



Driving distracted with friends: Effect of passengers and driver distraction on young drivers' behavior

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ABSTRACT

Both passengers and driver distraction can have negative effects on young driver behavior. However, it is not known how these two concepts interact to influence driver behavior. The objective of this study was to examine the effect of passenger presence and driver distraction on young drivers' behavior. Forty-eight participants aged 18–20 participated in a driving simulator study. Participants completed three distracting tasks (visual, cognitive, or combined) while navigating a highway scenario. Results indicated that passenger presence interacted with driver distraction to have an effect on elevated g-force events in curves. Separately, distraction affected driving performance differently according to whether the task was visual, cognitive or combined. Having a close friendship resulted in less speeding and male drivers tended to maintain a better lane position compared to females. The results have implications for licensing laws as well as intervention programs aimed at improving young driver behavior.

1. Introduction

Traffic related crashes are the leading causes of death and injury among drivers 15 to 20 years old (Webb, 2016). In 2016, the number of young drivers between the ages of 16 to 20 years old involved in fatal crashes increased by 3.6 percent from 2015. Additionally, other crash report analyses suggest that young, inexperienced drivers (age 19 and younger) were more likely to be involved in traffic crashes than drivers who were older and more experienced (Tefft, 2017).

1.1. Influence of peers as passengers on young drivers

Past research has established that passengers have an influence on young drivers' crash risk. According to the 2015 US crash report (National Highway Traffic Safety Administration, 2015), 59% of passengers who were riding with a teenage driver were also 15–20 years old. Previous crash database analyses have shown that the presence of teenage passengers (age 16–20 years) negatively impacts driver behavior (Aldridge et al., 1999), particularly fatal crash risk for drivers less than 24 years old (Ouimet et al., 2015). These findings have been confirmed by examining computerized driving behavior indicating that the mere presence of a peer (age 18–22 years) yields greater risk taking (Gardner and Steinberg, 2005). Young drivers are affected extensively (positively or negatively) by the presence of passengers in the vehicle,

and the magnitude of the impact depends on the characteristics of the passenger (C. Lee and Abdel-Aty, 2008).

Increased crash risk due to the influence of passengers can be observed via driving performance metrics: measures that serve as proxy for crash risk, including speeding, maneuvering the vehicle in a safe manner, braking in a safe manner, and maintaining lane position (Ferguson, 2013; Mahmud et al., 2017). Peers may encourage a teen driver to speed up and negotiate a dangerous pass (Allen and Brown, 2008; Brechwald and Prinstein, 2011; Chipman et al., 1998; Cialdini and Goldstein, 2004; Vollrath et al., 2002). Past research has found that when riding with teen passengers, particularly male drivers with male passengers, teen drivers have higher instances of speeding (> 15 mph above the posted speed limit) than the general population (Simons-Morton et al., 2005). Additionally, Simons-Morton et al (2005) observed that speeding teen drivers have a smaller headway distance when riding with a teen passenger. In addition to high variability in speeding, hard braking is also a consequence of risky driving. Young drivers with passengers have higher braking events as compared to when they are driving alone (Simons-Morton et al., 2009). Follow up studies categorized hard-braking events in terms of elevated gravitational-force (g-force) events (Simons-Morton et al., 2012). The research found that when teen drivers misjudged the driving situation, they were forced to engage in hard braking as a potential evasive maneuver, which is likely to increase crash risk. While there is small effect of

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passengers on young drivers in terms of lane position of the vehicle, factors like distraction and inability to maintain attention have a higher impact on standard deviation of lane position (Caird et al., 2018). Overall, passengers may influence risky driving and therefore evaluating young drivers based on vehicle measures can help understand their risky driving behavior.

While there is sufficient evidence concerning the negative impact of teen passengers on driving, data from the 100-Car Naturalistic Driving Study have shown that crash risk is the same for anyone over the age of 18, regardless of passenger presence, and that passengers may even provide a positive effect (i.e., reduce crash likelihood; Klauer et al., 2006). Additionally, a study that analyzed a crash database found that driving with peer passengers (age 18 to 24 years) during the weekend provided a positive effect on young drivers (I. Engström et al., 2008). Furthermore, one simulator study stated that the presence of peer passengers can have mixed effects: when driving with a peer passenger, the percentage of total driven distance above the posted speed limit was greater while there was also decreased amber-light running and better hazard handling (Ross et al., 2016).

The effect of passengers on young drivers' behavior also changes depending on the gender of the driver and passenger, according to past reviews (Carli, 2001). These findings could be explained by a study where female drivers ($M = 19$ years) had more crashes than male drivers when encouraged by risky passengers. Additionally, having a female passenger that encouraged risky driving resulted in more crashes than having a male passenger that encourages risky behavior (Shepherd et al., 2011). In contrast, a review of crash reports combined with a national survey indicated that male drivers (16–20 years old) with young male passengers had the highest crash risk (Ouimet et al., 2010). Furthermore, the observational study by Simons-Morton et al (2005) found that male teenagers drove slightly faster than female teenagers, and they drove much faster in the presence of a male teenage passenger.

In summary, past research has shown that young drivers' behavior in the presence of passengers is a complex phenomenon that is influenced by multiple factors, including passenger gender, and the relationship between the driver and passenger. In the next section, we explore the impact of distraction on driving behavior and look into the gaps in the existing research.

1.2. The impact of distraction on young drivers

In 2017, 8.5% of all fatalities were caused by distraction or inattention (National Highway Traffic Safety Administration, 2018). An observational study has shown that in general, secondary tasks, which can be considered distractions, are a major cause of motor vehicle crashes, both among teenagers who are novice drivers and among adults who are experienced drivers (Siebe, 2014). A recent naturalistic study confirmed the high involvement of young drivers (16–20 years) in distraction-related crashes and near-crashes, with at least two times the involvement relative to older drivers. Additionally, these young drivers were more adversely impacted by secondary-task engagement than middle-aged drivers (Guo et al., 2017).

Teenage drivers (16–18 years) have been shown to be more easily distracted from the driving task than adult drivers (25–66 years), according to a simulator study (Greenberg et al., 2003). It is believed that the potential for a non-driving task to distract the driver is determined by the complex interaction of multiple factors such as task complexity, current driving demands, driver experience, and skill (Young and Regan, 2007). However, young drivers (16–18 years) have poor judgment in following distance and vehicle control skills (Greenberg et al., 2003) and it requires an extended period of time for them to achieve competence in those skills (Shope and Bingham, 2008). Combined with young drivers' intentional risk taking and susceptibility to peer influence (Buckley et al., 2014; J. D. Lee, 2007; Senserrick, 2006), young drivers can be more vulnerable to distractions.

The impact of distractions is usually underestimated, and hence fails

to garner enough attention from drivers. In fact, according to the 100-Car Naturalistic Driving Study (Klauer et al., 2006), estimates of distraction-related crashes range from 15 to 40% on the basis of crash descriptions, but by observing behavior directly, the estimate is even higher. Recent meta-analyses on the effects of driver distraction have indicated how secondary tasks could negatively impact driving behavior across a variety of measures such as response time, eyes-on-road time, and crashes (Caird et al., 2014, 2018).

Driver distraction can be categorized into three types: visual, cognitive, and manual. Generally speaking, visually distracting tasks result in eyes-off-the-road as these tasks necessarily induce a diversion of the gaze towards the competing activity (Bruyas, 2013). Visual distractions diminish drivers' ability to detect hazards and cause degradations in lane keeping, though drivers can perceive the outline of the roadway, according to a driving simulation study (Horrey and Wickens, 2004). This kind of distracting task has been proven to lead to more erratic steering wheel maneuvers (Caird et al., 2014; Liang and Lee, 2010) and reduced speed (J. Engström et al., 2005). Cognitive distractions, on the other hand, take the drivers' mind off the driving task. Cognitive distractions could lead drivers to concentrate their gaze on the center of the road (Bruyas, 2013) while also spending less time looking at mirrors, instruments, and checking the periphery for hazards (Schaap et al., 2013). As a specific example, some researchers have shown that cognitive workload imposed by casual conversation can hinder change detection for both younger drivers (mean age = 21.4 years) and older drivers (mean age = 68.4 years), and affect the availability of attention (Caird et al., 2018; McCarley et al., 2004). Cognitive distractions can also lead to less smooth steering wheel movement (Liang and Lee, 2010), hard braking events (Harbluk et al., 2007) or improved lane maintenance (Liang and Lee, 2010). Lastly, manual distractions cause hands or feet-off-the-road (e.g., drivers take their hands off of the steering wheel or their feet off of the pedals). Manual distractions are usually discussed in combination with visual or cognitive distractions and hence, the effects of manual distractions on driving performance are often intermingled with visual and cognitive distraction.

Young drivers (18–25 years) are significantly more likely to report different kinds of distracting activities during the most recent driving trip including mobile phone and CD player use, eating, and drinking (Young and Lenn, 2010). To be more specific, some studies have found that over 90% of young drivers ($M = 19$ years) read texts or talk on their cell phone while driving (Atchley et al., 2011; Nelson et al., 2009) while one experimental study has shown that both younger ($M = 20$ years) and older ($M = 70$ years) drivers' performance is significantly impaired when conversing on a cell phone (Strayer and Drew, 2004). Additionally, for young novice drivers (18–21 years), the amount of time spent not looking at the road when text messaging was up to 400% greater than that recorded in baseline (no-text-messaging) conditions (Hosking et al., 2009).

Furthermore, it should be noted that the presence of peer passengers can lead to nontechnological distractions (Caird and Horrey, 2017) or even more distracting in-vehicle interactions. For example, researchers found that compared to baseline driving, passenger conversation resulted in slower detection and a decline in the percentage of targets detected for drivers of all ages (14–84 years) (Caird et al., 2018). Given the findings above, it can be easily seen that distractions and distraction-related activities are common among drivers and their effects on young drivers' performance are typically negative.

1.3. Gap in research and the present study

According to past research, the association between the presence of passengers and young drivers' behavior is mixed: the presence of peer passengers can provide a positive effect in some cases and a negative effect in other cases. In addition to the complexities introduced by driving with a passenger, driver distraction is a common activity amongst this age group. However, the only studies that have combined

passenger presence and driver distraction merely compared how conversing with a passenger in the vehicle differed from having conversations on a cell phone (Caird et al., 2018; Charlton, 2009). No studies have examined how the presence of a passenger can intensify or diminish the negative effects of driver distraction on young drivers' behavior.

As such, the objective of this experiment was to examine the effect of passenger presence and driver distraction on young drivers' behavior. The hypotheses were: (1) the presence of a passenger would degrade driving performance (Ouimet et al., 2015); (2) male drivers or being in the presence of male passengers would have poor driving performance (Ouimet et al., 2010; Williams, 2003); (3) distraction would degrade driving performance (Klauer et al., 2006), with the effect being worse under the presence of a passenger; and (4) visually demanding distracting tasks would degrade driving performance (Bruyas, 2013). In comparison to past work that was either observational, relied on incomplete data, or used confederate peers, this research employed actual friends to complete a set of predetermined distracting tasks in a controlled driving environment. The present study focused on drivers between the age of 18–20. As in comparison to 16–17 years old drivers, this age group is allowed to drive with peer passengers under most states' driver licensing laws and gives this study more practical implications.

2. Methods

2.1. Participants

A total of 48 people (i.e., 24 pairs of people), ages 18–20 ($M = 18.96$ years, $SD = 0.74$ years), were recruited for this study using flyers and email advertisements placed on the University of Massachusetts Amherst campus. There were 20 males and 28 females. Each participant had a valid U.S. driver's license ($M = 2.56$ years of licensure, $SD = 1.07$ years of licensure). All participants were asked to come to the experiment with a friend (i.e., in pairs). Participants were informed that the friend could be anyone they would like to bring to the experiment, such as a classmate or roommate.

2.2. Equipment

Participants drove an advanced, high-fidelity driving simulator with a full-sized vehicle cab (modified 2013 Ford Fusion) and standard controls (Fig. 1). The field of view was approximately 330 degrees. The side-view mirrors, virtual dash, and 17-inch touch screen center stack were simulated with LCD panels. An audio system external to the car cab provided environmental sounds such as traffic, passing vehicles, and road noise while the internal audio system provided engine sounds

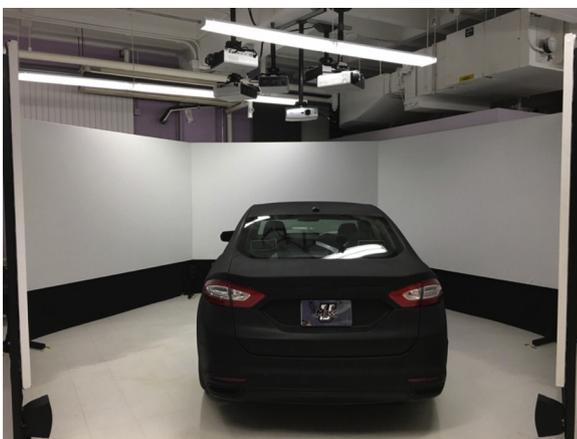


Fig. 1. Driving Simulator.

and vibrations, as well as pre-programmed voice commands. Vehicle data were continuously collected at a frequency of 96 Hz.

An ASL (Applied Science Lab) Mobile Eye XG head mounted eye tracker, which consists of a scene camera, eye camera, and a small reflective non-obtrusive monocle, was used to monitor and record eye movements at 33 Hz. Data from the eye tracker were not analyzed in this study.

2.3. Highway scenario

To ensure minimal distraction from roadway conditions (e.g., pedestrians or traffic lights), the driving environment was a highway scenario. The scenario was developed in accordance with the road conditions of I-93 in Massachusetts and included three lanes in each direction along with four curves. Participants were instructed to drive as they normally would, observe the speed limit while driving, which was 65 mph, and remain in the middle or rightmost lane. Participants drove through the same highway scenario four times, which is described further in Section 2.5.

2.4. Distracting tasks

There were three types of distraction tasks: visual, cognitive, and combined visual and cognitive, in addition to a period of no distraction. All four tasks, which included the no distraction task, were presented in each of the four drives and were counterbalanced to prevent any bias due to task ordering. Participants had to complete the distracting tasks while a situation presented itself that required drivers to either brake or change lanes (Fig. 2). This situation accompanied each of the distracting tasks and happened in each drive.

For the visual task, participants were asked to dial a phone number that was shown on the center screen of the simulator using their personal cell phone (Angell et al., 2006). There were two versions of the cognitive task: when participants were driving alone (with no passenger) and when participants drove with a passenger. When driving alone, the cognitive distraction task required participants to listen to flight information and answer two questions based on the information (Angell et al., 2006). When driving with a passenger, the cognitive task required both the driver and passenger to play a word or number "chain

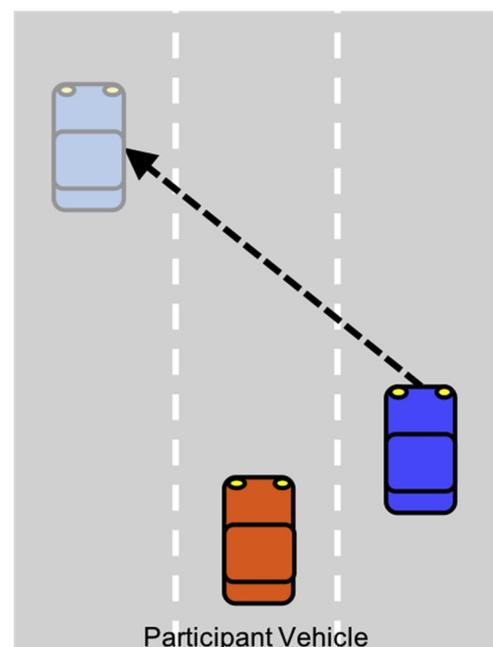


Fig. 2. Example driving situation where a vehicle cuts across the participant's lane of travel.

	1	2	3	4
A	↓	↗	↖	↑
B	↗	→	↘	↘
C	↑	↖	←	↓
D	↖	←	→	↖

Fig. 3. Matrix of arrows used in combined task.

task”, which was a combination of the n-back task (Reimer et al., 2014) and a competitive verbal task (Crundall et al., 2005). In the word chain task, one participant said a word. The next participant then said the first word and added their own word. This task continued, thereby forming a chain of words, for 45 s. The number chain task was similar to the word chain task, except participants were required to say two-digit numbers. For the combined visual and cognitive task, participants were first shown a table comprised of several arrows on the center screen of the simulator and were then asked two follow-up questions regarding the direction of those arrows (J. Engström et al., 2005), as shown in Fig. 3.

2.5. Procedure and experimental design

Upon arrival, participants gave consent and completed a simulator sickness questionnaire as well as the friendship questionnaire assessing stimulating companionship, which refers to doing things together that arouse enjoyment, amusement, and excitement (Mendelson and Aboud, 1999). Then, the researchers explained the distraction tasks (visual, cognitive and combined) to the participants and asked them to behave normally during the experiment and to complete the tasks themselves (i.e., by the driver). Next, the eye tracker was configured for each participant and they drove a test drive that was approximately 3 min, in turn. Immediately after the test drive, participants were asked to fill out a simulator sickness questionnaire (Kennedy et al., 1993). Afterwards, there were a total of four experimental drives: individual A driving alone, individual A driving with individual B as a passenger, individual B driving alone, and individual B driving with individual A as passenger. The order of the four drives was counterbalanced to prevent any bias due to ordering. Each drive had the same highway scenario. In cases when one participant did not need to be in the vehicle, the participant watched an irrelevant video and wore headphones in an area that was separated from the driving simulator.

After each drive, the driver and passenger were required to complete the latter portion of the simulator sickness questionnaire. When all the drives were complete, participants were told to fill out the remaining questionnaires: a post experiment questionnaire, driver behavior questionnaire (DBQ; Reimer et al., 2005) and sensation seeking questionnaire (Hoyle et al., 2002). Finally, after completing the payment voucher, participants received compensation. The entire experiment lasted approximately 90 min. Those who were not able to participate in the full experiment (i.e., one pair did not complete the experiment due to equipment issues) were paid partially according to the time they spent in the laboratory.

2.6. Independent and dependent variables

There were six independent variables: passenger status (with or without a passenger), driver distraction (i.e., no distraction, visual, cognitive, and combined), driver gender (male or female), stimulating companionship (on a numeric scale from zero to eight, Fig. 4), length of friendship (< 6 months, 6 months to 1 year, or > 1 year, Table 1), and type of friendship (friends, dating/engaged/married, live together, classmates, teammates, and multiple types of friendship, Table 1). Passenger status and driver distraction were within-subjects variables while all other variables were between-subjects variables.

Dependent measures included: driving performance (e.g.,

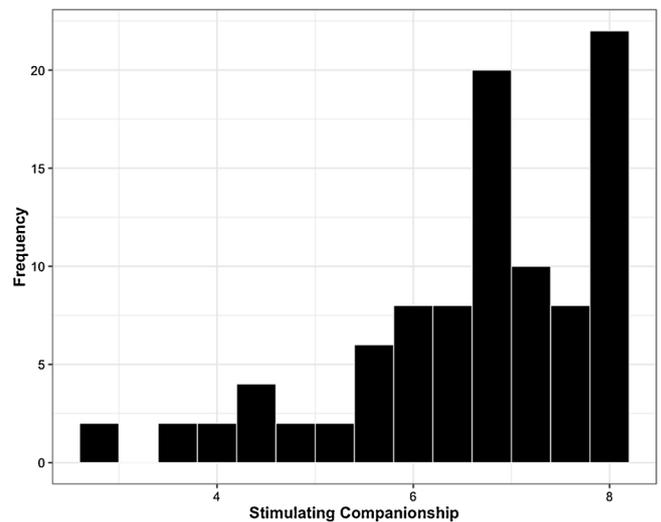


Fig. 4. Distribution of stimulating companionship scores.

Table 1

Distribution of responses for type of friendship and length of friendship.

Friendship Measures	Count
Type of Friendship ^a	
Just Friends	3
Classmates	10
Teammates	2
Live Together	18
Dating/Engaged/Married	8
More than One	7
Length of Friendship	
1-6 Months	17
6-12 Months	11
> 1 Year	20

^a Participants could choose more than one

proportion of time the driver was speeding and standard deviation of lane offset), eye movements (e.g., mean duration of glance and number of glances), and task performance (e.g., completion of the distraction task). This study builds on preliminary work (Zhang et al., 2018) and mainly focuses on the driving performance measures, which are proportion of time the driver was speeding (> 65 MPH, (Ouimet et al., 2013)), proportion of time the driver had elevated g-force events (longitudinal acceleration > 0.35 g or deceleration > 0.45 g, (Simons-Morton et al., 2012)), proportion of time the driver had elevated g-force events in curves (lateral acceleration > 0.05 g, (Simons-Morton et al., 2012)), proportion of extremely large steering wheel movements (steering wheel movement angle > 10 degrees, (Ting et al., 2008)), and standard deviation of lane offset (Caird et al., 2008). Eye tracking data along with participants’ task performance were not analyzed in this study, but can be found elsewhere (Mehrotra et al., 2018).

Raw driving performance data, specifically, velocity, lateral velocity, acceleration, lateral acceleration, lane offset, and steering wheel angle, were automatically collected by the driving simulator at a frequency of 96 HZ during each drive. Average driving performance metrics were calculated for the areas of the drive where participants completed the distracting tasks. Preliminary analysis indicated that lateral acceleration did not vary in the straight driving sections. As such, only the curved roadway sections were analyzed for lateral-acceleration-related elevated g-force events (elevated g-force events in curves) to allow for inferences as to how the participants managed curves, which are areas of increased crash risk (Torbic et al., 2004).

With six independent variables and five dependent variables, a power analysis is warranted. To ensure the power analysis was

tractable, equal sample sizes were assumed across all groups and only 2-way interactions were considered as higher order interactions were less interpretable. Following the ANOVA power analysis procedure as documented by Cohen (1988), using a large effect size (0.4) and a significance level 0.05, across all main and interaction effects, there was a minimum of 78% power.

2.7. Data analysis

After collecting and preprocessing the experimental data, the data were analyzed. Statistical test showed that violations from DBQ (participants' rating regarding violations in the driver behavior questionnaire) was significantly linearly associated with proportion of time the driver was speeding and standard deviation of lane offset. Given that all of our independent variables were categorical, besides stimulating companionship, DBQ violations was therefore incorporated as a covariate in the ANCOVA.

Each independent variable was sequentially entered into the analysis according to its importance and the order of the hypothesis: (1) passenger presence, (2) driver distraction, (3) driver gender, (4) friendship quality (e.g., stimulating companionship score, length of friendship, and type of friendship), and (5) covariates (i.e., violations from the DBQ). Additionally, for the drives with a passenger, the driver/passenger gender combination was also analyzed as an independent variable. The significance level for this study was 5%. Given the sequential entry of independent variables, the Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) were used to determine which model best fits the data. R (R Core Team, 2018) and the IDE program RStudio were used to aggregate and analyze the data.

One participant did not complete the entire demographic questionnaire. Because the missing data were random (i.e., the participant did not provide information for one entire page), multiple imputation using Bayesian linear regression and Gibbs sampling via the 'mice' package (Van Buuren and Groothuis-Oudshoorn, 2011) in R was used to replace the missing information.

3. Results

3.1. Overall results

Table 2 shows the means and standard deviations for each combination of driver distraction and passenger presence and for each of the five dependent variables. The presence of a passenger had a main effect on elevated g-force events in curves. Driver distraction was significant

in influencing driving behavior across multiple aspects. While type of friendship was not a significant factor, length of friendship and stimulating companionship did affect driving behavior, as described below and summarized in Table 3. Additionally, driver gender had effect on participants' driving behavior, but the driver/passenger gender combination did not have an effect on any driving behavior.

3.2. Proportion of time speeding

Stimulating companionship had an effect on the proportion of time the driver was speeding such that the driver sped less as the stimulating companionship score increased. This suggests that there is protective effect of having a friend who arouses enjoyment, amusement, and excitement.

3.3. Elevated g-force events proportion

Only length of friendship had an effect on the proportion of time having elevated g-force events. More specifically, compared to the mean proportion of such events for people who had a friendship of "1-6 months" and "6-12 months", people who possessed a friendship for more than a year had a significantly higher value.

3.4. Elevated g-force events in curves proportion

Several factors had an effect on the proportion of time the driver had elevated g-force events in curves, including passenger presence, driver distraction, length of friendship, the interaction between passenger presence and driver distraction, and the interaction between driver distraction and length of friendship.

With the presence of a passenger, the mean proportion of time having elevated g-force events in curves was significantly higher than when there was no passenger. As for driver distraction, results showed that compared to driving with cognitive distraction, driving with no distraction, visual distraction, and combined distraction led to significantly higher proportion of time having elevated g-force events in curves, respectively (e.g., combined distraction produced the highest proportion). The mean proportion of time the driver had elevated g-force events in curves was significantly lower for participants who had a "6-12 months" long friendship compared to those who possessed a friendship of "1-6 months". This indicates friendship quality, as measured by length of friendship, is positively associated with driver behavior.

Fig. 5 presents the interaction effect of driver distraction and

Table 2 Means and standard deviations for each passenger/distraction condition and dependent variable.

Condition	Driving Performance				
	Proportion of Time Speeding (%)	Elevated g-Force Events Proportion (%)	Elevated g-Force Events Proportion in Curves (%)	Extremely Large Steering Wheel Movement Proportion (%)	Standard Deviation of Lane Offset (m)
No Passenger	$\mu = 70.34$	$\mu = 0.35$	$\mu = 29.30$	$\mu = 8.95$	$\mu = 0.44$
No Distraction	$\sigma = 26.08$	$\sigma = 0.38$	$\sigma = 25.82$	$\sigma = 3.37$	$\sigma = 0.21$
No Passenger	$\mu = 66.44$	$\mu = 0.45$	$\mu = 14.51$	$\mu = 14.12$	$\mu = 0.34$
Visual Distraction	$\sigma = 33.11$	$\sigma = 1.49$	$\sigma = 31.16$	$\sigma = 16.41$	$\sigma = 0.26$
No Passenger	$\mu = 58.09$	$\mu = 0.33$	$\mu = 7.41$	$\mu = 16.90$	$\mu = 0.32$
Cognitive Distraction	$\sigma = 35.40$	$\sigma = 0.70$	$\sigma = 21.33$	$\sigma = 18.57$	$\sigma = 0.21$
No Passenger	$\mu = 64.91$	$\mu = 0.73$	$\mu = 37.46$	$\mu = 22.33$	$\mu = 0.47$
Combined Distraction	$\sigma = 33.48$	$\sigma = 2.33$	$\sigma = 47.97$	$\sigma = 17.91$	$\sigma = 0.36$
Passenger	$\mu = 76.08$	$\mu = 0.32$	$\mu = 37.12$	$\mu = 10.01$	$\mu = 0.43$
No Distraction	$\sigma = 20.73$	$\sigma = 0.57$	$\sigma = 20.56$	$\sigma = 3.08$	$\sigma = 0.21$
Passenger	$\mu = 66.36$	$\mu = 0.40$	$\mu = 48.77$	$\mu = 24.19$	$\mu = 0.43$
Visual Distraction	$\sigma = 33.66$	$\sigma = 1.78$	$\sigma = 45.86$	$\sigma = 16.96$	$\sigma = 0.31$
Passenger	$\mu = 67.87$	$\mu = 0.44$	$\mu = 7.47$	$\mu = 5.01$	$\mu = 0.40$
Cognitive Distraction	$\sigma = 32.29$	$\sigma = 0.96$	$\sigma = 18.12$	$\sigma = 11.97$	$\sigma = 0.39$
Passenger	$\mu = 61.94$	$\mu = 0.93$	$\mu = 45.53$	$\mu = 20.76$	$\mu = 0.48$
Combined Distraction	$\sigma = 39.96$	$\sigma = 2.41$	$\sigma = 46.53$	$\sigma = 17.27$	$\sigma = 0.35$

Table 3
Results of statistical tests for each of the five dependent variables.

Factor	Dependent Variable				
	Proportion of Time Speeding	Elevated g-Force Events Proportion	Elevated g-Force Events Proportion in Curves	Extremely Large Steering Wheel Movement Proportion	Standard Deviation of Lane Offset
Passenger Presence			$F(1,216) = 6.07, p < 0.05$		
Driver Distraction			$F(3,216) = 14.79, p < 0.001$	$F(3,358) = 14.38, p < 0.001$	$F(2,356) = 3.50, p < 0.05$
Driver Gender					
Stimulating Companionship					
Length of Friendship		$F(1,360) = 37.12, p < 0.001$			
Passenger Presence x Driver Distraction		$F(2,359) = 3.17, p < 0.05$			$F(2,356) = 11.26, p < 0.001$
Driver Distraction x Length of Friendship					
Friendship					
Driver Gender x Length of Friendship					$F(2,356) = 3.50, p < 0.05$

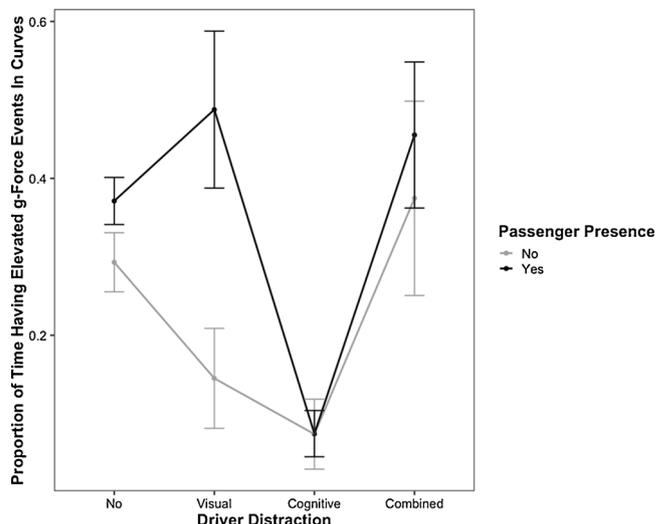


Fig. 5. Interaction effect of driver distraction and passenger presence on proportion of time having elevated g-force events in curves.

passenger presence on proportion of time having an elevated g-force events in curves. Post hoc analysis indicated that when driving without the presence of a passenger and with cognitive distraction, the mean value was significantly lower compared to driving with a passenger with all kinds of distracting status besides driving with cognitive distraction. In other words, with cognitive distraction, no significant difference was found in the mean proportion of time having elevated g-force events in curves between driving with and without a passenger. Although the analysis provided us with various interaction effects, many of them did not produce much practical meaning. However, we still found that, in general, driving with the presence of a passenger tended to result in a higher proportion of elevated g-force events in curves.

The interaction effect of driver distraction and length of friendship on the proportion of time having elevated g-force events in curves is shown in Fig. 6. Again, due to the complexity and interpretability, we only present partial results here. When participants had a friendship of “6-12 months”, the mean proportion of time such events occurred was lower than those who had a friendship of “1-6 months” for all types of distractions. In general, participants in these two groups appeared to follow a similar pattern in the mean proportion of time having elevated

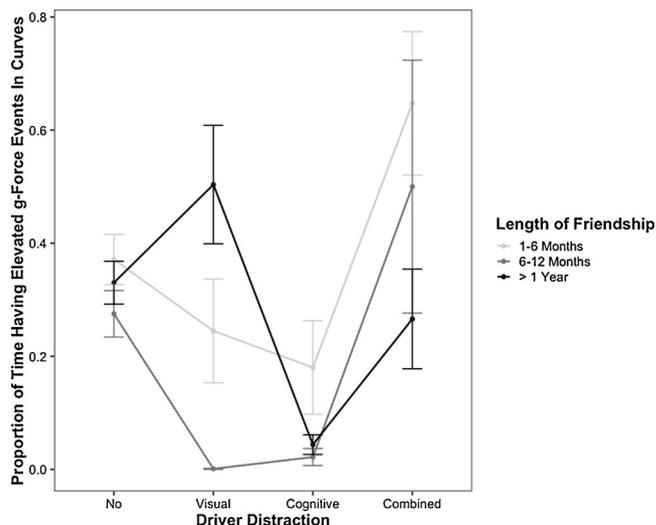


Fig. 6. Interaction effect of driver distraction and length of friendship on proportion of time having elevated g-force events in curves.

g-force events in curves when encountering different distraction tasks, as can be seen in Fig. 6. Participants with a “> 1 year” friendship, however, behaved differently according to the distraction tasks compared to people in the other two groups.

3.5. Extremely large steering wheel movement proportion

Only driver distraction had an effect on extremely large steering wheel movement proportion. Results showed that the mean proportion of time having extremely large steering wheel movement was significantly higher when the driver encountered visual distraction than no distraction. The value was also significantly higher when the driver was faced with combined distraction when compared to no distraction. This indicates that when young drivers are visually distracted, their steering wheel movement becomes less controlled.

3.6. Standard deviation of lane offset

Driver gender, length of friendship, and the interaction between them had a significant effect on standard deviation of lane offset. Specifically, male drivers had a significantly lower mean standard deviation of lane offset than female drivers. This suggests that young male drivers may actually have better control of their lane position than young females. Compared to people who had a friendship of “6-12 months”, those with “1-6 months” and “> 1 year” friendships had a significantly higher mean standard deviation of lane offset. This phenomenon indicates that the length of friendship is not simply positively or negatively associated with young drivers’ ability to maintain the lane position.

The interaction effect is presented in Fig. 7. Results showed that male drivers with friendships that were “1-6 months” or “> 1 year” had a significantly lower mean standard deviation of lane offset than females. However, female drivers with a friendship of “6-12 months” had a significantly lower mean standard deviation of lane offset than male drivers who had friendship of “6-12 months”.

4. Discussion

The objective of this study was to examine the effect of passenger presence and driver distraction on young drivers’ behavior. Forty-eight young drivers completed four types of distracting tasks while navigating a highway scenario in a driving simulator. For each driver, driving performance was measured using proportion of time speeding,

elevated g-force events, extremely large steering wheel movements, and standard deviation of lane position. These measures were used to evaluate the effect of passenger presence, driver distraction, and the interaction between them on driving performance.

With respect to the first hypothesis, the mere presence of a passenger only influenced elevated g-force events in curves. This is similar to the findings reported by Simons-Morton et al. (2011), who found higher number of elevated g-force events in the presence of passengers while negotiating sharp turns. While elevated g-force events in curves were reported to be significant, other vehicle measures were not significant (e.g., speeding). While conclusive reasons for differences between our results and past literature cannot be established, we suggest the following potential reasons for why these differences occurred. First, this study focused on driving behavior in a controlled environment with few confounding variables, which differs from studies that used crash reports to identify the effect of peer passengers (Aldridge et al., 1999; C. Lee and Abdel-Aty, 2008; Ouimet et al., 2015, 2010). Second, in comparison to studies in controlled environments (Gardner and Steinberg, 2005; Shepherd et al., 2011), this study used actual friends instead of confederate peers who were risk-seeking or risk-averse, and is therefore more consistent with realistic driving situations. Last, this study focused on young drivers between the ages of 18–20; it’s possible that the effect of passenger presence on driving behavior is strongest for younger age groups (e.g., 16 and 17-year old) and diminishes as they mature. While these could be potential reasons for the lack of significance, follow up studies under different experimental conditions may help confirm or contrast from these findings.

Relatedly, though passenger presence only influenced driving performance in curves, the quality of the relationship between the driver and passenger had an effect on more aspects of driving performance. Specifically, having a relationship that provides more enjoyment, amusement, and excitement has a protective effect with respect to speeding. This suggests that having a quality relationship results in better driving behavior. Past research on social support confirms this finding as teenagers with strong social support systems are less likely to engage in risky behavior (Abbott-Chapman et al., 2008). Social support concerns assistance and protection that allows one to achieve their goals (Langford et al., 1997). The prominence of social support could indicate that 18 to 20-year-old young drivers who have good driving habits (e.g., do not speed) are not persuaded or influenced, but rather supported by their friends. Conversely, young drivers in this age group may drive poorly with friends whom they have weaker relationships.

The effect of gender on driving behavior was subtle, contrary to the second hypothesis. The only difference between male and females’ drivers was seen with standard deviation of lane offset. This is in contrast to past research finding no effect of passenger gender (Aldridge et al., 1999) and other research indicating increased speed and crash risk in the presence of male passengers with male drivers (Ouimet et al., 2010). Potential reasons for the contrasting findings could be due to the age group (18–20 years old): research done by Williams (2003) found that although the age group of 16–19 was at high risk for traffic crashes, the risk was highest for drivers who were 16 and 17 years old.

Regarding the third and fourth hypothesis, distraction degraded driving performance across elevated g-force events in curves and extremely large steering wheel movement. Completing a distracting task with a visual or combined component resulted in more erratic steering wheel movements whereas completing a task with a cognitive component resulted in fewer elevated g-force events. This is in line with past research in which visually distracting tasks have been shown to cause more erratic steering wheel maneuvers (Caird et al., 2014; Liang and Lee, 2010) and that distracted driving tends to have an effect on g-force events (Harbluk et al., 2007). Last, driving performance was degraded further when a passenger was present, but not for the cognitively distracting tasks. More specifically, having a passenger resulted in a higher proportion of g-force events in the curves for visual and combined distraction as well as no distraction. This is a new finding that could

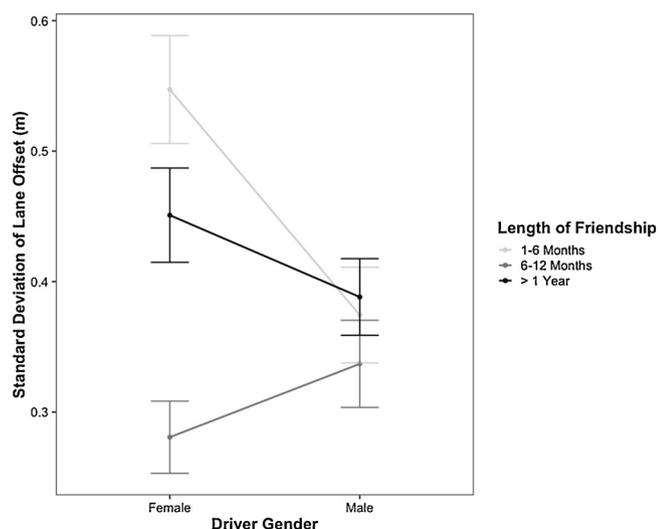


Fig. 7. Interaction effect of driver gender and length of friendship on standard deviation of lane offset.

support the notion that distraction and passenger presence are compounded together when influencing young drivers' behavior. It could also suggest that passengers encourage drivers to become distracted, but only in certain cases. However, further testing and data analysis is required to fully substantiate these notions.

4.1. Limitations and future work

Given that this is a driving simulator experiment, it is important to note that driver behavior shown here may not represent actual driving tendencies. Though participants in this study did seem to engage with their friends in a natural manner, the results must be treated in light of simulator validity. Future research could focus on ensuring that the experimental conditions duplicate the real-world situations. In addition, the focus of this study was driver behavior as determined by driving metrics. Future work shall disentangle eye glances, secondary task performance, and actual dialog between participants. Preliminary analysis of these measures indicate that many young drivers did not look at their cell phone in the visual task (i.e., they instinctively knew what buttons to press without looking) and that almost all of the secondary tasks were successfully completed. Last, given that many states licensing restrictions are placed on teenage drivers and peer passengers, the focus of present study was young drivers of 18–20 years old driving with only one passenger. Future work should consider younger drivers (i.e., 16 and 17-year old) as well as multiple passengers.

4.2. Conclusion

Past research has shown that both passengers and distracting tasks can have a negative impact on young driver behavior. Given that crashes are highly prevalent within this age group, it is important to study how the presence of passengers interacts with distracting tasks to change the young driving environment. Results from this study indicate that the mere presence of a passenger only has an effect on elevated g-force events. However, having a closer friend results in better driving performance. Similar to past studies, distraction did have an effect on driving performance, with the effect depending on the type of distraction. Additionally, distraction interacted with passenger presence and had an effect on driving performance in the curves. These results are intriguing and can shed light into the interaction between passengers and driver distraction. Furthermore, although interaction effects were indeed found significant in this study, no clear pattern or interpretation was concluded. This further verifies that driving itself, or young drivers' behavior, is complicated and influenced by multiple factors. The findings have implications for the effectiveness of licensing laws that restrict the type of passengers to reduce crash risk. They also shed insight into the effectiveness of intervention programs that rely on peer pressure or passengers to change behavior.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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