Driver Distraction in Commercial Vehicle Operations

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ABSTRACT

The purpose of this study was to investigate the prevalence of driver distraction in commercial motor vehicle safety-critical events (e.g., crashes, near-crashes). Safety-critical events, recorded in a naturalistic data set that included over 200 drivers and 3 million miles of data, were analyzed. Key findings were that drivers were engaged in tertiary (non-driving related) tasks in 71 percent of crashes, 46 percent of near-crashes and 60 percent of all safety-critical events. Tasks that significantly increased risk included texting, interacting with a dispatching device, and dialing a cell phone. Eye glance analyses found that tasks that drew the driver's eyes away from the forward road were those with significantly elevated risk.

KEY WORDS
Commercial motor vehicle, truck, distraction, texting, cell phone, naturalistic data

INTRODUCTION

Up until 2006, it was widely believed that "driver distraction" was a contributing factor in as many as 30 percent of all crashes (e.g., [1]). The basis for this belief was that crash databases (comprised of police accident reports), were the primary data source for understanding pre-crash driver behavior. In 2006, a report was released that detailed a "naturalistic driving study," conducted with 100 light vehicles, which substantially impacted the scientific community's understanding of driver distraction [2]. Called the "100-Car Study", 100 light-vehicles were instrumented with a vast array of data collection sensors and video cameras, including cameras to record the driver's face and eye glance patterns and to capture driver behavior and driving performance before, during, and after crashes. This landmark study found that driving inattention was present in 78 percent of crashes; far more than the 30 percent that was previously believed to be the case.

Consider that with crash databases, based on police accident reports, the investigating officer, however well-trained and well-meaning, may not indicate "driver distraction" or "driver inattention" on the accident report form unless these factors are indicated by the driver or an eyewitness. As such, the crash database approach may greatly underestimate, for example, where

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drivers are looking immediately prior to crash occurrence. As found in the 100-Car Study, in most cases, the driver was either engaged in a non-driving task (e.g., reaching for an object, dialing a cell phone) and/or not looking at the roadway immediately before the crash unfolded. Arguably, the only way to obtain a clear understanding of what non-driving tasks drivers engage in or where driver's look before a crash occurs is from naturalistic driving studies where cameras continuously record the driver's face and eye glance movements creating an "instant replay" of the event.

Much of the previous research on "driver distraction" has been directed at light-vehicle drivers. As such, the impact of driver distraction in commercial motor vehicle (CMV) crashes is not well understood. Transport crashes involving CMVs is a significant problem. Recently published U.S. crash data indicates that 12 percent (4,808) of the 41,059 traffic-related fatalities in 2007 involved large trucks. Though this represents a net decrease in fatalities, down 7.5 percent from 1998 to 2007, CMV crashes account for far too many deaths on U.S. roads. Based on previous research, it is well-understood that "driver factors" are by far the most prominent contributing factor in traffic crashes [3, 4].

Driver distraction, the focus of the current study, is one type of driver factor (or "driver error"). As noted, information related to the impact of driver distraction on CMV critical events is unclear. Klauer et al. [2] described prior research using naturalistic data from light vehicles to investigate the issue of driver distraction; however, there is a paucity of research directed at investigating this issue in commercial vehicle operations (CVO). The objective of the current study was to fill this gap using data from two recently completed naturalistic CMV studies. These two CMV studies provided a large, naturalistic data set that allowed researchers to study pre-critical event driver behavior and assess the impact that driver distraction has on critical event occurrence.

What is Driver Distraction?

Before outlining the method used to assess "driver distraction" in CVO for this study, it is important to first define what is meant by "driver distraction." Though many researchers have presented variations of definitions (e.g., [5, 6, 7]), Pettitt, Burnett and Stevens [8] developed a comprehensive definition that accounts for four key components of distraction. Pettitt, Burnett, and Stevens [8] indicated that driver distraction occurs:

- When a driver is delayed in the recognition of information necessary to safely maintain the lateral and longitudinal control of the vehicle (the driving task) **(Impact)**

- Due to some event, activity, object or person, within or outside the vehicle **(Agent)**

- That compels or tends to induce the driver's shifting attention away from fundamental driving tasks **(Mechanism)**

- By compromising the driver's auditory, biomechanical, cognitive or visual faculties, or combinations thereof **(Type)** (Pettitt, Burnett, and Stevens [8]; p. 11).

A study by Hanowski, Perez and Dingus [9] provided an approach to identifying driver distraction that could be implemented in the analysis of naturalistic driving data. In addition, Hanowski, Perez and Dingus [9] developed a taxonomy of secondary/tertiary tasks by analyzing naturalistic critical incident data. To accomplish this, video of critical incidents collected during a naturalistic heavy-vehicle study were reviewed to determine what behaviors the driver engaged in prior to the occurrence of a critical incident. These behaviors reflect the *Agents* and underlying *Mechanisms*, as described by Pettitt, Burnett, and Stevens [8], that can distract and lead to a safety-critical event (or *Impact*).

In the current study, safety-critical events (*Impact*) and baseline (normative driving) epochs were filtered from a continuous CMV naturalistic data set and reviewed to look for potential distractions (*Agents*). Because the data set included video of the driver, biomechanical and visual distraction was the *Type* of distraction evaluated. As there was no audio with the video recording, auditory distraction could not be investigated. In addition, as described later, though it may be possible to investigate cognitive distraction, it was not considered in the current study.

CMV Naturalistic Data Sets

To investigate driver distraction in CVO, data were analyzed from two large-scale naturalistic truck driving studies. Naturalistic data collection is a method used to study driver behavior and performance by installing sensors and video cameras in trucks and providing these vehicles to drivers to use as part of their normal revenue-producing deliveries. For the current analyses, two naturalistic CMV data sets were combined. One data set was collected in a field operational test of a drowsy driver warning system [10] while the second data set was collected in the Naturalistic Truck Driving Study (NTDS) [11]. In Hanowski et al. [10], 103 CMV drivers operated in-service fleet trucks, on average for 12 weeks per driver. In Blanco et al. [11], 100 CMV drivers participated, each using a data collection truck for approximately 4 weeks. Taken together, these data sets represent 203 CMV drivers, 55 instrumented trucks, seven trucking fleets, and 16 fleet locations. In terms of data, the data set used includes approximately 3 million miles of continuously collected kinematic and video data, and represents (currently) the most comprehensive naturalistic CMV driving set in the world.

In both naturalistic studies, data were collected “continuously;” that is data were recorded and saved whenever the truck was on and in motion. This resulted in very large data sets that primarily included normative (non-event) driving. However, as will be defined later, crashes, near-crashes, crash-relevant conflicts, and unintentional lane deviations were also recorded.

Though the findings from crash database analyses have shaped our understanding on the impact of driver error on crash causation, there are obvious benefits of naturalistic data collection that cannot be obtained through traditional database analysis. The foremost benefit is the inclusion of video cameras that record video of the driver’s face and video of the driving scene. Figure 1 shows a split-screen image comprised of five camera views used in the NTDS. Camera views are synched with the sensor data to provide kinematic data along with the video. This combination of kinematic and video data allows researchers to determine pre-event (e.g., crash) behavior (e.g., driver inputs, eye glance locations) in developing a comprehensive picture of the contributing factors associated with the event. As noted, the video provides an "instant replay" of the event providing substantive, and replayable, data in which to evaluate the event. Unlike site investigations which must rely on driver and eye-witness testimony, along with engineering site evaluations, the video and sensor/kinematic data recorded in naturalistic studies tends to provide a clear understanding as to *why* the event occurred.

Figure 1. Split-Screen Presentation of the Five Camera Views Used in the NTDS. Driver shown is an employee of the Virginia Tech Transportation Institute.

Research Questions

As noted, much of the previous research on "driver distraction" has focused on light-vehicle drivers. The present study investigated driver distraction with CMV drivers. Though the naturalistic data set is rich and many analyses and research questions can be investigated, this paper is focused on two distraction-related questions: (i) what types of distraction tasks/behaviors to CMV drivers engage in and do they increase risk? and (ii) what is the impact of distraction tasks/behaviors on drawing the driver's eyes away from the forward roadway?

METHOD

As noted, data to conduct this analysis were collected in two naturalistic CMV studies. An algorithm was developed to scan through the 3 million miles of driving data and identify potential safety-critical events. Safety-critical events were defined as crashes, near-crashes, crash-relevant conflicts, and unintentional lane deviations. Crashes involve contact with an object; near-crashes are events that required a rapid evasive maneuver by one of the parties involved; crash-relevant conflicts are similar to near-crashes, though the severity of the evasive maneuver is less than that in a near-crash; and unintentional lane deviations involve drifting outside of the driving lane. Sensor trigger values for safety-critical events are shown in table 1. As shown, the key triggers used to identify safety-critical events were longitudinal acceleration (e.g., hard braking), time-to-collision, swerve, and lane deviation. In addition, a button near the dash was available for the driver to self-initiate an event flag.

Table 1. Algorithm metrics and values used to identify potential safety-critical events

Trigger Type	Trigger Values Used in the Current Study
Longitudinal Acceleration	Deceleration greater than or equal to $\lvert 0.20\ g \rvert$. Speed greater than or equal to 1 mph (1.6 km/h).
Time-to-Collision	A forward TTC value of less than or equal to 2 s, coupled with a range of less than or equal to 250 ft, a target speed of greater than or equal to 5 mph (8 km/h), a gyro rate of less than or equal to $\lvert 6°/s \rvert$, and an azimuth of less than or equal to $\lvert 0.12° \rvert$.
Swerve	Swerve value of greater than or equal to 2 rad/s^2. Speed greater than or equal to 5 mph (8.05 km/h).
Lane Deviation	Lane tracker status = abort. Distance from center of lane to outside of lane line < 44 in.

Potential safety-critical events that were electronically identified were then subjected to video review to determine the validity of the event. That is, using video, a determination was made as to whether the potential safety-critical event was, in fact, a valid event and not the result of a spurious sensor reading or a non-event situation (e.g., hitting a bump in the road). This process resulted in 4,452 safety-critical events comprised of 21 crashes, 197 near-crashes, 3,019 crash-relevant conflicts, and 1,215 unintentional lane deviations. In order to conduct the planned analyses, a baseline data set of non-event (normative driver) was also developed. Random selection of the continuous data was conducted with driver's driving time (exposure) factoring into the number of baselines included for each driver. As such, the 203 drivers that took part in the two naturalistic studies were equally represented in the baseline data set as a function of the time (exposure) they spent in the study. The baseline data set was comprised of 19,888 normative driving epochs.

All of the safety-critical event data and the non-event data were reviewed (including video review) and characterized in terms of potential contributing factors. Following the method used in the 100-Car Study [2], a 6-s time window was used (5 s prior to the precipitating factor and 1 s after) for the characterization. This characterization included the video analyst documenting tasks and behaviors that were "secondary" or "tertiary" to the driving task [12]. Secondary tasks were defined as being related to the (primary) driving task (e.g., turn signal use), but not necessary to keeping the vehicle on course. Tertiary tasks are extraneous tasks (e.g., cell phone use, eating) that are not related to driving.

Eye glance analysis was conducted on all safety-critical events and baseline epochs to determine, within the 6-s window, where the driver was looking. Because of the placement of the cameras, it was difficult to distinguish between outside mirror glances and side window glances. As such, though each 1/10th of a second video frame was evaluated for location, locations were "collapsed" and the analysis was directed at the duration of time, with the 6-s window, the driver was looking forward versus not forward.

RESULTS

The results are grouped into three sections. First, a general overview of the impact of driver distraction in CVO is presented. Second, tasks that were found to be particularly high risk are described. And third, the results of the eye glance analysis are highlighted which provide a potential reason for *why* certain tasks were high risk.

Distraction as a Contributing Factor in Safety-Critical Events

Using the method outlined in the 100-Car Study [2], of the 4,452 safety-critical events, 100 percent of crashes and 81.5 percent of all events had some type of driver distraction listed as a potential contributing factor. Note that the approach used by Klauer et al. [2] considered *any* eye glance away from the forward roadway as a distraction (including glances to the side mirrors). Including mirror checks as a distraction type, particularly for CMV drivers, was not believed to be appropriate since truck drivers are taught to frequently check their mirrors [13]. Including mirror checks would, in effect, inflate the percentages and thus may not truly reflect the impact of "driver distraction."

A follow-up analysis was conducted that only included tertiary task distraction; that is, the occurrence of safety-critical events where the driver was engaged in a non-driving related task. The results from this analysis are shown in table 2. As shown, driver distraction due to non-driving related tertiary tasks was a contributing factor in 71 percent of all crashes, 46 percent of all near-crashes and 60 percent of all events. Klauer et al. [2] did not distinguish between secondary and tertiary tasks in the 100-Car Study, so no tertiary task-only comparison can be made with the light-vehicle data. However, table 2 may capture the effects of "driver distraction" as most people think of it. That is, the events in table 2 represent all non-driving related activities such as using a cell-phone, texting, eating, etc.

Table 2. Percentage of any tertiary tasks in 'all' and 'vehicle 1 at-fault' events

Event Type	All Safety-Critical Events	Number and Percent of All Safety Critical Events	All Vehicle 1 At-Fault Events	Number and Percent of All Vehicle 1 At-Fault Events
All safety-critical events	59.9%	n= 4,452 (100.0%)	63.9%	n= 3,618 (100.0%)
Crashes	71.4%	n= 21 (0.5%)	40.0%	n= 10 (0.3%)
Near-crashes	46.2%	n= 197 (4.4%)	50.0%	n= 112 (3.1%)
Crash-relevant conflicts	53.6%	n= 3,019 (67.8%)	57.4%	n= 2,281 (63.0%)
Unintentional lane deviations	77.5%	n= 1,215 (27.3%)	77.5%	n= 1,215 (33.6%)
Baseline epochs	56.5%	n= 19,888 (100.0%)	56.5%	n= 19,888 (100.0%)

Specific Driver Tasks and Behaviors

Odds ratios (OR) were calculated to approximate relative safety-critical event risk compared to normal, baseline driving for various driver tasks. The OR is a way of comparing the odds of some outcome (e.g., a crash) occurring given the presence of some predictor factor, condition, or classification (e.g., CB use). In order to determine if an odds ratio is significant, a 95 percent confidence interval was calculated, including the upper and lower confidence limits (UCL and LCL).

Table 3 shows the results of the odds ratio analysis. Tertiary tasks were grouped as being “complex”, “moderate” or “simple” using definitions provided by Klauer et al. [2] and Dingus, Antin, Hulse, and Wierwille [14] and refer to the number of eye glances and/or steps/button presses required to complete the task. As can be seen, engaging in any, and all, of the complex tertiary tasks increased the risk of being involved in a safety-critical event when compared to baseline epoch. While most of the tasks listed in table 3 are self-evident from their title (e.g., text messaging on a cell phone), some of the tasks may not be as obvious. Examples of personal grooming included a driver shaving his head with an electric razor and drivers brushing their hair with a comb or brush; an example of use/reach for other electronic device included reaching for or using a video camera.

A few highlights from table 3 are that texting presented the most significant safety risk. Drivers were 23.2 times more likely to be involved in a safety-critical event while text messaging. Using a dispatching device increased risk significantly by 9.9 times, while writing, using a calculator, looking at a map, dialing a cell phone, and reading significantly increased risk by 9.0, 8.2, 7.0, 5.9, and 4.0, respectively.

An interesting finding from the analyses was the result for cell phone use. Though reaching for or dialing a cell phone was indicated to be a high-risk task, talking or listening on a hand-held phone was found to have an odds ratio that was not significantly different than one “1.0” (thus, it did not elevate the likelihood of being involved in a safety-critical event). Furthermore, talking or listening on a hands-free phone provided a significant protective effect (OR = 0.4). That is, tasks that had an OR less than “1.0” (and a UCL of less than “1.0”) indicated that engaging in the task or behavior provided a safety benefit. A similar significant protective effect was found for using a CB radio (OR = 0.6).

Table 3. Odds ratios and population attributable risk percentages, with 95% confidence intervals. Significant odds ratios are bold.

	Task	OR	LCL	UCL	PAR%	LCL	UCL
Complex Tertiary Task	Text message on cell phone	**23.24**	9.69	55.73	0.67	0.29	1.04
	Other – Complex *(e.g., cleaning side mirror, rummaging through grocery bag)*	**10.07**	3.10	32.71	0.18	-0.99	1.35
	Interact with/look at dispatching device	**9.93**	7.49	13.16	3.13	2.84	3.42
	Write on pad, notebook, etc.	**8.98**	4.73	17.08	0.56	-0.16	1.28
	Use calculator	**8.21**	3.03	22.21	0.22	-1.00	1.43
	Look at map	**7.02**	4.62	10.69	1.08	0.48	1.68
	Dial cell phone	**5.93**	4.57	7.69	2.46	2.02	2.91
	Read book, newspaper, paperwork, etc.	**3.97**	3.02	5.22	1.65	0.96	2.34
Moderate Tertiary Task	Use/reach for other electronic device	**6.72**	2.74	16.44	0.23	-1.10	1.56
	Other – Moderate *(e.g., opening bottle to take medicine, exercising in cab)*	**5.86**	2.84	12.07	0.32	-0.92	1.55
	Personal grooming	**4.48**	2.01	9.97	0.21	-1.58	2.00
	Reach for object in vehicle	**3.09**	2.75	3.48	7.64	7.27	8.02
	Look back in Sleeper Berth	**2.30**	1.30	4.07	0.23	-2.24	2.70
	Talk or listen to hand-held phone	1.04	0.89	1.22	0.18	-1.29	1.64
	Eating	1.01	0.83	1.21	0.02	-1.80	1.83
	Smoking-related behavior – lighting, extinguishing	**0.60**	0.40	0.89	.	.	.
	Talk or listen to CB microphone	**0.55**	0.41	0.75	.	.	.
	Look at outside vehicle, animal, person, object	**0.54**	0.50	0.60	.	.	.
	Talk or listen to hands-free phone	**0.44**	0.35	0.55	.	.	.
Simple Tertiary Task	Put on/remove/adjust sunglasses or reading glasses	**3.63**	2.37	5.58	0.62	-0.56	1.80
	Adjust instrument panel	**1.25**	1.06	1.47	0.82	-0.47	2.11
	Remove/adjust jewelry	1.68	0.44	6.32	0.03	-7.89	7.95
	Other – Simple *(e.g., opening and closing driver's door)*	2.23	0.41	12.20	0.02	-7.57	7.62
	Put on/remove/adjust hat	1.31	0.69	2.49	0.06	-4.85	4.98
	Use chewing tobacco	1.02	0.51	2.02	0.00	-6.75	6.76
	Put on/remove/adjust seat belt	1.26	0.60	2.64	0.04	-5.84	5.92
	Talk/sing/dance with no indication of passenger	1.05	0.90	1.22	0.23	-1.12	1.59
	Smoking-related behavior – cigarette in hand or mouth	0.97	0.82	1.14	.	.	.
	Drink from a container	0.97	0.72	1.30	.	.	.
	Other personal hygiene	**0.67**	0.59	0.75	.	.	.
	Bite nails/cuticles	**0.45**	0.28	0.73	.	.	.
	Interact with or look at other occupant(s)	**0.35**	0.22	0.55	.	.	.
Secondary Task	Look at left-side mirror/out left window	**1.09**	1.01	1.17	2.25	1.77	2.75
	Look at right-side mirror/out right window	0.95	0.86	1.05	.	.	.
	Check speedometer	**0.32**	0.28	0.38	.	.	.

Population Risk for Distracting Tasks

Population Attributable Risk (PAR) was also calculated on all significant odds ratios and is defined as the "risk of disease in the total population (pt) minus the risk in the unexposed group (pu)" [15; p.205]. For each odds ratio with an outcome greater than "1.0", the percentage PAR was calculated. While the odds ratio is measured at the individual level, the PAR is measured at the population level. This analysis provided an assessment of the percentage of safety-critical events that are occurring in the population and that are directly attributable to the specific behavior measured. The PAR percentage is defined as the "proportion of the risk to the disease in the study population that is attributable to the exposure, and thus could be avoided by limiting the exposure to the risk factor" [15; p.205].

It is important to keep in mind that odds ratios only inform part of the story; which tasks increase the likelihood of involvement in a safety-critical event. The other part of the story considers the frequency of occurrence of each task. For example, tasks that are rare occurrences, even though they might be risky, may not have a significant impact on reducing crashes in the population. In addition to the OR results, table 3 shows the results from the PAR analysis for the tertiary and secondary tasks with an odds ratio greater than one "1.0." As shown, tasks are ordered from largest PAR percentage to smallest PAR percentage. Specific tasks with the largest PAR percentage included: reaching for an object (PAR = 7.6), interacting with a dispatching device (PAR = 3.1), and dialing a cell phone (PAR = 2.5). Why were the PAR percentages for these tasks greater than the other tasks? The reason was that they were commonly performed tasks. Text messaging, on the other hand, though it had a very high odds ratio, was a task performed infrequently by drivers in the current study, thus it does not have a high PAR percentage. However, this does not mean that it should be ignored. On the contrary, it suggests that as texting while driving becomes a more prevalent task, the frequency of safety-critical events is likely to increase.

Visual Demand for Distracting Tasks

The eye glance analyses that were conducted on the various tasks provided a compelling rationale for the findings in the odds ratio analysis. Put simply, tasks that draw the drivers eyes away from the forward roadway were those with high odds ratios. For example, as shown in Figure 2, texting, which had the highest odds ratio of 23.2, also had the longest duration of eyes off road time (4.6 s over a 6-s interval). This equates to a driver travelling the length of a football field, at 55 mph, without looking at the roadway. Other high visual attention tasks included those tasks that involved the driver interacting with technology: calculator (4.4 s), dispatching device (4.1 s), and cell phone dialing (3.8 s).

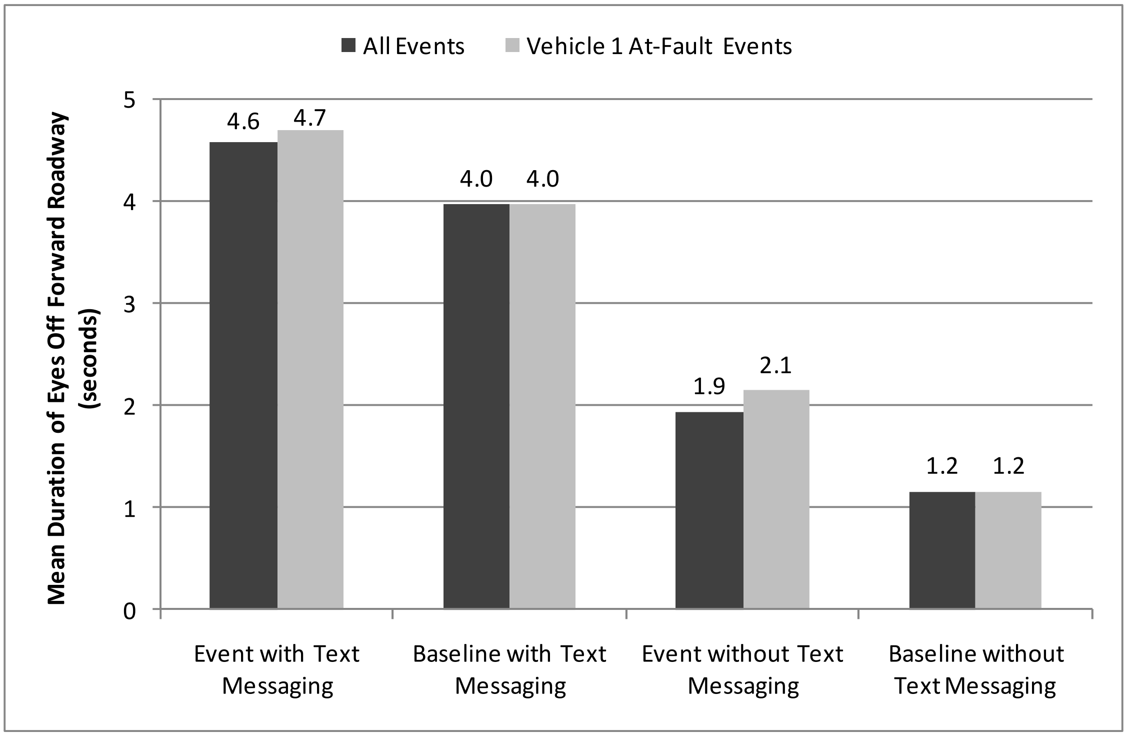

Figure 2. Mean duration of eyes off forward roadway for texting on cell phone

Technology-related tasks were not the only tasks with high visual demands. Non-technology tasks, including mundane or common activities, with high visual demands included: writing (4.2 s), reading a book/newspaper/other (4.3 s), looking at a map (3.9 s), and reaching for an object (2.9 s).

Just as tasks associated with high risk had associated high eyes off road times, tasks that did not have high odds ratios, or had protective effects, did not have significantly high eyes off road time. Figure 3 shows the shows the eye glance time for talk/listen to hands-free phone. Baselines (non-events) where the driver was talking/listening to a hands-free phone (1.0 s) had a significantly shorter mean duration of *eyes off forward roadway* than events without talk/listen to hands-free phone (2.0 s; $t_{(22617)} = 19.32$, $p < 0.0001$) and baselines without talk/listen to hands-free phone (1.2 s; $t_{(22617)} = 2.76$, $p = 0.030$). Collectively, considering the impact of mean glance duration on high-risk tasks and tasks that showed a protective effect, these findings suggest that the visual distraction associated with tasks is a key reason for the elevated risk.

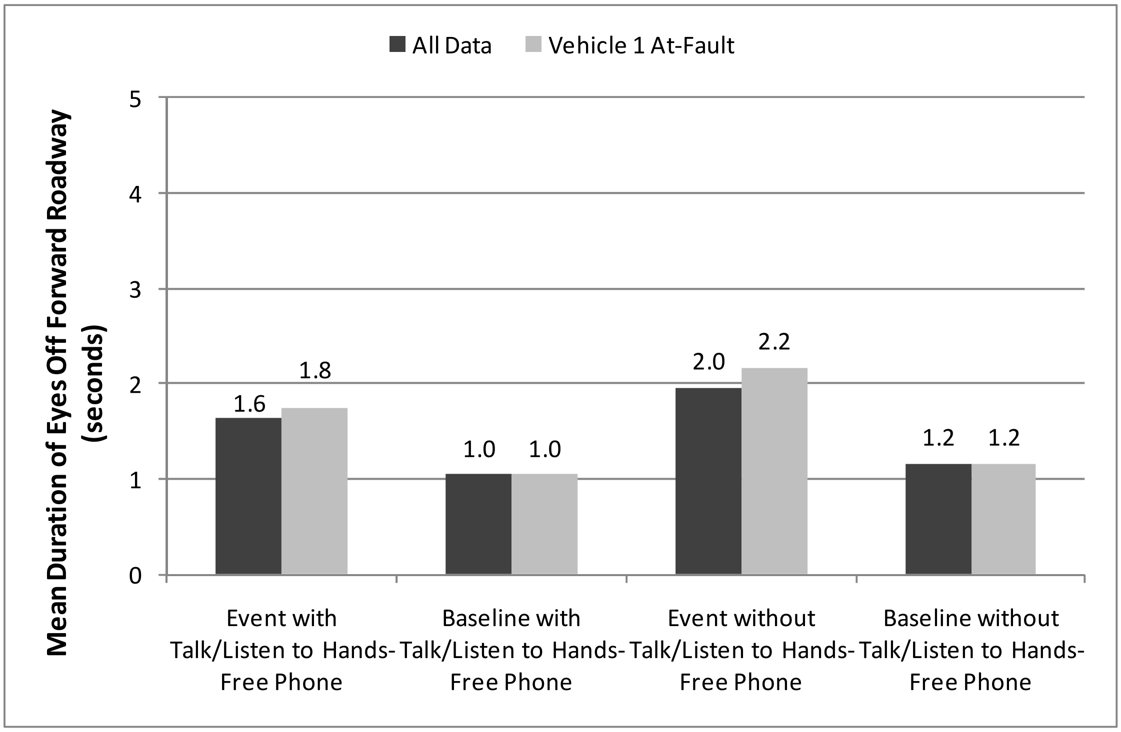

Figure 3. Mean duration of eyes off forward roadway for talk/listen to hands-free phone

SUMMARY AND CONCLUSIONS

The current study was directed at investigating behind-the-wheel distraction with CMV drivers. A key finding was that CMV driver distraction is a prevalent contributing factor in safety-critical events. When peeling out driving-related distractions (i.e., secondary tasks) and focusing only on non-driving related distraction (i.e., tertiary tasks), it was found that 71 percent of crashes, 46 percent of near-crashes, and 60 percent of all safety-critical events involved the driver engaging in a non-driving task just before the occurrence of the event. Though this does not mean that the distracting task or behavior necessarily *caused* the event, it is considered a potential contributing factor. In some cases, such as texting where during the performance of the task, the driver's eyes were off the forward roadway for, on average 77 percent of the studied time interval, there is strong evidence for causality. Nonetheless, the impact of driver distraction that was determined in the current evaluation is higher than previous crash report analyses have reported [1, 3, 4], albeit with light-vehicle drivers. One possible reason for this discrepancy is the video replay capability of the naturalistic method which allows researchers to determine, with greater precision, what drivers are doing behind the wheel. A second possible reason for the higher level of assessed driver distraction in this study is that the data set used was relatively current (through 2007) and included newer technologies (e.g., texting). A third possibility is that common tasks performed by CMV drivers in this study, such as using dispatching devices and calculators, are not (commonly) used by light-vehicle drivers.

A second important finding from this study was the assessment of specific tasks that were performed while driving and the impact that these tasks had on involvement in safety-critical events. Task associated with the highest risk (OR) also had high eyes off road durations. For example, texting, which had the dubious distinction of the highest OR at 23, also had the highest mean duration of eyes off road time of 4.6 s in a 6 s-window. Similarly, tasks that did not have high ORs also did not have high eyes off road durations; again, highlighting that driving is primarily a visual task and maintaining eyes forward is a key to avoiding safety-critical events [16].

A third key finding was the result for cell phone use. Reaching for or dialing a cell phone was determined to be a high-risk task. However, talking or listening on a hand-held phone did not elevate the likelihood of being involved in a safety-critical event; this finding was consistent with Klauer et al. [2]. In addition, talking or listening on a hands-free phone provided a significant *protective* effect (OR = 0.4), as did using a CB radio (OR = 0.6). It is noteworthy that recent empirical studies have shown benefits of hands-free phone interfaces [17, 18]. The findings regarding hands-free phones found in the current study may provide support for hands-free cell phone policies and regulations; as of June 2009, there are five states that banned hand-held cell phone use but allowed hands-free cell phone use; however, no state banned hands-free cell phone use [19].

The positive findings for "listening and talking" are consistent with results of two recent naturalistic studies with light-vehicle drivers. In the first study, protective effects were found for moderately complex tasks, which included talking/listening to handheld devices (F. Guo, personal communication, July 7, 2009). In the second study, when drivers were using a cell phone, they had improved speed variance (i.e., speeds changed more smoothly) and they maintained their eyes on the forward roadway [20]. One hypothesis to explain the results in the current study is that reaching for a phone and dialing a phone, like texting, requires manual manipulation (i.e., hand off wheel) and substantial visual attention to complete the task. This visual attention is directed away from the forward roadway such that the driver is not effectively, or safely, operating the CMV. Listening and talking, on the other hand, allows drivers to maintain their eyes on the road; however this hypothesis does not consider "gaze concentration" [21] and "cognitive distraction" which, as noted previously, has been associated with driving performance decrement [22, 23, 24, 25, 26, 27]. In addition, it could be that other performance decrements not assessed in this study (e.g., speed variability) may be affected by talking, though recent findings from an naturalistic study with light-vehicle drivers indicates that may not be the case [20]. The bottom line is that for real-world safety-critical events, defined as they were and recorded in the current study, talking on devices (including cell phones, both hand-held and hands-free, and CB radios) did not increase the risk of being involved in a safety-critical event.

As with any study, methodological limitations must be identified that may have affected the results and conclusions. First, because the data used in this study was collected naturalistically, and not in a controlled environment, the "cognitive distraction" effects of driver behaviors could not be easily determined. For instance, past research [22, 23, 24, 25, 26, 27] has found that cognitive demands impact the driver's ability to focus on the driving task while talking on a cell phone. In the current study, given the video camera placement, "visual distraction" and whether the driver was looking forward or not during task performance was more readily measurable than "cognitive distraction". It may be possible to investigate cognitive distraction in a follow-up data mining effort with this naturalistic data set by looking at changes (or decrements) in eye scanning behavior as a function of task performance. A reduction in normal scanning patterns may indicate “cognitive distraction”. However, based on research by Sayer, Devonshire and Flanagan [20], it should not be expected that findings from controlled studies will always be replicated in real-driving environments. For example, unlike the driving simulator studies referenced above, Sayer, Devonshire and Flanagan [20] found benign cell phone effects in a naturalistic study with light-vehicle drivers.

A second limitation of the current study was the lack of continuous audio data. While the results found that manual dialing was the riskiest part of using a cell phone (talking on a hand-held phone was not significantly risky and talking on a hands-free phone decreased the risk of being involved in a safety-critical event) it was not possible to analyze dialing a hands-free cell phone as audio data was not available to hear the driver use a voice-activated phone feature.

A third limitation of the current study is the small sample size of some of the individual distractions. While there were approximately 200 drivers and 3 million miles of driving, some distraction types were not frequent occurrences. Due to small sample sizes of some distractions, there were no statistical approaches that could be used to examine interactions (e.g., text messaging and raining). It is believed that as future CMV naturalistic studies are conducted and the naturalistic data set increases, there will be larger samples of distractions which may allow the ability to investigate interaction effects. While the current study resulted in many interesting findings, it is important that the reader keep these study limitations in mind.

Based on these study limitations, there are many additional follow-on efforts and analyses that could be conducted with this naturalistic CMV data set including, as noted, investigating the effects of cognitive distraction on cell phone conversations and other secondary/tertiary tasks. Additionally, future research could explore in more detail the impact of texting on the driving risk. For example, measures including task completion time, eyes-off-road time and hands-off-wheel-time (for the entire task) could be analyzed to provide a more complete picture of texting, along with other secondary and tertiary tasks, while driving.

The current study resulted in a number of important findings related to driver distraction and CMV driver safety. Because this was one of the first naturalistic studies focused on CMV driver distraction, it will be important to conduct follow-on research to assess the robustness of these findings. Many of the results were consistent with previous distraction studies with light-vehicle drivers [e.g., 2, 20]. However, there were some results which are novel to CMV operations (e.g., dispatching device use).

Finally, it is important to highlight that some results of the current study and other recent naturalistic driving studies [e.g., 2, 20] are at odds with results obtained from simulator studies [e.g., 22, 28] and future research should be conducted to explore the reasons why such studies often do not reflect studies conducted in actual driving conditions (i.e., the full context of the driving environment). It may be, as Sayer, Devonshire and Flanagan [20] note, that controlled investigations cannot account for driver choice behavior and risk perception as it actually occurs in real-world driving. If this assessment is accurate, the generalizability of simulator findings, at least in some cases, may be greatly limited outside of the simulated environment.

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