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Distracted Driver Behaviors and Distracting Conditions Among Adolescent Drivers: Findings From a Naturalistic Driving Study

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A B S T R A C T

Purpose: The proliferation of new communication technologies and capabilities has prompted concern about driving safety. This concern is particularly acute for inexperienced adolescent drivers. In addition to being early adopters of technology, many adolescents have not achieved the degree of automaticity in driving that characterizes experienced adults. Consequently, distractions may be more problematic in this group. Yet little is known about the nature or prevalence of distracted driving behaviors or distracting conditions among adolescent drivers.
Method: Vehicles of 52 high-school age drivers (N = 38 beginners and N = 14 more experienced) were equipped for 6 months with unobtrusive event-triggered data recorders that obtain 20-second clips of video, audio, and vehicle kinematic information when triggered. A low recording trigger threshold was set to obtain a sample of essentially random driving segments along with those indicating rough driving behaviors.
Results: Electronic device use (6.7%) was the most common single type of distracted behavior, followed by adjusting vehicle controls (6.2%) and grooming (3.8%). Most distracted driver behaviors were less frequent when passengers were present. However, loud conversation and horseplay were quite common in the presence of multiple peer passengers. These conditions were associated with looking away from the road, the occurrence of serious events, and, to a lesser extent, rough driving (high g-force events).
Conclusions: Common assumptions about adolescent driver distraction are only partially borne out by in-vehicle measurement. The association of passengers with distraction appears more complex than previously realized. The relationship between distractions and serious events differed from the association with rough driving.

IMPLICATIONS AND CONTRIBUTION

Because of measurement challenges, little is known about the nature or prevalence of distractions among adolescent drivers. Using a small in-vehicle camera, we were able to see distracting conditions and count distracted driver behaviors. All distractions were uncommon; chaotic conditions involving multiple passengers, although uncommon, appeared most risky.

Drivers have always had the opportunity to eat, chat with passengers, and engage in a variety of nondriving-related activities while operating a vehicle, and these have long been known to contribute to crashes [1]. Recently, distracted driving has come to the forefront of public awareness and the concern of injury prevention researchers, stemming in large part from the rapid increase in cell phone ownership and the explosion in availability of other portable and in-vehicle electronic devices (EDs). By their nature, these technologies can absorb more driver attention for longer periods than the distractions that have long been with us. There is particular concern about the potential detrimental effects of distraction among adolescent drivers because of their relative lack of driving experience in combination with the tendency to be early adopters of technology.

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Driver distractions can include physical tasks (e.g., eating, drinking, or manipulating dashboard controls), auditory or visual diversions (e.g., loud music or looking at a smartphone screen), or cognitive activities (e.g., talking on a phone or to a passenger). Some activities can incorporate all three modes of distraction. Sending a text message, for example, typically results in physical, visual, and cognitive distraction simultaneously. The potential for a particular form of distraction to increase crash risk depends on a number of factors. These include (1) the immediate degradation of driving competence posed by a distracted behavior; (2) the frequency with which the distraction occurs; and (3) the duration of the distracted behavior. Although reaching for a moving object in a vehicle entails a high degree of risk, such an action is relatively rare and generally of brief duration [2]. In contrast, a phone conversation involves less acute risk, but drivers may make several calls during a trip, and each can last several minutes—although most calls are brief [3]. Consequently, the attributable risk (population attributable fraction [4]) of driver cell phone use to crashes can be quite high, whereas the aggregate crash risk attributable to reaching for objects, waving at invading bees, or reacting to spilled coffee is far lower, despite the attendant high—but momentary—risks of doing so.

The driving context within which distractions occur is important as well. Having a phone conversation in busy traffic or on a narrow winding road likely increases crash risk more than engaging in the same conversation in light traffic or on a straight stretch of road. Drivers do attempt to minimize risks by selecting "safer" moments to engage in potentially distracting activities [5–7]. However, these efforts can only be partially effective. Individuals may underestimate the risks of distracted activities and may not fully realize when their driving is degraded [8–10]. Moreover, situations in which highly focused attention is required can appear unexpectedly (e.g., an object falls from a vehicle ahead). Precise measures of the incidence and duration of distracted driving behaviors are needed to estimate the chances drivers will fail to notice such rare events—or have insufficient time to react—when they occur.

Measuring the prevalence of distracted driving

Until recently, there has been no way to measure driver distraction with the precision necessary for productive scientific inquiry. Unlike the case with alcohol-induced impairment, there is no objective way to retrospectively measure a driver's degree of impairment by distraction at the time of a crash. Several studies have obtained self-reports of distracted driving behaviors, but such data are rarely specific enough to be of any research value. Drivers cannot accurately report how often, how long, or during what proportion of their driving, they engage in distracted behaviors. Nor can they report on cognitive distractions about which they have little or no awareness. Observational techniques have been used to measure distraction [11–14], but these are also severely limited. Most driver behaviors can be difficult for observers to see. Consequently, observations are generally conducted only in the daytime and usually when vehicles are stopped (although "distracted" behavior is known to be greater when vehicles are stopped [3,8]). Finally, cognitive distraction cannot be reliably observed in field driving conditions, nor can distracting conditions be identified or measured from fixed locations.

Fortunately, even as they have created more potential distractions, technologic advances have also enabled better measurement of distracted driving. Installation of unobtrusive cameras and other recording equipments inside vehicles has enabled researchers to directly observe driver behavior far more precisely and validly than ever before, to link measures of driver behavior with information about the driving context and to quantify these with substantial precision [3,8,15–18].

Distracted driving among adolescents

Concern about distraction among adolescent drivers has led to enactment of laws in most states prohibiting young drivers from using EDs [19] despite a paucity of evidence about the incidence or riskiness of this behavior. Nonetheless, there are legitimate reasons for concern. Adolescents tend to be early adopters and aggressive users of new technologies that can be quite distracting [20]. Driving is less automated for novices, requiring more of their attentional capacity than is the case for experienced drivers [21]. Additionally, areas of the brain involved in regulatory competence, forming judgments, and decision making—all of which are important functions in driving—are not fully developed among adolescents [22]. Accordingly, novice adolescent drivers may have greater difficulty than experienced adult drivers in managing potentially distracting conditions, rendering them more susceptible to a distraction-related crash [21].

Cell phone use among adolescent drivers has received some research attention. Observational and self-report surveys indicate that many adolescents use a phone at least occasionally while driving [7,23–25]. About a quarter of high-school age drivers report they "often" read text messages while driving, but they are far less likely to initiate texts than to read them [7]. The potential for passengers to distract a driver has also received some attention. Sixteen- and 17-year-old drivers tend to carry more passengers and do so more often, than older adolescents and adults, increasing the exposure of young and inexperienced drivers to distractions that passengers may create [26,27].

The distractions of greatest concern for adolescent drivers—passengers and phone use—appear to be inversely related. In a large observational study of young drivers departing from high schools, we found cell phone use was twice as common among drivers who were alone as among those with passengers [24]. And in a notable deviation from the greater tendency of males to engage in most risky behaviors, females were 70% more likely to be observed talking on a phone.

Despite the substantial concern about distracted driving among adolescents, almost no research has examined the many potential distractions often believed to be common and problematic for adolescent drivers, beyond those involving passengers and cell phone use. To address that gap, we used data collected in a naturalistic driving study of 16- to 18-year-old drivers in North Carolina to document the frequency of several distracted driving behaviors. We also examined the association of distractions with drivers' sex and gaze direction (toward or away from the road), number and characteristics of passengers as well as time of day. In addition, we looked at the association of distraction with the occurrence of critical events.

Methods

Data source

We used data collected during an earlier, naturalistic study of adolescent driving behavior [15]. Event-based data recorders were originally placed in participants' vehicles during the initial 4 months of the learner license period to observe parent and adolescent behaviors during supervised driving. Data recorders were re-installed for 6 months at the beginning of these adolescents' intermediate license period, a particularly high risk time for new drivers [28–30]. All data examined for the present study were collected during this 6-month period.

Sample of adolescent drivers

Fifty families were successfully recruited through two driver licensing offices in central North Carolina at the time adolescents applied for a learner license.[1] Of these, 38 families agreed to continue participating when the adolescent obtained an intermediate license. In 14 of these 38 families, an older high–school-aged sibling shared the vehicle with the original target driver. Driving data for these siblings were included in the present analyses, raising the total sample to 52 young drivers. All the "target" teens held an intermediate license during data collection, meaning they were not allowed to drive from 9 P.M. to 5 A.M. or carry more than one young passenger (except for family members) unless an adult was in the vehicle. The type of license held by siblings was not known, but all were old enough to have progressed beyond the night and passenger limits. All drivers studied were prohibited by restrictions on their license type from using a phone while driving. Data were collected from February 2008 to February 2010, but the majority were obtained during 2009. All aspects of the study were approved by the University of North Carolina Institutional Review Board.

Data recording

DriveCam event-based data recorders were installed in the vehicle most often driven by the new driver, usually within 1 week of the date of intermediate licensure, and remained in the vehicle for 6 months. A DriveCam is a palm-sized camera that records video, audio, and g-force information (which characterizes vehicle movements). The camera is mounted on the windshield behind the rearview mirror. A forward facing lens captures the scene in front of the vehicle, and a rearward facing lens records activity inside and behind the vehicle. Although the recorder runs continuously, it only saves information when a vehicle movement (decelerating, accelerating, or turning) produces a g-force that exceeds a predetermined threshold. Once triggered, the camera saves 20 seconds of data—the 10 seconds preceding and 10 seconds after the triggering movement. The g-forces required to trigger recording were set at .40 g for longitudinal (decelerating/accelerating) and .45 g for lateral (turning) movements. These are highly sensitive settings and were intended to capture routine moments of driving as well as instances of notably "rough" driving.[2] With these settings, it is unlikely occupants would notice anything unusual had occurred for most recorded events. In fact, in the study phase focused on supervised driving, which used these same settings, two thirds of all recorded events appeared to go unnoticed by parents and young drivers [15]. Previous studies using DriveCams with unaccompanied teen drivers have employed higher g-force settings to identify rough or "risky" driving [31,32].

[1] See [15] for a detailed description of recruitment procedures.

[2] Although a truly random sampling of driving episodes was desired, the DriveCams used could not randomly capture segments of driving, so we opted for this approach as an approximation of random sampling.

Selection of video clips for full coding

During the 228 total months data recorders were installed (6 months × 38 vehicles), 29,920 driving clips were recorded. Because vehicles were sometimes shared with other family members, each driving clip was screened to identify the driver and passengers.[3] For the 52 drivers in the study, 24,085 driving clips were recorded (19,384 from "target drivers" and 4,701 from high-school age siblings). On average, there were 463 clips per driver (range = 17–1,028).

Because coding clips is a labor-intensive, time-consuming process, a sample of clips was selected for coding. All clips with passengers were sampled. The remainders were stratified, treating each driver as a single stratum, and then clips were randomly sampled within strata, using a procedure designed to adjust for the substantial difference in the number of clips recorded for each driver. The median number of clips selected per driver was 151 (range = 17–315). In total, 7,858 driving clips from the 52 drivers were selected for full coding.

Data coding

A coding scheme was developed to identify the behaviors and characteristics of interest in the recorded driving clips. Two coders were specially trained in using the coding scheme, which included several measures of distraction and distracted driver behaviors as described below. Behaviors or conditions observed at any point during the entire 20-second clip were coded as present, unless otherwise indicated (e.g., behaviors occurring only while vehicle was stopped were not coded).

Date, time, maximum lateral and longitudinal g-force reached, and number of occupants were coded for each clip. When passengers were present, we coded their sex, age, belt use, and relation to the driver. Passenger age/relation to driver was coded as adolescent sibling (aged 13–20 years), adolescent nonsibling, child sibling (<13), child nonsibling, parent, or other adult. In many cases, the exact age of siblings was known. With peers, however, judgment was occasionally required in making age determinations.[4]

We also coded the presence of various distractions and distracted driver behaviors. Appendix 1 (see Supplementary Data) shows variables coded in all driving clips. Each variable was coded separately, so multiple distractions could be coded within a clip. Most of the distracted/distracting elements were coded only if the vehicle was moving. Appendix 2 (see Supplementary Data) shows additional distracting conditions that were coded only when a passenger was present. Finally, two characteristics of the driving setting were coded for each clip. Precipitation was coded as none, wet road but not raining, or raining. Traffic volume was judged as none, light, moderate, heavy, or N/A (e.g., parking lot).

We also coded gaze direction to measure (1) whether the driver looked away from the roadway at any point during the 10 seconds preceding the vehicle movement that triggered recording; (2) the total amount of time looking away; and (3) the longest continuous glance away from the road during this period.

[3] Because we had tracked families from the beginning of the learner stage, we were able to identify whether the vehicle occupants were target drivers, siblings, parents, or nonfamily members.

[4] The same passengers often appeared multiple times in clips. The repeated exposures, along with the conversation between driver and passengers, often helped to clarify the approximate age of passengers.

Looking away included any glance downward, at a passenger, or elsewhere that appeared unrelated to driving. Glances in the rearview mirror or in the direction of a turn were not counted as looking away. The DriveCam captures four images per second, so time looking away was coded in .25-second increments.

Data weighting and analysis

Odds ratios (ORs) and 95% confidence intervals (CIs) are estimated using univariate logistic regression. In addition, the ratio of the upper to lower 95% CI bounds—the confidence limit ratio (CLR [33])—is reported to give an indication of the precision of the point estimate (OR) and to provide a convenient way to compare the relative precision of ORs. Because the present study is both nonexperimental and largely exploratory, we do not generally report tests of statistical significance.

Multiple clips were obtained from each driver. Treating the resulting measures as if they were independent would result in underestimating the variance of measurements [34]. Additionally, because clips involving young passengers were oversampled and a smaller proportion of all recorded clips were sampled for those drivers who drove more often or more roughly, data were weighted (by the inverse of the sampling probability) in the analyses to adjust for the sampling design. We conducted the analyses reported below using the SPSS Complex Samples procedure, treating family as the clustering unit to adjust for effects of the sample design and ensure that variances (hence, CIs) were appropriately estimated.

Results

All 52 participating drivers were high-school students; 63% were aged 16 years when we began recording their driving behaviors, 17% were 17-year-olds, and 19% were 18-year-olds. Participants were predominantly female (69%). A majority of the sample drove a passenger car (56%); fewer drove a sport utility vehicle (17%), minivan (15%), or pickup truck (12%).

Distracted driver behaviors

Drivers were observed using an ED in 6.7% of all driving clips (Table 1). Females were twice as likely as males to be using an ED and more than three times as likely to be observed holding a phone to their ear.

ED use varied considerably across drivers (Figure 1). Nine drivers were never observed using an ED, whereas six were observed using an ED in >15% of their clips (median ED use = 4% of clips). ED use was twice as common among the slightly older and more experienced siblings as among the target drivers (11.2% vs. 5.1%, respectively; OR = 2.19, 95% CI = 1.86, 2.58, CLR = 1.37). All but one of the 14 siblings were observed using an ED at least once, whereas 8 of the 38 target drivers were never observed using an ED.

All distracted behaviors were relatively rare (Table 1). Adjusting vehicle controls was the most common, while reading was the least. Altogether, excluding ED use, drivers engaged in at least one of the distracted driving behaviors in 15.1% of all driving clips. Females were slightly more likely to engage in at least one distracted behavior (15.6% vs. 13.9% of clips, respectively; OR = 1.12, 95% CI = 1.00, 1.26, CLR = 1.26), and older high-school age siblings were somewhat more likely to do so than target drivers (17.6% vs. 14.2%, respectively; OR = 1.24, 95% CI = 1.11, 1.39, CLR = 1.25).

The frequency of distracted behaviors other than ED use varied considerably by driver, but the incidence was not concentrated so heavily among a small subset of drivers as was the case with EDs. Figure 2 shows the percent of clips in which each of the 52 drivers engaged in at least one distracted behavior (median = 13.5%).

Passengers and distractions

In almost two thirds of all clips, there were no passengers (Table 2). A peer was present in about 20% of clips, and siblings were present in almost 15%. Adults were present in only 3% of clips; the vast majority of these (90%) were parents. Note that clips with an adult present may have also included various

Table 1
Percent of recorded teenage driving clips in which ED use by drivers and other distracted driver behaviors were observed, by sex of driver

	Overall (N = 7,858 clips)		Female driver (N = 5,434 clips)		Male driver (N = 2,424 clips)		Female/male comparison	
	N	Percent of clips	N	Percent of clips	N	Percent of clips	OR (95% CI)	CLR
ED use by drivers								
Holding cell phone to ear	178	2.3	157	2.9	21	.9	3.30 (2.10, 5.18)	2.47
Talking on hands-free phone	4	.1	4	.1	0	.0	—	
Operating an ED (e.g., texting)	97	1.2	82	1.5	15	.6	2.42 (1.39, 4.18)	3.01
Suspected operating an ED	244	3.1	184	3.4	60	2.5	1.36 (1.02, 1.81)	1.77
Any ED use	523	6.7	427	7.9	96	4.0	1.96 (1.58, 2.44)	1.54
Other distracted driving behaviors								
Adjusting controls	471	6.2	352	6.7	119	5.0	1.33 (1.09, 1.63)	1.50
Grooming	287	3.8	207	4.0	80	3.4	1.16 (.90, 1.50)	1.67
Eating or drinking	211	2.8	154	2.9	57	2.4	1.22 (.90, 1.64)	1.82
Reaching for object in vehicle	191	2.5	146	2.8	45	1.9	1.47 (1.05, 2.04)	1.94
Communicating with someone outside vehicle	113	1.5	71	1.3	42	1.7	.77 (.53, 1.12)	2.11
Driver turns around (looks to rear)	71	.9	36	.7	35	1.5	.47 (.29, .74)	2.55
Reading	8	.1	6	.1	2	.1	1.35 (.27, 6.71)	24.85
Any distracted behavior[a]	1,186	15.1	848	15.6	338	13.9	1.12 (1.00, 1.26)	1.26

CI = confidence interval; CLR = confidence limit ratio; ED = electronic device; OR = odds ratio.

[a] Drivers could engage in more than one potentially distracting behavior during a clip. Consequently, the total N for "any distracted behavior" does not equal the sum of the individual distracted behaviors.

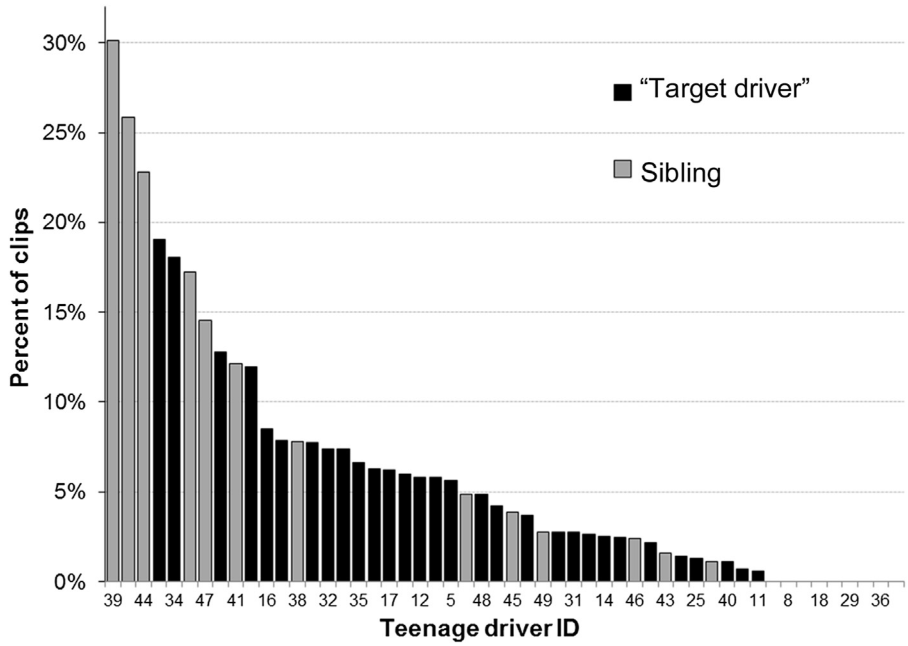

Figure 1. Percent of clips with any ED use, by teenage driver ID.

combinations of peers, siblings, or other adults. Males were about twice as likely to have multiple unrelated passengers.

Table 3 lists potentially distracting conditions involving passengers. Loud conversations were evident in 12.6% of driving clips when passengers were present. Horseplay was less common at 6.3% of clips, and the driver was an active participant in just over half of instances of horseplay (3.7% of clips). Other potentially distracting conditions, such as "dancing" by passengers or physical contact between the driver and passengers, were quite rare. There were no meaningful driver sex differences in exposure to distractions involving passengers.

Passenger distraction likely depends not only on their presence but also on the number of passengers and who they are. Table 4 lists how driver ED use and other distracted behaviors were related to passenger combinations. "Other distracted driver behavior" is defined as the occurrence of one or more of the

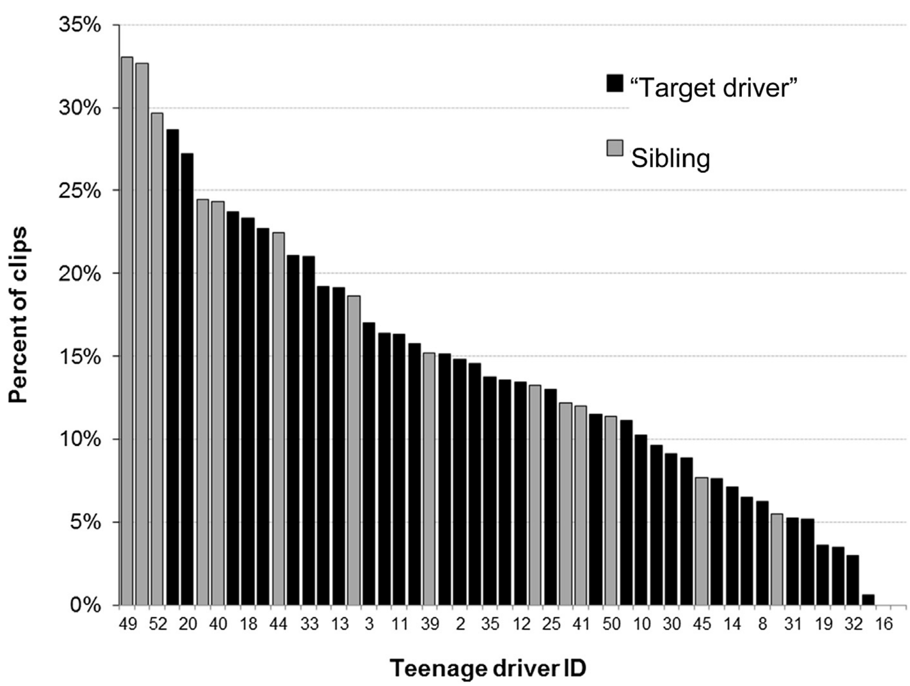

Figure 2. Percent of clips with at least one distracted driver behavior (excluding EDs), by teenage driver ID.

Table 2
Passenger combination by driver sex

	Overall (N = 7,858 clips)		Female driver (N = 5,434 clips)		Male driver (N = 2,424 clips)		Female/male comparison	
	N	Percent of clips	N	Percent of clips	N	Percent of clips	OR (95% CI)	CLR
No passengers	5,142	65.4	3,508	64.6	1,634	67.4	1.04 (1.01, 1.08)	1.07
One teenage peer	1,027	13.1	743	13.7	284	11.7	1.17 (1.03, 1.33)	1.29
Two or more teenage peers	322	4.1	175	3.2	147	6.1	.53 (.43, .66)	1.53
One sibling	885	11.3	638	11.7	247	10.2	1.15 (1.00, 1.32)	1.32
Two or more siblings	53	.7	38	.7	15	.6	1.13 (.62, 2.05)	3.31
Teenage peer(s) and sibling(s)	160	2	137	2.5	23	.9	2.66 (1.71, 4.12)	2.41
Parent or other adult present	269	3.4	195	3.6	74	3.1	1.18 (.90, 1.53)	1.70

CI = confidence interval; CLR = confidence limit ratio; OR = odds ratio.

seven distracted driver behaviors described above. Most of the individual distracted driver behaviors were so rare it is not possible to examine their separate association with different combinations of passengers.

ED use and other distracted driver behaviors were most common when there were no passengers. Solo drivers used an ED in 8.1% of clips and engaged in other distracted behaviors in 16.9% of clips. These behaviors were least common when an adult was in the vehicle. It is also noteworthy that driver ED use was particularly low in the presence of a single peer (60% less likely than for solo driving).

Table 5 lists the association of loud conversation and horseplay with various passenger combinations. Because loud conversation and horseplay could only occur when passengers were present, we used cases with one peer as the reference group. Loud conversation and horseplay were more than twice as likely when young drivers were carrying multiple peers than when only one peer was in the vehicle. Conversely, the likelihood of loud conversation and horseplay was markedly lower with one sibling passenger or when a parent/adult was present.

Distractions and characteristics of the driving setting

There was no clear pattern of distractions by time of week. Some were slightly more common on weekends, others more frequent on weekdays, but all differences are quite small. Figure 3 shows the distribution of distracted behaviors and distracting conditions in the morning (6 A.M.–11:59 A.M.), afternoon (12 P.M–5:59 P.M.), evening (6 P.M–8:59 P.M.), and night (9 P.M.–5:59 A.M.). ED use varied little over the course of the day, whereas other distracted driver behaviors showed a small, gradual decline. In contrast, loud conversation and horseplay appeared to increase throughout the day.

Some studies suggest drivers are more likely to engage in potentially distracting activities when the driving environment seems safer [5,7,8]. Accordingly, we examined whether distracted behaviors were less common in more challenging conditions such as busy traffic or rain. There was no evidence of a relationship between the frequency of distracted driver behaviors or distracting conditions and amount of traffic. Distracted driver behaviors and distracting conditions were slightly less common in clips recorded when it was raining, but the differences were relatively small and the CIs were large.

Looking away from the roadway

Drivers looked away from the roadway before the triggering vehicle movement, at least briefly, in 45% of clips. Looking away was somewhat more common among the slightly older and more experienced high-school age siblings than among target drivers (51.1% vs. 42.7%, respectively; OR = 1.20, 95% CI = 1.13, 1.27, CLR = 1.12).

Figure 4 shows the total amount of time that drivers looked away from the roadway during the 10 seconds preceding the triggering movement (median = 1.5 seconds) and the longest continuous glance away from the roadway (median = 1.0). Most drivers who looked away from the roadway did so only briefly. One third (35%) of drivers who looked away did so for 1 second or less. A similar proportion (31%) looked away for 1.25–2 seconds. However, it is noteworthy that 12% of drivers looked away from the roadway for at least 4 of the 10 seconds prior to the camera being triggered. Half of the longest glances were 1 second or less, 39% were 1.25–2.0 seconds, and 10% were >2 seconds.

Table 6 lists the relationship between distractions and looking away from the roadway. Drivers were three times as likely to look away from the roadway when using an ED and two and a half

Table 3
Percent of recorded teenage driving clips in which potentially distracting conditions involving passengers were observed, by sex of driver

	Overall (N = 2,716 clips)		Female driver (N = 1,926 clips)		Male driver (N = 790 clips)		Female/male comparison	
	N	Percent of clips	N	Percent of clips	N	Percent of clips	OR (95% CI)	CLR
Loud conversation	338	12.6	250	13.1	88	11.4	1.15 (.91, 1.45)	1.59
Horseplay (mild or rough)	170	6.3	111	5.8	59	7.6	.77 (.56, 1.04)	1.86
Passenger “dancing”	40	1.5	32	1.7	8	1.0	1.61 (.75, 3.48)	4.64
Passenger communicating with someone outside vehicle	30	1.1	17	.9	13	1.7	.53 (.26, 1.09)	4.19
Physical contact (affectionate)	17	.6	9	.5	8	1.0	.46 (.18, 1.18)	6.56
Physical contact (nonaffectionate)	7	.3	4	.2	3	.4	.54 (.12, 2.41)	20.08

CI = confidence interval; CLR = confidence limit ratio; OR = odds ratio.

Table 4
Association of driver ED use and other distracted driver behaviors with passenger combination

	%	OR (95% CI)	CLR
Driver ED use			
No passengers	8.1	1.00 (reference)	
One teenage peer	3.5	.40 (.29, .55)	1.90
Two or more teenage peers	5.3	.66 (.44, .99)	2.25
One sibling	5.0	.60 (.38, .96)	2.53
Two or more siblings	9.4	1.11 (.33, 3.77)	11.42
Teenage peer(s) and sibling(s)	3.8	.48 (.30, .77)	2.57
Parent or other adult present	1.1	.12 (.06, .25)	4.17
Other distracted driver behaviors[a]			
No passengers	16.9	1.00 (reference)	
One teenage peer	12.3	.69 (.56, .85)	1.52
Two or more teenage peers	19.0	1.15 (.84, 1.57)	1.87
One sibling	10.9	.60 (.47, .77)	1.64
Two or more siblings	8.9	.48 (.34, .67)	1.97
Teenage peer(s) and sibling(s)	9.3	.50 (.34, .75)	2.21
Parent or other adult present	4.2	.21 (.14, .34)	2.43

N = 6,356. In several cases, data are missing due to darkness of the clip or other circumstances that prevented clear determination of distracted driver behaviors. CI = confidence interval; CLR = confidence limit ratio; ED = electronic device; OR = odds ratio.

[a] Other distracted driver behaviors include any of the following: adjusting controls, grooming, eating or drinking, reaching for object in vehicle, communicating with someone outside vehicle, turning around, or reading.

times as likely to look away when engaging in some other distracted driver behaviors. They were also more likely to look away when there was loud conversation or horseplay in the vehicle. When using an ED, drivers spent a full second longer looking away than drivers who were not using an ED. Although loud conversation and horseplay were also associated with a greater likelihood of looking away from the roadway, the difference was small (.25 second).

Distractions and potentially serious incidents

“Serious” incidents were defined as (1) a collision (n = 3 clips); (2) near collision with evasive maneuver by the young driver (n = 22); (3) near collision with evasive maneuver by other driver (n = 8); or (4) other (e.g., losing control or leaving the roadway, n = 19).

Table 5
Association of loud conversation and horseplay with passenger combination

	%	OR (95% CI)	CLR
Loud conversation			
One teenage peer	15.0	1.00 (reference)	
Two or more teenage peers	27.1	2.11 (1.62, 2.75)	1.69
One sibling	5.5	.33 (.21, .52)	2.48
Two or more siblings	8.9	.55 (.23, 1.33)	5.87
Teenage peer(s) and sibling(s)	18.5	1.29 (.82, 2.02)	2.46
Parent or other adult present	6.7	.41 (.26, .63)	2.42
Horseplay (mild or rough)			
One teenage peer	7.1	1.00 (reference)	
Two or more teenage peers	16.3	2.53 (1.73, 3.69)	2.13
One sibling	2.3	.30 (.16, .57)	3.56
Two or more siblings	7.4	1.04 (.29, 3.71)	12.79
Teenage peer(s) and sibling(s)	10.5	1.53 (.93, 2.52)	2.71
Parent or other adult present	1.8	.24 (.08, .71)	8.88

Loud conversation and horseplay were only coded when passengers were present, so a “no passenger” comparison was not possible. N = 2,716 clips.
CI = confidence interval; CLR = confidence limit ratio; OR = odds ratio.

Of the 7,858 driving clips, only 52 (.7%) involved a serious incident. These were equally common among males and females (.6% vs. .7%, respectively; OR = .91, 95% CI = .50, 1.66). The difference between high-school age siblings and target drivers was also small (.8% vs. .6%, respectively; OR = 1.29, 95% CI = .72, 2.32). Half (27/52) of the drivers had no serious incidents during the 6-month observation period, while seven drivers (13%) accounted for 58% of the serious incidents. Three of these had five incidents each.

Table 7 lists the relationship of serious incidents to distracted driver behaviors and distracting conditions. Drivers were approximately six times more likely to have a serious incident when there was loud conversation in the vehicle. Although horseplay was also associated with driving incidents, this relationship is too small, given the width of the CI, to be considered meaningful.

Another potential indicator of the seriousness of an event is the g-forces involved. We examined events triggered by acceleration, deceleration, left, and right turns separately. High g-force events were defined as those in the top 10% of the g-force distribution[5] and included (1) events triggered by acceleration (longitudinal g-force $\geq$ .49, n = 86 clips); (2) events triggered by deceleration (longitudinal g-force $\leq -.55$, n = 166); (3) events triggered by left turns (lateral g-force $\geq$ .59, n = 214); and (4) events triggered by right turns (lateral g-force $\geq$ .59, n = 226).

There was substantial, although far from perfect, correspondence between serious incidents and high g-force events. Of the 52 serious incidents, half (26) involved high g-forces. Unlike serious incidents, high g-force events were widely distributed across drivers. All but three drivers recorded at least one high g-force event. High g-force events were almost twice as common among males as among females (13.1% of clips vs. 6.9%, respectively; OR = 1.89, 95% CI = 1.64, 2.18), but the difference between high-school age siblings and target drivers was small (7.9% vs. 9.1%, respectively; OR = .88, 95% CI = .74, 1.03).

The relationship between high g-force events and distracted driver behaviors and distracting conditions is listed in Table 8. Horseplay was consistently associated with high g-force events, whether they were triggered by acceleration, deceleration, left, or right turns. High g-force decelerations were also more common when loud conversation was present. Driver ED use and other distracted driver behaviors were not strongly related to high g-forces. In fact, the general pattern was for high g-force events to be *less* common when drivers were using EDs or engaging in other distracted behaviors. In some cases, the CIs are fairly wide, suggesting the need for caution to avoid over-interpreting relatively unstable point estimates.

Discussion

This study is among the first to examine distracted driving among adolescents who were mostly in their initial 6 months of unsupervised driving, a time of extremely high crash risk. Perhaps the greatest value of the study lies in the simple descriptive information we were able to obtain about the many

[5] Selection of the top 10% represents a somewhat arbitrary cutoff. However, the cut points to identify these high g-force events are similar to those used in other studies to identify “safety relevant” events. For example, researchers at the University of Iowa have employed threshold settings of .50 g for longitudinal forces and .55 for lateral forces as part of an intervention to reduce safety-relevant driving errors among young drivers [31,35].

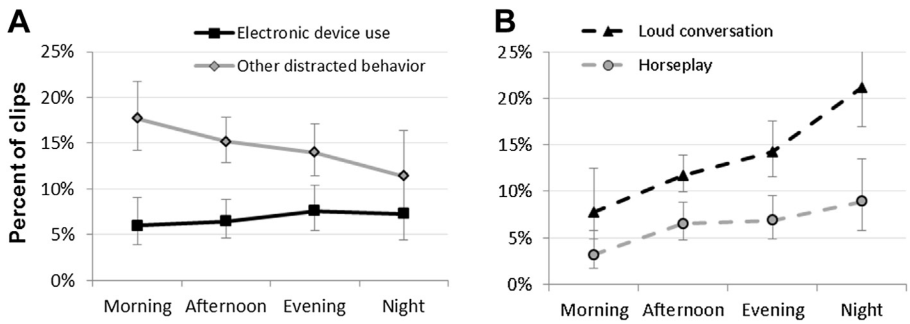

Figure 3. Distracted driver behaviors (A) and distracting conditions (B) by time of day. Note: other distracted driver behaviors include any of the following: adjusting controls, grooming, eating or drinking, reaching for object in vehicle, communicating with someone outside vehicle, turning around, or reading.

possible distracted driver behaviors and distracting conditions that exist in everyday driving for a sample of adolescents. Most of the distracted behaviors we examined were uncommon. ED use was the most frequent distracted behavior, followed closely by adjusting vehicle controls. Drivers looked away from the roadway for reasons apparently unrelated to driving in nearly half of all clips, but the duration of these glances was generally brief.

There was substantial individual variation in the frequency of distracted driving behaviors, especially ED use. This pattern—wherein a small subset of drivers accounts for a disproportionate share of problems—is routinely found for many problematic behaviors. Studies that measure young driver vehicle kinematics show the same pattern [31,35]. Despite the well-established nature of this general phenomenon, it has received little attention in efforts to address young driver crashes [36]. Most jurisdictions in the United States, Canada, and Australia have implemented most of the known effective policies focused on the entire young, novice driver population. Although some small policy improvements are still possible, attention to interventions that might address particularly problematic behaviors among a small subset of young drivers will likely be increasingly important if we are to further reduce adolescent driver crashes. Additional naturalistic studies to further document driver behaviors are needed to guide decisions about behaviors to target in such efforts.

By examining both auditory and visual information from inside the passenger compartment, we were able to obtain some sense of the nature and prevalence of the “craziness” adolescents are suspected of exhibiting, especially when there are multiple passengers. We did identify two indicators of conditions in the vehicle—loud conversation and horseplay—that are worrisome. They occurred with low, but nontrivial frequency and clearly indicate a degree of rowdiness or chaos in the vehicle that could be quite distracting to any driver, regardless of experience or age. Both these conditions were much more common when there were

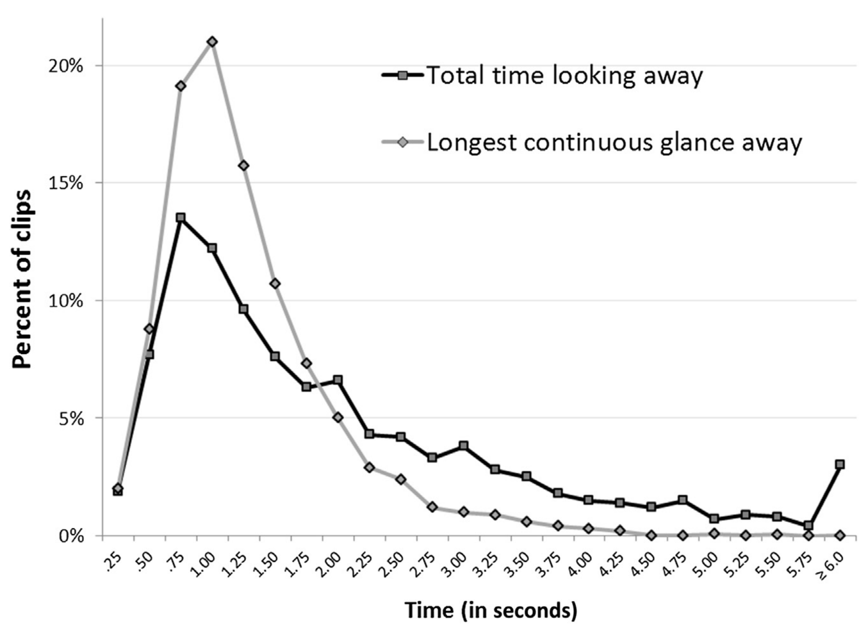

Figure 4. Longest continuous glance and total amount of time drivers looked away from the roadway during 10 seconds prior to the vehicle motion that triggered recording (among drivers who looked away).

Table 6
Association of driver ED use, other distracted driver behaviors, loud conversation and horseplay with looking away from the roadway

	Percent of clips driver looked away	OR (95% CI)	Median seconds looking away[b]	Mann–Whitney *U* Test
Driver ED use				
No	29.3	1.00 (reference)	1.50	$p < .001$
Yes	70.7	2.97 (2.43, 3.62)	2.50	
Other distracted driver behaviors[a]				
No	32.5	1.00 (reference)	1.50	$p < .001$
Yes	67.5	2.56 (2.27, 2.88)	2.25	
Loud conversation				
No	45.9	1.00 (reference)	1.50	$p < .01$
Yes	54.1	1.35 (1.07, 1.70)	1.75	
Horseplay (mild or rough)				
No	36.7	1.00 (reference)	1.50	$p = .058$
Yes	63.3	1.98 (1.40, 2.82)	1.75	

N = 7,858. In some cases, data are missing due to darkness of the clip or other circumstances that prevented clear determination of where the driver was looking.
CI = confidence interval; ED = electronic device; OR = odds ratio.
[a] Other distracted driver behaviors include one or more of the following: adjusting controls, grooming, eating or drinking, reaching for object in vehicle, communicating with someone outside vehicle, turning around, or reading.
[b] Among those who looked away.

multiple peers in the vehicle. Additionally, both were strongly associated with the occurrence of serious incidents and, to a lesser extent, high g-force events. In contrast, ED use and several other distracted driver behaviors were most common when young drivers carried no passengers. Hence, although the presence of multiple peers sometimes creates a degree of chaos in the vehicle that can lead to dangerous incidents, it appears passenger presence is associated with reduced frequency of other types of distracted driver behaviors.

Previous naturalistic driving research has identified looking away from the roadway for >2 seconds to be a highly risky driver behavior [37]. This is hardly surprising. No matter how experienced or skilled, a driver is completely helpless to deal with anything in the driving environment that is not seen and has less time to respond to something seen late. Looking away from the road for notably long periods was relatively rare in this study, but it was strongly associated with ED use and other distracted driver behaviors. Hence the present findings may help identify a mechanism by which various distractions increase crash risk—by taking the eyes, and not merely the brain, away from the driving task.

Serious incidents—crashes or incidents requiring an evasive maneuver—were observed in less than 1% of all clips, and ED use was only weakly related to the occurrence of serious incidents. Interestingly, conditions inside the vehicle that might be distracting (loud conversation and horseplay) were more strongly related to the occurrence of serious incidents than were actual distracted behaviors (e.g., adjusting controls and eating). The latter would seem more causally proximate to an incident. This finding may indicate that cognitive overload, which cannot be observed, is the more serious concern for young, largely inexperienced drivers. The general pattern of findings here appears to suggest that behaviors over which drivers can exert some conscious control—deciding when or whether to attend to an ED, adjust a dashboard control, reach for an object in the vehicle, or look away from the roadway—are not nearly so strongly associated with the occurrence of a dangerous incident as the presence of conditions in the vehicle that seem likely to reduce attention or increase the cognitive load for a driver. The small sample size here argues for caution in this interpretation, but this seems an important line of inquiry for future research.

Finally, the different pattern of results observed for serious incidents and high g-force events is noteworthy. The latter are more easily obtained and analyzed in naturalistic driving studies, requiring no human coder involvement to characterize them. Nonetheless, in view of the different associations of distractions with serious events and high g-force events, it would seem imprudent to focus future research attention too heavily on vehicle kinematics alone. Lacking substantial information about context, which presently can be extracted only by human coders looking at visual evidence, g-force data alone provide an unnecessarily limited measure of (young) driver behavior. A naturalistic study of hard braking by inexperienced adolescent drivers in conjunction with characteristics of their passengers nicely illustrates this point [18]. The vast majority of hard braking incidents were judged to have resulted from driver misjudgment, with only a small fraction resulting from distraction—a distinction that could not have been made from kinematic data alone.

Strengths and limitations

The main advantage of naturalistic driving studies, including the present one, is the opportunity to directly see, hear, and measure both driver and passenger behaviors with a level of precision that is impossible with any other approach. In-vehicle technologies also provide quantitative measures of vehicle movement in conjunction with information about driver and passenger behaviors as well as the driving context. When video and audio data from the passenger compartment are combined with vehicle kinematic information, it is possible to obtain a clear sense of the situation immediately preceding critical driving events. Such comprehensive, situation-specific information is unique in the history of research on driving. Despite the great advance in measurement capabilities afforded by DriveCams, the version used here sometimes did not provide good interior views in dark conditions and we could not see the driver's lap.

Because instrumenting vehicles is logistically complex and costly, these studies invariably involve relatively small samples, typically from a limited geographic area. As a consequence, parameter estimates are less stable, and there are concerns about the representativeness of drivers who participate. The present study included a disproportionate number of females and families of higher socioeconomic status [15]. However, neither a low participation rate nor a demographically atypical sample is, of itself, necessarily an indicator of important sample bias, as is often assumed [38]. The key issue for the present study is whether those who participated were more (or less) likely to engage in distracted driving behaviors or be exposed to distracting conditions than the general adolescent driving population. In this respect, it is somewhat reassuring that the frequency and patterns of ED use were similar to what has been found previously in large observational studies [24,31]. Nonetheless, the small sample is the single greatest limitation of this study and indicates particular caution in generalizing findings about, or which might be strongly associated with, characteristics of individual drivers.

Another concern is whether vehicle instrumentation may influence participant behavior. Although such reactivity cannot be

Table 7
Association of driver ED use, other distracted driver behaviors, loud conversation and horseplay with serious incidents

	Percent of clips with serious incident	OR (95% CI)	CLR
Driver ED use			
No	.6	1.00 (reference)	
Yes	1.2	1.85 (.79, 4.33)	5.48
Other distracted driver behaviors[a]			
No	.7	1.00 (reference)	
Yes	.7	1.00 (.47, 2.12)	4.51
Loud conversation			
No	.6	1.00 (reference)	
Yes	3.6	5.95 (2.79, 12.82)	4.63
Horseplay (mild or rough)			
No	.9	1.00 (reference)	
Yes	2.4	2.71 (.94, 7.75)	8.24

N = 7,858 clips.
CI = confidence interval; CLR = confidence limit ratio; ED = electronic device; OR = odds ratio.
[a] Other distracted driver behaviors include one or more of the following: adjusting controls, grooming, eating or drinking, reaching for object in vehicle, communicating with someone outside vehicle, turning around, or reading.

ruled out in the present study, several factors reduce this concern. First, study participants had driven with a camera in the vehicle during the supervised driving period; hence, the adolescent drivers and their siblings had a lengthy period to become acclimated to the camera prior to the present data collection. Second, there was no visible indication of when, or whether, the cameras were recording. Third, participants were told at the beginning of the study, they would not receive any feedback based on the recorded information, and none was provided. Finally, a recent study found that even direct feedback from a camera did not influence adolescent driving behaviors (high g-force events [32]).

The most likely influence of a camera in the vehicle would be avoidance of certain kinds of trips (e.g., driving in violation of a limit on multiple passengers) rather than an effect on specific instantaneous behaviors while in the vehicle (e.g., reading a text message or engaging in horseplay). The latter are likely far more responsive to the salient behavior-inducing cues (a smart phone tone announcing a message and passenger actions) than to the presence of a camera. Finally, other studies employing vehicles with extensive instrumentation to measure driver and vehicle behavior have generally shown that drivers acclimate to the devices relatively quickly and begin driving "normally" within a few days [37].

A final concern is whether the distractions and distracted behaviors observed in the present study can be considered representative of those to be found in "normal" driving, given that data were obtained through triggered sampling instead of continuous measurement. The data examined here clearly do not reflect a truly random sample of driving as they generally occurred in the vicinity of intersections, where vehicle movements that would trigger recording (e.g., stopping and turning) are more common. However, intersections are ubiquitous and include private driveways, parking lot entrances, merges as well as locations where roadways intersect. Hence, in all but the most rural driving environments, a large proportion of all driving takes place near intersections. Although some of the recorded clips involved atypically noteworthy "incidents," the large majority of them were, by design, triggered by vehicle movements so minor that occupants would not have noticed anything unusual [15].

The primary value of this exploratory study is in documenting, for the first time, the extent to which the many possible distractions for young drivers occur. This along with the few apparent relationships between distractions/distracted driving and measures of risk (eyes off road, serious incident and high g-force event) provides information that should prove useful to the design of future studies to better understand adolescent driver distractions and related risks. The findings reported here are much too preliminary to provide guidance for program or policy development.

Table 8
Association of driver ED use, other distracted driver behavior, loud conversation and horseplay with events involving high g-forces

	Clips triggered by acceleration (N = 727)			Clips triggered by deceleration (N = 1,565)			Clips triggered by left turns (N = 2,151)			Clips triggered by right turns (N = 1,966)		
	Percent of clips with high g-force	OR (95% CI)	CLR	Percent of clips with high g-force	OR (95% CI)	CLR	Percent of clips with high g-force	OR (95% CI)	CLR	Percent of clips with high g-force	OR (95% CI)	CLR
Driver ED use												
No	11.9	1.00 (ref)	5.57	10.8	1.00 (ref)	3.38	10.0	1.00 (ref)	2.90	11.8	1.00 (ref)	3.83
Yes	9.8	.83 (.35, 1.95)		7.9	.73 (.40, 1.35)		10.6	1.06 (.62, 1.80)		7.1	.60 (.31, 1.19)	
Other distracted driver behaviors[a]												
No	11.2	1.00 (ref)	2.66	10.7	1.00 (ref)	2.31	10.0	1.00 (ref)	2.08	11.6	1.00 (ref)	2.13
Yes	15.2	1.36 (.83, 2.21)		9.6	.89 (.59, 1.36)		9.6	.95 (.66, 1.37)		10.9	.94 (.64, 1.36)	
Loud conversation												
No	12.4	1.00 (ref)	4.67	9.3	1.00 (ref)	2.51	8.6	1.00 (ref)	3.18	10.6	1.00 (ref)	3.64
Yes	17.9	1.44 (.67, 3.13)		25.3	2.71 (1.71, 4.29)		14.5	1.67 (.94, 2.99)		14.5	1.37 (.72, 2.62)	
Horseplay (mild or rough)												
No	11.6	1.00 (ref)	4.04	10.6	1.00 (ref)	3.06	8.7	1.00 (ref)	3.80	10.2	1.00 (ref)	3.97
Yes	29.6	2.55 (1.27, 5.13)		22.6	2.13 (1.22, 3.73)		19.5	2.24 (1.15, 4.37)		23.3	2.29 (1.15, 4.57)	

CI = confidence interval; CLR = confidence limit ratio; ED = electronic device; OR = odds ratio; ref = reference.
[a] Other distracted driver behaviors include any of the following: adjusting controls, grooming, eating or drinking, reaching for object in vehicle, communicating with someone outside vehicle, turning around, or reading.

Supplementary Data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jadohealth.2014.01.005

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