Published in final edited form as:

Accid Anal Prev. 2018 September ; 118: 96–101. doi:10.1016/j.aap.2018.06.001.

Vehicle ownership and other predictors of teenagers risky driving behavior: Evidence from a naturalistic driving study

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Abstract

Objective: Risky driving behavior may contribute to the high crash risk among teenage drivers. The current naturalistic driving study assessed predictors for teenagers' kinematic risky driving (KRD) behavior and the interdependencies between them.

Method: The private vehicles of 81 novice teenage drivers were equipped with data acquisition system that recorded driving kinematics, miles driven, and video recordings of the driver, passengers and the driving environment. Psychosocial measures were collected using questionnaires administered at licensure. Poisson regression analyses and model selection were used to assess factors associated with teens' risky driving behavior and the interactions between them.

Results: Driving own vs shared vehicle, driving during the day vs at night, and driving alone vs with passengers were significantly associated with higher KRD rates (Incidence rate ratios (IRRs) of 1.60, 1.41, and 1.28, respectively). Teenagers reporting higher vs lower levels of parental trust had significantly lower KRD rates (IRR = 0.58). KRD rates were 88% higher among teenagers driving with a passenger in their own vehicle compared to teenagers driving with a passenger in a shared vehicle. Similarly, KRD rates during the day were 74% higher among teenagers driving their own vehicle compared to those driving a shared vehicle.

Conclusions: Novice teenagers' risky driving behavior varied according to driver attributes and contextual aspects of the driving environment. As such, examining teenagers' risky driving behavior should take into account multiple contributing factors and their interactions. The variability in risky driving according to the driving context can inform the development of targeted interventions to reduce the crash risk of novice teenage drivers.

Keywords

Kinematic risky driving (KRD); Vehicle ownership; Naturalistic driving; Graduated driver licensing (GDL)

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1. Introduction

Teenage drivers are one of the most vulnerable groups of road users and are overrepresented in crash statistics (National Highway Traffic Safety Administration (NHTSA, 2016). In 2014, teenage drivers at the age of 15–20 years old, represented 6% of U.S. licensed drivers, yet accounted for 9% of total fatal crashes. Motor vehicle crashes are the leading cause of injury and death for teenagers in the U.S., with 170,000 injuries and 1717 deaths in 2014 (National Highway Traffic Safety Administration (NHTSA, 2016). Teenagers over-involvement in crashes has been attributed to an array of interconnected factors, including young licensure age, lack of driving experience, and high risk-taking propensity, among others (Mirman et al., 2012; Shope, 2006; Shope and Bingham, 2008; Simons-Morton et al., 2011a; Williams, 2003).

Elevated g-force events provide an objective measure of Kinematic Risky Driving (KRD) and serve as a common focus for interventions (Carney et al., 2010; Prato et al., 2010; Simons-Morton et al., 2012a, 2013). Previous research indicated that KRD rates are substantially higher among young drivers than older, experienced drivers, and that engaging in KRD is prospectively associated with increased crash risk among teen drivers (Simons-Morton et al., 2012b, 2015). Klauer et al. (2009) showed that high KRD rates were strongly correlated with high crash and near-crash (CNC) rates among high mileage drivers. Similar findings were obtained in an instrumented vehicle study conducted with teenage drivers, showing significant positive association between monthly KRD and the CNC rates of the following month (Simons-Morton et al., 2013). The association between KRD and CNC rates make the former an important measure of driving behavior and represent an intervention target to reduce teen crash events (Carney et al., 2010).

Teenagers' kinematic risky driving behavior has been linked to multiple factors relating to either the driver or the driving environment (Simons-Morton et al., 2005; Falk et al., 2014), but research has identified only few consistent predictors. Although sensation-seeking temperament, risk-taking propensity, susceptibility to peer influence, and perception of risky driving (Prato et al., 2010; Simons-Morton et al., 2011a; Taubman-Ben-Ati et al., 2015; Mirman et al., 2012) have been theoretically linked to risky driving, prior studies have reported inconsistent associations. Parenting behaviors, such as monitoring and involvement in teenagers' pre- and post-licensure, have also been inconsistently associated with safer driving behavior (Mirman et al., 2012; Prato et al., 2010; Simons-Morton and Ouimet, 2006). Taubman-Ben-Ari et al. (2015) reported a positive association between higher risky driving reported by parents and their male teenage drivers. Similarly, perceived social norms favoring risky driving have been associated with teenagers' own risky driving (Simons-Morton et al., 2011a; Taubman-Ben-Ati et al., 2015; Shope, 2006). Simons-Morton et al. (2011a) reported that the perceived risky behavior of a teenage driver's closest friends was also a significant predictor of the teenage driver's own KRD rate. In a driving simulator study that assessed the effect of social norms on teenage driving, Simons-Morton and colleagues found greater risky driving among male teenagers driving with a risk-accepting peer versus teenagers driving with a risk-adverse peer (Simons-Morton et al., 2014).

Factors associated with the driving environment, such as weather conditions, passenger presence, and time-of-day may also contribute to teenagers' risky driving behavior. Driving with a teenage passenger is considered to be a factor uniquely associated with teen crash risk (Williams et al., 2007; Ouimet, et al., 2015; Tefft et al., 2012). Presumably, teenage passengers increase crash risk through social influence, either pressure to increase risk or social norms that favor more risky driving (Ouimet et al., 2015). In their review of driving restrictions at the provisional license stage, Lin and Fearn (2003) suggested that driving with a teen passenger significantly increased the likelihood of involvement in fatal crashes, and that the risk increased with the number of teenage passengers. In a recent systematic review, Ouimet et al. (2015) concluded that passenger presence increased the overall fatal crash risk of teenagers compared to driving alone. However, the relationship between teenage passenger presence and non-fatal crash outcomes could not be confirmed. Hence, the complex influence of teenage passenger presence on teenage driving behavior is still not fully understood. Finally, driving at night has also been found to be associated with significantly higher fatal crash risk compared to driving during the day among young drivers (Rajaratnam et al., 2015; Shope and Bingham, 2008; Williams, 2003). However, Simons-Morton et al. (2011a) found that KRD behavior among novice drivers was significantly lower at night than during the day.

Vehicle ownership may be a particularly important factor contributing to teenagers risky driving behavior and elevated crash risk. There is a growing body of research indicating that vehicle ownership is associated with teen driving exposure, risky driving behavior, and crash risk (Scott-Parker et al., 2015; Williams et al., 2006). Gershon et al. (2017) showed that teens with primary vehicle access had both higher miles driven, and greater number of trips compare to teens with shared vehicle access. García-España et al. (2009) reported that crash risk of teenagers driving their own vehicle was more than double than the crash risk of teenagers who had shared vehicle access. Gershon et al. (2017) found that teenagers with primary vehicle access were more likely to drive with teenage passengers, while teenagers with a shared access were more likely to drive with an adult in the vehicle. The combination of driving their own vehicle with teenage passenger may place teenage drivers at highly elevated crash risk.

The current study assesses naturalistic driving data to identify predictors for KRD and evaluate the variability in their associations according to the driving contexts. We focused on the interactions between vehicle ownership, passenger presence, day/night driving, and wet/dry road conditions and their associations with KRD rates.

2. Method

2.1. Participants

A total of 81 newly licensed teenaged drivers (53% females) participated in the study, average age 16.48 years old ($SD = 0.33$). Participants were recruited from a region of southwest Virginia, USA soon after obtaining a learner's permit and were followed for up to 12 months after earning a provisional driver's license. All participants had normal or corrected-to-normal vision, access to a reliable vehicle with a liability insurance, and had to be residing within a one-hour drive of the research center. Identical twins and teens

diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) were excluded from the study. No other selection criteria were applied. All procedures followed an approved institutional protocol. Parental consent and teen assent were obtained.

2.2. Vehicle instrumentation

Participants' private vehicles were equipped with Data Acquisition System (DAS), which was developed at the Virginia Tech Transportation Institute (Dingus et al., 2006). The DAS included: (i) a computer to record vehicle kinematic data such as vehicle speed, and three-dimensional acceleration, (ii) Global Positioning System (GPS) to assess location and distance driven and (iii) video cameras to monitor the driver's face, hands, body positioning, and the dashboard. An additional camera was used to capture a snapshot of the vehicle interior once every 10 min. The images were used to assess vehicle occupancy. Data collection and coding were conducted on the trip level and followed a rigid, systematic protocol. Data were collected from 2011 to 2014.

2.3. Measures

2.3.1. Kinematic risky driving (KRD) measure—G-force events were classified as KRD based on the following thresholds: (i) longitudinal acceleration (> 0.30 g), (ii) longitudinal deceleration (< -0.45 g), (iii) lateral negative (left) turn (< -0.50 g), (iv) lateral positive (right) turn (> 0.50 g), and (v) yaw ($\pm 6^\circ$ per second). The thresholds used to determine the events were based on previous studies (Simons-Morton et al., 2011b, 2012a). Rates were calculated as events per one thousand miles.

2.3.2. Demographic and environmental measures—In addition to gender and vehicle ownership, the following factors were documented for each driver in each trip: wet/dry road conditions, day/night driving, and passenger presence. The coding process of these factors was done by experienced coders who reviewed every video clip of each recorded trip. Coders identified the driver, passenger presence, number of passengers, and passenger attributes, such as gender and age. Day/night was determined by the recorded times of sunrise and sunset of the day the trip occurred.

2.3.3. Self-reported measures—A battery of questionnaires was administered at licensure, 6- and 12-months after licensure. This study considered only data collected at licensure, focusing on the following variables: driver's risk perception (e.g., "How much risk for crash or injury do you think newly licensed teens have if they drive late at night on the weekend?", scale ranging from 1-lowest risk to 5-highest risk); sensation-seeking behavior (e.g., "I like to do frightening things," scale ranging from 1-strongly disagree to 5-strongly agree); friends' risky driving, a sub-scale of Akers measure (e.g., "My friends think it is cool for us to drive all over the place at night on the weekend looking for parties?", scale ranging from 1-strongly disagree to 5-strongly agree); friends' substance use (e.g., "How many of your friends would you estimate use marijuana?", scale ranging from 1-none to 5-all); perceived parental trust (e.g., "How much do your parents trust that you will not hang out with bad people?", scale ranging from 1-not at all to 4-a lot); parental restrictions on driving (e.g., "How likely is it that your parents would restrict your driving privileges if you got pulled over by the police or got a ticket?" scale ranging from 1-not at all likely to 7-

extremely likely); parental monitoring knowledge (e.g., “How often do your parents know where you go and what you do after school?” scale ranging from 1-always to 5-never); and parental limits on driving (e.g., “Do you have a limit on how late you are allowed to drive on the weekend when driving with no adults present?” scale ranging from 1-never to 10-very frequently).

The average score of each measure was dichotomized according to the median split, accounting for differences in scale and response distributions. The list of psychosocial measures, their properties, and the source of the instrument are shown in Table 1. For all psychosocial measures used, Cronbach’s alpha values were .0.7.

2.4. Analysis

The analyses and modeling process consisted of three phases that identified the factors associated with teenagers KRD rates and examined the interdependencies between significant factors (Hosmer et al., 1999; Simons-Morton et al., 2011a).

The first phase included bivariate analysis where Poisson regression models were fitted to evaluate the relationship between KRD rates for each of the following factors: driver’s gender, vehicle ownership, day/night driving, wet/dry road conditions, passenger presence, risk perception, sensation seeking, perceived parental trust, parental monitoring knowledge, parental driving limits, parental restrictions, friends’ substance use, and friends’ risky driving behavior. As some of these variables are inherently dichotomous (e.g., daytime vs nighttime, own vs shared vehicle, wet vs dry roads, with vs without passenger), we dichotomized all other variables according to their median split to simplify the statistical model and the interpretation of the interactions. Bivariate quasi-likelihood Poisson regression models were used to estimate KRD incident rates (IRs) per 1000 miles driven for each factor. In cases where the factor had more than one measurement for each participant (e.g., day/night, wet/dry, with/without passenger), participant-specific random-effect captured the within-participant variability. To account for the variability in driving exposure, the logarithm of miles driven per participant at each condition (e.g. at wet, night, and when passenger presence) was added to the models as an offset. Incident Rate Ratios (IRRs) were used as the measure of association. An IRR with confidence intervals that do not overlap 1.0 indicates significant difference in IRs for each dichotomy. An IRR of 1.5 would indicate a 50% higher incidence rate, while an IR of 0.5 would indicate a 50% lower incidence rate.

The second phase included multivariate analysis of the factors with p-values .05 in the previous phase. We constructed an initial multivariate Poisson regression model with subject random effect that uni-fied all of the significant factors (Akaike Information Criterion (AIC) = 11,796.53). We applied backward model selection that led to a model which included all significant factors (AIC = 11,791.72). Lastly, to evaluate the contextual effect of vehicle ownership on KRD rates, we added the two-way interactions with vehicle ownership to the model (AIC = 11,685.48). The logarithm of miles driven by each participant was added to the models as an offset. Bonferroni adjustment was used when testing the different contrasts for each interaction.

3. Results

The total miles driven by all participants was approximately 380,000 miles. On average, participants drove 4636 miles ($SD = 3244$; range = 5.2–14,895) during data collection period (i.e., 12 months for most participants). A total of 10,883 KRD events were documented, and the mean number of KRD per participant was 134 events ($SD = 182.3$; range = 0–973).

3.1. Bivariate analysis

Bivariate models assessed the relationship between KRD rates and each of the factors (e.g., IR for male vs IR for female). Table 2 summarizes IRs and IRRs for KRD and the corresponding confidence intervals (CIs) of all of the evaluated factors. The bivariate analyses yielded multiple significant main effects. Teenage male drivers ($IR = 34.53$ KRD events/1000 miles) had 43% higher KRD rates compared to female drivers ($IR = 24.09$ KRD events/1000 miles). KRD rates were higher for driving own vehicle, day driving, and driving on dry roads compared to driving a shared vehicle, at night, or driving on wet roads (44%, 41% and 14% respectively). By contrast, driving with a passenger, high perceived parental trust, high parental knowledge, high driving limitations, and high-risk perception were all significantly associated with lower KRD rates (see Table 2). Sensation seeking, parental restrictions, friends' substance use, and friends' risky driving behavior were dropped from further analysis as they did not meet the criteria of association with $p < .05$.

3.2. Multivariate analysis

Shown in the right-most columns in Table 2 is the multivariate Poisson regression main effect model for the variables with p -values $< .05$. The results indicated that KRD rates were significantly higher for own vs shared vehicle, driving on dry vs wet road conditions, and day vs night driving. KRD rates were also lower when driving with a passenger compared to driving alone and with higher vs lower perceived parental trust.

We next fit a single multivariate Poisson regression model that included all significant factors and two-way interactions with vehicle ownership. The significant interactions illustrated in Fig. 1, indicate higher KRD rates among those with own vs shared vehicle driving during the day or with passengers (adjusted $p < .0001$ and adjusted $p < .0001$ respectively). Contrast analyses showed that teenagers driving with a passenger in their own vehicle had 88% higher KRD rates compared to teenagers driving with a passenger in a shared car (adjusted $p < .014$, see Fig. 1a). During the day, KRD rates were 74% higher for teens driving their own vehicle compared to teens driving a shared vehicle (adjusted $p < .03$, see Fig. 1b).

4. Discussion

High KRD rates among novice teenage drivers motivate the efforts to better understand the factors associated with these endangering behaviors. The current study used quantitative models to identify factors that were associated with teenagers' KRD behavior and evaluated how their association vary under different conditions. We analyzed data from a comprehensive naturalistic driving study with a reasonably large sample of teens for a period of one year starting at licensure.

The results suggest that driving under relatively favorable conditions, such as driving during the day and on dry roads, was associated with increased KRD rates among teen drivers. These findings are consistent with those reported in previous studies (Klauer et al., 2011; Simons-Morton et al., 2011a, 2015; Hartos et al., 2002; Simons-Morton et al., 2003; Simons-Morton and Ouimet, 2006; and Taubman-Ben-Ati et al., 2015). Having primary vehicle access was also associated with increased KRD rates compared to driving a shared vehicle. Curiously, other psychosocial factors, including sensation seeking, risk perception, parental restrictions, parental monitoring knowledge, parent's limitations, friends' substance use, friends' risky behavior, and self-reported risky driving were not significant in the multivariate analyses. Although there is a substantial body of research supporting the association of these factors with teens' risky driving behavior (Prato et al., 2010; Shope, 2006; Simons-Morton et al., 2011a, b; Simons-Morton et al., 2015), in the current study when employing multivariate methods, the associations with KRD were relatively weak and not independent. One possible explanation is that such measures are highly susceptible to individual differences and, as such, larger sample size may be needed to detect these associations.

The growing body of research on vehicle ownership, its association with teenage driver crash risk (García-España et al., 2009; Gershon et al., 2017), and its potential for modification, motivated our interest in the variability in the KRD rates, among teenagers with greater vehicle access, under certain driving conditions. Our analyses revealed significant multivariate interactions between vehicle ownership and passenger presence, and between vehicle ownership and day/night driving, indicating that teenager risky driving behavior was contextual. While by itself, the presence of a passenger was associated with lower KRD rates, when combined with vehicle ownership, teenagers driving with a passenger in their own vehicle had higher KRD rates compared to teenagers driving a shared vehicle. Possible explanations for these findings are that vehicle ownership itself, may foster greater independence of teenagers from their parents and that those with exclusive access to a vehicle may not only engage in more risky driving, but also are more likely to drive with risk-accepting teenage passengers (Simons-Morton et al., 2005; Gershon et al., 2017). Further research should examine possible mechanisms (e.g., exposure, selection, parental management practices, and driver dispositions) through which vehicle ownership may be associated with increased risky driving propensity among teenagers.

The current findings show that teenagers risky driving behavior should be studied within a broad prospective that examines multiple factors and their interactions. As most of the existing literature focused on the assessment of a single factor or a scarce number of factors and their influence on KRD, the current study advances the understanding of teenagers' risky behavior by blending multiple aspects of the teenage driver and the driving environment. Our findings indicate that risky driving is contextual, depending on driving conditions such as vehicle ownership, day/night driving, and passenger presence. Larger studies are needed to determine how psychosocial factors may moderate these complex relationships.

Our findings suggest that multi-level and coordinated interventions may be necessary to reduce risky driving among novice teenage drivers. There are three possible approaches for

intervention, including (1) those that address individual driver risk factors; (2) those that target parents; and (3) those that address graduated driver licensing (GDL) policy, each of which can address exposure to driving conditions. Young driver and parent interventions could augment GDL by focusing on conditions that are associated with risky driving, possibly discouraging passenger presence, at least under certain driving conditions and delaying vehicle ownership or minimizing exclusive vehicle access.

Finally, although this study is based on an extensive naturalistic data set documenting teens' driving for 12 months or more, there are some limitations to its use. The sample of teenage drivers is derived from a specific region; as such, socioeconomic and cultural factors might limit the generalizability of these findings to teenage drivers nationally. Future research may benefit from including additional factors such as traffic density, speeding, or additional socioeconomic measures.

Acknowledgment

This research was supported by the Intramural Program of the Eunice Kennedy Shriver National Institute of Child Health and Human Development, contract # N01-HD-5-3405.

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Fig. 1. Kinematic Risky Driving (KRD) Incident Rates (IRs) per1000 miles as function of (a) vehicle ownership and day/night and (b) vehicle ownership and passenger presence.

Table 1

Mean, SD, median and Cronbach alpha for the psychosocial measures.

Measure	Number of items	Range	Mean (SD)	Median	Cronbach's alpha	Source
Driving risk perception	14	1–5	3.36(0.68)	3.36	0.85	Simons-Morton et al. (2012b)
Sensation seeking	8	1–5	2.90(1.18)	3.00	0.73	Simons-Morton et al. (2013)
Parental trust	6	1–4	3.58(0.43)	3.67	0.83	Simons-Morton et al. (2013)
Parental monitoring knowledge	8	1–5	3.97(0.60)	4.00	0.80	Simons-Morton et al. (2013)
Parental driving limits	13	1–10	4.83(5.45)	4.92	0.88	Simons-Morton et al. (2003)
Parental restrictions	13	1–7	5.39(2.24)	5.54	0.90	Simons-Morton et al. (2003)
Friends' substance use	4	1–5	1.91(0.85)	2.00	0.84	Simons-Morton et al. (2012b)
Friends' risky driving	10	1–5	1.98(0.54)	1.90	0.83	Akers et al. (1979)

Incident Rates (IRs) and Incident Rate Ratios (IRRs) of Kinematic Risky Driving (KRD) and the corresponding confidence intervals (CIs) for all factors.

Table 2

Factor	Bivariate Analysis	p-value	Multivariate Analysis	p-value ^a
Gender				
Males, IR	34.53 (31.20–38.22)			
Females, IR	24.09 (21.49–27.00)			
IRR	1.43 (1.23–1.67)	<.0001		
Vehicle ownership				
Owned, IR	36.23 (32.61–40.26)		22.43 (14.92–33.74)	
Shared, IR	25.20 (23.00–27.61)		13.62 (10.44–17.76)	
IRR	1.44 (1.25–1.65)	<.0001	1.60 (1.02–2.66)	0.04
Day/Night driving				
Day, IR	19.44 (15.46–24.43)		20.73 (16.21–26.52)	
Night, IR	13.78 (10.93–17.37)		14.73 (11.48–18.90)	
IRR	1.41 (1.35–1.48)	<.0001	1.41 (1.34–1.48)	<.0001
Dry/Wet road conditions				
Dry, IR	18.32 (14.58–23.01)		18.75 (14.67–23.97)	
Wet, IR	16.08 (12.72–20.33)		16.29 (12.66–20.95)	
IRR	1.14 (1.07–1.21)	<.0001	1.15 (1.08–1.23)	<.0001
Passenger presence				
With passenger, IR	15.62 (12.40–19.68)		15.43 (12.04–19.77)	
Without passenger, IR	20.11 (15.97–25.32)		19.80 (15.46–25.35)	
IRR	0.78 (0.75–0.81)	<.0001	0.78 (0.75–0.81)	<.0001
Risk perception				
High, IR	22.44 (20.26–24.85)			
Low, IR	37.34 (34.14–40.84)			
IRR	0.60 (0.52–0.69)	<.0001		
Sensation seeking				
High, IR	30.36 (27.66–33.31)			
Low, IR	26.94 (23.89–30.38)			
IRR	1.13 (0.97–1.31)	0.123		

Factor	Bivariate Analysis	p-value	Multivariate Analysis	p-value ^a
Parental trust				
High, IR	23.89 (21.53–26.50)		13.34 (9.91–17.96)	
Low, IR	37.90 (33.99–42.26)		22.90 (15.89–33.01)	
IRR	0.63 (0.54–0.73)	<.0001	0.58 (0.37–0.91)	0.018
Parental monitoring				
High, IR	26.34 (23.92–29.00)			
Low, IR	33.76 (30.11–37.86)			
IRR	0.78 (0.67–0.91)	<.0001		
Parental driving limits				
High, IR	22.25 (19.77–25.03)			
Low, IR	34.70 (31.81–37.85)			
IRR	0.64 (0.55–0.74)	<.0001		
Parental restrictions				
High, IR	28.68 (25.99–31.65)			
Low, IR	29.34 (26.37–32.65)			
IRR	0.98 (0.85–1.13)	0.757		
Friends' substance use				
High, IR	28.87 (26.23–31.78)			
Low, IR	29.13 (26.09–32.52)			
IRR	0.99 (0.86–1.15)	0.906		
Friends' risky driving				
High, IR	29.84 (27.42–32.47)			
Low, IR	26.97 (23.54–30.90)			
IRR	1.11 (0.94–1.30)	0.216		

Note. IR = KRD incidence rate per 1000 miles; IRR = incidence rate ratio.

IR's differed significantly with p-value of < 0.05, (95% CI).

^a Adjusted for the other factors in the model.