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Examining teen driver crashes and the prevalence of distraction: Recent trends, 2007–2015

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ABSTRACT

Introduction: Teen drivers crash at a much higher rate than adult drivers, with distractions found as a factor in nearly 6 out of 10 moderate-to-severe teen crashes. As the driving environment continues to rapidly evolve, it is important to examine the effect these changes may be having on our youngest and most vulnerable drivers. *Method:* The purpose of this study was to identify types of vehicle crashes teens are most frequently involved in, as well as the distracting activities being engaged in leading up to these crashes, with a focus on identifying changes or trends over time. We examined 2,229 naturalistic driving videos involving drivers ages 16–19. These videos captured crashes occurring between 2007 and 2015. The data of interest for this study included crash type, behaviors drivers engaged in leading up to the collision, total duration of time the driver's eyes were off the forward roadway, and duration of the longest glance away from forward. *Results:* Rear-end crashes increased significantly (annual % change = 3.23 [2.40–4.05]), corresponding with national data trends. Among cell phone related crashes, a significant shift occurred, from talking/listening to operating/looking (annual % change = 4.22 [1.15–7.29]). Among rear-end crashes, there was an increase in the time drivers' eyes were off the road ($\beta = 0.1527$, $P = 0.0004$) and durations of longest glances away ($\beta = 0.1020$, $P = 0.0014$). *Conclusions:* Findings suggest that shifts in the way cell phones are being used, from talking/listening to operating/looking, may be a cause of the increasing number of rear-end crashes for teen drivers. *Practical applications:* Understanding the role that cell phone use plays in teen driver crashes is extremely important. Knowing how and when teens are engaging in this behavior is the only way effective technologies can be developed for mitigating these crashes.

1. Introduction

The number one cause of teen deaths is driving or riding in a car. In 2014, 1,717 young drivers died in motor-vehicle crashes, with an additional estimated 170,000 injured (NHTSA, 2015a). Inexperience (Greenberg et al., 2003; McKnight & McKnight, 2003; Patten, Kircher, Östlund, Nilsson, & Svenson, 2006), overconfidence (Brown & Groeger, 1988; Finn & Bragg, 1986), social pressure (Allen & Brown, 2008; Farrow, 1987; Simons-Morton, Lerner, & Singer, 2005), a tendency to underestimate risk (Albert & Steinberg, 2011; Evans & Wasielewski, 1983; Horrey, Lesch, & Garabet, 2008), and engaging more often in risky behaviors (McEvoy, Stevenson, & Woodward, 2006; Sayer, Devonshire, & Flannagan, 2005) are just some of the factors influencing teen drivers.

Proportionally more than any other age group, teens involved in fatal crashes are reported to have been distracted at the time of the crash (NHTSA, 2016), with distractions found as a factor in nearly 6 out of 10 moderate-to-severe crashes (Beanland, Fitzharris, Young, & Lenné, 2013). In the context of driving, a distraction has been defined as the diversion of attention from activities critical for safe driving toward a competing activity (Regan, Hallett, & Gordon, 2011). Distractions vary widely, with the most prevalent behaviors including attending to passengers, cell phone use, and attending to something inside the vehicle (Carney, McGehee, Harland, Weiss, & Raby, 2015). Those identified as particularly dangerous for young drivers—peer passengers and technology, most notably cell phones—have been the focus of recent research.

For teens, in particular, the cell phone has become the primary mode of communication: in 2015, 92% of teens age 15–17 owned a cell phone, with 76% of those owning a smartphone (Lenhart et al., 2015). With the evolution of cell phones to smartphones, this technology has evolved from talking into texting and engagement in social media. In a 2015 survey, nearly 70% of drivers ages 16 to 18 reported they had talked on a cell phone, 42% had read a text or e-mail, and 32% had typed/texted while driving in the past 30 days (AAA, 2016).

However, determining what activities teens are engaging in before a crash occurs is not an easy task. Previous research has largely relied on survey and crash data to attempt to obtain this type of information.

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While surveys can inquire about drivers' attitudes toward and frequency of engaging in certain distracting activities, there are issues associated with the reliability and validity of these self-reported data. Additionally, though crash data can be found in the large national databases, these rely on police reports in which distraction is notably underreported for a variety of reasons, including: (a) reliance on driver to self-report, (b) information being unavailable, and (c) variability in reporting across jurisdictions. Naturalistic data provides researchers with an unbiased view inside the vehicle during the critical seconds leading up to a crash and micro-level analyses to be conducted, providing invaluable data that would not otherwise be available.

The objective of this study was to use naturalistic crash data to examine the types of crashes teens are most frequently involved in, with a focus on analyzing whether the distractions or competing activities leading up to those crashes have changed over time. In addition, we investigated if eye glance behavior, including total eyes off road time and duration of the longest glance off road, have changed over time by crash type and potential distractions. The current analysis expands on a previous naturalistic teen driving study (Carney et al., 2015) and broadens knowledge of teen driver distractions from an earlier publication that focused on rear-end crashes (Carney, Harland, & McGehee, 2016).

2. Methods

2.1. Study sample

Nearly 15,000 drivers ages 16 to 19 were enrolled in a teen driving program between 2007 and 2015. The participants were licensed drivers in Arizona, Colorado, Illinois, Iowa, Minnesota, Missouri, Nevada, and Wisconsin. The program provided teens and their families with weekly web-based feedback regarding the young driver's performance and promoted safe driving behaviors through the use of the Lytx DriveCam system. This system, mounted on the inner windshield of a vehicle, recorded video, audio, and accelerometer data when a crash or other high g-force event (e.g., hard braking, acceleration, or impact) was detected. The system afforded a view of the inside of the cab and driver of the vehicle, as well as a view out the front. Each 12-second video provided data from the 8 s before to 4 s after the event.

Between August 2007 and April 2015, 8,228 videos of teen driver crashes had been collected by Lytx. These crashes were de-identified and released by the families and made available for review in order to further the understanding of contributing factors associated with young driver crashes (Carney et al., 2015). A single teen could have multiple crash videos within the data but, due to the anonymous nature of the videos, we were unable to control for multiple measurements (videos) on the same teen. Based on a review of the data, crashes in which the vehicle sustained forces less than 1 g were excluded to eliminate minor dings and curb strikes from the analysis. Additional videos were excluded for other reasons, as presented in Fig. 1. A total of 2,229 crashes met the inclusion criteria and were analyzed: 1,034 vehicle-to-vehicle (V2V) and 1,195 single-vehicle (SV) crashes.

2.2. Crash coding

The six seconds preceding each usable crash were coded for analysis, as this timeframe had the most potential to be contributory and allowed for comparison with previous naturalistic studies (i.e., the 100-car study; Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). The coding methodology focused on identifying the factors present in crashes as has been described in detail in previous publications (Carney et al.,

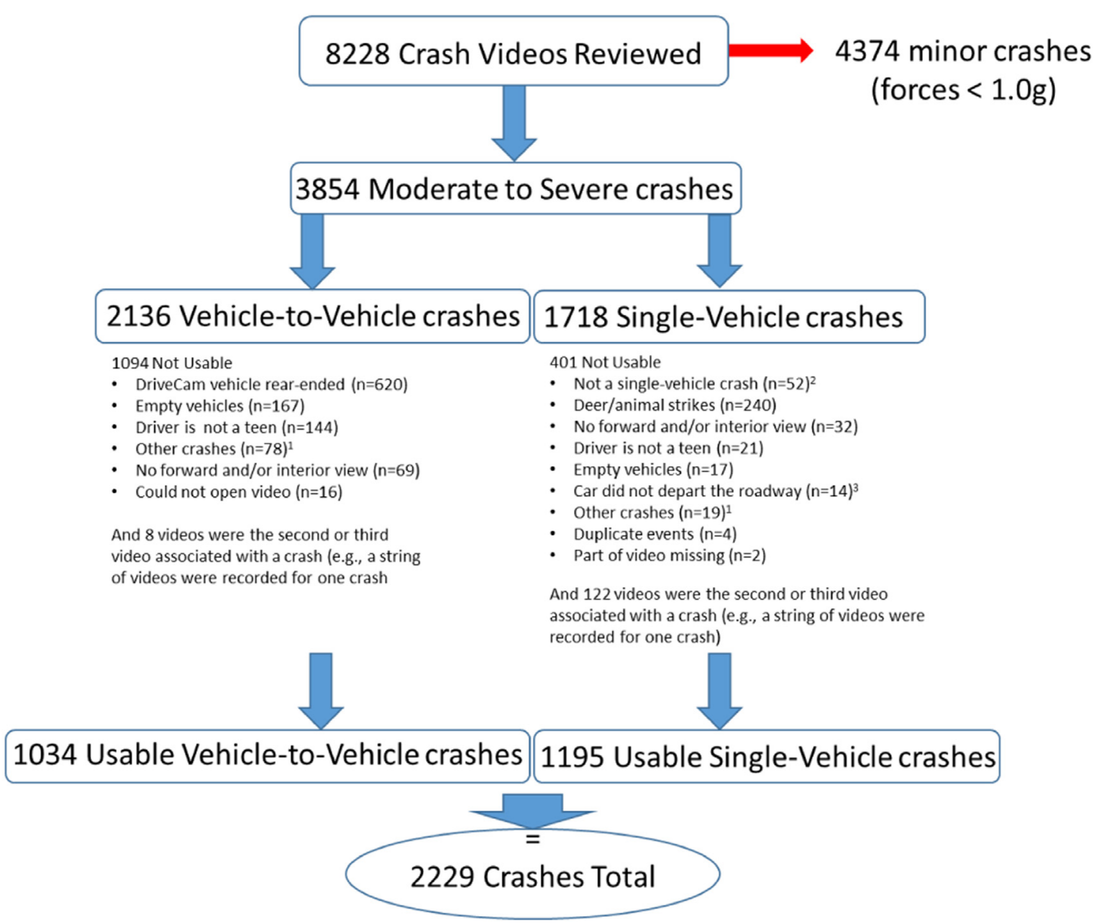

Fig. 1. Breakdown of video review process.

2015, 2016). Briefly, four broad categories of data included: (a) general background and environmental variables (e.g., time of day, weather, light conditions); (b) variables specific to the crash (e.g., contributing circumstances); (c) variables specific to the driver (e.g., gender, condition, behaviors); and (d) variables specific to passengers (e.g., estimated age, gender, behaviors). The data of particular interest for this study included: crash type (i.e., rear-end, angle, loss of control, and road departure), behaviors drivers engaged in leading up to the collision, total duration of time the driver's eyes were off the forward roadway (EOFR), and duration of the longest glance away from forward.

Multiple potentially distracting behaviors could be present in the vehicle leading up to the crash (Table 1). In coding, analysts made no judgments as to whether the driver was actually distracted by any behavior observed, but simply coded what was occurring inside the vehicle.

Information regarding the duration of the longest glance and total time EOFR in the six seconds leading up to the crash was coded, when available (Table 2). Under certain circumstances (e.g., high glare, drivers wearing sunglasses, and poor night time lighting), this data could not be coded (14%).

Table 1
Driver behaviors and definitions.

Driver behavior	Definition or description
Talking to self	Driver is talking out loud without a passenger present and hands-free cell use has been ruled out
Reading	Driver is looking at reading material (e.g., book, magazine, papers)
Attending to passenger(s)	Driver is looking at, in conversation with, or otherwise interacting with passenger(s). A driver is not coded as attending to a passenger who is conversing with the driver *unless* the driver looks at or engages in such conversation
Attending to a moving object	Driver is looking at or interacting with an object/animal moving around inside the vehicle
Use of cell phone (talking/listening)	Driver is having a conversation with another party using a cell phone (i.e., handheld or hands-free). This includes communication with the cell phone (e.g., Siri or Google)
Use of cell phone (operating/looking)	Driver is operating/looking at a cell phone (e.g., texting, Facebook, navigating)
Use of cell phone is likely but not visible	Driver is likely operating/looking at cell phone but device is out of view of the camera
Adjusting controls	Driver is operating/looking at an in-vehicle control (e.g., heating, ventilation, air conditioning, radio)
Using electronic device	Driver is operating/looking at a device other than a cell phone brought into the vehicle (e.g., mp3, iPod)
Reaching for object	Driver is picking something up, putting something down, or handing object to another person
Eating or drinking	Driver is looking at food or drink; holding or putting food or drink to mouth
Smoking related	Driver is looking at, lighting, holding, flicking ashes, or extinguishing cigarette
Personal grooming	Driver is engaged in some form of personal hygiene, with or without mirror glance (e.g., fixing hair, picking teeth)
Singing or dancing to music	Driver is singing (regardless of volume) or moving any part of the body to the music
Attending to person outside the vehicle	Driver is looking at or communicating with someone outside of the vehicle (e.g., pedestrian, cyclist)
Attending to another vehicle or passengers of another vehicle	Driver is looking at another vehicle or looking at or communicating with the passengers of another vehicle
Attending inside the vehicle, unknown	Driver is looking at something at an unknown location inside the vehicle
Attending outside the vehicle, unknown	Driver is looking at something at an unknown location outside the vehicle
Attending elsewhere, unknown	Driver is looking somewhere other than forward roadway, unknown

Table 2
EOFR time variables and definitions.

Behavior	Definition or description
Eye glance	A glance is defined as a movement of a driver's eyes away from the forward roadway until their eyes return to forward. Transitions to and from forward are appended to the glance. Multiple glance locations can occur in a single glance.
Duration of longest glance	The duration of the longest glance away from the forward roadway during the six seconds prior to impact (calculated at 4 Hz)
Total EOFR time	The total time the driver's eyes are off the forward roadway during the six seconds prior to impact (calculated at 4 Hz)

Each crash was coded by two highly-trained independent reviewers. The data files were then merged and any discrepancies were identified. If the discrepancy was due to an error, it was corrected in the data file. However, if the discrepancy was due to a disagreement, the event was turned over to a third reviewer for mediation. Glance durations and reaction times differing by even as little as one frame (0.25 s) were mediated in an attempt to achieve the highest possible level of accuracy. Due to the high level of training of the coders and the fact that 100% agreement was required, intra/inter-rater reliability was not calculated.

2.3. Data analysis

A trend analysis was completed for the crash data from 2007 to 2015. Years 2007 and 2015 were incomplete, containing data from only a portion of the year; therefore, the trend analysis estimated the average change over a 12-month period (as opposed to a calendar year). To examine changes over time, unadjusted logistic regression models for each outcome of interest (e.g., rear-end crash, cell phone use) were used and included month and year of the crash as the continuous predictor (e.g., 1 = August 2007, through 94 = April 2015) to estimate the average change in prevalence over a 12-month period (the 12-month change rate).

Due to small numbers, all regression models are unadjusted. If the percent change over 12 months is positive, it indicates an increasing prevalence. If it is negative, it indicates a decreasing prevalence. If the 95% CI around the percent change includes zero, the increase/decrease in prevalence is not statistically significant at a P value of 0.05. To see if including partial years (2007 and 2015) affected the prevalence change estimates, a sensitivity analysis was completed with each model being run with and without the partial years. In finding a no greater than 10% difference in the prevalence change estimate when including the partial years, it was concluded they were not significantly affecting the estimates and the partial years were included in all trend analyses. Due to the small sample size when examining cell phone use by crash type, logistic regression was used to model each outcome of interest (e.g., talking/listening on a cell phone vs. operating/looking at a cell phone) by year (rather than month and year) stratified by the crash type. If the β was statistically significant ($P < 0.05$) then the time trend was considered significant. A positive β can be interpreted as the outcome of interest increased over time while a negative β can be interpreted as a decrease over time. For continuous variables (e.g., EOFR time), linear regression was used and the β was interpreted as stated previously.

3. Results

Overall, drivers were evenly split by gender (51% male) and, in most cases (93.5%) the driver was observed wearing a seatbelt. Passengers were present in the vehicle in one-third of crashes (34.3%), with one passenger present in 24.5%, and two or more passengers present in 9.8%. Results showed significant decline in the percentage of crashes in which passengers were present (annual average % change = −1.63 percentage points per year [−2.54–−0.72]). Of crashes with passengers, 25.0% had at least one passenger that was unbelted. However, there was a significant trend toward increasing belt use for passengers across time (annual % change = 1.64 [0.25–3.04]). The majority of passengers, when present, were estimated to be 16 to 19 years old (84.8%) and male in 54.4% of crashes and female in 44.9%.

3.1. Crash type

As presented in Table 3, from 2007 to 2015 the proportion of angle crashes remained relatively consistent. However, there was a significant increase in the number of rear-end crashes, thus accounting for the significant overall increase in V2V crashes. There was a significant reduction in both road departure and loss of control (LOC) crashes and, therefore, a significant decrease in SV crashes overall.

3.2. Potentially distracting behaviors

Results did not show a significant change over time in the proportion of crashes containing drivers engaged in potentially distracting behavior. Table 4 presents the full breakdown of distracting behaviors. Between 2007 and 2015, an average of 58.5% of crashes contained some type of potentially distracting behavior during the six seconds leading up to a crash. While proportions fluctuated over time, the most common distractions remained the most common: attending to passengers (14.6%), cell phone use (11.9%), and attending inside the vehicle (10.7%). There were no significant increases or decreases in the proportion of crashes in which drivers were seen engaging in these behaviors.

3.3. Cell phones

Although there was not a significant change in the percentage of crashes with drivers using cell phones, changes were observed in *how* drivers were using their phones. A significant decrease in the proportion (among all crashes) with drivers talking/listening (annual % change = −0.39 [−0.68–0.09]) was found. Although it appeared as though the proportion of crashes that involved a driver operating/looking at the phone increased over time, there was too much variability in the data to show a significant increase as a proportion of all crashes. However, among cell phone-related crashes only, the proportion that involved a driver operating or looking at the cell phone, as opposed to talking/listening, increased significantly over the years examined (annual % change = 4.22 [1.15–7.29]).

When cell phone use was examined by crash type (Table 5), drivers were operating/looking at the cell phone significantly more frequently in road departure crashes and rear-end crashes than in LOC or angle crashes. Over time, there was a decline in the proportion of both road departure and angle crashes in which the driver was seen talking/listening, though neither was significant ($\beta = -0.3968$, $P = 0.0813$; $\beta = -0.3533$, $P = 0.0546$). There was, however, a significant increase in the proportion of rear-end crashes with drivers operating/looking at a cell phone ($\beta = 0.1715$, $P = 0.0262$).

3.4. Eyes off forward road (EOFR) and duration of longest glance

The average EOFR time for all crashes was 1.5 s during the six seconds immediately prior to the crash. Table 6 shows the percent of crashes in which EOFR time was available, to the mean EOFR time (in seconds) and the duration of longest glance by year and crash type. Among rear-end crashes, the average EOFR time significantly increased over time, from 2.0 s in 2008 to 3.1 s in 2014 ($\beta = 0.1527$, $P = 0.0004$), as did the duration of the longest glance, from 1.5 s to 2.1 s ($\beta = 0.1020$, $P = 0.0014$).

4. Conclusions

Distraction continues to be a leading cause of teen vehicle crashes and this study contributes to better understanding the shifts currently taking place in the types of crashes and potential distractions facing young drivers. In general, results did not show an increase over time in the proportion of crashes in which the driver was distracted prior to a crash. Teen drivers were seen engaging in some type of secondary activity in the seconds leading up to 59% of crashes, results similar to several other studies (Beanland et al., 2013; Treat et al., 1979). Also consistent with other research (Foss & Goodwin, 2014; Royal, 2003; Thor & Gabler, 2010; Tison, Chaudhary, & Cosgrove, 2011), the most frequent distractions—attending to passengers, cell phone use, and attending to something inside the vehicle—continued to remain most common.

When looking at crash type, there was a significant increase in the proportion of rear-end collisions, corresponding to what is being seen in the data nationally. According to data obtained from the National Automotive Sampling System/General Estimates System, teen driver rear-end crashes have increased from 24.7% in 2000 to 32.2% in 2014. Rear-end crashes are most often caused by following too closely and/or responding late due to inattention or distraction (McDonald, Curry, Kandadai, Sommers, & Winston, 2014; Neale, Dingus, Klauer, Sudweeks, & Goodman, 2005). While it is possible that teens have started following closer, it is more likely that distraction has led to an increase in EOFR, resulting in an increase in the proportion of rear-end crashes. For rear-end crashes, the mean EOFR time and mean duration of the longest glance both increased in this study.

At the same time, a significant increase was observed in the proportion of rear-end crashes with drivers operating/looking at their cell phone. While there was not a significant increase in overall cell phone use between 2007 and 2015, there was a significant decline in the

Table 3
Percentage of crash type, by year of crash, August 2007–April 2015.

Crash type	2007 N (col %)	2008	2009	2010	2011	2012	2013	2014	2015	Total	Time trend % change/12 months (95% CI)
Vehicle-to-vehicle (V2V)	**20 (50.0)**	**122 (39.7)**	**128 (36.1)**	**108 (44.3)**	**100 (38.5)**	**165 (53.4)**	**175 (52.7)**	**170 (56.3)**	**46 (57.5)**	**1,034 (46.4)**	**3.05 (1.63–4.46)**
Angle	11 (27.5)	59 (19.2)	65 (18.3)	39 (16.0)	47 (18.1)	41 (13.3)	59 (17.8)	53 (17.5)	15 (18.8)	389 (17.5)	−0.28 (−0.99–0.44)
Rear-end	9 (22.5)	59 (19.2)	59 (16.6)	66 (27.0)	52 (20.0)	114 (36.9)	107 (32.2)	104 (34.4)	29 (36.3)	599 (26.9)	3.23 (2.40–4.05)
Other vehicle-to-vehicle	0	4 (1.3)	4 (1.1)	3 (1.2)	1 (0.4)	10 (3.2)	9 (2.7)	13 (4.3)	2 (2.5)	46 (2.0)	Not calculated
Single vehicle (SV)	**20 (50.0)**	**185 (60.3)**	**227 (63.9)**	**136 (55.7)**	**160 (61.5)**	**144 (46.6)**	**157 (47.3)**	**132 (43.7)**	**34 (42.5)**	**1,195 (53.6)**	**−3.05 (−4.46–−1.63)**
Loss of control	18 (45.0)	131 (42.7)	179 (50.4)	114 (46.7)	138 (53.1)	119 (38.5)	134 (40.4)	107 (35.4)	28 (35.0)	968 (43.4)	−2.11 (−3.06–−1.15)
Road departure	2 (5.0)	54 (17.6)	48 (13.5)	22 (9.0)	22 (8.5)	25 (8.1)	23 (6.9)	25 (8.3)	6 (7.5)	227 (10.2)	−1.18 (−1.72–−0.65)
All crashes	**40**	**307**	**355**	**244**	**260**	**309**	**332**	**302**	**80**	**2,229**	

Table 4
Percent of all crashes containing a potentially distracting behavior by year.[a,b]

Potentially distracting behavior	2007 n = 40	2008 n = 307	2009 n = 355	2010 n = 244	2011 n = 260	2012 n = 309	2013 n = 332	2014 n = 302	2015 n = 80	Total n = 2229	Time trend % change/12 months (95% CI)
	N (% of all crashes in a year)										
Any distraction	21 (52.5)	185 (60.3)	201 (56.6)	147 (60.3)	150 (57.7)	183 (59.2)	182 (54.8)	189 (62.6)	46 (57.5)	1,304 (58.5)	0.11 (−0.84–1.06)
Attending to passenger(s)	4 (10.0)	55 (17.9)	48 (13.5)	47 (19.3)	39 (15.0)	35 (11.3)	42 (12.7)	47 (15.6)	9 (11.3)	326 (14.6)	0.62 (−1.0–2.3)
Attending inside vehicle, unknown	4 (10.0)	39 (12.7)	26 (7.3)	24 (9.8)	27 (10.4)	30 (9.7)	37 (11.1)	44 (14.6)	7 (8.8)	238 (10.7)	0.32 (−0.25–0.89)
Any cell phone use	5 (12.5)	38 (12.4)	45 (12.7)	27 (11.1)	25 (9.6)	43 (13.9)	34 (10.2)	40 (13.3)	9 (11.3)	266 (11.9)	−0.05 (−0.66–0.56)
Use of cell phone (operating/looking)	2 (5.0)	27 (8.8)	29 (8.2)	21 (8.6)	16 (6.2)	36 (11.7)	30 (9.0)	36 (11.9)	6 (7.5)	203 (9.1)	0.42 (−0.13–0.96)
Use of cell phone (talking, listening)	3 (7.5)	11 (3.6)	17 (4.8)	6 (2.5)	9 (3.5)	7 (2.3)	6 (1.8)	5 (1.7)	3 (3.8)	67 (3.0)	−0.39 (−0.68–0.09)
Attending outside vehicle, unknown	1 (2.5)	21 (6.8)	28 (7.9)	18 (7.4)	24 (9.2)	35 (11.3)	40 (12.1)	40 (13.3)	12 (15.0)	219 (9.8)	1.24 (0.68–1.80)
Singing/dancing to music	1 (2.5)	18 (5.9)	29 (8.2)	17 (7.0)	20 (7.7)	32 (10.4)	23 (6.9)	28 (9.3)	7 (8.8)	175 (7.9)	0.41 (−0.13–0.94)
Reaching for object	1 (2.5)	17 (5.5)	22 (6.2)	14 (5.7)	16 (6.2)	16 (5.2)	14 (4.2)	19 (6.3)	4 (5.0)	123 (5.5)	−0.03 (−0.47–0.42)
Operating in-vehicle controls/devices	2 (5.0)	9 (2.9)	11 (3.1)	8 (3.3)	9 (3.5)	8 (2.6)	14 (4.2)	14 (4.6)	2 (2.5)	77 (3.5)	0.14 (−0.21–0.49)
Personal grooming	1 (2.5)	19 (6.2)	18 (5.1)	13 (5.3)	11 (4.2)	20 (6.5)	16 (4.8)	12 (4.0)	5 (6.3)	115 (5.2)	−0.13 (−0.55–0.29)
Eating or drinking	0	5 (1.6)	5 (1.4)	5 (2.1)	3 (1.2)	6 (1.9)	6 (1.8)	9 (3.0)	1 (1.3)	40 (1.8)	0.14 (−0.13–0.42)
Attending to another vehicle or its passenger (s)	0	11 (3.6)	17 (4.8)	9 (3.7)	14 (5.4)	20 (6.5)	8 (2.4)	8 (2.7)	2 (2.5)	89 (4.0)	−0.15 (−0.58–0.27)
Talking to self	2 (5.0)	8 (2.6)	4 (1.1)	1 (0.4)	10 (3.9)	10 (3.2)	4 (1.2)	7 (2.3)	3 (3.8)	49 (2.2)	0.05 (−0.21–0.32)
Attending elsewhere, unknown	0	1 (0.3)	1 (0.3)	2 (0.8)	1 (0.4)	2 (0.7)	1 (0.3)	2 (0.7)	0	10 (0.5)	0.02 (−0.12–0.16)
Use of electronic device (not cell phone)	1 (2.5)	0	1 (0.3)	0	2 (0.8)	5 (1.6)	6 (1.8)	1 (0.3)	1 (1.3)	17 (0.8)	0.14 (0.02–0.27)
Attending to a person outside the vehicle	1 (2.5)	1 (0.3)	0	2 (0.8)	1 (0.4)	3 (1.0)	4 (1.2)	1 (0.3)	3 (3.8)	16 (0.7)	0.11 (−.01–0.24)
Attending to a moving object inside vehicle	0	1 (0.3)	2 (0.6)	1 (0.4)	1 (0.4)	0	1 (0.3)	0	0	6 (0.3)	−0.07 (−0.19–0.05)
Smoking related	0	6 (2.0)	5 (1.4)	4 (1.6)	1 (0.4)	1 (0.3)	3 (0.9)	0	0	20 (0.9)	−0.49 (−0.91–0.07)

[a] More than one behavior of a driver could be coded. Therefore, the percentages shown are of each column total and will not equal 100%.
[b] Years 2007 and 2015 are only partial years of data (August–December 2007 and January–April 2015).

proportion of crashes in which the driver had been talking/listening on the cell phone. Among crashes involving any type of cell phone use, the prevalence of operating/looking at the cell phone increased significantly compared to talking/listening. This study is not able to say that the increase in rear-end crashes was caused by any of these factors. However, a recent meta-analysis of over 28 experimental studies examined the effects of cell phone use on driving, with findings suggesting that the cognitive effects of cell phone use both slow reaction times and increase the amount of time drivers look away from the road, thus leading to an increase in all crashes, particularly rear-end crashes as observed in this study (Caird, Willness, Steel, & Scialfa, 2008).

Table 5
Cell phone use, by year of crash and crash type.[a,b]

	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
	N (% of all crashes involving cell phone distraction in a year)									
Loss of control										
Talking/listening	1 (5.6)	5 (3.8)	9 (5.0)	4 (3.5)	7 (5.1)	3 (2.5)	4 (3.0)	3 (2.8)	0	36 (3.7)
Operating/looking	0	1 (0.8)	2 (1.1)	2 (1.8)	1 (0.7)	3 (2.5)	2 (1.5)	0	1 (3.6)	12 (1.2)
Road departure										
Talking/listening	0	4 (7.4)	2 (4.2)	1 (4.6)	2 (9.1)	0	0	0	1 (16.7)	10 (4.4)
Operating/looking	1 (50.0)	12 (22.2)	16 (33.3)	10 (45.5)	4 (18.2)	10 (40.0)	3 (13.0)	6 (24.0)	1 (16.7)	63 (27.8)
Angle										
Talking/listening	2 (18.2)	2 (3.4)	5 (7.7)	1 (2.6)	0	1 (2.4)	1 (1.7)	0	2(13.3)	14 (3.6)
Operating/looking	0	4 (6.8)	2 (3.1)	0	3 (6.4)	1 (2.4)	1 (1.7)	1 (1.9)	1 (6.7)	13 (3.3)
Rear-end										
Talking/listening	0	0	1 (1.7)	0	0	3 (2.6)	0	2 (1.9)	0	6 (1.0)
Operating/looking[1]	1 (11.1)	9 (15.3)	8 (13.6)	9 (13.6)	8 (15.4)	22 (19.3)	24 (22.4)	29 (27.9)	3 (10.3)	113 (18.9)

Trend over time [1]$P < 0.05$.
[a] Crashes categorized as "other" are not included in these numbers.
[b] Years 2007 and 2015 are only partial years of data (August–December 2007 and January–April 2015).

Table 6
EOFR time and duration of longest glance by year of crash and crash type.

Year	Crash type	Total crashes N	# of crashes with EOFR time N (%)	EOFR time (seconds) Mean (SD)	Longest glance (seconds) Mean (SD)
2007	LOC	18	17 (94.4)	0.2 (0.4)	0.2 (0.4)
	Road departure	2	2 (100)	5.5 (0.0)	4.5 (1.4)
	Angle	11	10 (90.9)	1.2 (1.4)	0.8 (1.1)
	Rear-end	9	8 (88.9)	1.1 (1.5)	0.8 (1.0)
2008	LOC	131	111 (84.7)	0.5 (0.9)	0.4 (0.6)
	Road departure	54	47 (87.0)	3.8 (1.7)	3.2 (1.6)
	Angle	59	47 (79.7)	0.7 (1.3)	0.5 (0.9)
	Rear-end	59	53 (89.8)	2.0 (2.0)	1.5 (1.4)
2009	LOC	179	152 (84.9)	0.6 (1.1)	0.4 (0.7)
	Road departure	48	44 (91.7)	3.8 (1.7)	2.9 (1.6)
	Angle	65	54 (83.1)	0.5 (1.0)	0.4 (0.8)
	Rear-end	59	53 (89.8)	2.1 (1.7)	1.6 (1.3)
2010	LOC	114	81 (71.1)	0.4 (0.8)	0.3 (0.6)
	Road departure	22	17 (77.3)	4.9 (1.0)	4 (1.4)
	Angle	39	36 (92.3)	0.7 (1.0)	0.5 (0.6)
	Rear-end	66	61 (92.4)	2.5 (1.7)	1.7 (1.3)
2011	LOC	138	109 (79.0)	0.5 (0.8)	0.4 (0.6)
	Road departure	22	18 (81.8)	3.5 (1.4)	2.8 (1.3)
	Angle	47	40 (85.1)	0.7 (1.1)	0.5 (0.7)
	Rear-end	52	50 (96.2)	3.1 (1.8)	2.1 (1.6)
2012	LOC	119	90 (75.6)	0.4 (1.0)	0.3 (0.7)
	Road departure	25	19 (76.0)	4.1 (1.7)	3.1 (1.6)
	Angle	41	38 (92.7)	0.7 (1.3)	0.4 (0.7)
	Rear-end	114	108 (94.7)	2.6 (1.9)	2 (1.6)
2013	LOC	134	112 (83.6)	0.4 (0.8)	0.3 (0.6)
	Road departure	23	16 (69.6)	3.4 (1.7)	2.7 (1.5)
	Angle	59	53 (89.8)	0.6 (1.1)	0.5 (1.0)
	Rear-end	107	95 (88.8)	2.7 (2.0)	2.1 (1.7)
2014	LOC	107	94 (87.9)	0.4 (0.7)	0.3 (0.5)
	Road departure	25	20 (80.0)	3.6 (2.3)	3.1 (2.1)
	Angle	53	49 (92.5)	0.8 (1.5)	0.7 (1.3)
	Rear-end	104	98 (94.2)	3.1 (2.0)	2.1 (1.6)
2015	LOC	28	27 (96.4)	0.6 (1.2)	0.4 (0.9)
	Road departure	6	4 (66.7)	3.8 (2.7)	2.9 (2.4)
	Angle	15	15 (100)	0.7 (1.5)	0.5 (1.2)
	Rear-end	29	29 (100)	2.9 (2.0)	2.2 (1.7)
Total	LOC	968	793 (81.9)	0.5 (0.9)	0.4 (0.6)
	Road departure	227	187 (82.4)	3.9 (1.7)	3.1 (1.6)
	Angle	389	341 (87.7)	0.7 (1.2)	0.5 (0.9)
	Rear-end	599	554 (92.5)	2.6 (1.9)	1.9 (1.5)

In contrast, there was a significant reduction in the proportion of crashes that were road departure crashes, coinciding with a significant decline in the proportion of road departure crashes in which a driver was seen operating/looking at a cell phone. It is possible that more drivers are choosing to check messages or text at times they perceive to be safer, such as while slowing for, stopped at, or departing from an intersection (Huth, Sanchez, & Brusque, 2015). Observational data of young drivers has shown that visible manipulation of handheld devices at controlled intersections has quadrupled in recent years (NHTSA, 2015b). This may also help to explain the rise in rear-end crashes, as many of these types of crashes occur at intersections. As more and more people text/interact with the phone while driving, usually without consequence, glances slowly become longer and longer without drivers realizing that they have glanced away longer than they should. It has also been suggested that people are engaged in "task preservation" where they become fixated on completing a task such as reading an e-mail or finishing a text and neglect the goal of safely operating the vehicle (Lee, Roberts, Hoffman, & Angell, 2012). Thus, glances become more frequent and longer glances lead to even longer glances.

It is not clear why there was a significant decline in the proportion of LOC crashes. As described previously, self-regulation may play a role. We did not see a significant decrease in the proportion of crashes that occurred on poor road surface conditions. It is possible that the fleet of vehicles teens are driving are evolving and the prevalence of safety features such as electronic stability control have increased over time. However, that data is not available for this study.

This study has several limitations. As with all naturalistic driving research, there are concerns regarding the representativeness of the drivers involved in the study. These drivers were participating in a program intended to improve teen driver safety, and most were likely encouraged or required by their parents to participate. Drivers were aware they were participating in the program and that their driving was being monitored, potentially making them less likely to engage in risky or distracting behaviors. However, if this were the case, the proportions reported may only underestimate certain behaviors among the general teen driver population. Additionally, the type of data analyzed here cannot be used to draw inferences regarding crash risk, as the video data examined was only available when a crash triggered the recording; no video was available for ordinary, uneventful driving. It is also important to note that there was no driver information linked to the videos and it was therefore not possible to determine whether more than one crash involved a particular driver.

As one of the first naturalistic studies to examine changes in teen vehicle crashes over a number of years and the largest to date, this study offers new insight into the continually evolving driving environment. It is important to identify those crashes that teens are most frequently involved in as well as their engagement in distractions or competing activities leading up to these crashes. While causality cannot be inferred in this study, the trend suggests that more research be conducted in the area of cell phone use, with specific regard to how and when teens are choosing to engage in this behavior, whether it is truly *causing* an increase in rear-end crashes, and whether existing technologies can be effective in mitigating these crashes. Examining naturalistic teen driving data to identify those distractions or competing activities most often engaged in is the first step toward better educating drivers, informing policy makers, and aiding in the design of both in-vehicle technologies and vehicle safety systems, potentially saving thousands of lives.

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