were developed using SPSS software (version 22).

Modeling aggressive driver behavior
Each driver has a tendency to drive in their comfortable style (aggressive, normal, or cautious). To quantify the effects of personality traits and other variables on aggressive driver behavior, a Multinomial Logit Model was developed. All the variables listed in Table A2 (see Appendix A, online supplement) were considered as independent variables and the driver behavior (aggressive, normal, and cautious) was taken as a dependent variable. All the explanatory variables used in the model were free from multicollinearity. A detailed explanation of the statistical approach used in modeling aggressive driver behavior was mentioned in Appendix B (see online supplement). The final model was shown in Table 1, which includes odds ratio (OR), and parameter estimates (β). The odds ratio provides the magnitude of the association between dependent and independent variables; it is obtained by exponents of the parameter estimates

Table 1. Results of multinomial logit model for aggressive, normal, and cautious driver behavior based on self-reported measures.

Variables		Normal drivers			Aggressive drivers		
		Estimate	Exp(β)	Wald	Estimate	Exp(β)	Wald
Intercept		−9.23		26.114***	−21.29		61.821***
Driver characteristics	Gender (Male)	1.382	3.985	5.814**	2.567	13.032	11.771***
	Age	−0.158	0.854	17.731***	−0.301	0.740	40.027***
Moving violations	Excessive speeding	1.366	3.919	4.372**	2.984	19.759	12.949***
	Frequent risky overtaking	1.633	5.118	3.177*	2.154	8.622	4.393**
Personality traits	Driving anger	0.253	1.288	33.913***	0.495	1.641	78.965***
	Physical aggression	0.295	1.343	29.273***	0.327	1.387	20.321***
	Hostility	0.102	1.108	5.395**	0.290	1.336	24.811***

Reference category: Cautious drivers, *** = $p < 0.001$; ** = $p < 0.05$; * = $p < 0.1$.
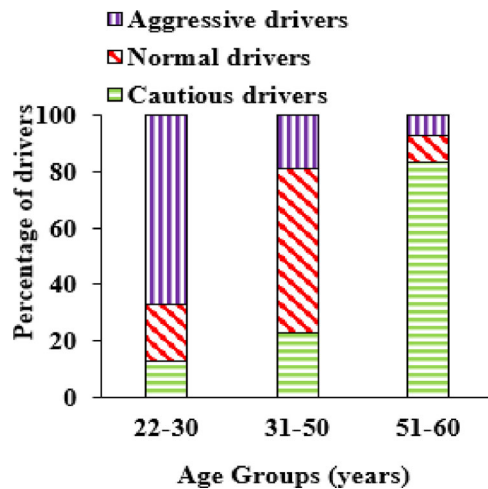
Figure 1. Proportions of drivers of three driver categories with respect to age.
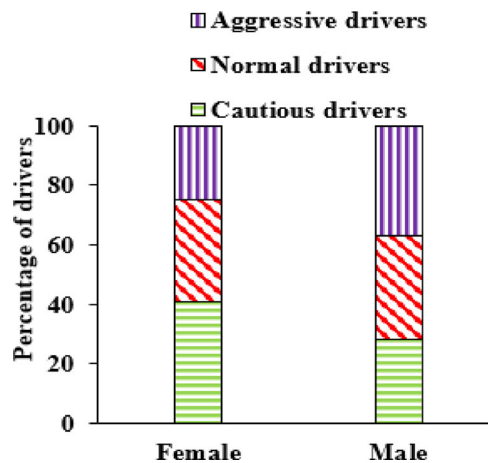
Figure 2. Proportions of drivers of three driver categories with respect to gender.

(exp(β)). The odds ratio explains the relative change that occurs in the dependent variable with one unit change in the explanatory variable.

The clustered drivers' proportions with respect to age and gender were plotted in Figures 1 and 2, respectively. The proportions of young male drivers were higher in the aggressive driver category compared to female and older drivers. It can be observed from Figure A1 (see Appendix A, online supplement), that the highest proportion of young male drivers (age from 22 to 30 years) were involved in aggressive driver behavior (59%), followed by male drivers

of age groups 31–50 years (32%) and young female drivers (18%). The results presented in Table 1 showed that with one year increment in driver's age, the tendency of a driver to engage in aggressive driver behavior is decreased by 26%. The results also showed that the likelihood of being engaged in aggressive driver behavior was 2.56 times greater for male drivers than female drivers. It was observed that personality traits were significantly influencing driving aggression. In addition, the drivers with higher scores on self-reported personality measures such as driving anger, physical aggression, and hostility were more likely to engage in aggressive driving. In addition, results showed that the likelihood of being engaged in aggressive driving was 2.98 times and 2.15 times greater for the drivers who engage in excessive speeding and risky overtaking.

Modeling crash probabilities

Crash involvement probability was estimated based on self-reported data of crash involvement in the last two years. A Binary Logit Model was developed to quantify the effects of explanatory variables such as marital status, driving expertise (professional versus nonprofessional), and driver behavior (aggressive, normal, and cautious driver behavior) on crash occurrence (with two categories: crash involvement =1 and no crash involvement =0). The final model shown in Table 2 indicates that the likelihood of being involved in a crash was 2.79 times and 1.81 times greater for aggressive drivers than cautious and normal drivers, respectively. The interaction effects of marital status and driver behavior on crash involvement were plotted in Figure 3. Total, 64% of the aggressive unmarried drivers were being involved in crashes, and this was 39% in aggressive married drivers. The results showed that marital status (of all drivers) effect on crash involvement was significant and married drivers were approximately 89% less likely to be involved in crashes than unmarried drivers. The relationship between aggressive driver behavior and crash involvement was mediated by marital status. Whereas, for normal and cautious married drivers, this effect was not significant on crash involvement. The results also showed that the likelihood of being involved in crashes was 0.564 times (odds of the professional drivers getting involved in a crash was 75% (exp (β) =1.756) greater for the professional drivers than nonprofessional drivers.

Table 2. Results of binary logit model of crash involvement of self-reported measures.

Coefficient	Estimate	Exp(β)	SE	Wald	p-value
Intercept	−1.090	0.336	0.333	10.713	<0.001***
Cautious drivers[a]					
Aggressive drivers	2.790	16.286	0.684	16.623	<0.001***
Normal drivers	0.974	2.648	0.366	7.068	<0.05**
Marital status (married drivers)	−2.173	0.114	0.369	34.676	<0.001***
Professional drivers	0.564	1.758	0.315	3.218	<0.1*
Aggressive driver behavior* Married drivers	−1.184	0.306	0.706	2.814	<0.1*

[a]Reference category, SE = Standard error, *** = $p < 0.001$; ** = $p < 0.05$; * = $p < 0.1$.
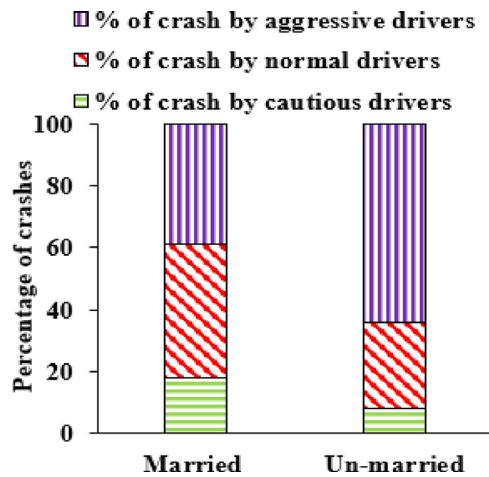
Figure 3. Percentage of crashes involved versus mediation effect of marital status and driver behavior.

Discussion

Aggressive driver behavior and crash involvement probability were modeled to quantify the effects of various contributing factors. The results obtained from the Multinomial Logit Model indicate that all the explanatory variables had a significant effect on aggressive driver behavior as observed in the earlier studies. For instance, age was negatively correlated with aggressive driver behavior (Krahé and Fenske 2002; Dahlen and White 2006). Moreover, it was found that the likelihood of a driver being involved in aggressive driving behavior was reduced by 26% for the older drivers compared to younger drivers. Further, the gender effect was also in line with the previous studies. Compared to females, male drivers were more likely to drive aggressively (Dahlen and White 2006; Sârbescu et al. 2014). Personality traits such as driving anger (Li et al. 2014), physical aggression (Deffenbacher et al. 2004), and hostility (Kovácsová et al. 2014) were positively correlated and had significant effects on aggressive driving. as concluded in earlier studies. However, the scores of the verbal aggression were not significant, the reason for this could be due to the higher verbal aggression the drivers tend to be involved in aggressive arguments or abusive gestures instead of using the vehicle to express their driving aggression. Subsequently, the study investigated the effects of driver behavior, marital status, and driving expertise on crash involvement. It was found that aggressive driving was a significant factor influencing crash involvement and married drivers were less likely to be involved in crashes. However, despite greater driving expertise, professional drivers were more likely to be involved in crashes than nonprofessional drivers. This may be because professional drivers are more prone to stress and frustration due to continuous exposure to traffic and exhibit risky driver behavior (Öz et al. 2010) results in increased crash risk. In addition, due to prolonged driving hours and compromised sleep schedules, professional drivers may experience fatigue during driving. This may affect the driving performance of professional drivers especially during critical situations, results in an increased probability of crash involvement (Harris 1999).

This study faced a few limitations while investigating the effects of various explanatory measures on aggressive driving behavior and crash involvement. The study quantified the effect of explanatory variables based on self-reported measures, but crash involvement measures may suffer from the social desirability bias. However, experimental validation (crash probability under various hazardous conditions) based on a simulator study may provide required compensations for the results obtained from self-reported measures. The study identified aggressive drivers based on personality traits alone, but in real world, aggressive driver behavior can be observed in multi-dimensional due to complexities involved in real world scenarios. However, identifying the drivers based on driver attributes, personality traits, and history of violations committed along with driving attributes attained from real driving may improve the accuracy in detecting aggressive drivers. Further, the driving exposure (vehicle kilometers driven) of professional drivers is much higher than nonprofessional drivers, which may affect the crash involvement of an individual due to prolonged vehicle kilometers driven. This limitation can be addressed in future research by controlling the effect of driving exposure of the participants to avoid any interaction effect.

In addition, the study highlighted the contributions as follows based on the research gaps observed in the literature. In the existing literature on aggressive driver behavior, the findings were inconsistent and misleading. For instance, in some studies, age was found to be a significant predictor of aggressive driver behavior (Dahlen and White 2006), whereas, other studies stated that the age effect was insignificant (Moore and Dahlen 2008). Jovanović et al. (2011b) reported that gender effect on aggressive driving was insignificant, whereas, Sârbescu et al. (2014) found that male drivers were more prone to aggressive driving than female drivers. The reason for mixed findings could be the inconsistency in the selection of sample (e.g., the sample consists of only young or specific age group drivers or is dominated by male drivers). To investigate the driver behavior and crash involvement probability, considering multi-dimensional

explanatory measures (demographics, personality traits, and violation/crash history) provide more realistic results, as the driving environment is more complex and influenced by many factors. However, in the existing literature, the studies only considered limited factors while investigating driver behavior and crash involvement probability. The present study quantified the effects of various factors such as age, gender, personality traits, and excessive speeding and frequent risky overtaking on aggressive driver behavior simultaneously. The effect of aggressive driving on crash probability was scarcely explored in previous studies. Therefore, the study investigated and quantified this effect of driving aggression on crash involvement. In addition, the study also investigated the effects of the marital status of the driver and driving profession on crash probability.

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