Distraction and Drowsiness in Motorcoach Drivers

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

November 2016

FOREWORD

The mission of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce crashes, injuries, and fatalities involving large trucks and buses. Agency research supports this FMCSA mission. The purpose of this study was to analyze naturalistic driving data collected from motorcoach drivers to investigate driver distraction and drowsiness. This study includes over 600,000 miles of data from 43 motorcoach vehicles and 65 drivers. This report includes a literature review on the motorcoach industry, a description of the methods used to collect, reduce, and analyze the data, and a discussion of the results and conclusions.

The intended audience is FMCSA and those who work in the commercial motor vehicle (CMV) industry. There were no previous printings of this document in its entirety.

NOTICE

QUALITY ASSURANCE STATEMENT

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FMCSA-RRR-15-017		

4. Title and Subtitle **Distraction and Drowsiness in Motorcoach Drivers**	5. Report Date **November 2016**
	6. Performing Organization Code
7. Author(s) **Hammond, Rebecca, L.; Hanowski, Richard, J.; Miller, Andrew, M.; Soccolich, Susan, A.; Farrell, Laura J.**	8. Performing Organization Report No.
9. Performing Organization Name and Address **Virginia Tech Transportation Institute** **3500 Transportation Research Plaza** **Blacksburg, Virginia 24061**	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address **U.S. Department of Transportation** **Federal Motor Carrier Safety Administration** **Office of Analysis, Research, and Technology** **1200 New Jersey Ave. SE** **Washington, DC 20590**	13. Type of Report and Period Covered **Final Report, September 2014–September 2015**
	14. Sponsoring Agency Code **FMCSA**

15. Supplementary Notes

Contracting Officer's Representative: Martin R. Walker

16. Abstract

Despite the large number of motorcoaches in the United States, there has been limited research on motorcoach operations. With more than 15 billion miles traveled per year and the transport of millions of people, crashes, when they occur, can involve multiple injuries and deaths. Driver error is often cited as a factor in these crashes, with distraction and drowsiness being primary concerns. The current study analyzed naturalistic driving data from two motorcoach fleets, 43 instrumented motorcoaches, and 65 drivers. Data analyzed for this study were collected from May 2013 to July 2014. The data set produced 1,086 valid safety critical events (SCEs) events, including 17 crashes. To support the analyses, 4,600 baseline epochs (normative driving) were identified and coded. Four sets of analyses focused on the following:

- **Secondary and driving-related task engagement.**
- **Environmental conditions.**
- **Eye glance analyses.**
- **Drowsiness.**

Task types with the highest risk (odds ratios) were: reaching for an object; external distractions; and a novel distraction for motorcoach drivers, intercom use. Very few SCEs were coded with high drowsiness. This study provides needed insight into motorcoach operations, but additional studies are needed to further investigate domain-specific issues.

17. Key Words	18. Distribution Statement
Motorcoach, bus, naturalistic driving, distraction, drowsiness	**No restrictions**

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	**Unclassified**	**147**	**N/A**

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

SI* (MODERN METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
		Length		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		Area		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	Acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		Volume (volumes greater than 1,000L shall be shown in m^3)		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		Mass		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		Temperature (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		Illumination		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
		Length		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		Area		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		Volume		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		Mass		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		Temperature (exact degrees)		
°C	Celsius	1.8c+32	Fahrenheit	°F
		Illumination		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force and Pressure or Stress		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003, Section 508-accessible version September 2009.)

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

Acronym	Definition
ANOVA	analysis of variance
CAN	controller area network
CMV	commercial motor vehicle
DAS	data acquisition system
DDWS	Drowsy Driver Warning System
FMCSA	Federal Motor Carrier Safety Administration
FOT	field operational test
GES	General Estimates System
GPS	global positioning system
HOS	hours of service
IMU	inertial measurement unit
LCL	lower confidence limit
LD	lane deviation
LOS	level of service
mi/h	miles per hour
NHTSA	National Highway Transportation Safety Administration
NTSB	National Transportation Safety Board
NTSC	National Television System Committee
NTDS	Naturalistic Truck Driving Study
OBMS	onboard monitoring system
OR	odds ratio
ORD	observer rating of drowsiness
PAR	population attributable risk
POV	personally owned vehicle
S	swerve
SAE	Society of Automotive Engineers
SCE	safety-critical event
SHRP	Strategic Highway Research Program

Acronym	Definition
TTC	time-to-collision
UCL	upper confidence limit
USB	universal serial bus
USDOT	U.S. Department of Transportation
V1	Vehicle 1 At-fault
VMT	vehicle miles traveled
VORAD	Vehicle Onboard Radar
Wi-Fi	wireless fidelity

EXECUTIVE SUMMARY

BACKGROUND

Motorcoach crashes—when they occur—can involve multiple injuries and deaths, beyond what is typically experienced in light vehicle crashes.[(1)] Driver error is often cited as a factor in these crashes, with distraction and drowsiness being primary concerns.[(2)] When compared to truck crashes, bus fatalities occur at a rate that is more than one-third higher than large truck fatalities per 100 million vehicle miles traveled (VMT).[(3)] Despite the large number of motorcoaches registered in the United States and the higher fatality rates associated with motorcoach crashes, very limited research has been conducted on motorcoach operations. The primary aim of this study was to investigate the impact that driver distraction and drowsiness have on motorcoach operations.

PROCESS

The current study used data from the recently completed Onboard Monitoring System (OBMS) Field Operational Test (FOT).[(4)] The OBMS FOT collected snippets of data using an OBMS. As part of the study method, the research team also installed a data acquisition system (DAS) in each vehicle in order to collect continuous, naturalistic data. The goal of the current study was to assess driver distraction and drowsiness in motorcoach drivers, following the analysis method employed by Olson et al., which assessed distraction and drowsiness in truck drivers.[(5)]

Two motorcoach fleets (Fleets A and B) participated in the OBMS FOT. While data were collected for these two fleets from May 2013 to July 2015, the current analysis effort was conducted in parallel with the second year of data collection for Fleet B. As such, the data included in this report were collected between May 2013 and July 2014.

For the current analysis, each fleet participated in the study for approximately 1 year. During this time, the research team collected approximately 600,000 miles of naturalistic driving data from 43 motorcoaches. Fleet A was based in California and transported passengers between the airport and bus stations. Data from Fleet A were collected from May 2013 to June 2014. Fleet B, based in Texas, operated a combination of local and long-distance tours. Data from Fleet B were collected from July 2013 to July 2014.

Sixty-five bus drivers participated in this study. The average driver age was 49, and participating drivers reported an average of 16 years of driving experience. Select demographic information from the current study is shown in

Table 1, along with select demographic data from the previous distraction study on truck drivers (which included data from two previous naturalistic driving studies).(6) In general, there is greater variability among the motorcoach driver population in terms of gender, age, and driving experience.

Table 1. Comparison of motorcoach and truck driver demographic data.

Measure	Motorcoach Data (current study)	Truck Data: Drowsy Driver Warning System (DDWS) FOT (Olson et al.)	Truck Data: Naturalistic Truck Driving Study (NTDS) (Olson et al.)
Total Drivers	65	103	100
Male	48	102	95
Female	17	1	5
Average Age	49 (Range: 23–79)	40 (Range: 24–60)	44.5 (Range: 21–73)
Average Years of Driving Experience	16.05 (Range: 1–53)	10.6 (Range: 0.5–42)	9.1 (Range: 0.1–54)

The DAS used in the study included five video cameras. The multiplexed image in Figure 1 illustrates the five views: forward, face, over-the-shoulder, left mirror, and right mirror. In addition to the continuous collection of video data, various channels of kinematic data were continuously collected.

Figure 1. Photo. Five camera images multiplexed into a single image.

The study data were processed with a set of sensor trigger values to identify safety-critical events (SCEs). Manual review of the video and data were conducted to ensure SCE validity and to bin them into one of five categories:

1. Crash.
2. Crash—tire strike.
3. Near-crash.
4. Crash-relevant conflict.
5. Unintentional lane deviation.

This process resulted in 1,086 valid events (17 crashes, 37 tire strikes, 431 near-crashes, 562 crash-relevant conflicts, and 39 unintentional lane deviations). To support the analyses, 4,600 baseline epochs (normative driving) were created and coded using the same process as the SCEs. Analyses were conducted to investigate four research questions, the results of which are summarized below.

STUDY FINDINGS AND CONCLUSIONS

Secondary Tasks

The focus of the first research question was to understand the tasks that motorcoach drivers engage in and to determine the relationship of these different tasks with SCE involvement. Following previous analyses in Olson et al., video data were reviewed within a 6-second window: 5 seconds prior to the precipitating event and 1 second after.[7,8] Key findings for this research question are as follows:

- Approximately 59 percent of all recorded SCEs involved secondary and driving-related task engagement. When considering only at-fault crashes, that percentage jumps to 89 percent.
- Secondary task engagement, which involves non-driving-related tasks, was identified in 37 percent of all recorded SCEs and 56 percent of at-fault crashes.
- Specific types of secondary tasks associated with a significant odds ratio (OR) included reaching for an object, looking outside (external distraction), and intercom use, which is novel to motorcoach drivers.
- Motorcoach drivers rarely used cell phones and none of the observed cell phone subtasks were associated with an increase in risk.

An analysis of SCEs and baseline (normative) driving found that motorcoach drivers can be impacted by driver distraction. Though some of the secondary tasks that increase risk are common across driver domains (i.e., light vehicle and truck), there were some new findings for this driver group.[9,10] In particular, driver interaction with an intercom system (to talk to passengers) may warrant further investigation.

Environmental Conditions

The second research question addressed in this study focused on understanding the environmental conditions in which motorcoaches operate and the impact that those different conditions may have on a driver's choice to engage in secondary and driving-related tasks. Key findings (summarized) for this research question are as follows:

- Most SCEs occurred in daylight with no adverse conditions.
- Most baseline epochs occurred in non-junctions and interchange areas. Similarly, most SCEs occurred in non-junctions. A second notable area for SCEs, but not baselines, was intersections.
- Entrance/exit ramps had some of the highest values for OR calculations.

A seemingly consistent finding was that roadway conditions and characteristics that involved significant vehicle interaction produced many of the SCEs. For example, buses at airports, on entrance/exit ramps, and at intersections were all found to have high ORs. This could be due, in part, to the difficulty that motorcoach drivers face when interacting in relatively confined spaces with other vehicles.

Eye Glance Analysis

The third research question focused on the eyes-off-roadway measure to determine the relationship between eyes off forward roadway and SCE involvement. Eye glance analysis was manually calculated using a frame-by-frame approach for the 6-second window of the event: 5 seconds before the precipitating event and 1 second after. Half-second bins were constructed to determine frequency of SCEs as a function of bin time. Several important findings were determined through the various analyses conducted:

- The distribution of ORs was nearly linear from 0.05 seconds or less through 1.5–2.0 seconds. However, the risk jumped significantly and exponentially when the driver's eyes were off the forward roadway for more than 2 seconds.
- The eyes-off-forward-roadway times across the different SCE types were similar, ranging from 1.7 to 1.9 seconds for at-fault events.
- Baseline data were shown to have mean eye glance times that were 0.5 seconds less than any of the SCE sub-category times.
- The intercom task had one of the highest mean eyes-off-forward-roadway times of any secondary task.
- The high mean duration of eyes-off-forward-roadway time for the turn signal task was surprising, though it is suspected that this relates to the drivers' need to look in multiple directions when changing lanes or direction of travel.

Collectively, the results from the eye glance analyses show a pattern consistent with similar analyses conducted with light vehicle drivers and truck drivers.[11,12] The longer the eyes-off-roadway time, the more likely an SCE is to occur. Furthermore, this study validates the 2.0-second demarcation as the threshold where risk of an SCE increases exponentially.

Drowsiness

The fourth research question focused on the relationship of task engagement and observed drowsiness. Each event and baseline was reviewed for up to 60 seconds, and analysts assessed the driver level of drowsiness using the observer rating of drowsiness (ORD) scale. Key findings for this research question are as follows:

- Most of the SCEs and baseline data reviewed involved an alert motorcoach driver. Approximately 1 percent of the data involved a driver who was judged to have been in the high drowsiness category.
- Consistent with research on truck drivers, motorcoach drivers may use secondary task engagement as a countermeasure to drowsiness.[13,14] Both SCEs and baselines with a secondary task tended to have lower drowsiness ratings than SCEs and baselines without a secondary task. Similar results were found when SCEs were limited to at-fault. For driving-related tasks, the results were not as strong and events and baselines showed similar distributions of drowsiness levels in the presence and absence of the task.

Though other analyses on drowsiness are possible with this data set, this study focused on how drowsiness may influence secondary task engagement. To this end, it appears that motorcoach drivers may engage in secondary tasks (though usually not driving-related tasks) as a strategy to counteract the negative impact of drowsiness.

STUDY LIMITATIONS AND NEW OPPORTUNITIES

As in most research studies, there are some limitations that must be acknowledged and considered. First, this study provided possibly the most extensive data set to date on motorcoach operations, a transport domain lacking in research and data. However, the study involved only 2 fleets, 43 instrumented buses, and 65 drivers. Though this may be a good start to understanding some of the issues motorcoach drivers encounter, additional research is needed to further explore this domain.

With that primary limitation noted, the resulting data set from this study is rich and could be mined to answer other research questions. This could be conducted alone with the motorcoach data set or in combination with various truck data sets. In general, much of the cost associated with a large-scale naturalistic study like this is for data collection. However, because these data have now been collected, there is a unique opportunity to conduct a host of follow-on analyses in a cost-effective manner.

Furthermore, the current analysis utilized only the first year of data collection from the two study fleets. An additional year of data was collected from one fleet. This additional data could be analyzed to gain further insights and answer other research questions outside the scope of this study.

By mining the current data set, additional insights will be gained; however, given the scale, this study may be best treated as a pilot, with a clear need for additional efforts, including larger studies that would provide additional data for Federal Motor Carrier Safety Administration

(FMCSA) and industry stakeholders to gain a better understanding of the safety issues that might provide the scientific foundation for countermeasure development.

1. INTRODUCTION

1.1 PROJECT OVERVIEW

The objective of this study was to analyze naturalistic driving data collected from motorcoach drivers to investigate driver distraction and drowsiness. In 2009, the research team conducted a similar analysis on truck drivers (Olson et al., or "the Olson study").[15] To draw comparisons between the two driver groups (i.e., truck drivers and motorcoach drivers), researchers followed the methods and analytical procedures used in Olson et al.[16] Though the analytical procedures between the Olson study and this new study are similar, primary differences included driver population and the period of data collection.[17] The Olson study collected data from truck drivers between 2003 and 2007; the current study used motorcoach data collected between 2013 and 2014.[18]

1.2 DEFINING THE PROBLEM

In 2013, there were approximately 11.5 million commercial motor vehicles (CMVs) registered in the United States.[19] Of these registered vehicles, 864,549 were buses, with a collective 15.2 billion miles traveled in 2013.[20] Although fatal crashes involving buses made up only 7.3 percent of all fatal crashes involving CMVs in 2013, bus fatalities occurred at a rate more than one-third higher than large truck fatalities per 100 million miles traveled (see Table 2).[21] Additionally, due to multiple passengers traveling in buses, the most severe crashes have high potential for catastrophic loss of life. However, this loss of life is not limited to bus occupants: in 2013, the majority of bus crash fatalities were occupants of other vehicles, followed by non-motorists (who accounted for 17 percent of all non-motorist fatalities), and then bus occupants.[22]

Table 2. Fatality statistics for crashes involving large trucks and buses, 2013.

Crashes Involving:	Registered Vehicles	Total Vehicle Miles Traveled (VMT)	Number of Fatal Crashes (per 100 million VMT)	Number of Fatalities (per 100 million VMT)	Fatality Rate (per 100 million VMT)
Large Trucks	10,597,356	275,018,000,000	3,541	3,964	1.44
Buses	864,549	15,167,000,000	280	310	2.04

Source: Federal Motor Carrier Safety Administration (FMCSA), Large Truck and Bus Crash Facts, 2013.[23]

Despite the notable severity of non-motorist fatalities and high potential for bus occupant fatalities, there is a dearth of bus-specific research.[24,25,26] Research topics including preventable versus non-preventable collision types, near-crash descriptions, or the impact of distraction and drowsiness are not well understood. However, the existing bus crash data suggest a need for guidance on safer bus operating practices. For example, in 56 percent of the bus crashes investigated by the National Transportation Safety Board (NTSB), driver error (e.g., drowsiness, medical conditions, and inattention) was identified as the critical reason for the crash.[27]

Perhaps the lack of domain-specific research relates to a lack of definitional clarity when discussing these vehicle types. A bus describes any vehicle designed to carry nine or more people, including the driver.[28] More precisely, a motorcoach (also referred to as a coach, charter bus, or motorcoach bus) generally has an elevated deck over a baggage compartment and is usually designed for long-distance passenger transport.[29] A transit bus vehicle frequently loads and unloads passengers and usually operates in a local or urban area.[30] Further, specialized buses are distinct from other buses (e.g. double-decker, school, etc.). Many studies have discussed buses as a whole, and even collectively with large trucks under the banner of CMVs; in some cases, "bus" and "coach" are used interchangeably, and in other instances discussion of public vehicles are grouped as one entity, containing school and trolley buses with motorcoaches.[31] Figure 2 displays examples of commonly found types of buses.

Figure 2. Photo. Examples of three types of buses. The current study focused on motorcoaches.

Apart from differentiating among types of buses, researchers must identify the safety implications associated with different bus functions, bus routes, and passenger types. For example, curbside, intercity, and charter or tour motorcoaches have higher reports of running off the road and rollover crashes than other bus types and functions, with the highest percentage of fatal occupant injuries overall.[32]

The focus of this initial study was to develop a data set of crashes, near-crashes, and other safety-critical events (SCEs), along with baseline (normative) driving data, for use in examining the impact that driver distraction and drowsiness may have on SCE occurrence in motorcoach operations.

2. REVIEW OF THE LITERATURE

2.1 DRIVER ERROR

Driver error, mistakes, and misbehaviors are often cited as either primary or contributing factors in most crashes and hazardous actions performed by motorcoach drivers.(33) In the Large Truck Crash Causation Study (LTCCS), co-sponsored by FMCSA and the National Highway Traffic Safety Administration (NHTSA), researchers found that 48 percent of serious large truck crashes had a “critical reason” assigned to the driver of the large truck.(34) In a 2008 report to Congress on its National Motor Vehicle Crash Causation Survey, NHTSA determined that the critical reason for the pre-crash event was attributed to drivers in the vast majority of crashes (of 5,361 crashes where a critical reason was identified, 5,096 had a critical reason assigned to the driver).(35)

Causes and precursors of driver error have received significant research interest in the transportation field. The driver error type classifications used in the above-referenced studies are as follows: recognition, decision, performance, and driver nonperformance.(36) Each of these classifications has a variety of sub-types (e.g., overcompensation, panic or freezing, drowsiness, etc.). Of the driver error sub-types, distraction and drowsiness are among the most common topics of research. It should be noted that the terms fatigue and drowsiness are often used interchangeably in the literature; however, drowsiness is used in place of fatigue throughout this report.

Increasing interest in studying bus driver distraction and drowsiness can be attributed to the potential for tragedy when one of these factors is present. For example, as crash report data suggest, operator drowsiness may be the antecedent of 20–40 percent of CMV fatal crashes, while distraction may cause roughly 6 percent of CMV fatal crashes.(37,38) Interestingly, distraction and drowsiness have been noted to be related in that drowsiness decreases general attention while distraction diverts selective attention from a task.(39) Therefore, with both distraction and drowsiness, the attention required for safe vehicle operation is not present or properly allocated. What has yet to be understood is how pervasive these factors and interacting mechanisms are for certain occupational drivers, and more specifically, for motorcoach drivers.

2.2 BUS STATISTICS AND CHARACTERISTICS OF CRASHES

Very little research has been conducted specifically on buses. Despite this minimal research, a few studies have revealed some interesting findings. For example, Cheung and Braver examined motorcoach driver violation rates and found that young or small businesses report the most SCEs and inspection violations when compared to more established or larger fleets.(40) Cheung and Braver also noted that of all carriers, unscheduled charter carriers were most often responsible for higher inspection violations and crash rates.(41) A third study by Blower et al. revealed transit and charter buses to have one of the highest levels of crashes and fatalities, second and third to school buses, respectively.(42) The Blower et al. study points to a potential driver-related factor with charter buses: that is, curbside, intercity drivers endure a high demand of attention to job-related tasks such as itinerary changes while maneuvering through both roadway and pedestrian traffic.[43] As such, bus drivers with intercity routes seem to require sustained, heightened attention while operating their vehicles.

In the realm of driver distraction research, few studies have assessed the prevalence of driver error in bus crashes. Hickman et al. collected nearly 100,000 baseline events from 8,509 transit, distribution, and small-to-medium sized buses.[44] Data analyses revealed 740 crashes, 6,145 near-crashes, and 18,576 crash-relevant conflicts. An analysis of these events and other similar events involving heavy vehicles suggests that drivers who use cell phones to send text messages/emails or access the internet while driving have an increased likelihood of being involved in these events. ’Talking or listening with a hands-free device while driving shows no increase in events for studied drivers overall; however, when examining bus drivers alone, analysis shows that their odds of involvement in a SCE was increased by 1.4 times for any cell phone usage while driving. Because this finding contradicts many conclusions surrounding hands-free cell phone use with regard to CMVs and light vehicles, further exploration of distractions is warranted with relation to bus drivers.[45,46,47]

Regarding infrastructure, monotonous roadways appear to involve the greatest risk for motorcoach drivers.[48] A monotonous roadway lacks visual or environmental stimulation for drivers and requires little driver input beyond lane guidance in order to drive functionally.[49] The decreased attention requirement increases drowsiness in drivers and may encourage drivers to perform countermeasures to combat drowsiness.[50,51,52] Alternatively, those who believe boring roads require less attention may have increased risk as well, due to a decrease in autonomic response times to environmental abnormalities.[53] In a simulated experiment, drivers exhibited subsided cognitive load and alertness after driving on a monotonous roadway when compared to driving on an engaging roadway.[54] Grant et al. found that nearly 90 percent of drowsiness-related crashes occur on highways or inter-urban roads.[55]

2.2.1 Distraction in Motorcoach Drivers

Similar to drivers of light and heavy vehicles, bus drivers are affected by many of the same internal and environmental distractions. However, bus drivers also experience distractions that drivers of light or heavy vehicles do not, specifically passenger behaviors, which can be labeled as a high risk for bus drivers.[56] Such distractions include unruly kids, passengers moving around, and direct interactions with passengers. If passengers divert driver attention during memory encoding, the recognition error during driving greatly increases.[57] Also, interaction with passengers can divert a driver’s eyes off the forward roadway, which has been linked to an increase in SCEs.[58]

A frequent topic for driver distraction research is cell phone use (discussed briefly above).[59] Certain laws state that CMV drivers, including both truck and motorcoach drivers, must refrain from hand-held cell phone use.[60] As noted in the regulations, certain jurisdictions may have even more stringent specifications than the Federal Government.[61] Despite this, Hickman et al. found that State cell phone laws do not significantly impact cell phone use by drivers, and it is possible that this finding may extend to Federal regulations as well. [62] Bus drivers have responded better to company guidelines and policies surrounding cell phone use. Hickman et al. determined that drivers were 83 percent less likely to use a cell phone when there was an established company policy against usage, suggesting a greater desire to adhere to rules that are more proximal to the driver.[63]

Though distraction on its own can account for anywhere from 10 to 15 percent of crashes, the complex interaction between distraction and drowsiness warrants discussion.(64) Successful bus operation demands complex mental processes, inherently making drowsiness, distraction management, and cognitive load an important focus during driving activities.(65) These drivers have a unique set of environmental layers to attend to, as they must regularly process internal and external stimuli (i.e., internal to themselves and external to the vehicle). The subsequent juggling in working memory that must occur demands greater cognitive and self-regulation resources, which can be depleted by overexertion.(66) Possible judgment or perceptive errors due to distraction or drowsiness should be explored. Details on the types of errors that bus drivers make at certain points of the day and through varying levels of distraction or drowsiness (e.g., forgetting, interference, or false memory) should be researched further, as well.

One of the difficulties in examining the interaction between distraction and drowsiness is the intersection of the two. For example, long-haul truck drivers sometimes engage in secondary-task activities (e.g., listening to or talking on a cell phone, drinking coffee, eating, smoking, and singing) to counteract drowsiness.(67) Although these behaviors might lead to distraction, which would be expected to increase crash risk, Hanowski showed that these behaviors instead do not increase the risk of SCEs in CMV drivers and may even reduce it.(68) However, if drivers attempt to alleviate drowsiness using methods that divert more attention away from the roadway (e.g., texting, reading, or writing), the likelihood of being involved in an SCE increases by up to 23 times.(69,70) With bus operators, practicality and feasibility of many countermeasures for drowsiness are limited due to customer proximity. For example, bus drivers, as compared to truck drivers, may be less likely to stop for a nap or stretch their legs. Furthermore, interactions with dispatchers may lead to increased pressure to partake in dangerous activities such as speeding or driving while drowsy, while simultaneously reducing autonomy of the drivers.(71) Due to these limitations, boredom from repetition such as a monotonous roadway may lead to decreased cognitive load and ultimately decreased awareness during SCEs.

Ultimately, bus drivers have significant exposure to the consequences of occupational distraction and drowsiness. Drivers currently attempt to alleviate these effects through napping, caffeine, and increased training.(72) Motorcoach drivers, often responsible for traveling long distances, experience similar driving environments as truck drivers. As such, understanding how distraction and drowsiness affect motorcoach drivers, both as independent factors and as an interaction, is an important addition to the bus safety literature.

2.2.2 Drowsiness in Motorcoach Drivers

Crum et al. suggested two external constructs that influence bus driver drowsiness—driving environments and economic pressures.(73) They also suggested the relationship between these constructs and drowsiness is moderated by carrier support for driving in a safe manner, which is represented by the carrier's willingness to incorporate hours-of-service (HOS) regulations into bus schedules.(74) Bus schedules may be defined as split-shift, rotating, or unpredictable.(75) Current FMCSA rules state that drivers may spend a maximum of 15 hours on duty while maintaining a minimum of 8 hours off duty, with only 10 of their 15 on-duty hours actually spent driving.(76) Poor scheduling can result in repeated consecutive days of this on-off duty time, when drivers work a 23-hour day, rather than a 24-hour day, as required in the current HOS regulations for truck drivers. Subsequently, each day may require the driver to wake up earlier, therefore maintaining an unstable sleep schedule that combines night driving with inadequate time to adjust.[77] For example, a driver may regularly work at 9:00 a.m. on weekdays, but in the case of poor scheduling, may be required to start work an hour earlier each successive day. Charter buses have even more unstable schedules than transit due to varied daily itineraries.[78]

In a study examining drivers across bus types, Belenky et al. found that bus drivers are on duty performing driving and non-driving work tasks at an average of 43.2 hours per week; those drivers operating tour buses work the longest, at an average of 50.1 hours per week.[79] Start times mainly occur around 9:00 a.m., and a typical day is approximately 9 hours long. Although drivers obtain an average total sleep time of 8 hours per 24-hour period, reports spanning 40 years have consistently found variations in driver sleep schedules due to work demands. It is possible that drivers sleep more during off-duty days than work days and obtain less sleep prior to irregular bus operating schedules.[80,81] This may indicate that job demands lead to driver exhaustion and overexertion despite obtaining the overall recommended amount of sleep.

With regard to operating time of day, night driving is a major concern in bus service; however, consensus on the time of day that holds the highest crash risk has not been reached. Crash potential due to drowsiness and high speeds may increase between night and early morning.[82,83] However, the trend appears to fluctuate with typical traffic flow, suggesting a relationship between crash potential and number of on-road vehicles.[84] Preventable collisions have a higher-than-average likelihood to occur during early afternoons and on weekdays, which supports this premise.[85] It should be noted that split shifts also follow the same pattern of apparent crash occurrences, although the reasoning has not yet been determined.[86]

Despite schedules focusing on improving drowsiness through HOS regulations, an imbalance still exists between the breaks required by the HOS regulations and what ultimately occurs on the road. Motorcoach drivers have reported their breaks were not true moments of ease, since these rest periods require other work duties, such as inspection of the vehicle, providing directions, and additional passenger services.[87] Furthermore, the designated parking and rest spots are geographically separate from the passenger areas—this decreased accessibility expands the time and effort of drivers to incorporate breaks into their routine. As motorcoaches do not have sleeper berths and drivers do not have appropriate rest facilities during layovers, they report feelings of inadequate rest opportunities during break periods.[88] Difficulty finding a suitable place to rest has also been related to motorcoach drivers' "close calls."[89]

This lack of rest causes measurably detrimental effects as evident in circadian rhythm imbalances within the motorcoach driver population. Long-distance drivers display circadian rhythm disturbances reaching peak cortisol concentration around 11 a.m. instead of early morning.[90] Additionally, biological and physiological antecedents of drowsiness include insulin intake, obesity, and neurotransmitter levels.[91] Increased adrenaline and noradrenaline levels fluctuate with job schedules, suggesting that sleep debt from job demands may also affect driver performance.[92] Obesity, a common cause of sleep apnea, leads to increased drowsiness levels and sleep debt.[93] Drowsiness mediates the relationship between sleep apnea and crash risk, and obesity has also been shown to increase crash risk by affecting driving position.[94] Apart from crash risk, Horne and Reynor discussed the link between drowsiness and high speeds, while Blower noted that speeding is one of the most repeated violations by charter bus operators.[95,96]

To understand the ubiquitous nature of driver drowsiness, it is important to recognize driver motivations for continuing these maladaptive behaviors that lead to increased levels of drowsiness. Drivers' perceived pressure to agree to trips to ensure future work motivates driving beyond normal levels of exhaustion.[97,98] By rewarding drivers who operate beyond drowsiness with more jobs and income, companies reinforce an atmosphere that discounts proper drowsiness management. Although motorcoach drivers report lower personal motivations to continue driving while tired than CMV truck drivers, pressure to bend driving rules from dispatchers was equivalent between both groups.[99] Managers have indirectly validated these perceptions by reporting their own feelings of pressure and reporting that passengers compel them to have operators drive for longer periods of time to reach their destination.[100]

Unfortunately, company potential relies on the driver. Hospitality literature suggests reliability, luggage service, frequent comfort breaks, schedule flexibility, seat rotation opportunities, and friendliness of the coach driver as consumer satisfaction attributes.[101] This creates economic competition resulting in pressure on the driver that yields drowsiness, judgment errors, and lack of vehicle maintenance.[102] A comprehensive answer must be found to prevent the cycle of stress from company and client pressure, drowsiness, and crashes from reoccurring.

2.3 SUMMARY

Driver error plays a significant role in crash causation. Two factors that are often noted as precursors to driver error are distraction and drowsiness. With both constructs related to driver attention, it is estimated that drowsiness may contribute to 20–40 percent of fatal CMV crashes, while distraction may be a factor in roughly 6 percent of CMV fatal crashes.[103,104,105] Despite increasing interest in distraction and drowsiness with respect to large trucks and light vehicles, little research has been conducted on these factors in the motorcoach bus domain. Recent efforts have examined antecedents to crashes related to buses although those efforts lack naturalistic data to understand driver behavior. Examination of naturalistic data using SCEs is necessary to garner an understanding of the implications of bus-related driver error when considering the impact that drowsiness and distraction have on safety.

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3. METHODS

This study used data from the recently completed Onboard Monitoring System (OBMS) Field Operational Test (FOT), which collected snippets of data using an OBMS.[106] As part of the study method, the research team also installed a data acquisition system (DAS) in each vehicle and collected continuous naturalistic data. The objective of the current study was to analyze naturalistic driving data collected from motorcoach drivers to investigate driver distraction and drowsiness. In 2009, the research team conducted a similar analysis on truck drivers (Olson et al.).[107] The goal of the current study was to assess driver distraction and drowsiness in motorcoach drivers, following the analysis method employed by Olson et al.[108]

3.1 PARTICIPANTS AND SETTING

Two motorcoach fleets (Fleets A and B) participated in the OBMS FOT. While data were collected for these two fleets from May 2013 to July 2015, the current analysis effort was conducted in parallel with the second year of data collection for Fleet B. As such, the data included in this report were collected between May 2013 and July 2014.

For the current analysis, each fleet participated in the study for approximately 1 year. During this time, the research team collected approximately 600,000 miles of naturalistic driving data from 43 motorcoaches. Fleet A was based in California and transported passengers between the airport and bus stations. Data from Fleet A were collected from May 2013 to June 2014. Fleet B, based in Texas, operated a combination of local and long-distance tours. Data from Fleet B were collected from July 2013 to July 2014.

Sixty-five bus drivers participated in this study. The average driver age was 49, and participating drivers reported an average of 16 years of driving experience. Select demographic information from the current study is shown in Table 3, along with select demographic data from the previous distraction study on truck drivers.[109] In general, there is greater variability among the motorcoach driver population in terms of gender, age, and driving experience.

Table 3. Comparison of motorcoach and truck driver demographic data.

Measure	Motorcoach Data (current study)	Truck Data: Drowsy Driver Warning System (DDWS) FOT (Olson et al.)	Truck Data: Naturalistic Truck Driving Study (NTDS) (Olson et al.)
Total Drivers	65	103	100
Male	48	102	95
Female	17	1	5
Average Age	49 (Range: 23–79)	40 (Range: 24–60)	44.5 (Range: 21–73)
Average Years of Driving Experience	16.05 (Range: 1–53)	10.6 (Range: 0.5–42)	9.1 (Range: 0.1–54)

3.2 DATA ACQUISITION SYSTEM

The DAS collected and stored video and dynamic performance (i.e., kinematic) data via a network of sensors distributed around the vehicle. The unit itself consisted of seven major components: the main central processing unit, video cameras, vehicle network box, front radar, lane tracker, inertial measurement unit (IMU), and head unit. Each component was active when the vehicle ignition system was turned on; the DAS itself remained active and recorded data as long as the engine was on and the vehicle was in motion. The system shut down when the ignition was turned off and paused if the vehicle ceased motion for 5 minutes or longer.

There were two main DAS output files—digital video files and vehicle dynamic performance data files—which were stored on the DAS's external hard drive. The vehicle performance file contained the kinematic driver input measures (e.g., lateral and longitudinal acceleration, steering movement, etc.) and the vehicle-related measures (e.g., global positioning system [GPS], light level, etc.) The digital video file contained the video recorded continuously during the trip.

The DAS contained multiple communication ports, including ethernet, serial, universal serial bus (USB), controller area network (CAN), and National Television System Committee (NTSC) video. It also contained onboard wireless communication capabilities through cellular, wireless fidelity (Wi-Fi), and Bluetooth. The base sensor suite included real-time H264 encoding, a multiplexed video channel permitting up to six total video inputs, lane tracker, sound level meter, three axis gyroscopes, three axis accelerometers, and radar. Other sensors could be added and supported by the DAS as required by research requirements. Data and video were encrypted in order to protect participants and overall data collection.

Video Cameras. Real-time H264 encoding digital video cameras were used to record the driver and the driving environment continuously. The five video cameras—forward (enclosed in the head unit), driver's face (enclosed in the head unit), over-the-shoulder, rear-facing left, and rear-facing right—were multiplexed into a single image, thus providing good visual coverage of the driving environment. By viewing the driver's face, researchers could conduct eye glance and observer rating of drowsiness (ORD) analyses. The over-the-shoulder view provided a top-down view of the driver and the steering wheel, allowing for easier detection of secondary behaviors such as cell phone interaction. Figure 3 shows the camera views for the five cameras used in the study.

Figure 3. Photo. Five camera images multiplexed into a single image.

Vehicle Network. The Society of Automotive Engineers' (SAE) J1939 defines the format of messages and data collected by heavy vehicles onboard microprocessors. Depending upon the vehicle model, year, and manufacturer, several data network protocols or standards are used with heavy vehicles. A network box interface was developed to access the data from this network and merge it into the DAS data set. Typical measures found on the vehicle network of most vehicles include, but are not limited to, vehicle speed, distance since vehicle ignition, ignition signal, throttle position, and brake pressure. In addition to the truck network measures, other driver input measures that were collected with sensors include right and left turn-signal use, and headlight status (on/off).

Front Vehicle Onboard Radar. A vehicle onboard radar (VORAD) unit was installed on the front bumper of each bus (see Figure 4) to provide a measure of range to lead vehicles and objects. From the range measure, range rate and time-to-collision (TTC) can also be derived.

Figure 4. Photo. Front VORAD installed on a motorcoach vehicle.

Lane Tracker. The lane tracker in the DAS consisted of a single, high-dynamic range NTSC color camera coupled with a DM648 digital signal processor running machine vision firmware to track the lines and compute parametric data with regard to the position in the lane and state of the lane markings. Once the initial camera offsets were entered (e.g., height and offset), the rest of the calibration and tuning was automatic while driving. The following variables were reported:

- Distance from center of truck to left and right lane markings (estimated maximum error less than 6 inches, average error less than 2 inches).
- Approximate road curvature.
- Confidence in reported values for each marking found.
- Marking characteristics, such as dashed versus solid and double versus single.
- Status information, such as in-lane or solid line crossed.

IMU. The IMU contains yaw rate sensors (three axis gyro) providing a measure of steering instability (i.e., jerky steering movements) and an X/Y/Z accelerometers (three axes) used to measure longitudinal (x), lateral (y), and vertical (Z) accelerations.

Head Unit. The head unit contained the forward and face video cameras, as well as a GPS sensor to capture GPS position and speed.

3.3 DATA REDUCTION

3.3.1 Characterize Safety-critical Events

As in previous naturalistic truck studies, the data for this study were processed with a set of sensor trigger values in order to identify SCEs.[110,111,112] After manual video review and confirmation that a triggered event was a valid SCE, it was classified as a crash, crash—tire strike, near-crash, crash-relevant conflict, or unintentional lane deviation, as defined below:[113]

- Crash: Any contact that the subject vehicle has with an object, either moving or fixed, at any speed. Also included are non-premeditated departures of the roadway where at least one tire leaves the paved or intended travel surface of the road.
- Crash—Tire Strike: Tire strike only with little or no risk element (e.g., clipping a curb during a tight turn).
- Near-crash: Any circumstance that requires a rapid evasive maneuver by the subject vehicle or any other vehicle, pedestrian, cyclist, or animal to avoid a crash.
- Crash-relevant Conflict: Any circumstance that requires an evasive maneuver on the part of the subject vehicle or any other vehicle, pedestrian, cyclist, or animal, that is less urgent than a rapid evasive maneuver (as defined above in near-crash), but greater in urgency than a normal maneuver to avoid a crash. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs.
- Unintentional Lane Deviation: Any single vehicle situation where the subject vehicle unintentionally drifts or crosses over a lane line (e.g., into the shoulder or adjacent lane) where there is NOT a hazard present (i.e., guardrail, steep ditch, vehicle, etc.) or the hazard is never closer than one lane-width to the subject. If the hazard is closer than one lane-width away, the event should be classified as crash-relevant, near-crash, or crash, as appropriate.

3.3.2 Running the Event Trigger Program

To find SCEs of interest, the data were scanned for notable actions, including hard braking events, quick steering maneuvers, short TTC, and lane deviations. To identify these actions, threshold values from previous truck studies were used to flag instances in the video and quantitative data where the threshold values were met or exceeded.[114] These triggers are defined in Table 4.

Table 4. Trigger definitions used in the OBMS data set.

Trigger Type	Definition	Description
Longitudinal Acceleration (LA)	Hard braking	Deceleration greater than or equal to $\lvert 0.20g \rvert$. Speed greater than or equal to 3.5 miles per hour (mi/h).
Time-to-Collision (TTC)	The amount of time (in seconds) that it would take for two vehicles to collide if one vehicle did not perform an evasive maneuver.	A forward TTC value of less than or equal to 2 seconds (s), coupled with a range of less than or equal to 250 feet (ft), a target speed of greater than or equal to 5 mi/h, a yaw rate of less than or equal to $\lvert 6°/s \rvert$, and an azimuth of less than or equal to $\lvert 12° \rvert$.
Swerve (S)	A sudden "jerk" of the steering wheel to return the truck to its original position in the lane.	S value of greater than or equal to $2°/s^2$. Speed greater than or equal to 5 mi/h.
Lane Deviation	Any time the truck aborts the lane line.	A lateral acceleration value of greater than 0.2*g* (either left or right) while traveling greater than 25 mi/h with a lane distance off center greater than 1.4 meters (m).

3.3.3 Checking the Validity of the Triggered Events

A custom software program scanned the data to identify potential SCEs of interest, resulting in a data set that included both valid and invalid events. Valid events were those events where recorded dynamic motion values actually occurred and were verified by video and other sensor data. Invalid events were those where sensor readings were spurious due to a transient spike or some other anomaly such as driving over a pothole (i.e., false positive). To determine the validity of the events, data analysts observed the recorded video and data plots of the various sensor measures associated with each trigger.

During this process, approximately 123,000 total potential SCEs were identified, 1,086 of which were confirmed to be valid events (17 crashes, 37 tire strikes, 431 near-crashes, 562 crash-relevant conflicts, and 39 unintentional LDs). While valid events were further analyzed and classified as conflicts or non-conflicts, invalid events were not further analyzed. Conflicts were valid events that also represented a traffic conflict (i.e., crash, near-crash, crash-relevant conflict, and unintentional lane deviation). Non-conflicts were events that were not safety-critical per se, even though their trigger values were valid (true trigger). These types of non-conflicts were analogous to nuisance alarms—where the threshold value for that particular event was set ineffectually. Examples of valid events that were non-conflicts included hard braking by a driver in the absence of a specific crash threat or a high swerve value from a lane change not resulting in any loss-of-control, lane departure, or proximity to other vehicles. While such situations may have reflected at-risk driving habits and styles, they did not result in a discernible SCE.

3.3.4 Applying the Data Dictionary to the Validated Events

An event-coding data dictionary, adapted from what was used in Olson et al. and Dingus et al., reduced and analyzed all valid SCEs (see Appendix A for the complete data directory).[115,116] The data viewing software presented the data analyst with a series of variables consisting either of a pull-down menu to select the most applicable code, check boxes for analysts to choose all options that apply to a particular variable, or a blank space for entry of specific comments (e.g., event comments). Different variables had different coding rules. For most variables, only one code was selected; however, for a few variables, the data analyst could select up to four applicable codes. For example, analysts could select multiple secondary tasks. It should be noted that though the complete data directory is included in Appendix A, only a small number of the variables listed were used in the current analysis.

3.4 BASELINE EPOCHS

In addition to the SCEs described, more than 4,600 baseline epochs were created. The creation of a baseline data set enabled researchers to describe and characterize "normal" driving for the study sample, and thereby infer the increased or decreased risk associated with various conditions and driver tasks with comparisons between the control (baseline) data set and the SCE data set. Baseline epochs were defined as "an epoch of data selected for comparison to any of the conflict types listed above rather than due to the presence of conflict."[117]

A random sampling method was used to obtain baseline epochs, which were selected based on driver exposure. That is, the more mileage a given driver drove during the study, the more baseline epochs that driver had included in the baseline data set. In addition, all baseline epochs involved the bus traveling at a minimum speed of 5 mi/h. More specifically, the proportion of an individual driver's driving mileage (when the bus was traveling faster than 5 mi/h) was divided by the total driving mileage across this data set (when the bus was traveling faster than 5 mi/h) and multiplied by 100 percent. This percentage reflected an individual driver's exposure and was used to determine the frequency of baseline epochs needed. Data analysts used a subset of variables from the data dictionary to reduce and analyze baseline epochs. Baseline epoch variables are noted as such in the dictionary.

3.5 QUALITY CONTROL

In order to ensure SCE and baseline epoch data-coding accuracy, several quality control steps were implemented during the reduction process. At the beginning of each analyst's training, the analyst reviewed the data dictionary and discussed each variable of the annotation with a supervisor, who then led the analyst through a reduction. Afterwards, the analyst worked on data reduction under the direction of experienced analysts. The supervisor checked 100 percent of the completed work, leaving notes on errors for analysts to review and correct at the beginning of their next shift. Throughout the reduction period, supervisors performed spot checks, and analysts were required to take an inter-rater test of corrected annotations. The supervisor would use the results to grade the analyst's understanding of the data dictionary, using the grade and any continuous mistakes noted on work completed to provide progress updates and guidance if necessary. Once supervisors deemed analysts proficient, the percentage of quality control for the analyst would be lowered. The percentage drop of randomly selected events began at 75 percent and continued to fall until it achieved 25 percent.

3.6 EYE GLANCE REDUCTION

To measure visual attention or inattention, an eye glance analysis was conducted for each SCE and baseline epoch. For SCEs, the eye glance analysis was conducted on the 20 seconds prior to the precipitating event and the 10 seconds after the event. For baseline epochs, eye glance analysis was conducted on the 20 seconds prior to the trigger (i.e., random marker in the file) and the 1 second after the trigger. Although the eye glance analysis for SCEs covered a longer period of time, only 6 seconds of eye glance data (5 seconds before the precipitating event and 1 second after) was used in order to be consistent with previous research.(118,119) Data analysts viewed the video through the data viewing and reduction software and held down the appropriate letter/key when the driver's eye glance was in a specific direction. If the driver's eyes were not visible due to sunglasses or glare from the sun, driver head movement was used to identify glance location. Eye glance locations used in this study (adapted from Olson et al. and Dingus et al.) are listed below: (120,121)

- Forward.
- Right windshield.
- Right mirror/out right window.
- Left windshield.
- Left mirror/out left window.
- Rearview mirror.
- Over-the-shoulder (left or right).
- Instrument cluster.
- Center stack.
- Passenger.
- Cell phone.
- Portable media device.
- Interior object.
- Other.
- No eyes visible—glance location unknown.
- No eyes visible—eyes are off road.
- Eyes closed.

Each glance location was assigned a different letter, as shown in Figure 5. For example, the data analysts would input an "f" when the driver glanced at the forward roadway.

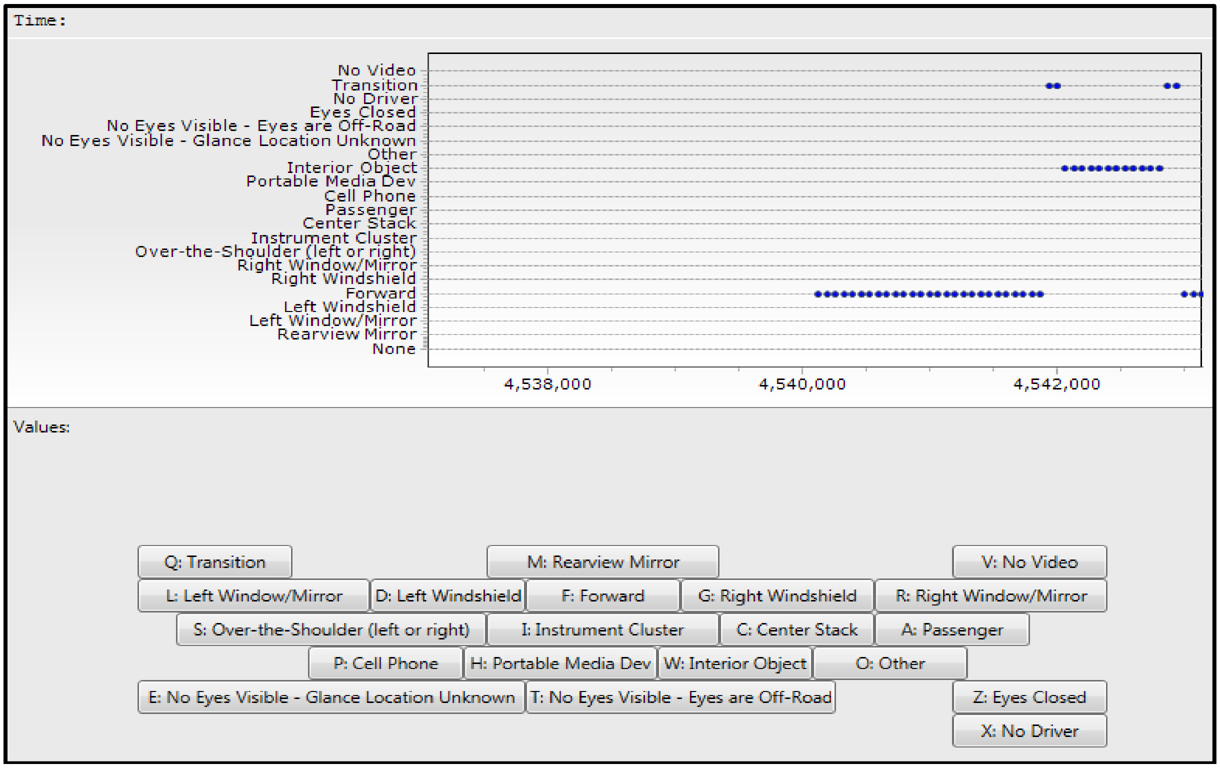

Figure 5. Screen capture. Eye glance location window in data viewing software.

Though each of the above eye glance locations was coded during eye glance reduction, all glances away from the forward roadway were grouped together for the analysis. For example, if the driver looked forward, then out the window, then to the instrument panel, the analysis would consider that as one forward glance and one non-forward glance; an out-the-window and instrument panel glance would combine to form a single glance. Right-windshield and left-windshield glances were grouped together with forward glances.

3.7 OBSERVER RATING OF DROWSINESS

The final step of reduction was to conduct ORD on all SCEs and baselines. ORD is defined as "a subjective assessment of how drowsy a naturalistic driving participant is based on his/her physical appearance, behaviors, and mannerisms," [122,123] and is conducted on up to 60 seconds of video data. If the full 60 seconds of video was not available, analysts used whatever video was available, as long as it was not shorter than 30 seconds.

The methods described in Weigand et al. provided the basis for analyst ORD training.[124] First, analysts participated in a training session where they reviewed pre-determined videos clips of varying levels of drowsiness. Once the training session was complete, analysts rated each video clip by using the scale shown in Figure 6 and the drowsiness category descriptions listed below.

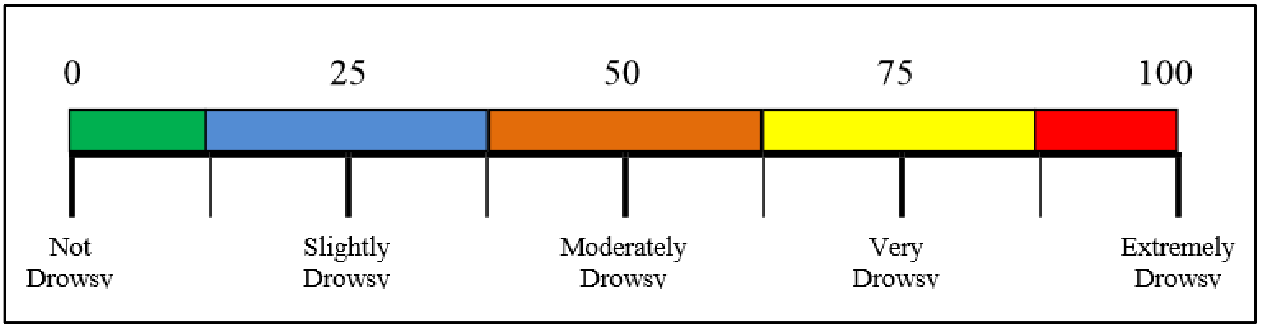

Figure 6. Illustration. ORD of drowsiness scale.

Descriptions for each of the drowsiness categories are provided below:[125]

- Not Drowsy (0–12.49): A driver who is not drowsy while driving will exhibit behaviors such that the appearance of alertness will be present. For example, normal facial tone, normal fast eye blinks, and short ordinary glances may be observed. Occasional body movements and gestures may occur.
- Slightly Drowsy (12.5–37.49): A driver who is slightly drowsy while driving may not look as sharp or alert as a driver who is not drowsy. Glances may be a little longer and eye blinks may not be as fast. Nevertheless, the driver is still sufficiently alert to be able to drive.
- Moderately Drowsy (37.5–62.49): As a driver becomes moderately drowsy, various behaviors may be exhibited. These behaviors, called mannerisms, may include rubbing the face or eyes, scratching, facial contortions, and moving restlessly in the seat, among others. These actions can be thought of as countermeasures to drowsiness. They occur during the intermediate stages of drowsiness. Not all individuals exhibit mannerisms during intermediate stages. Some individuals appear more subdued, they may have slower closures, their facial tone may decrease, they may have a glassy-eyed appearance, and they may stare at a fixed position.
- Very Drowsy (62.5–87.49): As a driver becomes very drowsy, eyelid closures of 2–3 seconds or longer usually occur. This is often accompanied by a rolling upward or sideways movement of the eyes themselves. The individual also may appear to not be focusing the eyes properly or may exhibit a cross-eyed (lack of proper vergence) look. Facial tone will probably be decreased. Very drowsy drivers also may exhibit a lack of apparent activity and there may be large isolated (or punctuating) movements, such as providing a large correction to steering or reorienting the head from a leaning or tilted position.
- Extremely Drowsy (87.5–100): Drivers who are extremely drowsy are falling asleep and usually exhibit prolonged eyelid closures (4 seconds or more) and similar prolonged periods of lack of activity. There may be large punctuated movements as they transition in and out of intervals of dozing.

Analysts used a sliding scale in the video viewing software and moved the slide to a point on the scale that represented the drowsiness level for each video clip. The only numbers shown on the scale are those shown in Figure 6; the slide placement was converted to a numerical value after the assessment was complete. The results of the training test were then compared to a “gold standard" rating and each analyst was scored. Additional training and retesting was done if analyst scores were greater than 30 points in either direction from the "gold standard."

The same sliding scale was used for the ORD reduction. Each 60-second video clip was reviewed by three different analysts, and the average rating was the final ORD value. Each of the three ratings was required to be within 30 points of each other to be considered valid.

3.8 RESEARCH QUESTIONS

This study asked the following research questions, which are further outlined in the next section.

1. What are the types and frequencies of tasks in which drivers engage prior to involvement in SCEs? What are the ORs and the population attributable risk (PAR) percentages for each task type?
2. What are the environmental conditions associated with driver choice of engagement in tasks? What are the odds of being in an SCE while engaging in tasks while encountering these conditions?
3. What are the ORs of eyes off forward roadway? Does the behavior of eyes off forward roadway significantly affect safety and/or driving performance?
4. How does ORD vary when drivers are involved in a secondary task and/or driving-related task?

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4. DATA ANALYSIS AND RESULTS

Once all SCEs and baseline epochs were identified and reduced (coded), the data were analyzed to evaluate the risk associated with engaging in secondary tasks and driving-related tasks. Secondary tasks are defined as non-driving related tasks, such as cell phone use (with multiple sub-categories), eating, and external distraction. Driving-related tasks are defined as tasks directly related to driving, such as checking the speedometer and turn signal use. Mirror checks were not included in any analyses as these are considered part of safe driving practices. Each analysis grouped the data into the following categories:

- All secondary tasks and/or driving-related tasks.
- All secondary tasks.
- All driving-related tasks.

The analyses described in this section follow those used in Olson et al. and Klauer et al.[126,127] Though the data set lends itself to additional analyses, the current study sought to follow the Olson et al. approach as closely as possible.[128] Odds ratios (ORs) were calculated to estimate the risk of being involved in an SCE when the driver was engaged in a secondary task and/or driving-related task, as compared to when the driver was not engaged in those behaviors. PAR calculations were also conducted in an effort to generalize the data to a larger population of drivers. Definitions of ORs and PAR calculations are described in more detail below.

4.1 DATA ANALYSIS METHODS

4.1.1 Odds Ratio

ORs were conducted to estimate relative SCE risk compared to baseline driving risk for various driver tasks. The OR is a way of comparing the odds of some outcome occurring (e.g., a crash), given the presence of some predictor factor, condition, or classification (e.g., talking on a cell phone). As shown in Table 5, an OR is a measure of association commonly employed in the analysis of 2 × 2 contingency tables.[129]

Table 5. 2 × 2 contingency table used to calculate OR.

Incidence Occurrence	Driver Inattention	No Driver Inattention
Incidence occurrence	n_{11}	n_{12}
No incidence occurrence	n_{21}	n_{22}

Odds of occurrence are defined as the probability of event occurrence (i.e., SCE) divided by the probability of non-occurrence (i.e., baseline epoch). The OR is then a comparison of the odds of occurrence based on the presence or absence of a condition (e.g., driver inattention versus no driver inattention). The following formula was used to perform the calculation to determine the OR of a driver having an SCE (compared to a baseline epoch), in the presence of driver inattention versus no driver inattention:

$$OR = (n_{11})(n_{22})/(n_{21})(n_{12})$$

Figure 7. Formula. Odds ratio calculation.

ORs of 1.0 indicate the independence of the two categorical variables, such that the outcome is equally likely to occur despite the condition. An OR greater than 1.0 indicates the odds of an outcome occurring are higher in one condition when compared with the other. Conversely, ORs of less than 1.0 indicate the odds of an outcome occurring are lower in that same condition when compared with the other. Functionally, if the categorical variables are not independent, an OR will produce both odds greater than 1.0 and odds less than1.0, depending on the initial set-up of the table.(130)

ORs analyze the relationship between the two categorical variables, but caution must be used when interpreting the results. One possible explanation for the relationship between two categorical variables may lie with other extraneous variables not included in the analysis. That is, it is not certain that one categorical variable caused a change in the values of the other categorical variable without considering the situation or environment in which the tasks occurred. For example, if windshield wiper use was found to occur more frequently during SCEs than baseline epochs, it is likely that the underlying variable is inclement weather, which is associated with both windshield wiper use and increased risk. Therefore, it is crucial to consider the context of the SCEs to obtain a clearer understanding of the results.

The hypothetical data presented in Table 6 illustrates how ORs are calculated. For this example, assume there are a total of 100 SCEs and 100 baseline epochs. The driver talks on a cell phone while driving during 45 of the SCEs and 23 of the baseline epochs.

Table 6. OR example.

Event	Cell Phone Talking	No Cell Phone Talking
SCEs (100 Total)	45 (A)	55 (B)
Baseline Epochs (100 Total)	23 (C)	77 (D)

The formula for this calculation is shown in Figure 8:

$$OR = \frac{A \times D}{B \times C}$$

$$OR = \frac{45 \times 77}{23 \times 55}$$

$$OR = 2.74$$

Figure 8. Formula. Sample odds ratio calculation, using data from Table 6.

In this context, drivers who talk on cell phones while driving are 2.74 times more likely to have an SCE than a baseline epoch, compared to drivers who do not talk on cell phones while driving.

In order to determine if the OR of 2.74 is significant, a 95-percent confidence interval is calculated, including the upper confidence limits (UCL) and lower confidence limits (LCL). The formulas to calculate the UCL and LCL are shown in Figure 9 and Figure 10:

$$UCL = OR \times e^{1.96\sqrt{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}}$$

$$UCL = 2.74 \times e^{1.96\sqrt{\frac{1}{45}+\frac{1}{55}+\frac{1}{23}+\frac{1}{77}}}$$

$$UCL = 5.04$$

Figure 9. Formula. Upper confidence limits (UCL) calculation.

$$LCL = OR \times e^{-1.96\sqrt{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}}$$

$$LCL = 2.74 \times e^{-1.96\sqrt{\frac{1}{45}+\frac{1}{55}+\frac{1}{23}+\frac{1}{77}}}$$

$$LCL = 1.49$$

Figure 10. Formula. Lower confidence limits (LCL) calculation.

Because 1.0 is not included between the LCL and the UCL, the OR is significant, suggesting the two categorical variables are not independent, and the odds of talking on a cell phone during an SCE are different than the odds of talking on a cell phone during a baseline epoch. There is 95 percent certainty that the true OR lies somewhere between 1.49 and 5.04.

4.1.2 Population Attributable Risk

PAR is defined as the "risk of disease in the total population (p_t) minus the risk in the unexposed group (p_u)."[(131)] In this context, "disease" refers to SCEs. For each OR with an outcome significantly different than 1.0, the PAR percentage also was calculated. While the OR is measured at the individual level, the PAR is measured at the population level. This analysis provided an assessment of the percentage of SCEs that occur in the population and are directly attributable to the specific behavior measured (i.e., driver inattention).

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."[(132)] Because these rarely occur in the population, ORs may be complemented with relative risk; as such, the PAR percentage can be used. The PAR percentage is calculated as follows (see Figure 11):

$$PAR\ percentage = \frac{(P_e(OR-1))}{(1+P_e(OR-1))} \times 100$$

Figure 11. Formula. Population attributable risk (PAR) percentage calculation.

In this formula, P_e is the population exposure estimate (e.g., number of baseline epochs with a secondary task/total number of baseline epochs) and OR is the OR estimate.

This calculation provides a percentage value estimating the proportion of events or epochs in the study population that is attributable to the exposure. For example, if drivers who talk on cell phones while driving are two times as likely to be involved in an event (e.g., crash) than when they are not talking on a cell phone, but events are a rare occurrence in the entire population, a PAR percentage is utilized to demonstrate risk attributable to cell phone use. Again, using the hypothetical data presented in Table 6, the PAR percentage is calculated below (see Figure 12):

$$P_e = \frac{23\ baseline\ epochs\ with\ cell\ \ phone\ talking\ while\ driving\ present}{100\ total\ baseline\ epochs} = 0.23$$

$$OR = 2.74$$

$$PAR\ percentage = \frac{(0.23(2.74-1))}{(1+0.23(2.74-1))} \times 100$$

$$PAR\ \ percentage\ \ = 28.58$$

Figure 12. Formula. Sample PAR percentage calculation, using data from Table 6.

In order to interpret the PAR percentage, the standard error estimate, UCL, and LCL must first be calculated. Table 7 displays the hypothetical data used in Table 6 in the OR example; these data will be used to explain the calculations shown below.

Table 7. PAR—confidence limits example.

Events	Cell Phone Talking	No Cell Phone Talking	Total
SCEs	45 (A)	55 (B)	**100 (m_1)**
Baseline epochs	23 (C)	77 (D)	**100 (m_2)**
Total	**68 (n_1)**	**132 (n_2)**	**(n)**

First, it is necessary to calculate the standard error using the formula shown in Figure 13:

$$Var(PAR\ percentage) = \left(\frac{Bm_2}{Dm_1}\right)^2 \left[\frac{A}{Bm_1} + \frac{C}{Dm_2}\right] \times 100$$

$$Var(PAR\ \ percentage) = \left(\frac{55 \times 100}{77 \times 100}\right)^2 \left[\frac{45}{55 \times 100} + \frac{23}{77 \times 100}\right] \times 100$$

$$Var(PAR\ \ percentage\ ) = 0.57$$

Figure 13. Formula. Standard error calculation.

Next, the 95-percent UCL and LCL are calculated, using the standard error, with the formulas shown in Figure 14 and Figure 15:

$$UCL\ = PAR\ \ percentage + 1.96\sqrt{Var(PAR\ \ percentage)}$$

$$UCL = 28.58 + 1.96\sqrt{0.57}$$

$$UCL\ = 30.06$$

Figure 14. Formula. 95-percent UCL calculation.

$$LCL\ = PAR\ \ percentage - 1.96\sqrt{Var(PAR\ \ percentage)}$$

$$LCL = 28.58 - 1.96\sqrt{0.57}$$

$$LCL\ = 27.10$$

Figure 15. Formula. 95-percent LCL calculation.

Then, it can be reported that talking on a cell phone while driving leads to an SCE in 27–30 percent of the population when compared to driving while not talking on a cell phone.

4.2 RESEARCH QUESTION 1: WHAT ARE THE TYPES AND FREQUENCIES OF TASKS IN WHICH DRIVERS ENGAGE PRIOR TO INVOLVEMENT IN SAFETY-CRITICAL EVENTS? WHAT ARE THE ODDS RATIOS AND THE POPULATION ATTIBUTABLE RISK PERCENTAGE FOR EACH TASK TYPE?

4.2.1 Frequency of Tasks

As noted in the previous section, each task was grouped into one of two categories—secondary or driving-related. Table 8 shows a breakdown of each event type and the percentage of each that involved a secondary task, a driving-related task, or both. Analysis revealed that 58.7 percent of the 1,086 identified SCEs had some type of driver distraction (occurring within the 6-second analysis window of the event—see Section 3.6) listed as a potential contributing factor. Table 8 shows the percentage of any secondary and/or driving-related task present in SCEs and events where the Vehicle 1 driver (i.e., the participant driver) was judged to be at fault. A vehicle was judged to be at fault if there was observable evidence that the driver committed an error that led to the conflict.(133) It should be noted that crash—tire strike events are counted with crashes as a sub-row under the crashes category; the same approach is followed with near crashes and crash-relevant conflicts.

Table 8. Frequency and percentage of any secondary and/or driving-related task in "All" and "Vehicle 1 At-fault" events.

Event Type	All SCEs	Frequency and Percent of All SCEs	Vehicle 1 At-fault SCEs	Frequency and Percent of Vehicle 1 At-fault SCEs
All SCEs	58.7%	n = 1,086 (100.0%)	64.6%	n = 427 (100.0%)
• Crash	70.6%	n = 17 (1.6%)	88.9%	n = 9 (2.1%)
– Crash + Crash: Tire Strike	100.0%	n = 3 (0.3%)	100.0%	n = 3 (0.7%)
• Crash: Tire Strike	48.6%	n = 37 (3.4%)	48.6%	n = 37 (8.7%)
• Near-crash	58.7%	n = 431 (39.7%)	62.4%	n = 157 (36.8%)
– Near-crash + Crash: Tire Strike	100.0%	n = 1 (0.1%)	0.0%	n = 0 (0.0%)
• Crash-relevant Conflict	57.5%	n = 562 (51.8%)	65.4%	n = 185 (43.3%)
– Crash-relevant Conflict + Crash: Tire Strike	0.0%	n = 2 (0.2%)	0.0%	n = 2 (0.5%)
• Unintentional Lane Deviation	79.5%	n = 39 (3.6%)	79.5%	n = 39 (9.1%)
Baseline Epochs	39.3%	n = 4,600 (100.0%)	39.3%	n = 4,600 (100.0%)

Table 9 shows the percentage of all SCEs and events where the Vehicle 1 driver was engaged in a non-driving-related secondary task and was judged to be at fault. As shown, driver distraction due to non-driving-related secondary tasks was a contributing factor in:

- 52.9 percent of crashes.
- 36 percent of near-crashes.
- 36.5 percent of all events.

It should also be noted that the crashes included in this data set were relatively minor (e.g., hitting an overhanging tree branch or curb). There were no vehicle-to-vehicle crashes included in this data set.

Table 9. Frequency and percentage of any secondary tasks in "All" and "Vehicle 1 At-fault" events.

Event Type	All SCEs	Frequency and Percent of All SCEs	Vehicle 1 At-fault SCEs	Frequency and Percent of Vehicle 1 At-fault SCEs
All SCEs	36.5%	n = 1,086 (100.0%)	45.2%	n = 427 (100.0%)
• Crash	52.9%	n = 17 (1.6%)	55.6%	n = 9 (2.1%)
– Crash + Crash: Tire Strike	33.3%	n = 3 (0.3%)	33.3%	n = 3 (0.7%)
• Crash: Tire Strike	29.7%	n = 37 (3.4%)	29.7%	n = 37 (8.7%)
• Near-crash	36.0%	n = 431 (39.7%)	43.3%	n = 157 (36.8%)
– Near-crash + Crash: Tire Strike	100.0%	n = 1 (0.1%)	0.0%	n = 0 (0.0%)
• Crash-relevant Conflict	33.8%	n = 562 (51.8%)	42.2%	n = 185 (43.3%)
– Crash-relevant Conflict + Crash: Tire Strike	0.0%	n = 2 (0.2%)	0.0%	n = 2 (0.5%)
• Unintentional Lane Deviation	79.5%	n = 39 (3.6%)	79.5%	n = 39 (9.1%)
Baseline Epochs	28.8%	n = 4,600 (100.0%)	28.8%	n = 4,600 (100.0%)

4.2.2 Odds Ratios of Driver Tasks

4.2.2.1 Task Categories

To approximate SCE risk compared to normal baseline driving, ORs were calculated on the different task categories. ORs for each category (secondary tasks and driving-related tasks) were calculated with the absence and presence of each task category. Table 10 shows the frequency of each task category during SCEs and baseline epochs across "All" and "Vehicle 1 At-Fault" events. SCEs and baseline epochs could have both secondary tasks and driving-related tasks present; therefore, the first row of Table 10 is not a sum of the next two rows (an event with both task types will be counted once in each of the three rows).

Table 10. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-Fault" events.

Type of Task	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	Vehicle 1 Frequency of Secondary and/or Driving-related Task SCEs	Vehicle 1 Frequency of Secondary and/or Driving-related Task Baselines
Secondary and/or Driving-related Task	637	1,808	276	1,808
Secondary Task	396	1,327	193	1,327
Driving-related Task	349	629	130	629

Each of the OR calculations was performed across all SCEs (n = 1,086) and on those events where the Vehicle 1 driver was judged to be at fault in the SCE (n = 427).[134,135] The results from these calculations are shown in Table 11, which shows the OR, LCL, and UCL for each driver task across "All" (analyses that included all SCEs are referred to as "All" from here on) and "Vehicle 1 At-fault" SCEs (analyses that included all SCEs where the Vehicle 1 driver was judged to be at fault in the SCE are referred to as "Vehicle 1 At-fault" [or V1] from here on).

"All" Events: As shown in Table 11, ORs were significant for all three driver task types when "All" events were considered. As compared to baseline epochs, drivers were:

- 2.19 times more likely to be involved in an SCE while engaging in any secondary task and/or driving-related task.
- 1.42 times more likely to be involved in an SCE while engaging in any secondary task.
- 2.99 times more likely to be involved in an SCE while engaging in any driving-related task.

"Vehicle 1 At-fault": When "Vehicle 1 At-fault" events were considered, ORs were significant for all three task types. As compared to baseline epochs, drivers were:

- 2.82 times more likely to be involved in an SCE while engaging in any secondary task and/or driving-related task.
- 2.03 times more likely to be involved in an SCE while engaging in any secondary task.
- 2.76 times more likely to be involved in an SCE while engaging in any driving-related task.

Table 11. ORs and 95-percent confidence intervals to assess likelihood of an SCE while engaging in a task across "All" and "Vehicle 1 At-fault" events.

Type of Task	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Secondary and/or Driving-related Task	**2.19***	1.92	2.51	**2.82***	2.29	3.47
Secondary Task	**1.42***	1.23	1.63	**2.03***	1.66	2.49
Driving-related Task	**2.99***	2.57	3.48	**2.76***	2.21	3.45

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.2.2.2 Manual/Visual Complexity

ORs were calculated for each secondary task. Because of the small sample size for some of these tasks, each task of interest may occur in addition to another task during an SCE or baseline epoch (i.e., if the task of interest is talking on a phone, the driver may also be smoking at the same time); therefore the results should be interpreted considering that at least the particular task was present.

"All" Events: The results for these calculations are presented in Table 12 and suggest that driver engagement in seven of the secondary tasks and one of the driving-related tasks increased the risk of being involved in an SCE when compared to baseline epochs. There was one driving-related task (checking speedometer) that was found to be protective (i.e., drivers were less likely to be involved in an SCE when compared to a baseline epoch when engaging in this behavior).

A few other highlights from Table 12 are as follows:

- Performing an "other known secondary task" (e.g., inserting a Bluetooth earpiece, checking a watch, or waving to someone outside the vehicle) while driving and using the intercom to communicate with passengers while driving were significant safety risks.
- Drivers were 4.06 times more likely to be involved in an SCE while engaging in an "other, known, secondary task," and 3.78 times more likely to be involved in an SCE while using an intercom.
- Other personal hygiene tasks (e.g., wiping or scratching arms, face, or ears) significantly increased risk by 3.47 times, while removing or adjusting clothing, reaching for an object, and "object in vehicle, other" significantly increased risk by 2.84, 2.14, and 1.69 times, respectively.
- Use of turn signals was the only driving-related task that significantly increased the risk of being involved in an SCE when compared to a baseline epoch.
  - One explanation for this may be the large number of SCEs that took place while the driver was approaching or leaving a parking spot in the loading area of an airport. This scenario often led to an SCE due to the large amount of surrounding traffic at an airport, because drivers often used their turn signals as they approached or left the parking spot.
  - This finding highlights the caution that must be used when interpreting these results, especially those in which ORs do not determine causality. For example, turn signal use itself would not be expected to decrease safety; considering the environment in which the SCEs occurred (i.e., parking lots and areas with high traffic density) offers a clearer picture of the situation.

Table 12. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-Fault" events.

Task Type	Task Description	ALL OR	ALL LCL	ALL UCL	ALL Frequency of SCEs	ALL Frequency of Baselines	V1 OR	V1 LCL	V1 UCL	V1 Frequency of SCEs	V1 Frequency of Baselines
Secondary	Talking/singing	1.22	0.98	1.53	110	388	1.28	0.92	1.77	45	388
Secondary	Dancing	0.40	0.16	1.00	5	53	-	-	-	1	53
Secondary	Reading	-	-	-	3	10	-	-	-	2	10
Secondary	Writing	-	-	-	1	3	-	-	-	0	3
Secondary	Passenger in rear seat	0.79	0.47	1.33	17	91	0.71	0.31	1.62	6	91
Secondary	Moving object in vehicle	-	-	-	1	0	-	-	-	0	0
Secondary	Insect in vehicle	-	-	-	1	2	-	-	-	0	2
Secondary	Reaching for object	**2.14***	1.23	3.72	19	38	**2.88***	1.42	5.82	10	38
Secondary	Object in vehicle, other	**1.69***	1.02	2.82	21	53	**2.06***	1.04	4.07	10	53
Secondary	Cell phone, holding	-	-	-	6	3	-	-	-	4	3
Secondary	Cell phone, talking/listening hand-held	1.93	0.67	5.57	5	11	-	-	-	3	11
Secondary	Cell phone, texting	-	-	-	3	3	-	-	-	3	3
Secondary	Cell phone, browsing	-	-	-	3	6	-	-	-	3	6
Secondary	Cell phone, dialing hand-held	-	-	-	1	2	-	-	-	1	2
Secondary	Cell phone, locating/reaching/answering	-	-	-	3	10	-	-	-	2	10
Secondary	Cell phone, other	-	-	-	5	3	-	-	-	5	3
Secondary	Intercom use	**3.78***	2.13	6.74	22	25	2.17	0.83	5.69	5	25
Secondary	Other electronic device	-	-	-	2	18	-	-	-	2	18
Secondary	Adjusting instrument panel	0.87	0.60	1.26	34	165	1.39	0.87	2.21	21	165
Secondary	Inserting/retrieving CD	-	-	-	0	1	-	-	-	0	1
Secondary	Adjusting/monitoring other devices integral to vehicle	1.64	0.98	2.76	20	52	1.25	0.53	2.92	6	52
Secondary	Looking at outside, vehicle, animal, object, etc.	**1.61***	1.26	2.07	91	247	**2.28***	1.65	3.16	49	247
Secondary	Reaching for food-related or drink-related object	-	-	-	3	28	-	-	-	3	28

Task Type	Task Description	ALL OR	ALL LCL	ALL UCL	ALL Frequency of SCEs	ALL Frequency of Baselines	V1 OR	V1 LCL	V1 UCL	V1 Frequency of SCEs	V1 Frequency of Baselines
Secondary	Eating	0.90	0.49	1.65	13	61	1.24	0.56	2.73	7	61
Secondary	Drinking from container	0.66	0.26	1.70	5	32	-	-	-	4	32
Secondary	Smoking-related: cigarette in hand or mouth	-	-	-	0	1	-	-	-	0	1
Secondary	Personal grooming	-	-	-	4	10	-	-	-	3	10
Secondary	Biting nails/cuticles	-	-	-	1	5	-	-	-	1	5
Secondary	Removing/adjusting clothing	**2.84***	1.37	5.92	12	18	-	-	-	4	18
Secondary	Removing/adjusting jewelry	-	-	-	0	4	-	-	-	0	4
Secondary	Removing/inserting/adjusting contact lenses or glasses	1.46	0.75	2.82	12	35	1.55	0.60	3.97	5	35
Secondary	Other personal hygiene	**3.47***	1.94	6.19	21	26	**5.96***	3.09	11.51	14	26
Secondary	Other non-specific internal eye glance	1.27	0.83	1.94	28	94	1.51	0.84	2.71	13	94
Secondary	Other known secondary task	**4.06***	2.13	7.77	18	19	**6.97***	3.36	14.46	12	19
Secondary	Unknown type (secondary task present)	-	-	-	4	9	-	-	-	1	9
Secondary	Unknown	-	-	-	0	2	-	-	-	0	1
Driving-related	Checking speedometer	0.51	0.37	0.70	47	375	0.38	0.22	0.66	14	375
Driving-related	Shifting gears	-	-	-	20	0	-	-	-	10	0
Driving-related	Using turn signal(s)	**4.37***	3.59	5.32	215	246	**5.63***	4.35	7.27	103	246
Driving-related	Adjusting headlights	-	-	-	5	5	-	-	-	2	5
Driving-related	Using windshield wipers	-	-	-	1	14	-	-	-	1	14
Driving-related	Horn	-	-	-	105	1	-	-	-	21	1
Driving-related	Parking brake	-	-	-	10	1	-	-	-	4	1
Driving-related	Voice/hand signals	-	-	-	4	6	-	-	-	3	6
Driving-related	Engine brake	-	-	-	2	0	-	-	-	0	0
Driving-related	Opening/closing bus door	-	-	-	7	0	-	-	-	4	0
Driving-related	Unknown driving tasks	-	-	-	2	4	-	-	-	1	4

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.2.3 Population Attributable Risk

The last step in answering Research Question 1 was to calculate the PAR percentages. Recall that PAR provides an assessment of the percentage of SCEs expected to occur in the population that may be attributed to the specific task or behavior measured. The PAR was calculated on all significant ORs (those with confidence interval values both greater or less than 1.0). The results from these calculations are presented in Table 13. The "Secondary Tasks (Overall)" and "Driving-related Tasks (Overall)" rows include all corresponding subtasks (regardless of significance of individual subtask) and the calculations are derived from values in Table 11.

Table 13. PAR and 95-percent confidence intervals for driver tasks across "All" and "Vehicle 1 At-fault" events.

Task	ALL PAR Percentage	ALL LCL	ALL UCL	V1 PAR Percentage	V1 LCL	V1 UCL
Secondary Tasks (Overall)	**10.70**	**10.27**	**11.14**	**22.98**	**22.30**	**23.66**
Talking/singing/dancing	1.85	1.64	2.06	2.30	1.97	2.63
Reaching for object	0.93	0.85	1.01	1.53	1.38	1.68
Object in vehicle, other	0.79	0.7	0.88	1.20	1.06	1.35
Cell phone, talking/listening hand-held	0.22	0.18	0.26	0.46	0.38	0.55
Intercom use	1.49	1.4	1.58	0.63	0.53	0.75
Adjusting/monitoring other devices integral to vehicle	0.72	0.63	0.81	0.28	0.16	0.39
External distraction	3.18	2.99	3.37	6.45	6.13	6.78
Removing/adjusting clothing	0.72	0.65	0.78	0.55	0.45	0.64
Removing/inserting/adjusting contact lenses or glasses	0.35	0.28	0.41	0.41	0.31	0.52
Other personal hygiene	1.38	1.29	1.46	2.73	2.56	2.9
Other non-specific internal eye glance	0.55	0.44	0.65	1.02	0.85	1.19
Other known secondary task	1.25	1.17	1.33	2.41	2.25	2.57
Driving-related Tasks (Overall)	**21.39**	**21.05**	**21.72**	**19.43**	**18.91**	**19.94**
Using turn signal(s)	15.27	15.01	15.52	19.83	19.4	20.27

As shown in Table 13, combining all secondary tasks (significant OR of 1.42) resulted in a PAR percentage of 10.70, with a LCL of 10.27 and a UCL of 11.14. This indicates that engaging in a secondary task led to 10 percent of the SCEs in the population (compared with driving while not engaged in a secondary task). When looking at specific tasks, external distraction resulted in the highest percentage of SCEs, with a PAR percentage of 3.18.

Combining all driving-related tasks (significant OR of 2.99) resulted in a PAR percentage of 21.39, with a LCL of 21.05 and UCL of 21.72. For individual driving-related tasks, using turn signal(s) was the only behavior with an OR greater than 1.0, and therefore the only behavior where a PAR was calculated. Because this is such a frequently occurring behavior, it is represented as a relatively high PAR percentage (PAR percentage of 15.27, LCL of 15.01, and UCL of 15.52). These findings illustrate the need for caution in interpreting these results, because the data and analysis methods do not identify a cause-and-effect relationship. It is probable that driving situations where a turn signal would be used are higher risk and turn signal use is not a cause of SCEs.

4.2.4 Summary of Key Findings for Research Question 1

The analysis of these calculations led to a number of key findings. First, secondary task and driving-related task activities were found to be prevalent in recorded SCEs. Across all SCEs, approximately 59 percent involved the motorcoach driver engaged in some secondary and/or driving-related task. When focusing on at-fault crashes, this percentage jumped to 89 percent. Though only nine at-fault crashes were identified, it is noteworthy that almost all of these involved the motorcoach driver engaged in a secondary or driving-related task at the time of the crash.

When the analysis focused only on non-driving-related secondary tasks, approximately 37 percent of SCEs occurred with the motorcoach driver engaged in a secondary task. When looking at at-fault crashes, approximately 56 percent of these crashes involved the motorcoach driver engaged in a secondary task.

In terms of the most risky observable secondary tasks engaged in by motorcoach drivers, several of the noted secondary tasks (e.g., reaching for an object and looking outside [external distraction]) have been shown to increase risk in other studies.[(136)] However, one secondary task that may be novel to motorcoach drivers is intercom use. With an OR of 3.8, this particular task had one of the highest ORs.

Regarding insignificant secondary tasks, cell phone use (including all subtasks) was both rarely observed and not associated with an increased risk. Though other driver groups have been shown to have an increased risk when using a cell phone, there were very few instances of such use in the current data; when it did happen, the impact on risk was not measurable.

One goal of this study is to generate a better understanding of motorcoach driver secondary and driving-related task use, and the impact that engagement in these tasks might have on risk. The results from this first analysis indicate that motorcoach drivers are not immune from secondary task engagement, and the resulting distraction from engagement in non-driving-related tasks may be a factor in SCE involvement.

4.3 RESEARCH QUESTION 2: WHAT ENVIRONMENTAL CONDITIONS ARE ASSOCIATED WITH DRIVER CHOICE OF ENGAGEMENT IN TASKS? WHAT ARE THE ODDS OF EXPERIENCING AN SCE WHILE ENGAGING IN TASKS AND ENCOUNTERING THESE CONDITIONS?

The second research question focused on task involvement as a function of environmental conditions. ORs were calculated to approximate the increased risk of being involved in an SCE, as compared to baseline epochs, while engaging in various tasks and encountering different environmental conditions.

The following environmental conditions were assessed for each SCE and baseline epoch during data reduction:

- Lighting levels.
- Weather conditions.
- Roadway surface conditions.
- Relation to junction.
- Traffic flow.
- Roadway alignment.
- Road grade.
- Traffic density.
- Locality.

During reduction, analysts were instructed to select the one option for each environmental condition that best described its status at the time of the SCE or baseline epoch. The individual conditions are explained in more detail in the following sections. Full definitions can be found in the data dictionary (Appendix A).[137]

For each environmental condition, a frequency table was created from which ORs and 95-percent confidence limits were calculated. The ORs provide information as to whether a driver was more likely to be involved in an SCE, compared to a baseline epoch, while engaged in a task during specific environmental conditions compared to not being engaged in a task in that environment. The following tasks were considered:

- Secondary tasks and/or driving-related tasks.
- Secondary tasks.
- Driving-related tasks.

ORs were calculated with the absence or presence of each task category. The data were parsed for analysis in two ways: “All” events and “Vehicle 1 At-fault” events. Each of the environmental conditions was considered, as described below. It should be noted that much of the data presented below occurred in “normal” environmental conditions, such as “daylight” or “no adverse weather” (e.g., clear and sunny). Because of this, there were often not enough samples to conduct ORs on many of the variables, leaving the most commonly occurring variables to produce significant results. The sample size for each condition is presented below along with the ORs, and should be taken into consideration when interpreting the results.

4.3.1 Lighting Levels

“Lighting levels” refers to the atmospheric light condition during the SCE or baseline epoch. Data analysts were instructed to use the video data as well as the time stamp from the data files to assist in determining the appropriate lighting level. During data reduction, analysts selected one of the following lighting conditions:

- Daylight.
- Darkness, not lighted.
- Darkness, lighted (i.e., street lights).

- Dawn.
- Dusk.

To clarify, “darkness, lighted” indicates the atmospheric lighting conditions were dark although the road had active artificial lighting.

Table 14 shows the frequency of secondary tasks and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each lighting level. Most of the data were collected in “daylight” conditions.

Table 14. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each lighting level.

Lighting Levels	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
Daylight	525	1,301	235	1,301
Darkness, not lighted	7	128	2	128
Darkness, lighted	88	319	34	319
Dawn	11	26	4	26
Dusk	6	34	1	34

Table 15, Table 16, Table 17, Table 18, and Table 19 show the results of the OR calculations for each lighting level analysis. Table 15 displays the OR calculations for engaging in a secondary and/or driving-related task across “All” and “Vehicle 1 At-fault” events for each lighting level. The results suggest that engaging in any secondary or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in three of the lighting conditions. When “All” events were considered and compared to baseline epochs, drivers were:

- 2.02 times more likely to be involved in an SCE when driving in daylight.
- 2.07 times more likely to be involved in an SCE when driving in darkness, not lighted.
- 4.06 times more likely to be involved in an SCE when driving in darkness, lighted.

When “Vehicle 1 At-fault” events were considered and compared to baseline epochs, drivers were:

- 2.53 times more likely to be involved in an SCE when driving in daylight.
- 3.12 times more likely to be involved in an SCE when driving in darkness, lighted conditions.

Table 15. ORs and 95-percent confidence intervals for the interaction of any secondary and/or driving-related task by lighting level across "All" and "Vehicle 1 At-fault" events.

Lighting Levels	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Daylight	**2.02***	1.74	2.35	**2.53***	2.02	3.17
Darkness, lighted	**2.07***	1.48	2.89	**3.12***	1.77	5.51
Dawn	**4.06***	1.27	12.95	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 16 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each lighting level.

Table 16. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-Fault" events for each lighting level.

Lighting Levels	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
Daylight	336	965	165	965
Darkness, not lighted	4	94	2	94
Darkness, lighted	48	224	23	224
Dawn	5	18	3	18
Dusk	3	26	0	26

Table 17 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each lighting level. The results suggest that engaging in any of the secondary tasks significantly increased the risk of a driver being involved in an SCE in two of the lighting conditions. When "All" events were considered and compared to baseline epochs, drivers were 1.36 times more likely to be involved in an SCE when driving in daylight. When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 1.84 times more likely to be involved in an SCE when driving in daylight.
- 2.25 times more likely to be involved in an SCE when driving in darkness, lighted conditions.

Table 17. ORs and 95-percent confidence intervals for the interaction of secondary tasks by lighting level across "All" and "Vehicle 1 At-fault" events.

Lighting Levels	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Daylight	**1.36***	1.16	1.59	**1.84***	1.48	2.29
Darkness, lighted	1.23	0.85	1.78	**2.25***	1.29	3.94
Dawn	1.41	0.43	4.62	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 18 shows the frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each lighting level.

Table 18. The frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each lighting level.

Lighting Levels	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Baselines
Daylight	278	441	109	441
Darkness, not lighted	3	39	0	39
Darkness, lighted	55	127	18	127
Dawn	8	9	2	9
Dusk	5	13	1	13

Table 19 displays the OR calculations for engaging in any driving-related task across "All" and "Vehicle 1 At-fault" events for each lighting level. The results suggest that engaging in any of the secondary tasks significantly increased the risk of a driver being involved in an SCE in three of the lighting conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 2.77 times more likely to be involved in an SCE when driving in daylight.
- 3.03 times more likely to be involved in an SCE when driving in darkness, lighted.
- 7.22 times more likely to be involved in an SCE when driving at dawn.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 2.59 times more likely to be involved in an SCE when driving in daylight.
- 3.06 times more likely to be involved in an SCE when driving in darkness, lighted conditions.

Table 19. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by lighting level across "All" and "Vehicle 1 At-fault" events.

Lighting Levels	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Daylight	**2.77***	2.33	3.29	**2.59***	2.02	3.31
Darkness, lighted	**3.03***	2.09	4.41	**3.06***	1.69	5.55
Dawn	**7.22***	2.17	24.04	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.2 Weather Conditions

"Weather conditions" indicate the atmospheric conditions at the time of the SCE or baseline epoch. Data analysts were instructed to use the video data to assist in determining the appropriate weather condition. During data reduction, analysts selected one of the following weather conditions:

- No adverse conditions.
- Wind gusts.
- Fog.
- Rain.
- Snowing.
- Sleeting.
- Rain and fog.
- Snow/sleet and fog.

Table 20 shows the frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each weather condition. Unobserved conditions are not included. Most of the data were collected in “No Adverse Conditions.”

Table 20. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each weather condition.

Weather Conditions	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
No adverse conditions	632	1,753	274	1,753
Wind gusts	1	1	0	1
Fog	1	8	1	8
Rain	3	45	1	45
Rain and fog	0	1	0	1

Table 21, Table 22, Table 23, Table 24, and Table 25 present the results of the OR calculations for each weather condition. Table 21 displays the OR calculations for engaging in any secondary and/or driving-related task across “All” and “Vehicle 1 At-fault” events for each weather condition. The results suggest that engaging in any secondary and/or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in one weather condition. When “All” events were considered and compared to baseline epochs, drivers were 2.23 times more likely to be involved in an SCE when driving in no adverse weather conditions. When “Vehicle 1 At-fault” events were considered and compared to a baseline epoch, drivers were 2.90 times more likely to be involved in an SCE when driving in no adverse weather conditions.

Table 21. ORs and 95-percent confidence intervals for the interaction of any secondary and/or driving-related task by weather condition across "All" and "Vehicle 1 At-fault" events.

Weather Conditions	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
No adverse conditions	**2.23***	1.95	2.56	**2.90***	2.35	3.57

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 22 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-Fault" events for each weather condition.

Table 22. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each weather condition.

Weather Conditions	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
No adverse conditions	395	1290	193	1290
Wind gusts	0	1	0	1
Fog	0	5	0	5
Rain	1	30	0	30
Rain and fog	0	1	0	1

Table 23 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each weather condition. The results suggest that engaging in any secondary task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in one weather condition. When "All" events were considered and compared to baseline epochs, drivers were 1.44 times more likely to be involved in an SCE when driving in no adverse weather conditions. When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were 2.09 times more likely to be involved in an SCE when driving in no adverse weather conditions.

Table 23. ORs and 95-percent confidence intervals for the interaction of secondary task by weather condition across "All" and "Vehicle 1 At-fault" events.

Weather Conditions	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
No adverse conditions	**1.44***	1.26	1.66	**2.09***	1.71	2.56

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 24 shows the frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each weather condition.

Table 24. The frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each weather condition.

Weather Conditions	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Task Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Task Baselines
No adverse conditions	344	604	128	604
Wind gusts	1	1	0	1
Fog	1	5	1	5
Rain	3	19	1	19
Rain and fog	0	1	0	1

Table 25 displays the OR calculations for engaging in any driving-related task across "All" and "Vehicle 1 At-fault" events for each weather condition. The results suggest that engaging in any driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in one weather condition. When "All" events were considered and compared to baseline epochs, drivers were 3.03 times more likely to be involved in an SCE when driving in no adverse weather conditions. When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were 2.80 times more likely to be involved in an SCE when driving in no adverse weather conditions.

Table 25. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by weather condition across "All" and "Vehicle 1 At-fault" events.

Weather Conditions	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
No adverse conditions	**3.03***	2.60	3.54	**2.80***	2.24	3.51

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.3 Roadway Surface Condition

The "roadway surface condition" indicates the condition of the road during the SCE or baseline epoch. Data analysts were instructed to use the video data to assist in determining the appropriate roadway surface condition. During data reduction, analysts selected one of the following roadway surface conditions:

- Dry.
- Wet.
- Snowy.
- Icy.
- Muddy.
- Oily.
- Other.

Data analysts were instructed to choose a single roadway surface condition value that best described the roadway at the time of the SCE or baseline epoch, with a roadway surface condition hierarchy in place if more than one condition was applicable (e.g., choose "icy" if it applies, regardless of other conditions present).

Table 26 shows the frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway surface condition. Unobserved conditions are not included. Most of the data were collected in "dry" conditions.

Table 26. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway surface condition.

Roadway Surface Condition	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
Dry	622	1,720	272	1,720
Wet	15	88	4	88

Table 27, Table 28, Table 29, Table 30, and Table 31 present the results of the OR calculations for each roadway surface condition. Table 27 displays the OR calculations for engaging in any secondary and/or driving-related task across "All" and "Vehicle 1 At-fault" events for each roadway surface condition. The results suggest that engaging in any secondary and/or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in one roadway surface condition. When "All" events were considered and compared to baseline epochs, drivers were 2.27 times more likely to be involved in an SCE when driving on dry roadway surface conditions. When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were 2.92 times more likely to be involved in an SCE when driving on dry roadway surface conditions.

Table 27. ORs and 95-percent confidence intervals for the interaction of any secondary and/or driving-related task by roadway surface condition across "All" and "Vehicle 1 At-fault" events.

Roadway Surface Condition	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Dry	**2.27***	1.98	2.60	**2.92***	2.37	3.60
Wet	0.82	0.38	1.73	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 28 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway surface condition.

Table 28. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway surface condition.

Roadway Surface Condition	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
Dry	387	1,266	191	1,266
Wet	9	61	2	61

Table 29 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each roadway surface condition. The results suggest that engaging in any secondary task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in one roadway surface condition. When "All" events were considered and compared to baseline epochs, drivers were 1.45 times more likely to be involved in an SCE when driving on dry roadway surface conditions. When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were 2.09 times more likely to be involved in an SCE when driving on dry roadway surface conditions.

Table 29. ORs and 95-percent confidence intervals for the interaction of secondary task by roadway surface condition across "All" and "Vehicle 1 At-fault" events.

Roadway Surface Condition	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Dry	**1.45***	1.26	1.67	**2.09***	1.71	2.57
Wet	0.69	0.30	1.59	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 30 shows the frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway surface condition.

Table 30. The frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway surface condition.

Roadway Surface Condition	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Task Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Task Baselines
Dry	340	593	128	593
Wet	9	36	2	36

Table 31 displays the OR calculations for engaging in any driving-related task across "All" and "Vehicle 1 At-fault" events for each roadway surface condition. The results suggest that engaging in any driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in one roadway surface condition. When "All" events were considered and compared to baseline epochs, drivers were 3.08 times more likely to be involved in an SCE when driving on dry roadway surface conditions. When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were 2.85 times more likely to be involved in an SCE when driving on dry roadway surface conditions.

Table 31. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by roadway surface condition across "All" and "Vehicle 1 At-fault" events.

Roadway Surface Condition	A LL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Dry	**3.08***	2.64	3.60	**2.85***	2.27	3.57
Wet	1.45	0.62	3.40	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.4 Relation to Junction

"Relation to junction" indicates an intersection or the connection between a driveway access and a roadway other than a driveway access during the SCE or baseline epoch. Data analysts were instructed to use the video data to assist in determining the appropriate relation to junction. During data reduction, analysts selected one of the following relation-to-junction options:

- Non-junction.
- Intersection.
- Intersection-related.
- Entrance/exit ramp.
- Rail grade crossing.
- Interchange area.
- Parking lot entrance/exit.
- Parking lot, within boundary.
- Driveway, alley access, etc.
- Crossover-related.
- Other.

Table 32 shows the frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway grade. Unobserved conditions are not included. Most of the data were collected in non-junction conditions.

Table 32. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each relation to junction.

Relation to Junction	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
Non-junction	329	846	126	846
Intersection	95	112	49	112
Intersection-related	46	111	14	111
Entrance/exit ramp	21	70	15	70
Rail grade crossing	0	2	0	2
Interchange area	70	553	33	553
Parking lot entrance/exit	41	53	26	53
Parking lot, within boundary	8	25	2	25
Driveway, alley access, etc.	2	29	0	29
Crossover-related	4	1	3	1
Other	21	6	8	6

Table 33, Table 34, Table 35, Table 36, and Table 37 present the results of the OR calculations for each relation to junction. Table 33 displays the OR calculations for engaging in any secondary and/or driving-related task across “All” and “Vehicle 1 At-fault” events for each relation to junction. The results suggest that engaging in any secondary task and/or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in five relation-to-junction conditions. When “All” events were considered and compared to baseline epochs, drivers were:

- 2.44 times more likely to be involved in an SCE when driving in a non-junction.
- 1.85 times more likely to be involved in an SCE) when driving in an intersection.
- 4.43 times more likely to be involved in an SCE when driving on an entrance/exit ramp.
- 1.77 times more likely to be involved in an SCE when driving in an interchange area.
- 2.36 times more likely to be involved in an SCE when driving in a parking lot entrance/exit.

When “Vehicle 1 At-fault” events were considered and compared to baseline epochs, drivers were:

- 3.24 times more likely to be involved in an SCE when driving in a non-junction.
- 2.16 times more likely to be involved in an SCE when driving in an intersection.
- 2.54 times more likely to be involved in an SCE when driving in an interchange area.
- 2.62 times more likely to be involved in an SCE when driving in a parking lot entrance/exit.

Table 33. ORs and 95-percent confidence intervals for the interaction of any secondary task and/or driving-related task by relation to junction across "All" and "Vehicle 1 At-fault" events.

Relation to Junction	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Non-junction	**2.44***	2.01	2.96	**3.24***	2.36	4.44
Intersection	**1.85***	1.24	2.74	**2.16***	1.29	3.62
Intersection-related	1.04	0.64	1.68	0.93	0.43	1.99
Entrance/exit ramp	**4.43***	1.86	10.52	-	-	-
Interchange area	**1.77***	1.24	2.51	**2.54***	1.46	4.39
Parking lot entrance/exit	**2.36***	1.24	4.47	**2.62***	1.21	5.68
Parking lot, within boundary	1.41	0.40	4.94	-	-	-
Other	2.15	0.61	7.63	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 34 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each relation to junction.

Table 34. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each relation to junction.

Relation to Junction	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
Non-junction	195	652	83	652
Intersection	57	86	35	86
Intersection-related	34	84	11	84
Entrance/exit ramp	17	51	14	51
Rail grade crossing	0	2	0	2
Interchange area	41	357	23	357
Parking lot entrance/exit	32	42	21	42
Parking lot, within boundary	8	24	2	24
Driveway, alley access, etc.	1	24	0	24
Crossover-related	1	1	1	1
Other	10	4	3	4

Table 35 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each relation to junction. The results suggest that engaging in any secondary task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in three relation-to-junction conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 1.32 times more likely to be involved in an SCE when driving in a non-junction.
- 3.81 times more likely to be involved in an SCE when driving on an entrance/exit ramp.
- 1.90 times more likely to be involved in an SCE when driving in a parking lot entrance/exit.

When “Vehicle 1 At-fault” events were considered and compared to a baseline epoch, drivers were:

- 1.87 times more likely to be involved in an SCE when driving in a non-junction.
- 2.28 times more likely to be involved in an SCE when driving in an interchange area.
- 2.21 times more likely to be involved in an SCE when driving in a parking lot entrance/exit.

Table 35. ORs and 95 percent confidence intervals for the interaction of secondary task by relation to junction across “All” and “Vehicle 1 At-fault” events.

Relation to Junction	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Non-junction	**1.32***	1.09	1.61	**1.87***	1.38	2.53
Intersection	1.09	0.72	1.64	1.61	0.96	2.69
Intersection-related	1.00	0.60	1.64	1.00	0.45	2.20
Entrance/exit ramp	**3.81***	1.70	8.52	-	-	-
Interchange area	1.35	0.92	1.99	**2.28***	1.32	3.94
Parking lot entrance/exit	**1.90***	1.02	3.56	**2.21***	1.05	4.64
Parking lot, within boundary	1.53	0.44	5.38	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 36 shows the frequency of driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each relation to junction.

Table 36. The frequency of driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each relation to junction.

Relation to Junction	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Task Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Task Baselines
Non-junction	183	250	62	250
Intersection	59	33	24	33
Intersection-related	24	43	6	43
Entrance/exit ramp	6	25	1	25
Rail grade crossing	0	1	0	1
Interchange area	39	245	17	245
Parking lot entrance/exit	14	19	9	19
Parking lot, within boundary	3	3	1	3
Driveway, alley access, etc.	1	8	0	8
Crossover-related	4	0	3	0
Other	16	2	7	2

Table 37 displays the OR calculations for engaging in any driving-related task across “All” and “Vehicle 1 At-fault” events for each relation to junction. The results suggest that engaging in any driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in three relation-to-junction conditions. When “All” events were considered and compared to baseline epochs, drivers were:

- 3.94 times more likely to be involved in an SCE when driving in a non-junction.
- 3.90 times more likely to be involved in an SCE when driving in an intersection.
- 2.02 times more likely to be involved in an SCE when driving in an interchange area.

When “Vehicle 1 At-fault” events were considered and compared to baseline epochs, drivers were:

- 3.83 times more likely to be involved in an SCE when driving in a non-junction.
- 3.00 times more likely to be involved in an SCE when driving in an intersection.
- 2.27 times more likely to be involved in an SCE when driving in an interchange.

Table 37. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by relation to junction across “All” and “Vehicle 1 At-fault” events.

Relation to Junction	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Non-junction	**3.94***	3.16	4.92	**3.83***	2.75	5.33
Intersection	**3.90***	2.40	6.34	**3.00***	1.64	5.48
Intersection-related	1.50	0.85	2.66	1.08	0.42	2.81
Entrance/exit ramp	1.70	0.63	4.59	-	-	-
Interchange area	**2.02***	1.36	3.00	**2.27***	1.26	4.09
Parking lot entrance/exit	1.50	0.70	3.26	1.60	0.65	3.92

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.5 Roadway Alignment

The “roadway alignment” condition indicates the alignment of the road during the SCE or baseline epoch. Data analysts were instructed to use the video data to assist in determining the appropriate roadway alignment. During data reduction, analysts selected one of the following roadway alignments options:

- Straight.
- Curve left.
- Curve right.
- Other.

Table 38 shows the frequency of secondary tasks and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each roadway surface condition. Unobserved conditions are not included. Most of the data were collected in “straight” conditions.

Table 38. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway alignment.

Roadway Alignment	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
Straight	545	1,574	236	1,574
Curve left	45	118	13	118
Curve right	47	116	27	116

Table 39, Table 40, Table 41, Table 42, and Table 43 present the results of the OR calculations for each roadway alignment. Table 39 displays the OR calculations for engaging in any secondary and/or driving-related task across "All" and "Vehicle 1 At-fault" events for each roadway alignment condition. The results suggest that engaging in any secondary task and/or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in three roadway alignment conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 2.13 times more likely to be involved in an SCE when driving on a straight roadway.
- 2.00 times more likely to be involved in an SCE when driving on a curve left.
- 3.79 times more likely to be involved in an SCE when driving on a curve right.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 2.60 times more likely to be involved in an SCE when driving on a straight roadway.
- 4.85 times more likely to be involved in an SCE when driving on a curve left.
- 5.00 times more likely to be involved in an SCE when driving on a curve right.

Table 39. ORs and 95-percent confidence intervals for the interaction of any secondary and/or driving-related task by roadway alignment across "All" and "Vehicle 1 At-fault" events.

Roadway Alignment	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Straight	**2.13***	1.84	2.46	**2.60***	2.08	3.24
Curve left	**2.00***	1.24	3.22	**4.85***	1.69	13.93
Curve right	**3.79***	2.19	6.55	**5.00***	2.34	10.70

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 40 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-Fault" events for each roadway alignment.

Table 40. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway alignment.

Roadway Alignment	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
Straight	333	1159	163	1,159
Curve left	32	82	9	82
Curve right	31	86	21	86

Table 41 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each roadway alignment condition. The results suggest that engaging in any secondary task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in three roadway alignment conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 1.34 times more likely to be involved in an SCE when driving on a straight roadway.
- 1.82 times more likely to be involved in an SCE when driving on a curve left.
- 2.26 times more likely to be involved in an SCE when driving on a curve right.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 1.87 times more likely to be involved in an SCE when driving on a straight roadway.
- 3.12 times more likely to be involved in an SCE when driving on a curve left.
- 3.74 times more likely to be involved in an SCE when driving on a curve right.

Table 41. ORs and 95-percent confidence intervals for the interaction of secondary task by roadway alignment across "All" and "Vehicle 1 At-fault" events.

Roadway Alignment	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Straight	**1.34***	1.15	1.55	**1.87***	1.50	2.32
Curve left	**1.82***	1.10	3.00	**3.12***	1.20	8.13
Curve right	**2.26***	1.33	3.85	**3.74***	1.87	7.49

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 42 shows the frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway alignment.

Table 42. The frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway alignment.

Roadway Alignment	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Task Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Task Baselines
Straight	304	548	118	548
Curve left	24	42	5	42
Curve right	21	39	7	39

Table 43 displays the OR calculations for engaging in any driving-related task across "All" and "Vehicle 1 At-fault" events for each roadway alignment condition. The results suggest that engaging in any driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in three roadway alignment conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 3.00 times more likely to be involved in an SCE when driving on a straight roadway.
- 2.68 times more likely to be involved in an SCE when driving on a curve left.
- 3.21 times more likely to be involved in an SCE when driving on a curve right.

When "Vehicle 1 At-fault" events were considered and compared to a baseline epoch, drivers were 2.87 times more likely to be involved in an SCE when driving on a straight roadway.

Table 43. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by roadway alignment across "All" and "Vehicle 1 At-fault" events.

Roadway Alignment	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Straight	**3.00***	2.55	3.54	**2.87***	2.26	3.63
Curve left	**2.68***	1.52	4.75	2.71	0.92	7.99
Curve right	**3.21***	1.74	5.91	1.75	0.72	4.25

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.6 Roadway Grade

The "road grade" condition indicates the grade of the road during the SCE or baseline epoch. Data analysts were instructed to use the video data to assist in determining the appropriate road grade. During data reduction, analysts selected one of the following road-grade options:

- Level
- Grade up.
- Grade down.
- Hillcrest.
- Dip.

Table 44 shows the frequency of secondary tasks and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway grade condition. Unobserved conditions are not included. Most of the data were collected in "level" conditions.

Table 44. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway grade.

Roadway Grade	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
Level	552	1525	238	1,525
Grade up	44	171	17	171
Grade down	39	107	19	107
Hillcrest	2	3	2	3
Dip	0	2	0	2

Table 45, Table 46, Table 47, Table 48, and Table 49 present the results of the OR calculations for each roadway grade condition. Table 45 displays the OR calculations for engaging in any secondary and/or driving-related task across "All" and "Vehicle 1 At-fault" events for each roadway grade. The results suggest that engaging in any secondary and/or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in three roadway grade conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 2.07 times more likely to be involved in an SCE when driving on a level grade.
- 2.81 times more likely to be involved in an SCE when driving on a grade up.
- 3.76 times more likely to be involved in an SCE when driving on a grade down.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 2.59 times more likely to be involved in an SCE when driving on a level grade.
- 5.65 times more likely to be involved in an SCE when driving on a grade up.
- 4.97 times more likely to be involved in an SCE when driving on a grade down.

Table 45. ORs and 95-percent confidence intervals for the interaction of any secondary and/or driving-related task by roadway grade across "All" and "Vehicle 1 At-fault" events.

Roadway Grade	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Level	**2.07***	1.79	2.39	**2.59***	2.08	3.22
Grade up	**2.81***	1.67	4.73	**5.65***	2.05	15.58
Grade down	**3.76***	2.07	6.83	**4.97***	2.03	12.21

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 46 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway grade condition.

Table 46. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway grade.

Roadway Grade	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
Level	346	1126	163	1,126
Grade up	27	120	15	120
Grade down	22	79	14	79
Hillcrest	1	1	1	1
Dip	0	1	0	1

Table 47 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each roadway grade condition. The results suggest that engaging in any secondary task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in three roadway grade conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 1.36 times more likely to be involved in an SCE when driving on a level grade.
- 1.75 times more likely to be involved in an SCE when driving on a grade up.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 1.83 times more likely to be involved in an SCE when driving on a level grade.
- 5.98 times more likely to be involved in an SCE when driving on a grade up.
- 3.31 times more likely to be involved in an SCE when driving on a grade down.

Table 47. ORs and 95-percent confidence intervals for the interaction of secondary task by roadway grade across "All" and "Vehicle 1 At-fault" events.

Roadway Grade	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Level	**1.36***	1.18	1.58	**1.83***	1.48	2.27
Grade up	**1.75***	1.04	2.96	**5.98***	2.38	15.03
Grade down	1.73	0.96	3.12	**3.31***	1.47	7.46

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 48 shows the frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway grade condition.

Table 48. The frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each roadway grade.

Roadway Grade	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Task Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Task Baselines
Level	303	525	117	525
Grade up	25	64	6	64
Grade down	20	36	6	36
Hillcrest	1	3	1	3
Dip	0	1	0	1

Table 49 displays OR calculations for engaging in a driving-related task across "All" and "Vehicle 1 At-fault" events for each roadway grade condition. The results suggest engaging in any driving-related task significantly increased the risk of being involved in an SCE (compared to a baseline epoch) in three roadway grade conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 2.93 times more likely to be involved in an SCE when driving on a level grade.
- 3.39 times more likely to be involved in an SCE when driving on a grade up.
- 3.90 times more likely to be involved in an SCE when driving on a grade down.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were 2.83 times more likely to be involved in an SCE when driving on a level grade.

Table 49. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by roadway grade across "All" and "Vehicle 1 At-fault" events.

Roadway Grade	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Level	**2.93***	2.48	3.45	**2.83***	2.24	3.59
Grade up	**3.39***	1.95	5.92	2.29	0.86	6.07
Grade down	**3.90***	2.05	7.43	2.23	0.84	5.91

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.7 Traffic Flow

"Traffic flow" indicates whether the SCE or baseline epoch occurred on a roadway that was not physically divided or was divided with a median strip (with or without a traffic barrier), and whether it served one-way or two-way traffic. Data analysts were instructed to use the video data to assist in determining the appropriate traffic flow at the time of the SCE. During data reduction, analysts selected one of the following traffic flow options:

- Not divided: two-way traffic.
- Not divided: center two-way left turn lane.
- Divided: median strip or barrier.

- One-way traffic.
- No lanes.

Table 50 shows the frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each traffic flow condition. Unobserved conditions are not included. Most of the data were collected in “divided: median strip or barrier,” with the next largest segments coming from “one-way traffic” and “not divided: two-way traffic” conditions.

Table 50. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each traffic flow.

Traffic Flow	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
Not divided: two-way traffic	114	275	55	275
Not divided: center turn lane	19	48	7	48
Divided: median strip/barrier	209	1,242	100	1,242
One-way traffic	283	217	109	217
No lanes	12	26	5	26

Table 51, Table 52, Table 53, Table 54, and Table 55 present the results of the OR calculations for each traffic flow condition. Table 51 displays the OR calculations for engaging in any secondary task and/or driving-related task across “All” and “Vehicle 1 At-fault” events for each traffic flow. The results suggest that engaging in any secondary task and/or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in four traffic flow conditions. When “All” events were considered and compared to baseline epochs, drivers were:

- 1.66 times more likely to be involved in an SCE when driving on an undivided 2-way traffic road.
- 3.81 times more likely to be involved in an SCE when driving on an undivided center turn lane road.
- 1.97 times more likely to be involved in an SCE when driving on a divided road.
- 2.09 times more likely to be involved in an SCE when driving on a one-way road.

When “Vehicle 1 At-fault” events were considered and compared to baseline epochs, drivers were:

- 1.91 times more likely to be involved in an SCE when driving on an undivided two-way traffic road.
- 2.60 times more likely to be involved in an SCE when driving on a divided road.
- 3.00 times more likely to be involved in an SCE when driving on a one-way road.

Table 51. ORs and 95-percent confidence intervals for the interaction of any secondary and/or driving-related task by traffic flow across "All" and "Vehicle 1 At-fault" events.

Traffic Flow	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Not divided: two-way traffic	**1.66***	1.19	2.32	**1.91***	1.20	3.04
Not divided: center turn lane	**3.81***	1.55	9.38	-	-	-
Divided: median strip/barrier	**1.97***	1.60	2.44	**2.60***	1.89	3.58
One-way traffic	**2.09***	1.62	2.70	**3.00***	2.05	4.40
No lanes	1.65	0.56	4.86	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 52 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic flow condition.

Table 52. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic flow.

Traffic Flow	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
Not divided: two-way traffic	83	220	40	220
Not divided: center turn lane	11	37	5	37
Divided: median strip/barrier	123	887	71	887
One-way traffic	167	158	72	158
No lanes	12	25	5	25

Table 53 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each traffic flow condition. The results suggest that engaging in any secondary task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in two traffic flow conditions. When "All" events were considered and compared to baseline epochs, drivers were 1.28 times more likely to be involved in an SCE when driving on a divided road. When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 2.09 times more likely to be involved in an SCE when driving on a divided road.
- 1.86 times more likely to be involved in an SCE when driving on a one-way road.

Table 53. ORs and 95-percent confidence intervals for the interaction of secondary task by traffic flow across "All" and "Vehicle 1 At-fault" events.

Traffic Flow	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Not divided: two-way traffic	1.27	0.91	1.77	1.39	0.88	2.19
Not divided: center turn lane	1.64	0.69	3.86	1.98	0.57	6.90
Divided: median strip/barrier	**1.28***	1.02	1.61	**2.09***	1.52	2.87
One-way traffic	1.24	0.95	1.62	**1.86***	1.29	2.67
No lanes	1.78	0.60	5.26	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 54 shows the frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic flow condition.

Table 54. The frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic flow.

Traffic Flow	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Task Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Task Baselines
Not divided: two-way traffic	46	81	20	81
Not divided: center turn lane	11	16	4	16
Divided: median strip/barrier	118	451	49	451
One-way traffic	170	78	55	78
No lanes	4	3	2	3

Table 55 displays the OR calculations for engaging in any driving-related task across "All" and "Vehicle 1 At-fault" events for each traffic flow condition. The results suggest that engaging in any driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in four traffic flow conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 1.97 times more likely to be involved in an SCE when driving on an undivided two-way traffic road.
- 4.68 times more likely to be involved in an SCE when driving on an undivided center turn lane road.
- 2.80 times more likely to be involved in an SCE when driving on a divided road.
- 3.18 times more likely to be involved in an SCE when driving on a one-way road.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 1.84 times more likely to be involved in an SCE when driving on an undivided two-way traffic road.

- 2.71 times more likely to be involved in an SCE when driving on a divided road.
- 2.94 times more likely to be involved in an SCE when driving on a one-way road.

Table 55. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by traffic flow across "All" and "Vehicle 1 At-fault" events.

Traffic Flow	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Not divided: two-way traffic	**1.97***	1.31	2.96	**1.84***	1.06	3.19
Not divided: center turn lane	**4.68***	1.85	11.87	-	-	-
Divided: median strip/barrier	**2.80***	2.21	3.55	**2.71***	1.91	3.83
One-way traffic	**3.18***	2.34	4.32	**2.94***	1.96	4.29

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.8 Traffic Density

"Traffic density" is listed in increasing order from level of service (LOS) A–F and was assessed at the time of each SCE or baseline epoch.(138) LOS A is described as conditions where the traffic flow is at or above the posted speed limit and all motorists have complete mobility between lanes. LOS B is slightly more congested, with some impingement of maneuverability. Two motorists might be forced to drive side by side, limiting lane changes. LOS C has more congestion than B, where ability to pass or change lanes is not always assured. In LOS D, speeds are somewhat reduced, and motorists are hemmed in by other cars and trucks. LOS E is a marginal service state. Flow becomes irregular and speed varies rapidly, but rarely reaches the posted limit. LOS F, the lowest measurement of efficiency for a road's performance, has a forced flow. Every vehicle moves in lockstep with the vehicle in front of it, with frequent drops in speed to nearly 0 mi/h.(139) Data analysts were instructed to use the video data to assist in determining the appropriate LOS. During data reduction, analysts selected one of the following LOS options:

- LOS A1: Free flow, no lead traffic.
- LOS A2: Free flow, leading traffic present.
- LOS B: Flow with some restrictions.
- LOS C: Stable flow, maneuverability, and speed are more restricted.
- LOS D: Unstable flow, temporary restrictions substantially slow the driver.
- LOS E: Unstable flow: vehicles are unable to pass, temporary stoppages, etc.
- LOS F: Forced traffic flow condition with low speeds and traffic volumes that are less than capacity; queues form in particular locations.

Table 56 shows the frequency of secondary and tertiary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each LOS. Most data were collected in the top three flowing conditions: LOS A1, A2, and B.

Table 56. The frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic density.

Traffic Density	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
LOS A1	46	351	32	351
LOS A2	71	676	32	676
LOS B	263	533	99	533
LOS C	143	94	54	94
LOS D	59	44	27	44
LOS E	37	69	25	69
LOS F	9	11	4	11

Table 57, Table 58, Table 59, Table 60, and Table 61 present the results of the OR calculations for each traffic density condition. Table 57 displays the OR calculations for engaging in any secondary task and/or driving-related task across "All" and "Vehicle 1 At-fault" events for each traffic density condition. The results suggest that engaging in any secondary task and/or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in seven traffic density conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 2.08 times more likely to be involved in an SCE when driving in LOS A1 traffic density.
- 1.73 times more likely to be involved in an SCE when driving in LOS A2 traffic density.
- 2.39 times more likely to be involved in an SCE when driving in LOS B traffic density.
- 3.06 times more likely to be involved in an SCE when driving in LOS C traffic density.
- 3.18 times more likely to be involved in an SCE when driving in LOS D traffic density.
- 2.97 times more likely to be involved in an SCE when driving in LOS E traffic density.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 2.09 times more likely to be involved in an SCE when driving in LOS A1 traffic density.
- 2.33 times more likely to be involved in an SCE when driving in LOS A2 traffic density.
- 3.19 times more likely to be involved in an SCE when driving in LOS B traffic density.
- 3.80 times more likely to be involved in an SCE when driving in LOS C traffic density.
- 3.93 times more likely to be involved in an SCE when driving in LOS D traffic density.
- 4.58 times more likely to be involved in an SCE when driving in LOS E traffic density.

Table 57. ORs and 95-percent confidence intervals for the interaction of any secondary and/or driving-related task by traffic density across "All" and "Vehicle 1 At-fault" events.

Traffic Density	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
LOS A1	**2.08***	1.28	3.38	**2.10***	1.18	3.74
LOS A2	**1.73***	1.20	2.48	**2.33***	1.31	4.15
LOS B	**2.39***	1.92	2.98	**3.29***	2.29	4.72
LOS C	**3.06***	2.13	4.39	**3.80***	2.26	6.38
LOS D	**3.18***	1.92	5.26	**3.93***	2.01	7.69
LOS E	**2.97***	1.71	5.14	**4.58***	2.25	9.33

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 58 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic density condition.

Table 58. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic density

Traffic Density	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
LOS A1	38	276	27	276
LOS A2	46	506	25	506
LOS B	161	360	67	360
LOS C	83	66	35	66
LOS D	32	30	16	30
LOS E	20	51	16	51
LOS F	7	9	4	9

Table 59 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each traffic density condition. The results suggest that engaging in any secondary task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in six traffic density conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 1.99 times more likely to be involved in an SCE when driving in LOS A1 traffic density.
- 1.65 times more likely to be involved in an SCE when driving in LOS B traffic density.
- 1.76 times more likely to be involved in an SCE when driving in LOS C traffic density.
- 1.87 times more likely to be involved in an SCE when driving in LOS D traffic density.
- 4.15 times more likely to be involved in an SCE when driving in LOS F traffic density.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 2.10 times more likely to be involved in an SCE when driving in LOS A1 traffic density.
- 2.10 times more likely to be involved in an SCE when driving in LOS A2 traffic density.
- 2.38 times more likely to be involved in an SCE when driving in LOS B traffic density.
- 2.40 times more likely to be involved in an SCE when driving in LOS C traffic density.
- 2.44 times more likely to be involved in an SCE when driving in LOS D traffic density.
- 2.66 times more likely to be involved in an SCE when driving in LOS E traffic density.

Table 59. ORs and 95-percent confidence intervals for the interaction of secondary task by traffic density across "All" and "Vehicle 1 At-fault" events.

Traffic Density	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
LOS A1	**1.99***	1.24	3.21	**2.10***	1.19	3.68
LOS A2	1.23	0.84	1.79	**2.10***	1.20	3.68
LOS B	**1.65***	1.31	2.07	**2.38***	1.68	3.36
LOS C	**1.76***	1.20	2.59	**2.40***	1.43	4.03
LOS D	**1.87***	1.06	3.30	**2.44***	1.19	5.02
LOS E	1.56	0.85	2.86	**2.66***	1.31	5.40
LOS F	**4.15***	1.11	15.49	-	-	-

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 60 shows the frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic density condition.

Table 60. The frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic density.

Traffic Density	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Task Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Task Baselines
LOS A1	14	113	10	113
LOS A2	31	232	8	232
LOS B	150	209	48	209
LOS C	91	31	34	31
LOS D	34	17	14	17
LOS E	21	21	13	21
LOS F	5	3	2	3

Table 61 displays the OR calculations for engaging in any driving-related task across "All" and "Vehicle 1 At-fault" events for each traffic density condition. The results suggest that engaging in any driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in four traffic density conditions. When "All" events were considered and compared to baseline epochs, drivers were:

- 1.90 times more likely to be involved in an SCE when driving in LOS A2 traffic density.

- 2.92 times more likely to be involved in an SCE when driving in LOS B traffic density.
- 5.06 times more likely to be involved in an SCE when driving in LOS C traffic density.
- 3.92 times more likely to be involved in an SCE when driving in LOS D traffic density.
- 4.69 times more likely to be involved in an SCE when driving in LOS E traffic density.

When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were:

- 2.72 times more likely to be involved in an SCE when driving in LOS B traffic density.
- 5.67 times more likely to be involved in an SCE when driving in LOS C traffic density.
- 3.87 times more likely to be involved in an SCE when driving in LOS D traffic density.
- 5.36 times more likely to be involved in an SCE when driving in LOS E traffic density.

Table 61. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by traffic density across "All" and "Vehicle 1 At-fault" events.

Traffic Density	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
LOS A1	1.42	0.77	2.62	1.47	0.72	3.02
LOS A2	**1.90***	1.24	2.92	1.11	0.51	2.39
LOS B	**2.92***	2.29	3.74	**2.72***	1.87	3.96
LOS C	**5.06***	3.20	7.98	**5.67***	3.18	10.09
LOS D	**3.92***	2.06	7.46	**3.87***	1.74	8.62
LOS E	**4.69***	2.37	9.26	**5.36***	2.40	11.95

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.9 Locality

"Locality" indicates the surroundings that influence, or may influence, the flow of traffic at the time of the SCE or baseline epoch. Data analysts were instructed to use the video data to assist in determining the appropriate locality. During data reduction, analysts selected one of the following locality options:

- Open country.
- Residential.
- Business/industrial.
- Church.
- Playground.
- School.
- Urban.
- Airport.
- Interstate.

- Other.

Table 62 shows the frequency of secondary and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each locality. Unobserved conditions are not included. Most of the data were collected in airport, business/industrial, and interstate conditions.

Table 62. The frequency of secondary tasks and/or driving-related tasks during SCEs and baseline epochs across “All” and “Vehicle 1 At-fault” events for each locality.

Locality	ALL Frequency of Secondary and/or Driving-related Task SCEs	ALL Frequency of Secondary and/or Driving-related Task Baselines	V1 Frequency of Secondary and/or Driving-related Task SCEs	V1 Frequency of Secondary and/or Driving-related Task Baselines
Open country	6	22	4	22
Residential	12	74	6	74
Business/industrial	164	224	74	224
Church	3	20	1	20
Playground	0	3	0	3
School	11	77	7	77
Urban	42	81	22	81
Airport	269	173	94	173
Interstate	128	1,133	67	1,133
Other	2	1	1	1

Table 63, Table 64, Table 65, Table 66, and Table 67 present the results of the OR calculations for each locality. Table 63 displays the OR calculations for engaging in any secondary and/or driving-related task across “All” and “Vehicle 1 At-fault” events for each locality. The results suggest that engaging in any secondary and/or driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in four localities. When “All” events were considered and compared to baseline epochs, drivers were:

- 1.98 times more likely to be involved in an SCE when driving in a business/industrial area.
- 1.71 times more likely to be involved in an SCE when driving in an airport.
- 1.88 times more likely to be involved in an SCE when driving on an interstate.

When “Vehicle 1 At-fault” events were considered and compared to baseline epochs, drivers were:

- 1.95 times more likely to be involved in an SCE when driving in a business/industrial area.
- 3.12 times more likely to be involved in an SCE when driving in an urban area.
- 2.46 times more likely to be involved in an SCE when driving in an airport.
- 2.84 times more likely to be involved in an SCE when driving on an interstate.

Table 63. ORs and 95-percent confidence intervals for the interaction of any secondary task and/or driving-related task by locality across "All" and "Vehicle 1 At-fault" events.

Locality	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Residential	1.81	0.67	4.84	1.26	0.37	4.32
Business/industrial	**1.98***	1.47	2.67	**1.95***	1.31	2.90
School	1.63	0.60	4.43	-	-	-
Urban	1.59	0.91	2.77	**3.12***	1.32	7.40
Airport	**1.71***	1.29	2.26	**2.46***	1.62	3.73
Interstate	**1.88***	1.45	2.45	**2.84***	1.91	4.22

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 64 shows the frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic density condition.

Table 64. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each locality.

Locality	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
Open country	5	20	4	20
Residential	9	68	5	68
Business/industrial	107	178	50	178
Church	3	15	1	15
Playground	0	3	0	3
School	8	59	6	59
Urban	27	66	17	66
Airport	158	128	60	128
Interstate	77	790	49	790
Other	2	0	1	0

Table 65 displays the OR calculations for engaging in any secondary task across "All" and "Vehicle 1 At-fault" events for each locality. The results suggest that engaging in any secondary task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in one locality. When "All" events were considered and compared to baseline epochs, drivers were 1.33 times more likely to be involved in an SCE when driving on an interstate. When "Vehicle 1 At-fault" events were considered and compared to baseline epochs, drivers were 2.43 times more likely to be involved in an SCE when driving on an interstate.

Table 65. ORs and 95-percent confidence intervals for the interaction of secondary task by locality across "All" and "Vehicle 1 At-fault" events.

Locality	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Residential	1.11	0.43	2.89	1.03	0.30	3.52
Business/industrial	1.23	0.91	1.67	1.29	0.87	1.93
School	1.33	0.50	3.56	2.49	0.68	9.19
Urban	0.97	0.55	1.72	2.12	0.97	4.65
Airport	1.02	0.76	1.37	1.45	0.97	2.16
Interstate	**1.33***	1.01	1.77	**2.43***	1.65	3.58

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Table 66 shows the frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each traffic density condition.

Table 66. The frequency of driving-related tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each locality.

Locality	ALL Frequency of Driving-related Task SCEs	ALL Frequency of Driving-related Task Baselines	V1 Frequency of Driving-related Task SCEs	V1 Frequency of Driving-related Task Baselines
Open country	1	3	0	3
Residential	3	15	1	15
Business/industrial	89	74	39	74
Church	2	6	1	6
Playground	0	1	0	1
School	5	23	2	23
Urban	19	24	7	24
Airport	164	58	52	58
Interstate	65	424	27	424
Other	1	1	1	1

Table 67 displays the OR calculations for engaging in any driving-related task across "All" and "Vehicle 1 At-fault" events for each locality. The results suggest that engaging in any driving-related task significantly increased the risk of a driver being involved in an SCE (compared to a baseline epoch) in four localities. When "All" events were considered and compared to baseline epochs, drivers were:

- 2.91 times more likely to be involved in an SCE when driving in a business/industrial area.
- 2.23 times more likely to be involved in an SCE when driving in an urban area.
- 3.10 times more likely to be involved in an SCE when driving in an airport.
- 2.27 times more likely to be involved in an SCE when driving on an interstate.

When “Vehicle 1 At-fault” events were considered and compared to baseline epochs, drivers were:

- 2.76 times more likely to be involved in an SCE when driving in a business/industrial area.
- 3.26 times more likely to be involved in an SCE when driving in an airport.
- 2.10 times more likely to be involved in an SCE when driving on an interstate.

Table 67. ORs and 95-percent confidence intervals for the interaction of driving-related tasks by locality across “All” and “Vehicle 1 At-fault” events.

Locality	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Business/industrial	**2.91***	2.04	4.14	**2.76***	1.76	4.34
School	2.24	0.73	6.88	-	-	-
Urban	**2.23***	1.13	4.39	1.89	0.73	4.88
Airport	**3.10***	2.21	4.36	**3.26***	2.09	5.08
Interstate	**2.27***	1.68	3.06	**2.10***	1.35	3.29

*Asterisk indicates a significant OR. These ratios are also shown in bold.

4.3.10 Summary

The analyses that focused on environmental conditions yielded several takeaways. First, by a wide margin, most SCEs occurred during daylight hours. In fact, 525 SCEs (accounting for all SCEs with both secondary and driving-related tasks) occurred in daylight, compared to 112 in all other categories combined—roughly a 5:1 ratio. Second, almost all SCEs occurred in no adverse weather conditions. Third, most SCEs occurred on a dry roadway.

With respect to the locations of SCEs in relation to junctions, most of the baseline data were recorded in non-junction (846) and interchange areas (553); most SCEs occurred in these areas, as well. When calculating ORs for the different locations, entrance/exit ramps had the highest OR, though several other areas were also statistically significant. Regarding the road alignment variable, most data were collected on straight roads. However, straight, curve left, and curve right alignments all produced significant ORs.

Traffic flow analysis also yielded another takeaway point. Most of the data were collected in the “divided: median strip or barrier” traffic flow option, which highlights the road condition that most motorcoach routes travel. Additionally, most of the traffic density that drivers encountered were low-density conditions (i.e., less than or equal to LOS B). Consistent with the traffic flow results, the results for locality found most data collection in interstate conditions.

The results from these analyses may help characterize motorcoach operations with respect to environmental and other roadway-related conditions. As far as insight into potentially higher risk conditions is concerned, some of the findings (e.g., increased occurrence of SCEs at airports, on entrance/exit ramps, and in intersections) may highlight the difficulties that these large vehicles face when interacting in tight quarters with other vehicles.

4.4 RESEARCH QUESTION 3: WHAT ARE THE ODDS RATIOS OF EYES-OFF-FORWARD-ROADWAY TIME? DOES EYES-OFF-FORWARD-ROADWAY TIME SIGNIFICANTLY AFFECT SAFETY AND/OR DRIVING PERFORMANCE?

The third research question intended to measure visual distraction using eye glance analysis. To answer this research question, all SCEs (n = 1,027) and baseline epochs (n = 4,447) with valid eye glance data were included. Eye glance location data were collected frame-by-frame for up to 30 seconds per event, as discussed in Section 3. Eye glance locations were analyzed for 5 seconds prior to the event onset (i.e., the initiating behavior such as a lead vehicle braking) and for 1 second after the event onset for all SCEs.[140,141] The entire 6 seconds was analyzed for all baseline epochs. Valid eye glance data meant that it was possible to conduct eye glance analysis on the entire 6-second window around the event (i.e., no shadows, camera malfunctions, or other issues blocking the view of the driver's eyes).

4.4.1 Eyes Off Forward Roadway

"Eyes off forward roadway" was operationally defined as any time the driver was not looking forward, regardless of where they looked. All non-forward glances (i.e., all non-forward eye glance locations) were combined to determine the total eyes-off-forward-roadway time for each 6 s interval (i.e., this time duration could be made up of a single long glance or multiple shorter glances). Total eyes-off-forward-roadway time was grouped into five different time bins:

- Less than or equal to 0.5 seconds.
- Greater than 0.5 seconds but less than or equal to 1.0 second.
- Greater than 1.0 second but less than or equal to 1.5 seconds.
- Greater than 1.5 seconds but less than or equal to 2.0 seconds.
- Greater than 2.0 seconds.

To approximate whether there was an increased risk of being involved in an SCE while looking away from the forward roadway (compared to a baseline epoch), ORs were calculated. The OR for this analysis used the frequency of SCEs and baseline epochs where drivers' eyes were off the forward roadway and the frequency of SCEs and baseline epochs where drivers' eyes were on the forward roadway. Table 68 illustrates the 2×2 contingency table used to calculate the ORs for the eyes-off-forward-roadway time analysis.

Table 68. Contingency tables used to calculate eyes off forward roadway ORs.

Event Type	Eyes Forward	Eyes Off Forward Roadway	Total
Baseline Epoch	n_{11} (A)	n_{12} (B)	$\mathbf{n_{1.}}$
SCE	n_{21} (C)	n_{22} (D)	$\mathbf{n_{2.}}$
Total	$\mathbf{n_{.1}}$	$\mathbf{n_{.2}}$	$\mathbf{n_{..}}$

Where:

A = frequency of baseline epochs where the driver's eyes were not off the forward roadway.

B = frequency of baseline epochs where the driver's eyes were off the forward roadway.

C = frequency of SCEs where the driver's eyes were not off the forward roadway.

D = frequency of SCEs where the driver's eyes were off the forward roadway.

Table 69 shows the frequency of SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for each (total) eyes-off-forward-roadway duration grouping.

Table 69. The frequency of secondary tasks during SCEs and baseline epochs across "All" and "Vehicle 1 At-fault" events for total eyes off forward roadway.

Total Eyes Off Forward Roadway	ALL Frequency of Secondary Task SCEs	ALL Frequency of Secondary Task Baselines	V1 Frequency of Secondary Task SCEs	V1 Frequency of Secondary Task Baselines
Less than or equal to 0.5 seconds	67	306	19	306
Greater than 0.5 seconds but less than or equal to 1.0 second	155	773	54	773
Greater than 1.0 second but less than or equal to 1.5 seconds	119	548	52	548
Greater than 1.5 seconds but less than or equal to 2.0 seconds	84	301	26	301
Greater than 2.0 seconds	287	564	151	564

Table 70 displays the results of the OR calculations for each of the five eyes-off-forward-roadway time bins across "All" events and "Vehicle 1 At-fault" events. The results indicate that all of the time periods for eyes off forward roadway, across "All" SCEs, had significant ORs. More specifically, when "All" events were considered and compared to baseline epochs, drivers were:

- 1.36 times more likely to be involved in an SCE when eyes-off-forward-roadway duration was less than or equal to 0.5 seconds.
- 1.24 times more likely to be involved in an SCE when eyes-off-forward-roadway duration was greater than 0.5 seconds but less than or equal to 1.0 second.
- 1.35 times more likely to be involved in an SCE when eyes-off-forward-roadway duration was greater than 1.0 second but less than or equal to 1.5 seconds.
- 1.73 times more likely when eyes-off-forward-roadway duration was greater than 1.5 seconds but less than or equal to 2.0 seconds.
- 3.16 times more likely when eyes-off-forward-roadway duration was greater than 2.0 seconds.

Table 70 also shows the ORs for each of the five eyes-off-forward-roadway time groupings across all “Vehicle 1 At-fault” SCEs. When “Vehicle 1 At-fault” events were considered and compared to baseline epochs, drivers were:

- 1.87 times more likely to be involved in an SCE when eyes-off-forward-roadway duration was greater than 1.0 second but less than or equal to 1.5 seconds.
- 1.71 times more likely when eyes-off-forward-roadway duration was greater than 1.5 seconds but less than or equal to 2.0 seconds.
- 5.29 times more likely when eyes-off-forward-roadway duration was greater than 2.0 seconds.

Table 70. ORs and 95-percent confidence intervals to assess likelihood of an SCE while eyes were off the forward roadway across “All” and “Vehicle 1 At-fault” events.

Total Eyes Off Forward Roadway	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Less than or equal to 0.5 seconds	**1.36***	1.02	1.82	1.23	0.74	2.03
Greater than 0.5 seconds but less than or equal to 1.0 second	**1.24***	1.01	1.53	1.38	0.98	1.94
Greater than 1.0 second but less than or equal to 1.5 seconds	**1.35***	1.07	1.70	**1.87***	1.32	2.66
Greater than 1.5 seconds but less than or equal to 2.0 seconds	**1.73***	1.32	2.27	**1.71***	1.09	2.67
Greater than 2.0 seconds	**3.16***	2.62	3.80	**5.29***	4.04	6.93

*Asterisk indicates a significant OR. These ratios are also shown in bold.

Figure 16 shows the OR values for “All” and “Vehicle 1 At-fault” events across the increasing total eyes-off-forward-roadway categories. This plot of the ORs shows the trend of growing risk as the total eyes-off-forward-roadway time increases, with an especially large jump in OR values when eyes-off-forward-roadway duration was greater than 2.0 seconds. The plot also visually demonstrates that OR calculations were higher for “Vehicle 1 At-fault” events as compared to “All” events at each eyes-off-forward-roadway category.

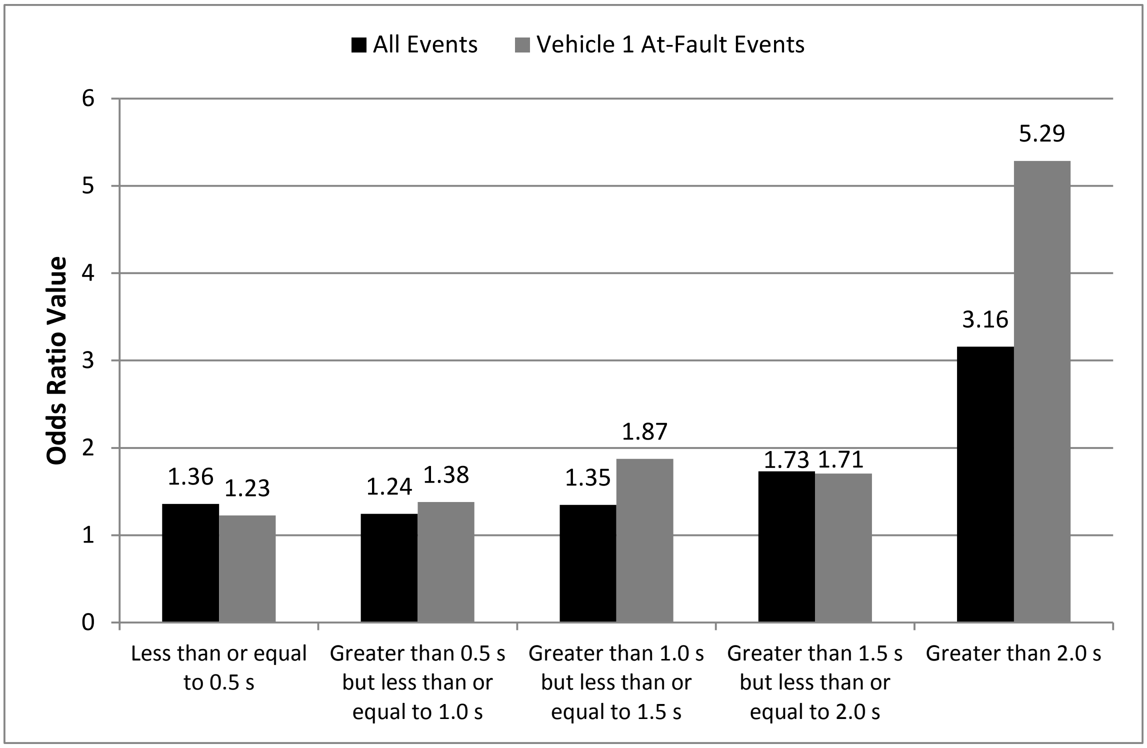

Figure 16. Graph. OR values for total eyes-off-forward-roadway time.

4.4.2 Duration of Eyes Off Forward Roadway

"Duration of eyes off forward roadway" was operationally defined as the total length of time (either a single glance or multiple glances) that the driver was not looking at the forward roadway during the 6-second interval surrounding the SCE or baseline epoch. The analyses in this section were grouped by event type (i.e., crash, crash—tire strike, near-crash, crash-relevant conflict, unintentional lane deviation, and baseline epochs) across "All" and "Vehicle 1 At-fault" events. These results include the following analyses:

- Secondary tasks and/or driving-related tasks.
- Secondary tasks.
- Driving-related tasks.

4.4.2.1 All Secondary Tasks and/or Driving-related Tasks

Figure 17 shows the mean eyes-off-forward-roadway duration for each event type across "All" and "Vehicle 1 At-fault" events for any task. A one-way analysis of variance (ANOVA) found a significant difference in the mean eyes-off-forward-roadway duration between the six event types across "All" events ($F_{(5, 2327)} = 6.87$, $p < 0.0001$).

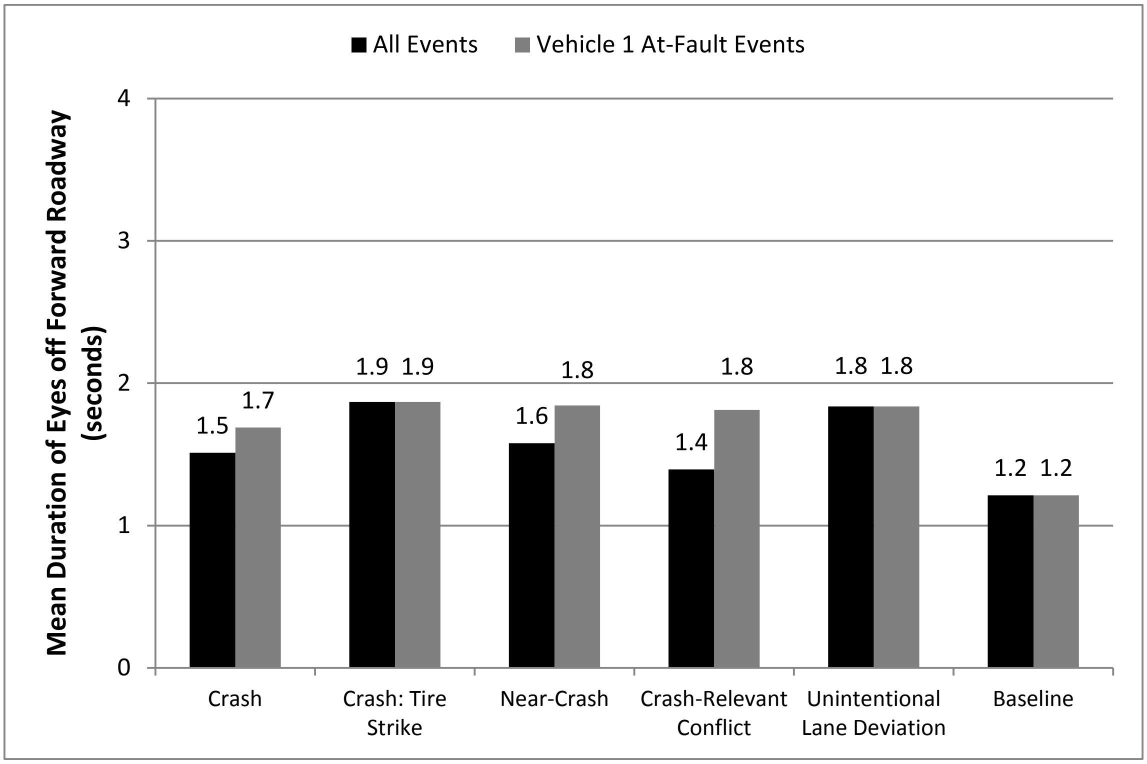

Figure 17. Graph. Mean eyes-off-forward-roadway duration by event type for all tasks.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations of event types to determine simple effects. Figure 17 shows the mean eyes-off-forward-roadway duration for each event type across "All" events. Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during near-crashes (1.6 seconds; $t_{(2327)} = 4.424$, $p = 0.0001$) and unintentional lane deviations (1.8 seconds; $t_{(2327)} = 2.861$, $p = 0.0488$) was significantly longer than during baseline epochs (1.2 seconds).

Figure 17 also shows the mean eyes-off-forward-roadway duration for each event type across "Vehicle 1 At-fault" events. A one-way ANOVA also found a significant difference in the mean eyes-off-forward-roadway duration between the six event types across "Vehicle 1 At-fault" events ($F_{(5, 1990)} = 12.50$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during near-crashes (1.8 seconds; $t_{(1990)} = 4.988$, $p < 0.0001$), crash-relevant conflicts (1.8 seconds; $t_{(1990)} = 5.368$, $p < 0.0001$), and unintentional lane deviations (1.8 seconds; $t_{(1990)} = 2.906$, $p = 0.0430$) was significantly longer than during baseline epochs (1.2 seconds).

4.4.2.2 Secondary Tasks

Figure 18 shows the mean duration of eyes off forward roadway for each event type across "All" events and "Vehicle 1 At-fault" events for any secondary task. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the six event types across "All" events ($F_{(5, 1643)} = 7.40$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during near-crashes (1.7 seconds) was significantly longer than during baseline epochs (1.2 seconds; $t_{(1643)} = 4.845$, $p < 0.0001$).

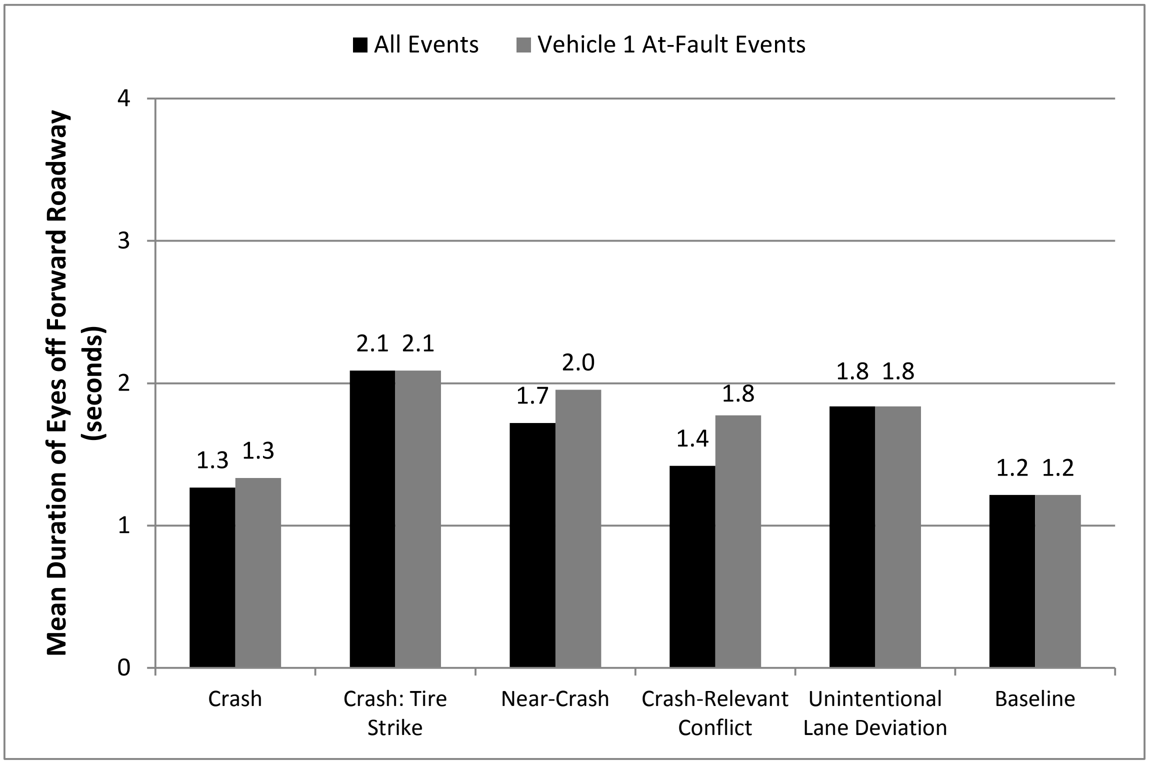

Figure 18. Graph. Mean eyes-off-forward-roadway duration by event type for secondary tasks.

Figure 18 also shows the mean duration of eyes off forward roadway for each event type across "Vehicle 1 At-fault" events. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the six event types across "Vehicle 1 At-fault" events ($F_{(5, 1453)} = 9.72$, $p < 0.0001$). Tukey t tests indicated that the mean eyes-off-forward-roadway duration during near-crashes (2.0 seconds; $t_{(1453)} = 4.854$, $p < 0.0001$) and crash-relevant conflicts (1.8 seconds; $t_{(1453)} = 4.003$, $p = 0.0009$) was significantly longer than during baseline epochs (1.2 seconds).

4.4.2.3 Secondary Task Breakout Analyses

Additional ANOVAs were calculated on the seven secondary tasks that were shown to be significant in Table 12. In conducting this analysis, the mean eyes-off-forward-roadway duration was calculated for four groupings:

- SCEs with distraction of interest.
- Baseline epochs with distraction of interest.
- SCEs without distraction of interest.
- Baseline epochs without distraction of interest.

Given the small sample size for many of the secondary tasks, any SCE or baseline epoch with the secondary task of interest was used. Therefore, it was possible that the SCE or baseline epoch contained additional tasks in the 6-second reduction window (e.g., if the distraction of interest was talking to a passenger, the driver may have also been looking outside during that 6-second period).

Other Known Secondary Task: "Other known secondary task" included tasks like inserting a Bluetooth earpiece, checking a watch, or waving to someone outside the vehicle. Figure 19 shows the mean eyes-off-forward-roadway duration across "All" and "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "All" events ($F_{(3, 5470)} = 69.50$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events with an other known secondary task (2.2 seconds) was significantly longer than:

- Baselines with an other known secondary task (0.9 seconds; $t_{(5470)} = 3.369$, $p = 0.0042$).
- Events without an other known secondary task (1.3 seconds; $t_{(5470)} = 3.349$, $p = 0.0045$).
- Baselines without an other known secondary task (0.8 seconds; $t_{(5470)} = 5.259$, $p < 0.0001$).

Events without an other known secondary task (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without an other known secondary task (0.8 seconds; $t_{(5470)} = 13.578$, $p < 0.0001$).

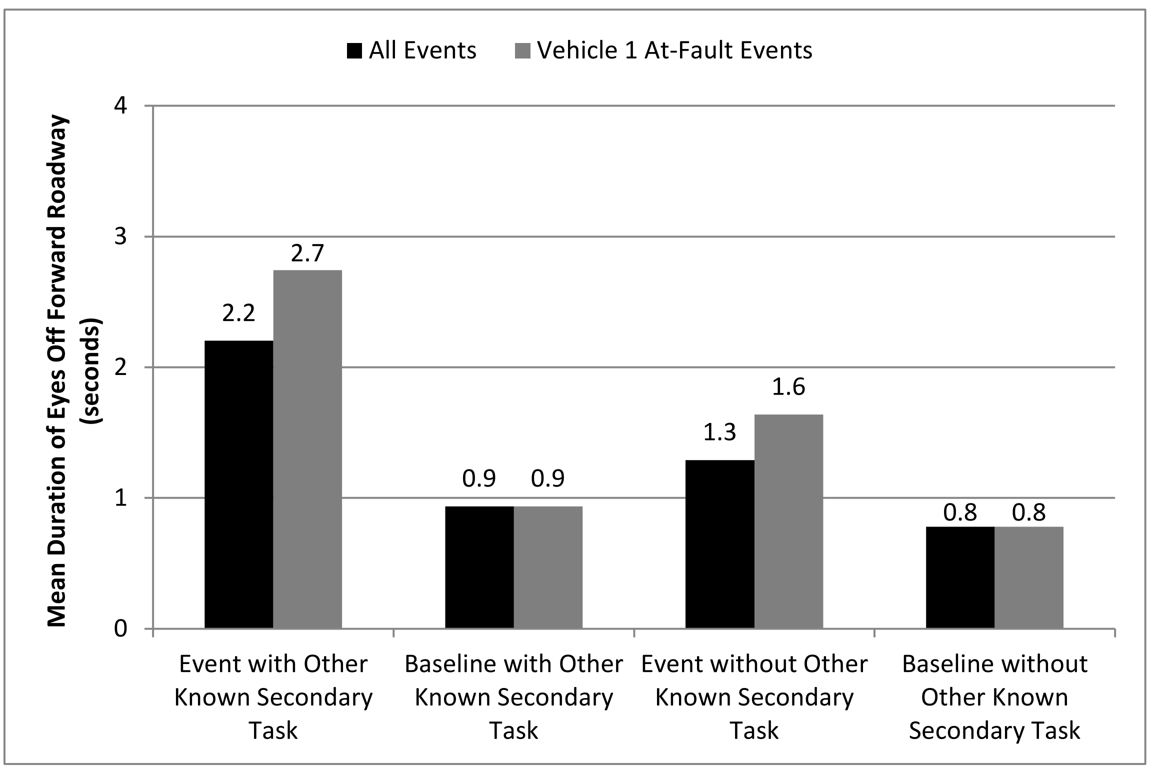

Figure 19. Graph. Mean eyes-off-forward-roadway duration for "other known secondary task."

Figure 19 also shows the mean eyes-off-forward-roadway duration for “Vehicle 1 At-fault” events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across “Vehicle 1 At-fault” events ($F_{(3, 4844)} = 90.33$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events with an other known secondary task (2.7 seconds) was significantly longer than:

- Baselines with an other known secondary task (0.9 seconds; $t_{(4844)} = 4.300$, $p = 0.0001$)
- Events without an other known secondary task (1.6 seconds; $t_{(4844)} = 3.264$, $p = 0.0061$).
- Baselines without an other known secondary task (0.8 seconds; $t_{(4844)} = 5.877$, $p < 0.0001$).

Events without an other known secondary task (1.6 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines with other known secondary tasks (0.9 seconds; $t_{(4844)} = 2.697$, $p = 0.0354$) and baselines without other known secondary tasks (0.8 seconds; $t_{(4844)} = 15.452$, $p < 0.0001$).

Interact with Intercom: “Interact with intercom” was coded when data analysts observed the driver using the intercom system to communicate with vehicle passengers. Figure 20 shows the mean eyes-off-forward-roadway duration across “All” and “Vehicle 1 At-fault” events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across “All” events ($F_{(3, 5470)} = 68.34$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events with intercom interaction (1.9 seconds) was significantly longer than baselines without intercom interaction (0.8 seconds; $t_{(5470)} = 4.618$, $p < 0.0001$). Events without intercom interaction (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without intercom interaction (0.8 seconds; $t_{(5470)} = 13.641$, $p < 0.0001$).

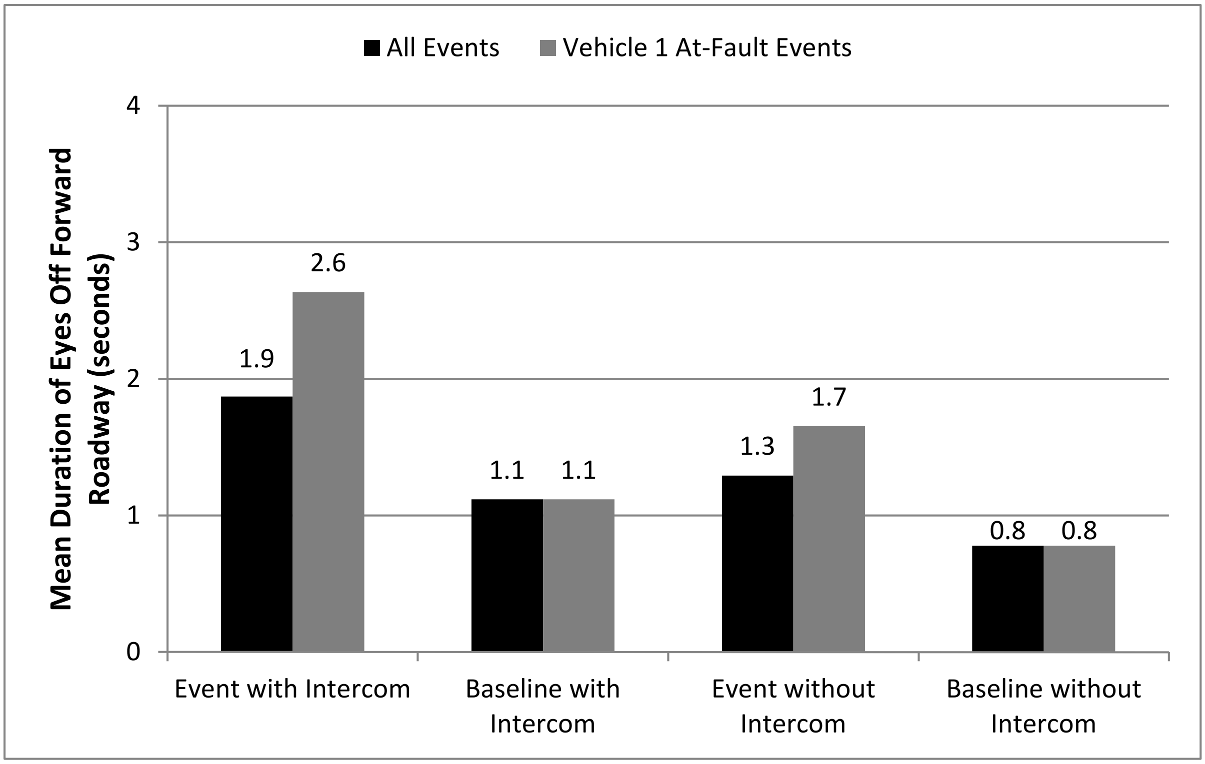

Figure 20. Graph. Mean eyes-off-forward-roadway duration for "interact with intercom."

Figure 20 also shows the mean eyes-off-forward-roadway duration across "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference between the four groupings across "Vehicle 1 At-fault" events ($F_{(3,\ 4844)}$ = 88.82, p < 0.0001). Tukey t tests indicated the mean eyes-off-forward-roadway duration during events with intercom interaction (2.6 seconds) was significantly longer than baselines without intercom interaction (0.8 seconds; $t_{(4844)}$ = 3.933, p = 0.0005). Events without intercom interaction (1.7 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without intercom interaction (0.8 seconds; $t_{(4844)}$ = 15.833, p < 0.0001).

Other Personal Hygiene: "Other personal hygiene" included behaviors like wiping or scratching arms, face, or ears. Figure 21 shows the mean eyes-off-forward-roadway duration across "All" and "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "All" events ($F_{(3,\ 5470)}$ = 67.57, p < 0.0001). Tukey t tests indicated that the mean eyes-off-forward-roadway duration during events involving other personal hygiene behaviors (2.2 seconds) was significantly longer than baselines not involving other personal hygiene behaviors (1.3 seconds; $t_{(5470)}$ = 14.144, p < 0.0001).

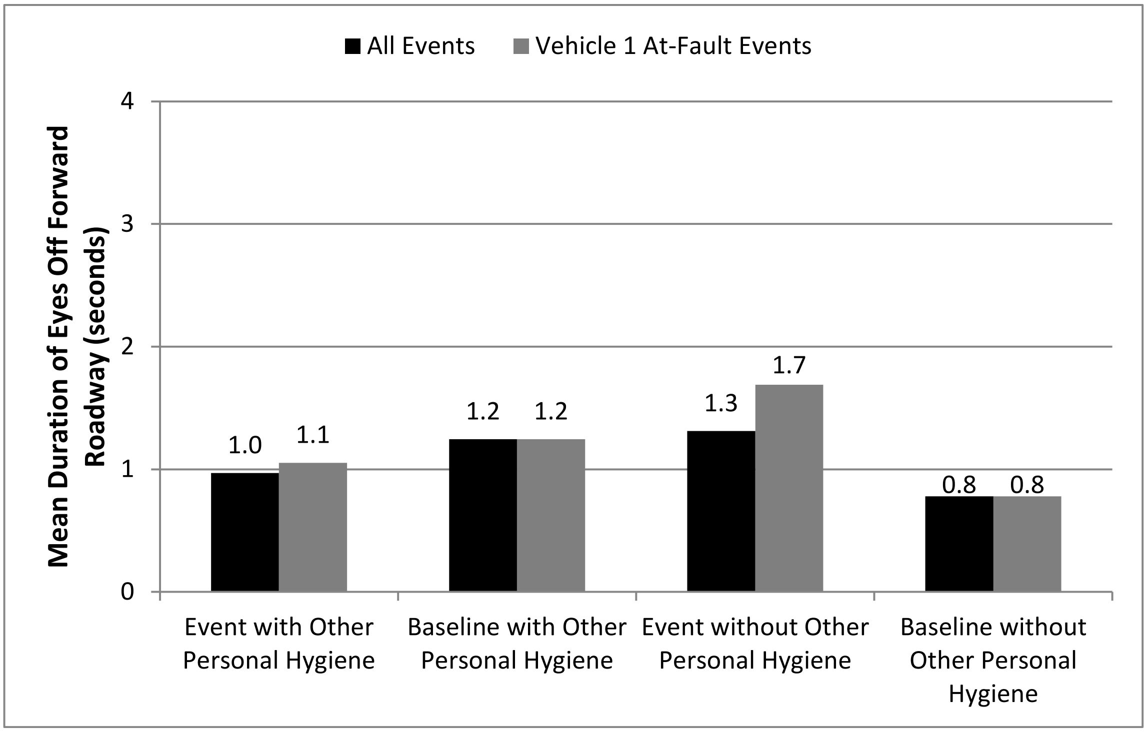

Figure 21. Graph. Mean eyes-off-forward-roadway duration for "other personal hygiene."

Figure 21 also shows the mean eyes-off-forward-roadway duration across "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "Vehicle 1 At-fault" events ($F_{(3, 4844)} = 89.69$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events without other personal hygiene behaviors (1.7 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without other personal hygiene behaviors (0.8 seconds; $t_{(4844)} = 16.296$, $p < 0.0001$).

Removing/Adjusting Clothing: The secondary task "removing/adjusting clothing" was coded when drivers were observed to remove, adjust, or put on clothing. Examples of clothing removed or adjusted were jackets, hats, and gloves, among other items. Figure 22 shows the mean eyes-off-forward-roadway duration across "All" and "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "All" events ($F_{(3, 5470)} = 65.62$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events without removing/adjusting clothing (1.9 seconds) was significantly longer than baselines without removing/adjusting clothing (1.3 seconds; $t_{(5470)} = 13.987$, $p < 0.0001$).

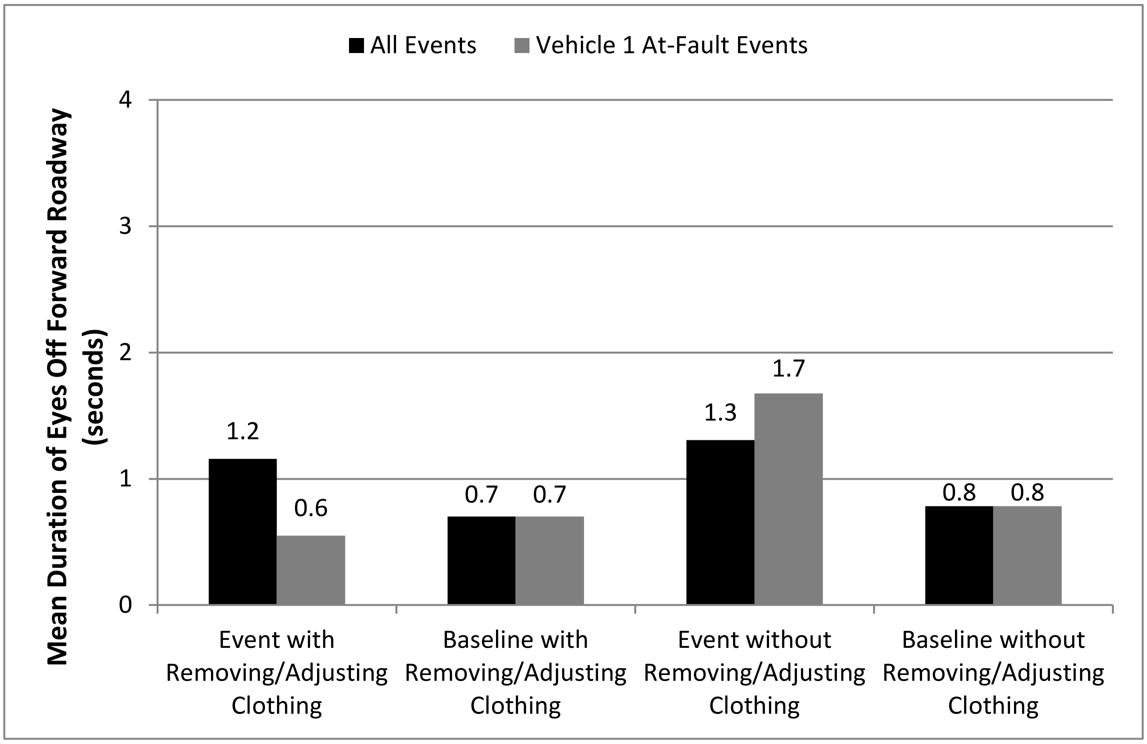

Figure 22. Graph. Mean eyes-off-forward-roadway duration for "removing/adjusting clothing."

Figure 22 also shows the mean eyes-off-forward-roadway duration across "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four event types across "Vehicle 1 At-fault" events ($F_{(3, 4844)} = 88.09$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events that did not involve removing/adjusting clothing (1.7 seconds) was significantly longer than baselines that did involve removing/adjusting clothing (0.7 seconds; $t_{(4844)} = 3.746$, $p < 0.0010$). Events that did not involve removing/adjusting clothing (1.7 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines that did not involve removing/adjusting clothing (0.8 seconds; $t_{(4844)} = 16.235$, $p < 0.0001$).

Reach for Object: When drivers were observed reaching for objects like clipboards, pens, personal bags, and pieces of paper, these instances were coded as "reach for object." Figure 23 shows the mean duration of eyes off forward roadway across "All" and "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "All" events ($F_{(3, 5470)} = 78.81$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events that involved reaching for an object (1.8 seconds) was significantly longer than baselines that did not involve reaching for an object (0.8 seconds; $t_{(5470)} = 4.077$, $p = 0.0003$). Events that did not involve reaching for an object (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines that did involve reaching for an object (0.7 seconds; $t_{(5470)} = 3.029$, $p = 0.0132$) and baselines that did not involve reaching for an object (0.8 seconds; $t_{(5470)} = 13.935$, $p < 0.0001$). Baselines that involved reaching for an object (1.9 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines that did not involve reaching for an object (0.8 seconds; $t_{(5470)} = 5.894$, $p < 0.0001$).

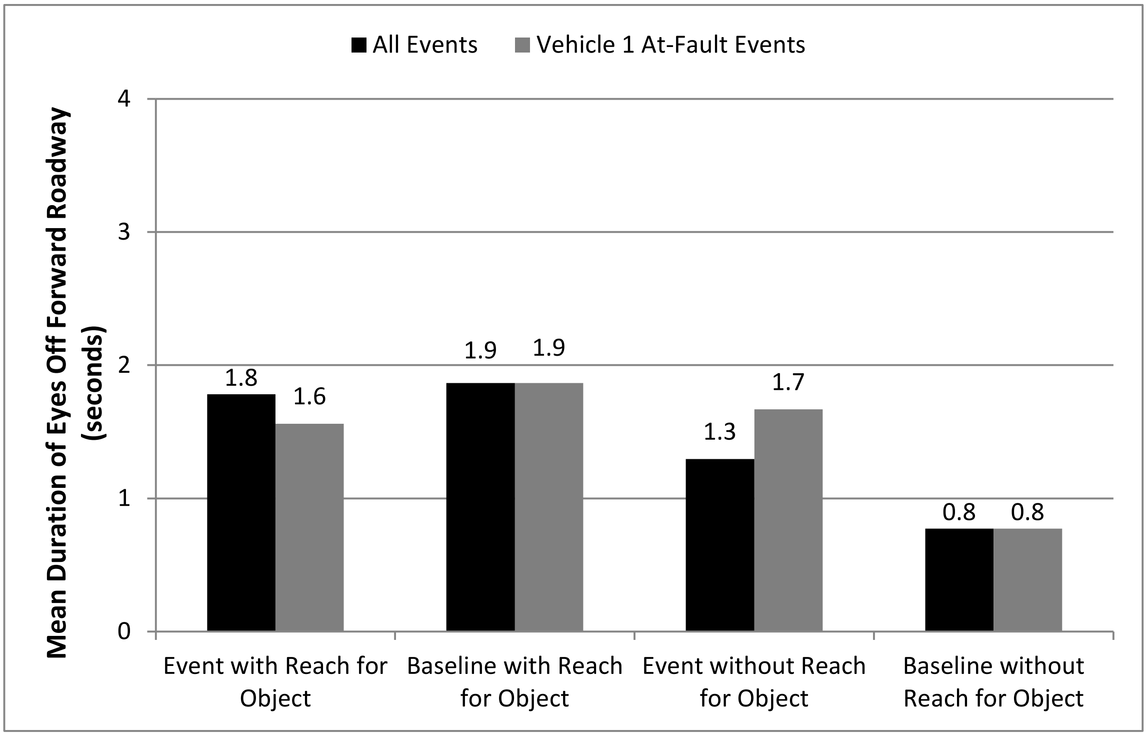

Figure 23. Graph. Mean eyes-off-forward-roadway duration for "reach for object."

Figure 23 also shows the mean eyes-off-forward-roadway duration across "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "Vehicle 1 At-fault" events ($F_{(3, 4844)} = 99.28$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events that did not involve reaching for an object (1.3 seconds) was significantly longer than baselines that did not involve reaching for an object (0.8 seconds; $t_{(4844)} = 16.175$, $p < 0.0001$). Baselines that involved reaching for an object (1.9 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines that did not involve reaching for an object (0.8 seconds; $t_{(4844)} = 6.033$, $p < 0.0001$).

Object in Vehicle: The secondary task "object in vehicle" was used to indicate the driver was holding or interacting with an object, but not necessarily reaching for the object. Objects observed in the current data set included clipboards, pens, and personal items like bags or sunglasses. Figure 24 shows the mean eyes-off-forward-roadway duration across "All" and "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "All" events ($F_{(3, 5470)} = 77.53$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events with "object in vehicle" (2.4 seconds) was significantly longer than during:

- Events without "object in vehicle" (1.3 seconds; $t_{(5470)} = 4.627$, $p < 0.0001$).
- Baselines with "object in vehicle" (1.3 seconds; $t_{(5470)} = 3.797$, $p = 0.0009$)
- Baselines without "object in vehicle" (0.8 seconds; $t_{(5470)} = 6.770$, $p < 0.0001$).

Events without “object in vehicle” (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without “object in vehicle” (0.8 seconds; $t_{(5470)} = 13.523$, $p < 0.0001$). Baselines with “object in vehicle” (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without “object in vehicle” (0.8 seconds; $t_{(5470)} = 3.661$, $p = 0.0014$).

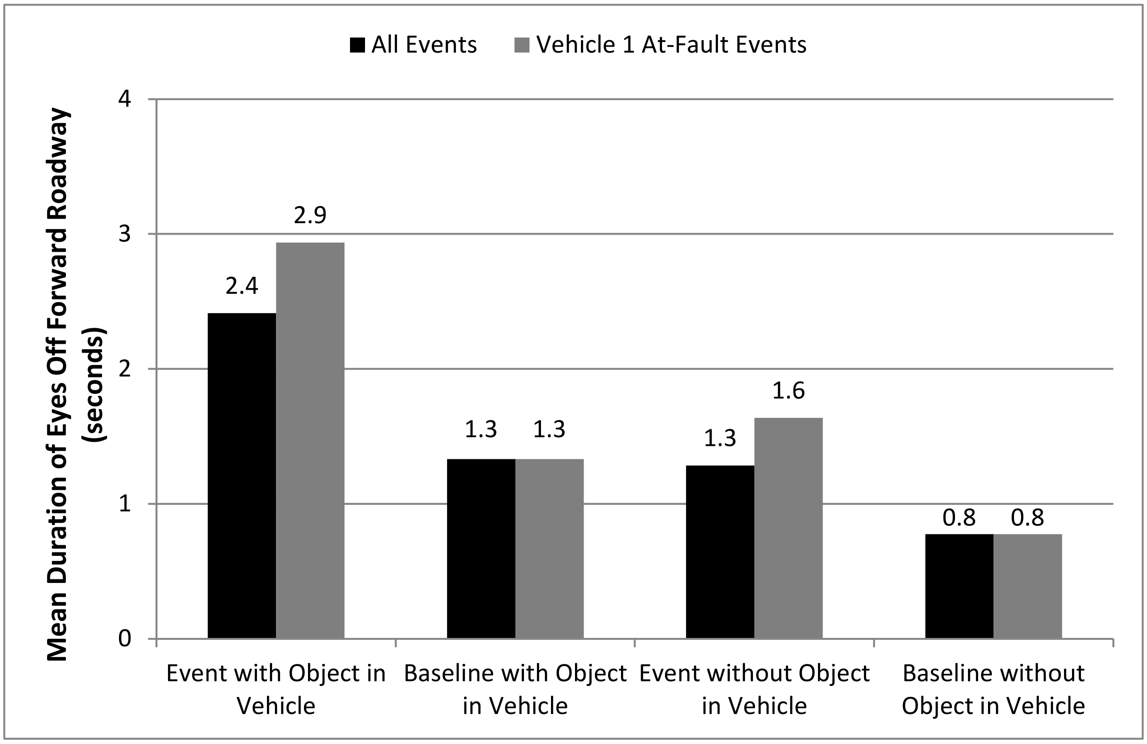

Figure 24. Graph. Mean eyes-off-forward-roadway duration for “object in vehicle.”

Figure 24 also shows the mean eyes-off-forward-roadway duration across “Vehicle 1 At-fault” events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across “Vehicle 1 At-fault” events ($F_{(3, 4844)} = 96.14$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events with “object in vehicle” (2.9 seconds) was significantly longer than during:

- Events without “object in vehicle” (1.6 seconds; $t_{(4844)} = 3.676$, $p = 0.0014$).
- Baselines with “object in vehicle” (1.3 seconds; $t_{(4844)} = 4.247$, $p = 0.0001$).
- Baselines without “object in vehicle” (0.8 seconds; $t_{(4844)} = 6.305$, $p < 0.0001$).

Events without “object in vehicle” (1.6 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without “object in vehicle” (1.3 seconds; $t_{(4844)} = 15.516$, $p < 0.0001$). Baselines with “object in vehicle” (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without “object in vehicle” (0.8 seconds; $t_{(4844)} = 3.745$, $p = 0.0010$).

External Distraction: Observed "external distraction" secondary tasks included looking at pedestrians, vehicles, animals, and objects outside of the vehicle. In some cases, it was not clear what the external distraction was. Figure 25 shows the mean eyes-off-forward-roadway duration across "All" and "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings types across "All" events ($F_{(3, 5470)} = 105.20$, $p < 0.0001$). Tukey t tests indicated that the mean eyes-off-forward-roadway duration during events involving external distractions (1.7 seconds) was significantly longer than events without external distractions (1.3 seconds; $t_{(5470)} = 3.689$, $p = 0.0013$) and baselines without external distractions (0.7 seconds; $t_{(5470)} = 8.380$, $p < 0.0001$). Events without external distractions (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without external distractions (0.7 seconds; $t_{(5470)} = 13.612$, $p < 0.0001$). Baselines with external distractions (1.5 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without external distractions (0.7 seconds; $t_{(5470)} = 10.306$, $p < 0.0001$).

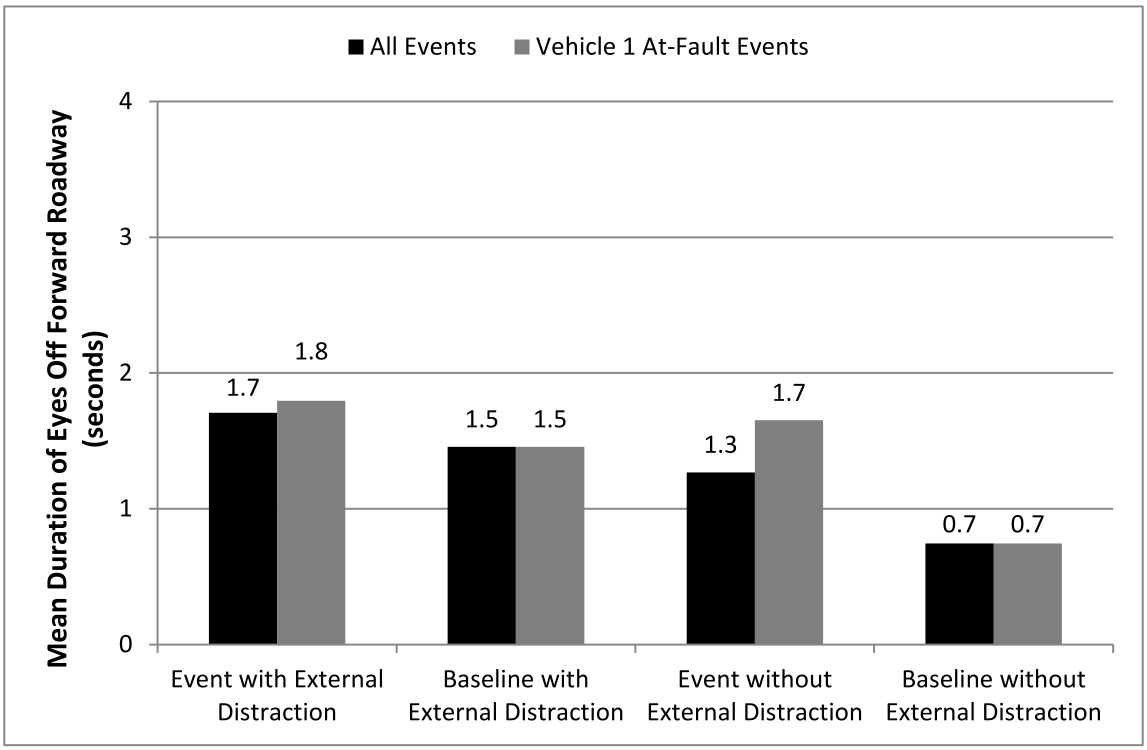

Figure 25. Graph. Mean eyes-off-forward-roadway duration for "external distraction."

Figure 25 also shows the mean eyes-off-forward-roadway duration across "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "Vehicle 1 At-fault" events ($F_{(3, 4844)} = 124.05$, $p < 0.0001$). Tukey t tests indicated the mean eyes-off-forward-roadway duration during events involving external distractions (1.8 seconds) was significantly longer than baselines without external distractions (0.7 seconds; $t_{(4844)} = 6.943$, $p < 0.0001$). Events without external distractions (1.7 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without external distractions (0.7 seconds; $t_{(4844)} = 15.690$, $p < 0.0001$). Baselines involving external distractions (1.5 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without external distractions (0.7 seconds; $t_{(4844)} = 10.306$, $p < 0.0001$).

4.4.2.4 Driving-related Tasks

Figure 26 shows the mean eyes-off-forward-roadway duration for six event types across "All" and "Vehicle 1 At-fault" events for any driving-related task. A one-way ANOVA did not find a significant difference in the mean eyes-off-forward-roadway duration between six event types across "All" events ($F_{(5, 918)} = 2.09$, $p = 0.0650$).

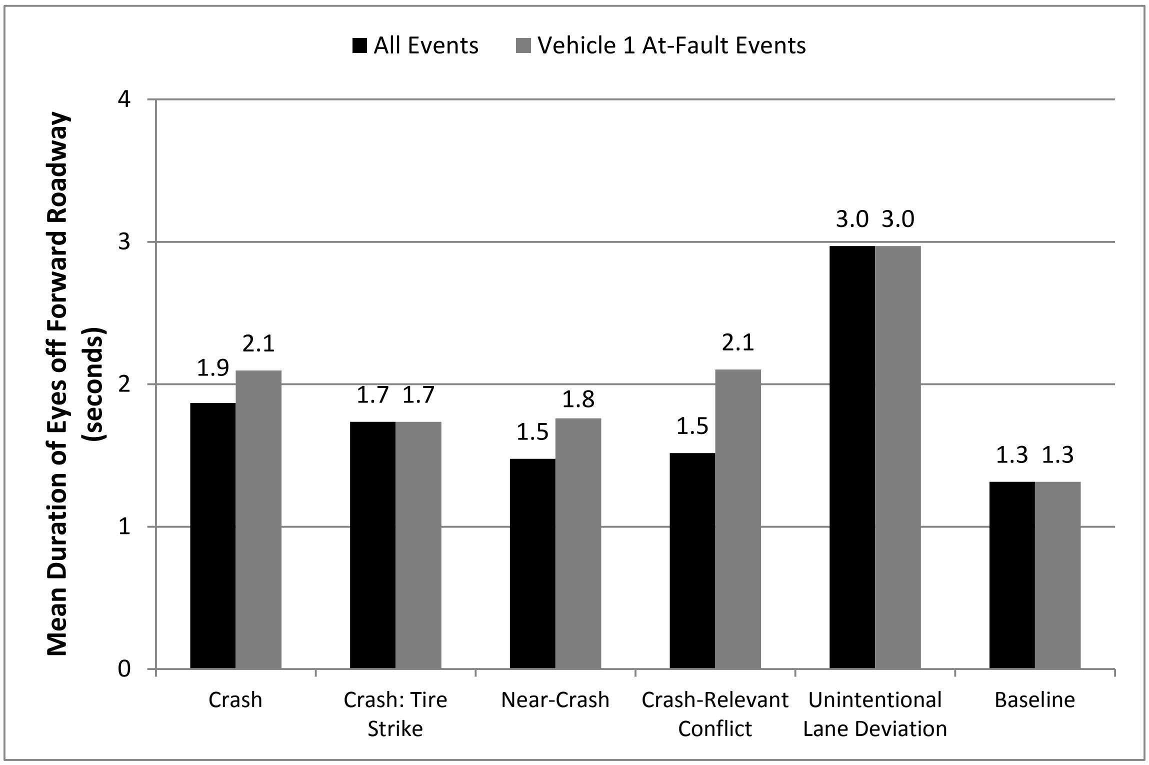

Figure 26. Graph. Mean eyes-off-forward-roadway duration by event type for driving-related tasks.

Figure 26 also shows the mean eyes-off-forward-roadway duration for six event types across "Vehicle 1 At-fault" events. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the six event types across "Vehicle 1 At-fault" events ($F_{(5, 714)} = 7.19$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during crash-relevant conflicts (2.1 seconds) was significantly longer than during baseline epochs (1.3 seconds; $t_{(714)} = 5.090$, $p < 0.0001$).

4.4.2.5 Driving-related Task Breakout Analyses

Additional ANOVAs were calculated on the two specific driving-related tasks that were shown to be significant in Table 12. In conducting this analysis, the mean eyes-off-forward-roadway duration was calculated for the following four groupings:

- SCEs with distraction of interest.
- Baseline epochs with distraction of interest.

- SCEs without distraction of interest.
- Baseline epochs without distraction of interest.

Turn Signal Use: Figure 27 shows the mean eyes-off-forward-roadway duration across "All" and "Vehicle 1 At-fault" events for each of the four "turn signal use" groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "All" events ($F_{(3,\ 5470)} = 113.86$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events with turn signal use (1.8 seconds) was significantly longer than during:

- Events without turn signal use (1.2 seconds; $t_{(5470)} = 6.894$, $p < 0.0001$).
- Baselines with turn signal use (1.4 seconds; $t_{(5470)} = 3.313$, $p = 0.0051$).
- Baselines without turn signal use (0.7 seconds; $t_{(5470)} = 13.252$, $p < 0.0001$).

Events without turn signal use (1.2 seconds) had a significantly shorter mean eyes-off-forward-roadway duration than baselines with turn signal use (1.4 seconds; $t_{(5470)} = 3.053$, $p = 0.0122$) and baselines without turn signal use (0.7 seconds; $t_{(5470)} = 11.091$, $p < 0.0001$). Baselines with turn signal use (1.4 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without turn signal use (0.7 seconds; $t_{(5470)} = 9.618$, $p < 0.0001$).

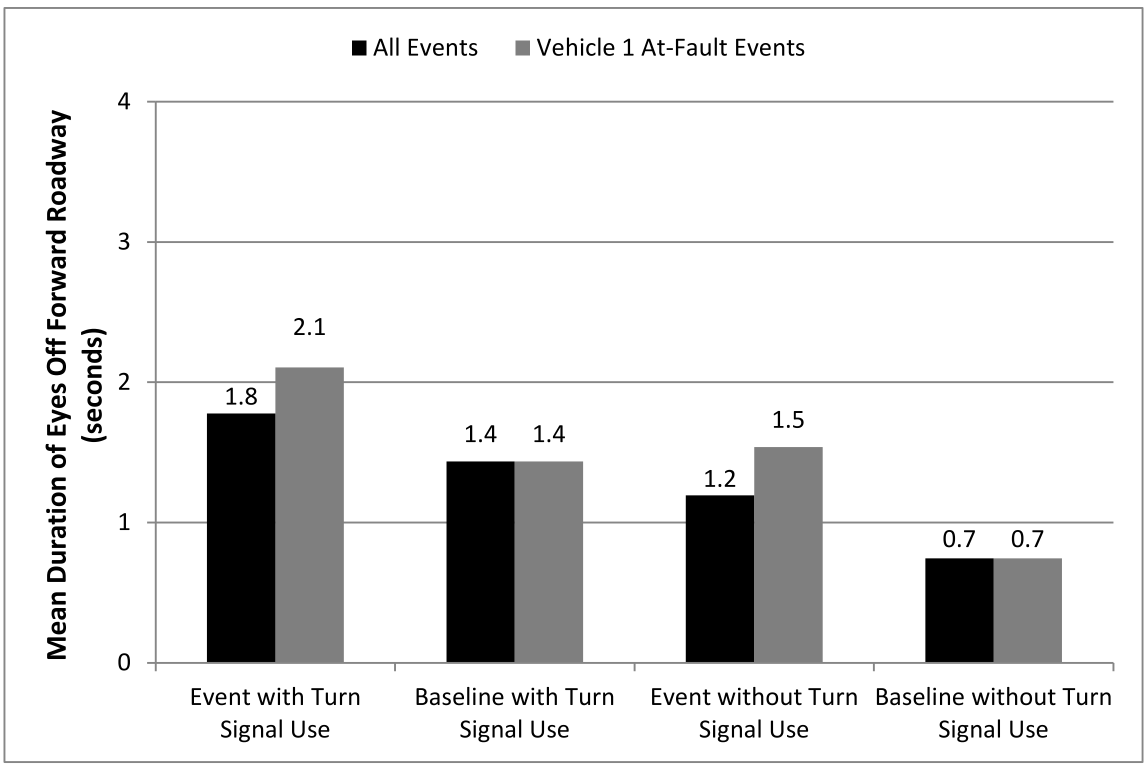

Figure 27. Graph. Mean eyes-off-forward-roadway duration for "turn signal use."

Figure 27 also shows the mean eyes-off-forward-roadway duration across "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "Vehicle 1 At-fault" events ($F_{(3,\ 4844)} = 127.57$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events with turn signal use (2.1 seconds) was significantly longer than during:

- Events without turn signal use (1.5 seconds; $t_{(4844)} = 4.508$, $p < 0.0001$).
- Baselines with turn signal use (1.4 seconds; $t_{(4844)} = 5.166$, $p < 0.0001$).
- Baselines without turn signal use (0.7 seconds; $t_{(4844)} = 12.232$, $p < 0.0001$).

Events without turn signal use (1.5 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without turn signal use (0.7 seconds; $t_{(4844)} = 12.992$, $p < 0.0001$). Baselines with turn signal use (1.4 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without turn signal use (0.7 seconds; $t_{(4844)} = 9.835$, $p < 0.0001$).

Check Speedometer: Figure 28 shows the mean eyes-off-forward-roadway duration across "All" and "Vehicle 1 At-fault" events for each of the four "check speedometer" groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "All" events ($F_{(3,\ 5470)} = 95.26$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events that involved speedometer checks (1.3 seconds) was significantly longer than baselines that did not involve speedometer checks (0.7 seconds; $t_{(5470)} = 3.582$, $p = 0.0019$). Events without speedometer checks (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without speedometer checks (0.7 seconds; $t_{(5470)} = 14.931$, $p < 0.0001$). Baselines with speedometer checks (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without speedometer checks (0.7 seconds; $t_{(5470)} = 9.281$, $p < 0.0001$).

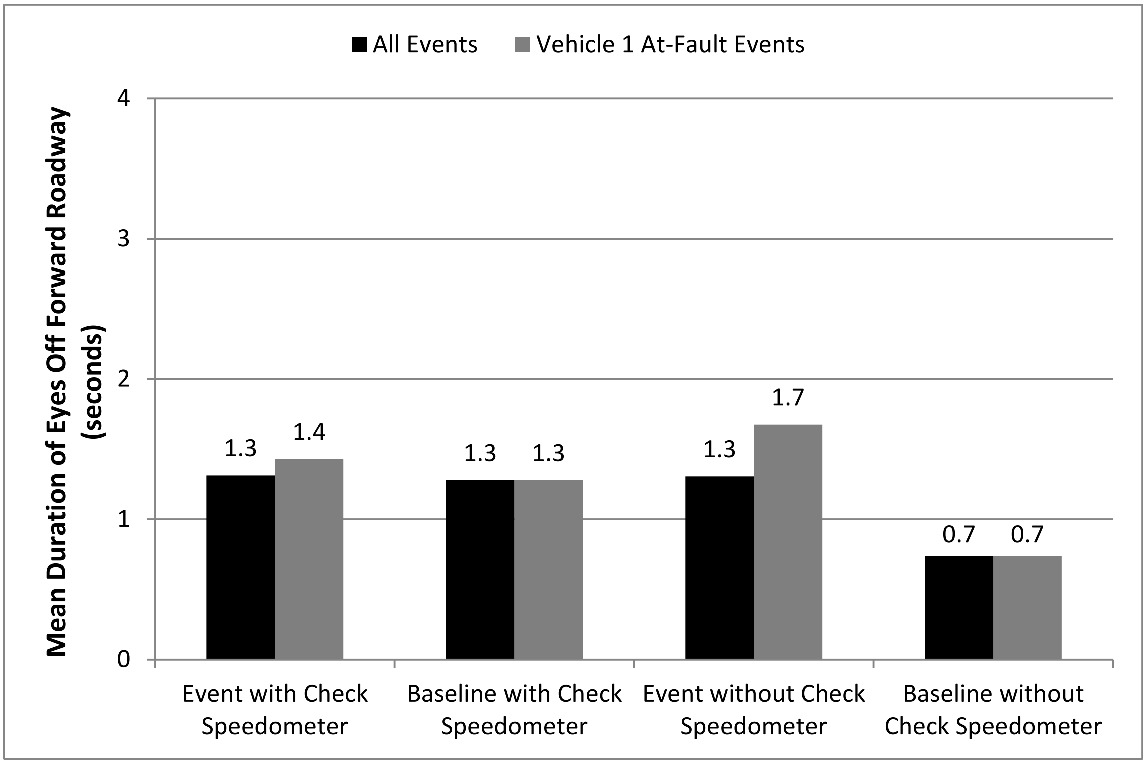

Figure 28. Graph. Mean eyes-off-forward-roadway duration for "check speedometer."

Figure 28 also shows the mean eyes-off-forward-roadway duration across "Vehicle 1 At-fault" events for each of the four groupings. A one-way ANOVA found a significant difference in the mean eyes-off-forward-roadway duration between the four groupings across "Vehicle 1 At-fault" events ($F_{(3,\ 4844)} = 118.51$, $p < 0.0001$). Tukey *t* tests indicated that the mean eyes-off-forward-roadway duration during events without speedometer checks (1.7 seconds) was significantly longer than during baselines with speedometer checks (1.3 seconds; $t_{(4844)} = 5.247$, $p < 0.0001$) and baselines without speedometer checks (0.7 seconds; $t_{(4844)} = 16.899$, $p < 0.0001$). Baselines with speedometer checks (1.3 seconds) had a significantly longer mean eyes-off-forward-roadway duration than baselines without speedometer checks (0.7 seconds; $t_{(4844)} = 9.512$, $p < 0.0001$).

4.4.3 Number of Glances Away From Forward Roadway

"Number of glances away from forward roadway" was operationally defined as the number of glances away from the forward roadway during the 6-second interval or epoch period. This may include partial glances at either the beginning or end of the 6-second interval. A glance was operationally defined as any time a driver took his eyes off the forward roadway, regardless of where he looked. For example, if the driver looked forward-right and then window-forward, that was considered to be one glance. In addition, if the driver looked forward-cell phone-right and then window-forward, that was also considered one glance.

The analyses in this section were grouped by event type (i.e., crash, crash—tire strike, near-crash, crash-relevant conflict, etc.) across "All" and "Vehicle 1 At-fault" events. These results are presented in Figure 29, Figure 30, and Figure 31 and include the following analyses:

- Secondary tasks and/or driving-related tasks.
- Secondary tasks.
- Driving-related tasks.

4.4.3.1 All Secondary Tasks and/or Driving-related Tasks

Figure 29 shows the mean number of glances away from the forward roadway for each event type across "All" and "Vehicle 1 At-fault" events for any task. A one-way ANOVA did not find a significant difference in the mean number of glances away from the forward roadway between the six event types across "All" events ($F_{(5, 2327)} = 1.68$, $p = 0.1351$).

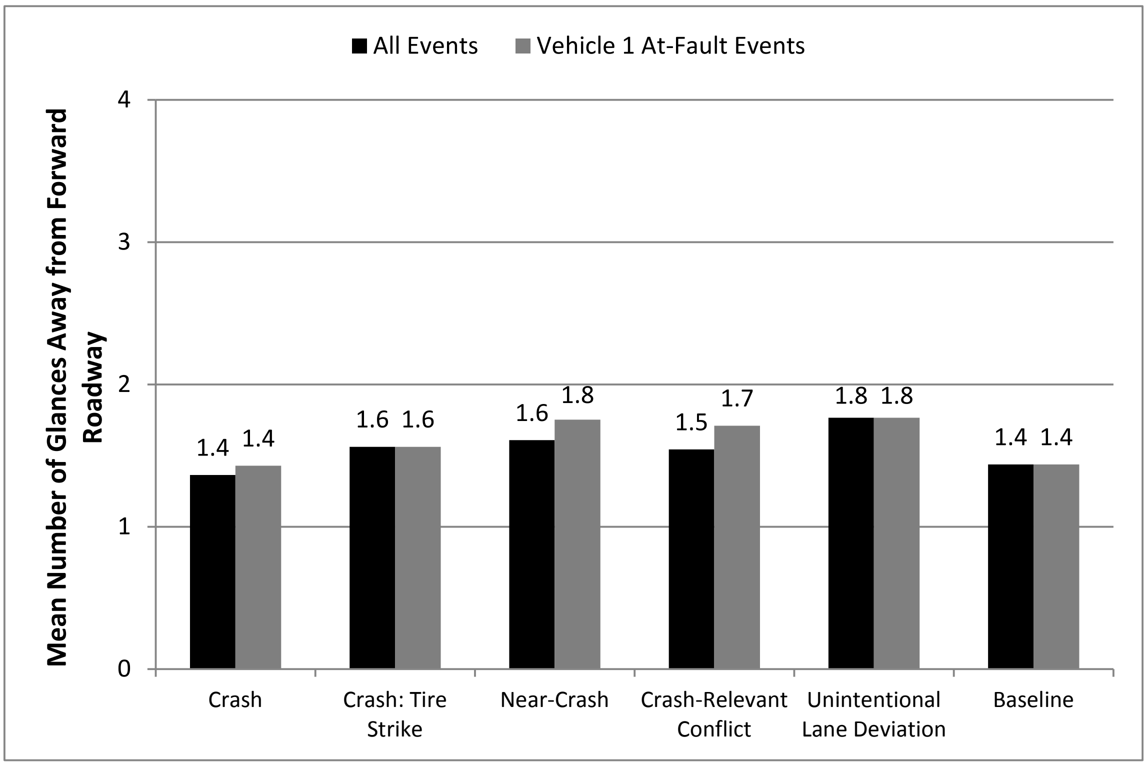

Figure 29. Graph. Mean number of glances away from the forward roadway by event type for all tasks.

Figure 29 also shows the mean number of glances away from the forward roadway for each event type across "Vehicle 1 At-fault" events. A one-way ANOVA found a significant difference in the mean number of glances away from the forward roadway between the six event types across "All" events ($F_{(5, 1990)} = 2.94$, $p = 0.0120$). Tukey *t* tests did not show significance between any of the pairwise comparisons.

4.4.3.2 Secondary Tasks

Figure 30 shows the mean number of glances away from the forward roadway for each event type across "All" and "Vehicle 1 At-fault" events for any secondary task. A one-way ANOVA found a significant difference in the mean number of glances away from the forward roadway between the six event types across "All" events ($F_{(5, 1643)} = 3.31$, $p = 0.0055$). Tukey *t* tests indicated that the mean number of glances away from the forward roadway during near-crashes

(1.7) had a significantly higher mean number of glances away from the forward roadway than during baseline epochs (1.4; $t_{(1643)} = 3.129$, $p = 0.0220$).

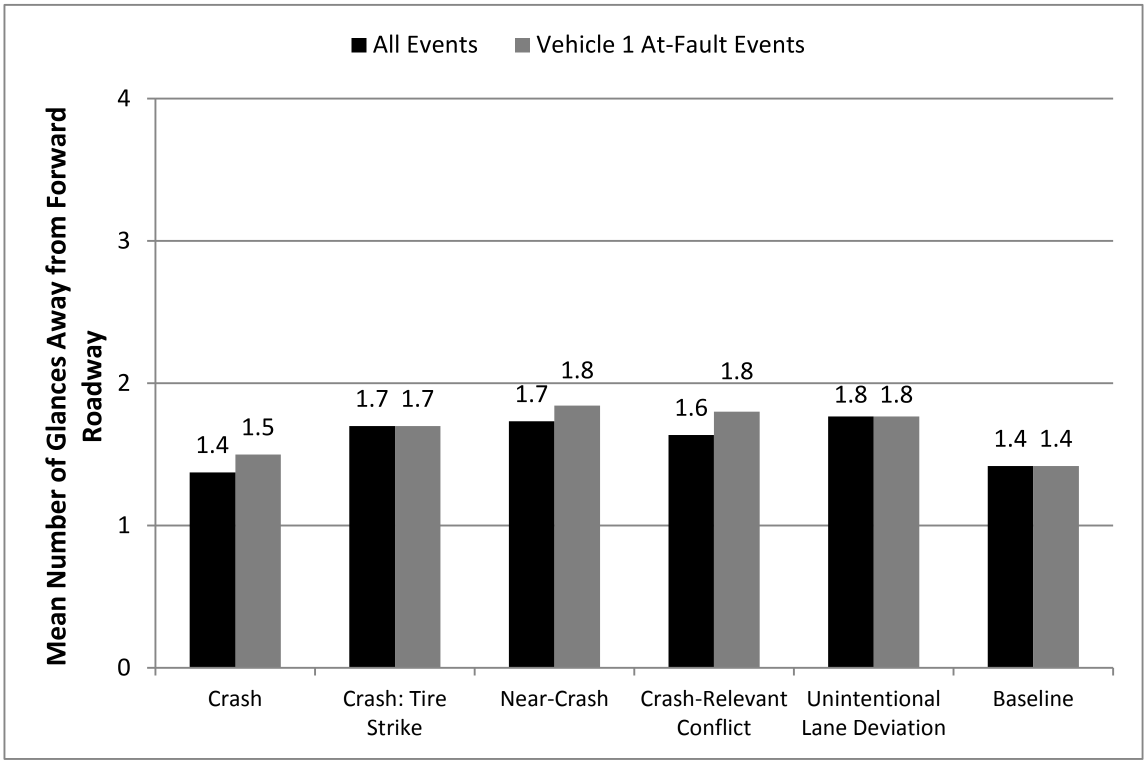

Figure 30. Graph. Mean number of glances away from the forward roadway by event type for all secondary tasks.

Figure 30 also shows the mean number of glances away from the forward roadway for each event type across "Vehicle 1 At-fault" events. A one-way ANOVA found a significant difference in the mean number of glances away from the forward roadway between the six event types across "Vehicle 1 At-fault" events ($F_{(5, 1453)} = 3.65$, $p = 0.0027$). Tukey *t* tests indicated the mean number of glances away from the forward roadway during near-crashes (1.8) had a significantly higher mean number of glances away from the forward roadway than baseline epochs (1.4; $t_{(1453)} = 2.918$, $p = 0.0416$).

4.4.3.3 Driving-related Tasks

Figure 31 shows the mean number of glances away from the forward roadway for each event type across "All" and "Vehicle 1 At-fault" events for any driving-related tasks. A one-way ANOVA did not find a significant difference in the mean number of glances away from the forward roadway between the six event types across "All" events ($F_{(5, 918)} = 1.13$, $p = 0.3423$).

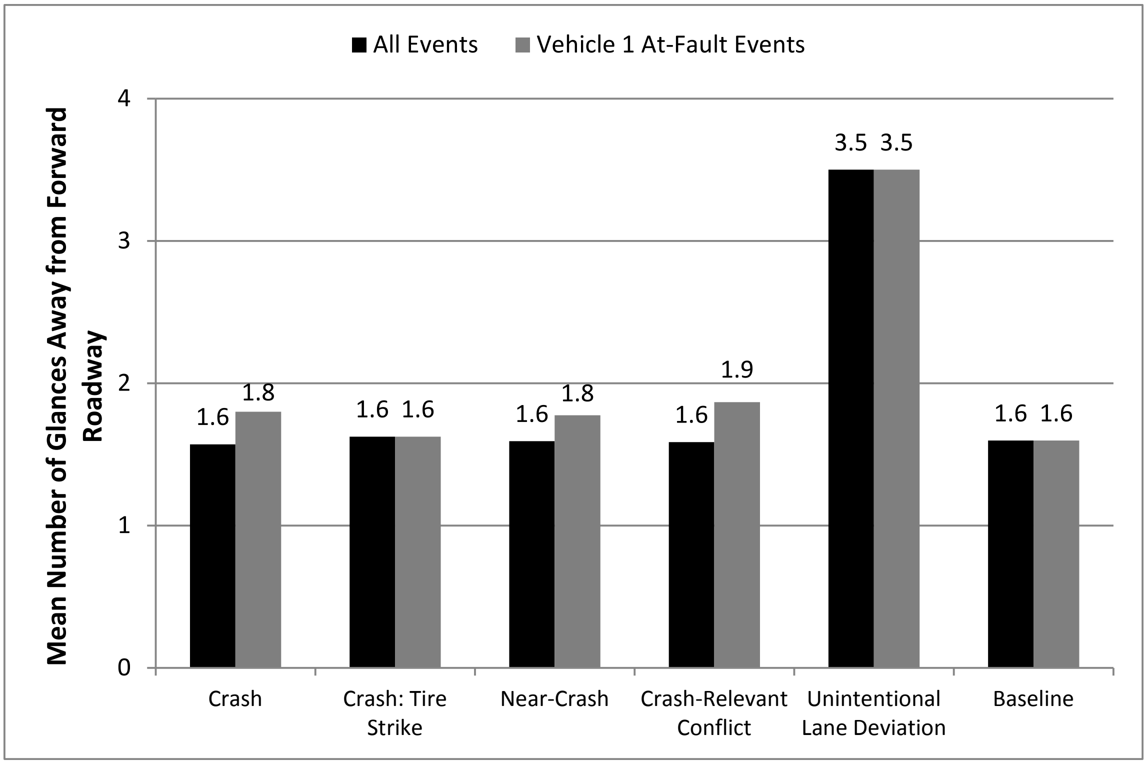

Figure 31. Graph. Mean number of glances away from the forward roadway by event type for driving-related tasks.

Figure 31 also shows the mean number of glances away from the forward roadway for each event type across "Vehicle 1 At-fault" events. A one-way ANOVA did not find a significant difference in the mean number of glances away from the forward roadway between the six event types across "Vehicle 1 At-fault" events ($F_{(5, 714)} = 1.97$, $p = 0.0810$).

4.4.4 Length of Longest Glance Away From Forward Roadway

"Length of longest glance away from forward roadway" was operationally defined as the longest single glance (defined in Section 3.5) where the driver was not looking forward during the 6-second SCE or baseline epoch. As in the previous analysis, this may include partial glances at either the beginning or end of the 6-second interval. The analyses in this section were grouped by event type (i.e., crash, near-crash, crash-relevant conflict, etc.) across "All" and "Vehicle 1 At-fault" events. These results are presented in Figure 32, Figure 33, and Figure 34 and include the following analyses:

- Secondary and/or driving-related tasks.
- Secondary tasks.
- Driving-related tasks.

4.4.4.1 All Secondary Tasks and/or Driving-related Tasks

Figure 32 shows the mean length of longest glance away from the forward roadway for each event type across "All" and "Vehicle 1 At-fault" events for any task. A one-way ANOVA found a significant difference in the mean length of longest glance away from the forward roadway between the six event types across “All” events ($F_{(4, 2327)} = 7.55$, $p < 0.0001$). Tukey t tests indicated that the mean length of longest glance away from the forward roadway during crash—tire strikes (1.4 seconds; $t_{(2327)} = 3.035$, $p = 0.0293$) and near-crashes (1.0 second; $t_{(2327)} = 4.773$, $p < 0.0001$) were significantly longer than during baselines (0.8 seconds).

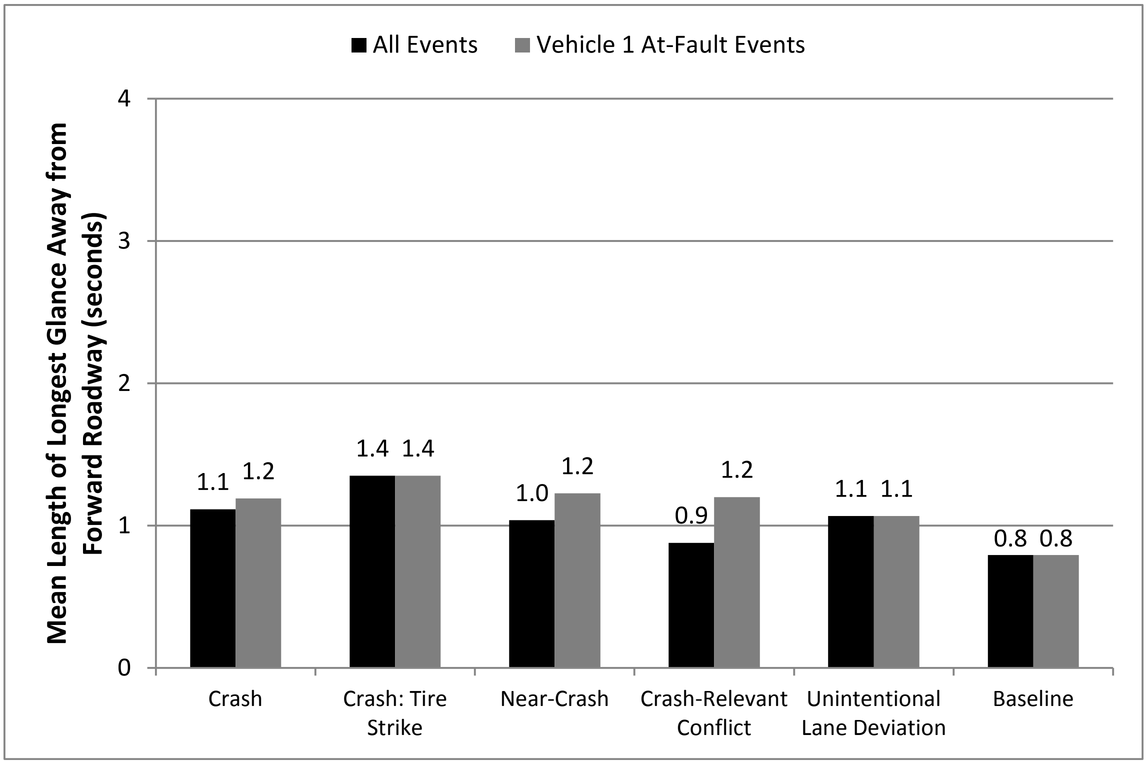

Figure 32. Graph. Mean length of longest glance away from the forward roadway by event type for all tasks.

Figure 32 also shows the mean length of longest glance away from the forward roadway for each event type across “Vehicle 1 At-fault” events. A one-way ANOVA found a significant difference between the six event types across “Vehicle 1 At-Fault” events ($F_{(5, 1990)} = 15.69$, $p < 0.0001$). Tukey t tests indicated the mean lengths of longest glance away from the forward roadway during crash—tire strikes (1.4 seconds; $t_{(1990)} = 3.102$, $p = 0.0239$), near-crashes (1.2 seconds; $t_{(1990)} = 5.570$, $p < 0.001$), and crash-relevant conflicts (1.2 seconds; $t_{(1990)} = 6.191$, $p < 0.0001$) were significantly longer than during baselines (0.8 seconds).

4.4.4.2 All Secondary Tasks

Figure 33 shows the mean length of longest glance away from the forward roadway for each event type across “All” and “Vehicle 1 At-fault” events for any tertiary task (i.e., any SCE or baseline epoch with a complex, moderate, or simple tertiary task). A one-way ANOVA found a significant difference in the mean length of longest glance away from the forward roadway between the six event types across “All” events ($F_{(5, 1643)} = 7.89$, $p < 0.0001$). Tukey t tests indicated that the mean length of longest glance away from the forward roadway during near-crashes (1.1 seconds) was significantly longer than during crash-relevant conflicts (0.9 seconds; $t_{(1643)} = 3.111$, $p = 0.0233$) and baselines (0.8 seconds; $t_{(1643)} = 5.359$, $p < 0.0001$).

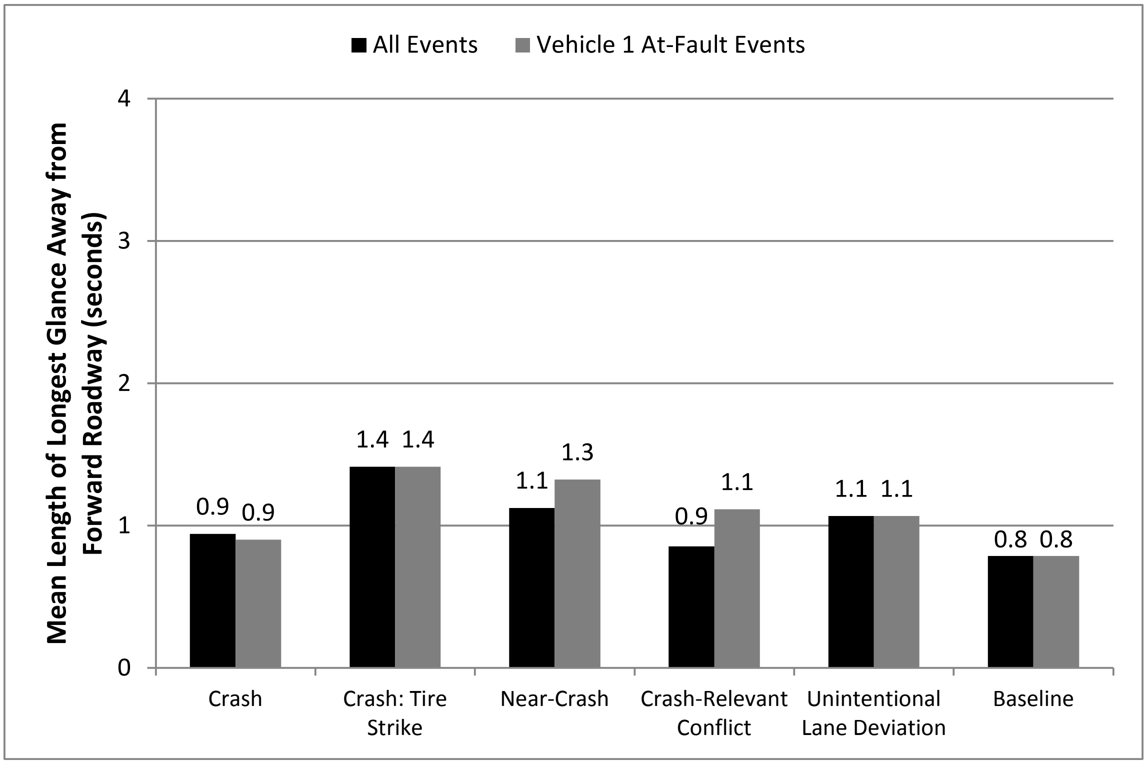

Figure 33. Graph. Mean length of longest glance away from the forward roadway by event type for secondary tasks.

Figure 33 also shows the mean length of longest glance away from the forward roadway for each event type across “Vehicle 1 At-fault” events. A one-way ANOVA found a significant difference in the mean length of longest glance away from the forward roadway between the six event types across “Vehicle 1 At-fault” events ($F_{(5, 1453)} = 11.16$, $p < 0.0001$). Tukey *t* tests indicated that the mean length of longest glance away from the forward roadway during near-crashes (1.3 seconds; $t_{(1453)} = 5.809$, $p < 0.0001$) and crash-relevant conflicts (1.1 seconds; $t_{(1453)} = 4.181$, $p = 0.0004$ was significantly longer than during baselines (0.8 seconds).

4.4.4.3 Driving-related Tasks

Figure 34 shows the mean length of longest glance away from the forward roadway for each event type across “All” and “Vehicle 1 At-fault” events for any driving-related task (i.e., any SCE or baseline epoch with only a driving-related inattention task). A one-way ANOVA did not find any significant difference in the mean length of longest glance away from the forward roadway between the six event types across “All” events ($F_{(5, 918)} = 2.04$, $p = 0.0704$).

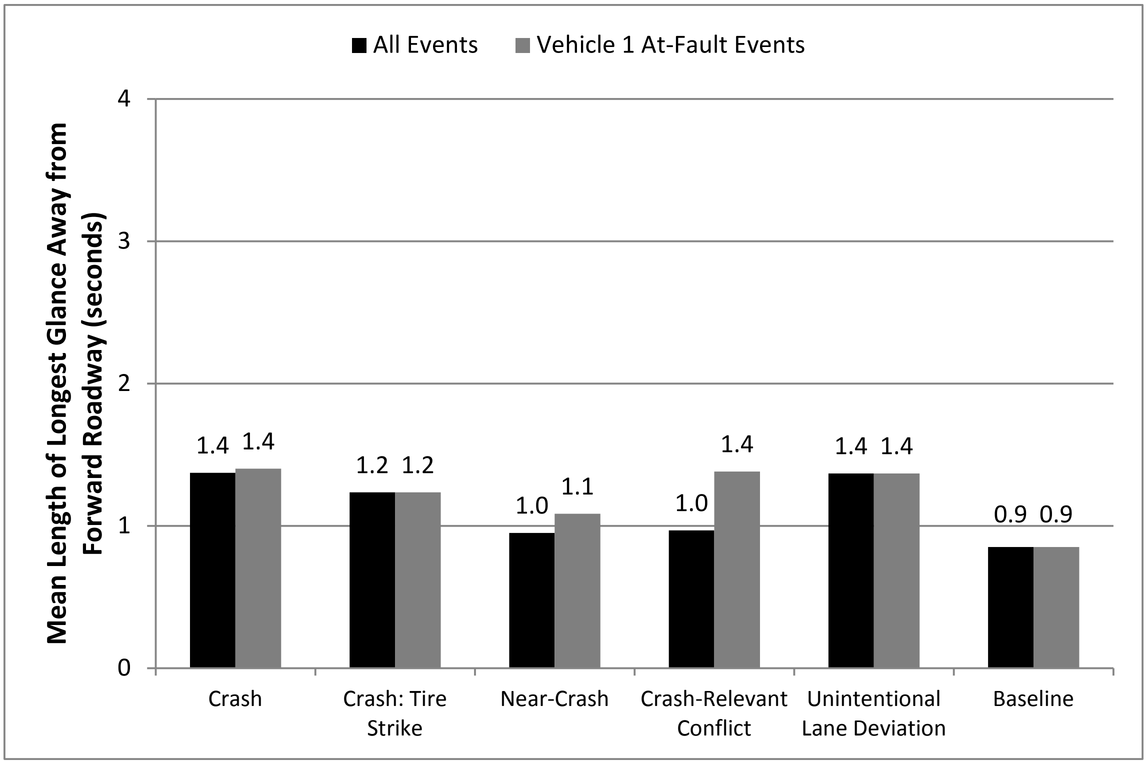

Figure 34. Graph. Mean length of longest glance away from the forward roadway by event type for driving-related tasks.

Figure 34 also shows the mean length of longest glance away from the forward roadway for each event type across "Vehicle 1 At-fault" events. A one-way ANOVA found a significant difference in the mean length of longest glance away from the forward roadway between the six event types across "Vehicle 1 At-fault" events ($F_{(5, 714)} = 8.41$, $p < 0.0001$). Tukey t tests indicated the mean length of longest glance away from the forward roadway during crash-relevant conflicts (1.4 seconds) was significantly longer than during baselines (0.9 seconds; $t_{(714)} = 5.906$, $p < 0.0001$).

4.4.5 Summary

The eye glance analysis provided some interesting findings but none that were unexpected. First, when the total eyes-off-forward roadway time data were binned in 0.5-second increments, the distribution of ORs was nearly linear from less than or equal to 0.05 seconds through 1.5–2.0 seconds. However, the risk jumped exponentially when the total eyes-off-forward-roadway time was greater than 2 seconds. In particular, for SCEs judged to be the motorcoach driver's fault, the OR was 1.71 in the 1.5- to 2.0-seconds bin, but jumped to 5.29 in the greater-than-2.0-seconds bin. This finding is not novel, but emphasizes the importance of drivers minimizing glances away from the forward roadway.

Another important takeaway from the eye glance analysis was the similarity in results across different SCE types. When focusing on SCE types where the motorcoach driver was at fault (see Figure 17), the eyes-off-forward-roadway time across the different SCE types ranged from 1.7 to 1.9 seconds. However, baseline (normative driving) eye glance times were less than 1.2 seconds, or 0.5 seconds less than the lowest in the SCE range. This result shows that though different SCE types may have slightly different eye glance times when comparing one type to another, these differences are modest when compared to baseline.

As noted previously, interaction with passengers is a task that is somewhat unique to motorcoach drivers. One tool that drivers use in this task is the intercom. As shown in Figure 35, the intercom microphone is often located near the headrest of the driver's seat. Although the task itself is verbal, drivers have to divert their eyes from the forward roadway for a relatively long duration in order to reach it. Additionally, drivers often glance at the rearview mirror to view the passenger area. This task was shown to have one of the highest mean eyes-off-forward-roadway times associated with performing a task.

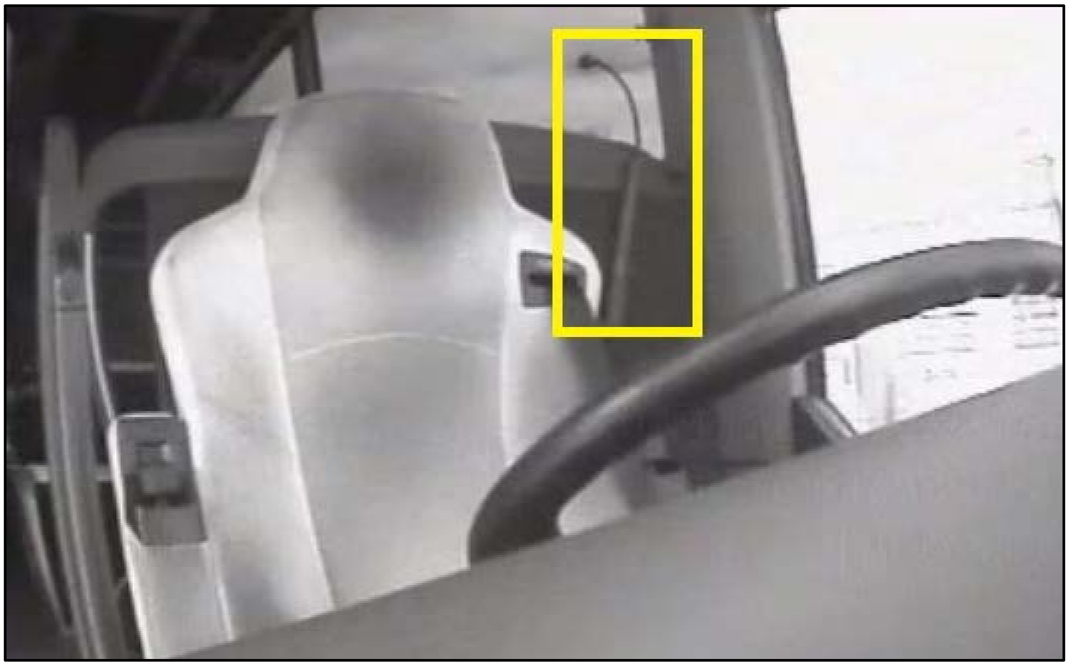

Figure 35. Image. Intercom system from a motorcoach bus cab (highlighted in yellow box).

Also of interest were the results for "external distraction" and "reaching for an object." In both cases, the relatively high eye glance results are consistent with results seen in other driver populations, including light vehicle and truck drivers.[(142,143)] These seemingly innocuous tasks that drivers may perform complacently result in increased risk and a significant mean duration of eyes away from the road.

An interesting finding from the eye glance analysis was the relatively high mean eyes-off-forward-roadway duration when the motorcoach drivers used their turn signals. One potential explanation for this finding is not the act of using a turn signal per se, but rather the maneuver associated with changing lanes or direction with surrounding traffic. This finding may point more toward light vehicle drivers' aggressiveness and difficulty driving near trucks and buses rather than any bus driver performance issues.[(144,145)]

4.5 RESEARCH QUESTION 4: HOW DOES THE OBSERVER RATING OF DROWSINESS VARY IN THE PRESENCE AND ABSENCE OF A TASK?

The final research question for this study focused on the assessment of drowsiness. For this analysis, all SCEs (n = 938) and baseline epochs (n = 4,503) with valid ORD data were grouped together to form a single data set. The data were then grouped by those with the task of interest and those without the task of interest.

Recall from Section 3 that ORD was divided into five categories: not drowsy, slightly drowsy, moderately drowsy, very drowsy, and extremely drowsy. Because of small sample sizes, not drowsy and slightly drowsy were collapsed into "low drowsiness," and very drowsy and extremely drowsy were collapsed into "high drowsiness;" moderate drowsiness was left as its own category. SCEs and baselines needed to have at least 30 seconds of data available to be considered valid for this analysis.[146]

A chi-squared test of independence was conducted to assess whether the distribution of ORD observations differed for data with a task of interest and data without a task of interest. Chi-squared tests of independence compare two categorical variables for association with each other in a set of observational units.[147] Observational units, classified by values of the two categorical variables, can then be summarized in a contingency table (see Table 71 for a 3 x 2 contingency table).

Table 71. 3 × 2 contingency table used to calculate chi-square test of independence.

	Cell Phone Talking	**No Cell Phone Talking**	**Row Total**
Low Drowsiness Rating	n_{11}	n_{12}	$\mathbf{n_{1.}}$
Moderate Drowsiness Rating	n_{21}	n_{22}	$\mathbf{n_{2.}}$
High Drowsiness Rating	n_{31}	n_{32}	$\mathbf{n_{3.}}$
Column Total	$\mathbf{n_{.1}}$	$\mathbf{n_{.2}}$	$\mathbf{n_{..}}$

The following formula, shown in Figure 36, is used to calculate the chi-squared test statistic:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - E_{ij}\right)^2}{Eij}$$

Figure 36. Formula. Chi-squared test statistic calculation.

where O_{ij} is the observed frequency in the cell with row i and column j and E_{ij} is the expected frequency for the same cell. The total number of rows is represented by r, and the total number of columns is represented by c; for Table 71, r = 3 and c = 2.

The expected frequency is calculated using the formula shown in Figure 37:

$$E_{ij} = \frac{n_{i.} \times n_{.j}}{n_{..}}$$

Figure 37. Formula. Expected frequency calculation.

Figure 38 shows the calculation for degrees of freedom (*df*).

$$df = (r - 1) \times (c - 1)$$

Figure 38. Formula. Degrees of freedom calculation.

The chi-squared test statistic χ^2 with *df* is then used to calculate a *p*-value, or the probability of the observed distribution being due entirely to chance. If the *p*-value is less than the chosen α value, then the finding is statistically significant and concludes the row and column variables have a relationship. A significant finding does not indicate the nature of the relationship or where exactly the distribution of one variable changes with the other.

These results included analyses on the following:

- Secondary tasks and/or driving-related tasks.
- Secondary tasks.
- Driving-related tasks.

Figure 39 Figure 40, Figure 41, Figure 42, Figure 43, and Figure 44 show the percentage of SCEs and/or baseline epochs that fall into each of the three categories. A chi-squared test was conducted on each to determine statistical significance.

4.5.1 Secondary Tasks and/or Driving-related Tasks

Figure 39 shows the percentage of SCEs and/or baseline epochs that include a secondary and/or driving-related task for "All" data. It can be seen that 86.2 percent of the data that included a secondary and/or driving-related task showed low drowsiness; 13.0 percent of the data showed moderate drowsiness; and 0.8 percent showed high drowsiness. Events without a secondary and/or driving-related task showed low drowsiness in 77.9 percent of the data; moderate drowsiness in 21.0 percent of the data; and high drowsiness in 1.0 percent of the data.

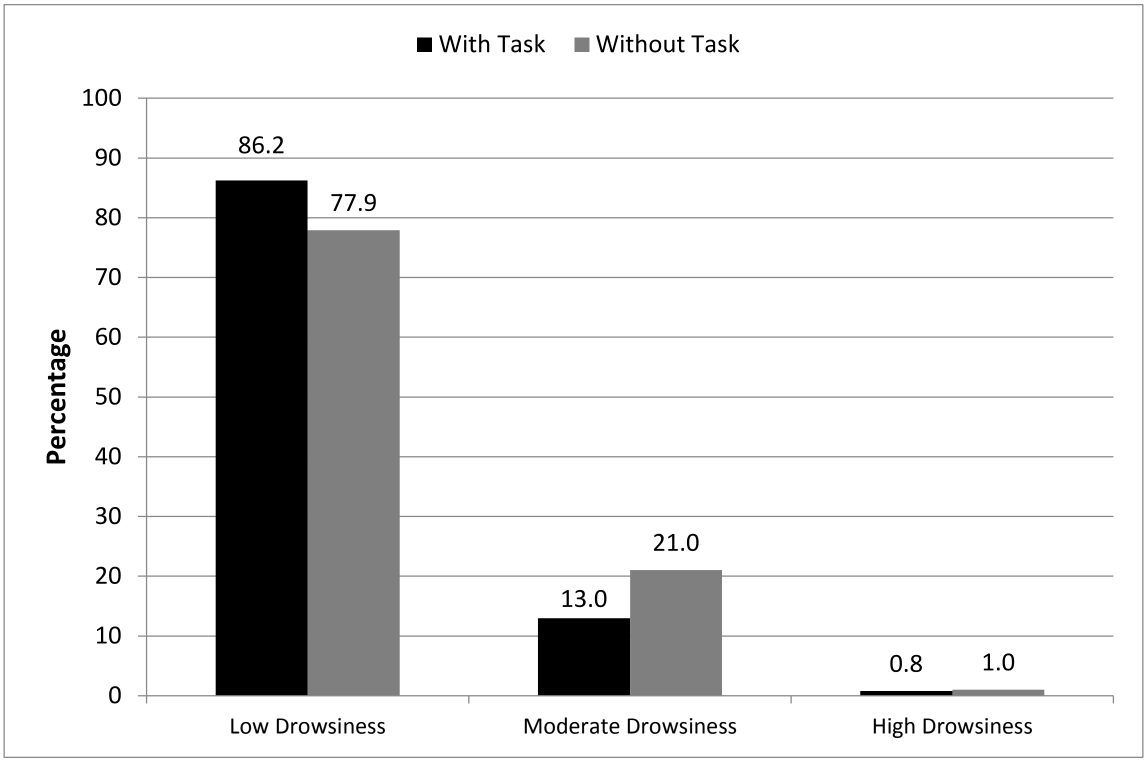

Figure 39. Graph. Percentage of data with and without secondary and/or driving-related tasks for "All" events.

A chi-square test comparing the distribution of ORD ratings in events with a secondary and/or driving-related task and events without a secondary and/or driving-related task was significant (χ^2=61.33, $p < 0.0001$). Events with a secondary and/or driving-related task had more frequent observations of low drowsiness and less frequent observations of moderate or high drowsiness.

The data were also grouped by "Vehicle 1 At-fault." Figure 40 shows the percentage of SCEs and/or baseline epochs that include a secondary and/or driving-related task for "Vehicle 1 At-fault" data. It can be seen that 85.6 percent of the data that included a secondary and/or driving-related task showed low drowsiness; 13.6 percent of the data showed moderate drowsiness; and 0.8 percent showed high drowsiness. Events without a secondary and/or driving-related task showed:

- Low drowsiness in 76.8 percent of the data.
- Moderate drowsiness in 22.2 percent of the data.
- High drowsiness in 1.1 percent of the data.

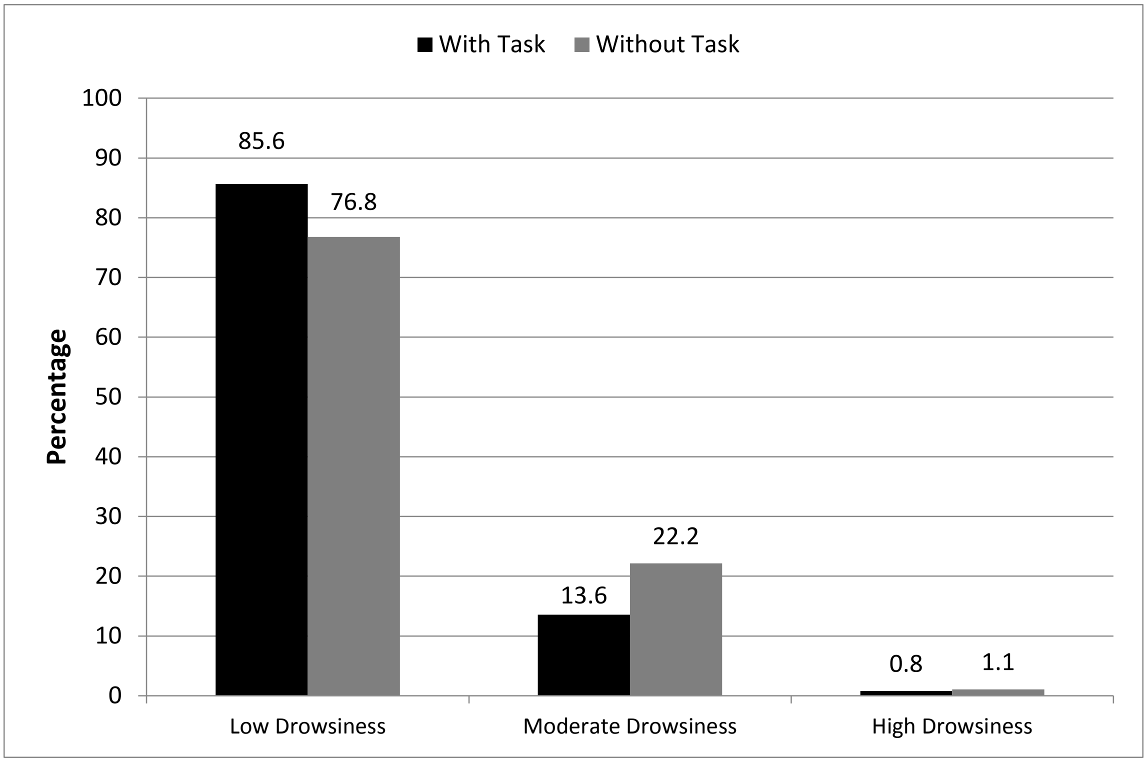

Figure 40. Graph. Percentage of data with and without secondary and/or driving-related tasks for "Vehicle 1 At-fault" events.

A chi-square test comparing the distribution of ORD ratings in events with a secondary and/or driving-related task and events without a secondary and/or driving-related task was significant (χ^2=59.42, $p < 0.0001$). Events with a secondary and/or driving-related task had more frequent observations of low drowsiness and less frequent observations of moderate or high drowsiness.

4.5.2 Secondary Tasks

Figure 41 shows the percentage of SCEs and/or baseline epochs that included a secondary task for "All" data. It can be seen that 87.9 percent of the data that included a secondary task showed low drowsiness; 11.7 percent of the data showed moderate drowsiness; and 0.4 percent showed high drowsiness. Events without a secondary task showed:

- Low drowsiness in 78.7 percent of the data.
- Moderate drowsiness in 20.2 percent of the data.
- High drowsiness in 1.1 percent of the data.

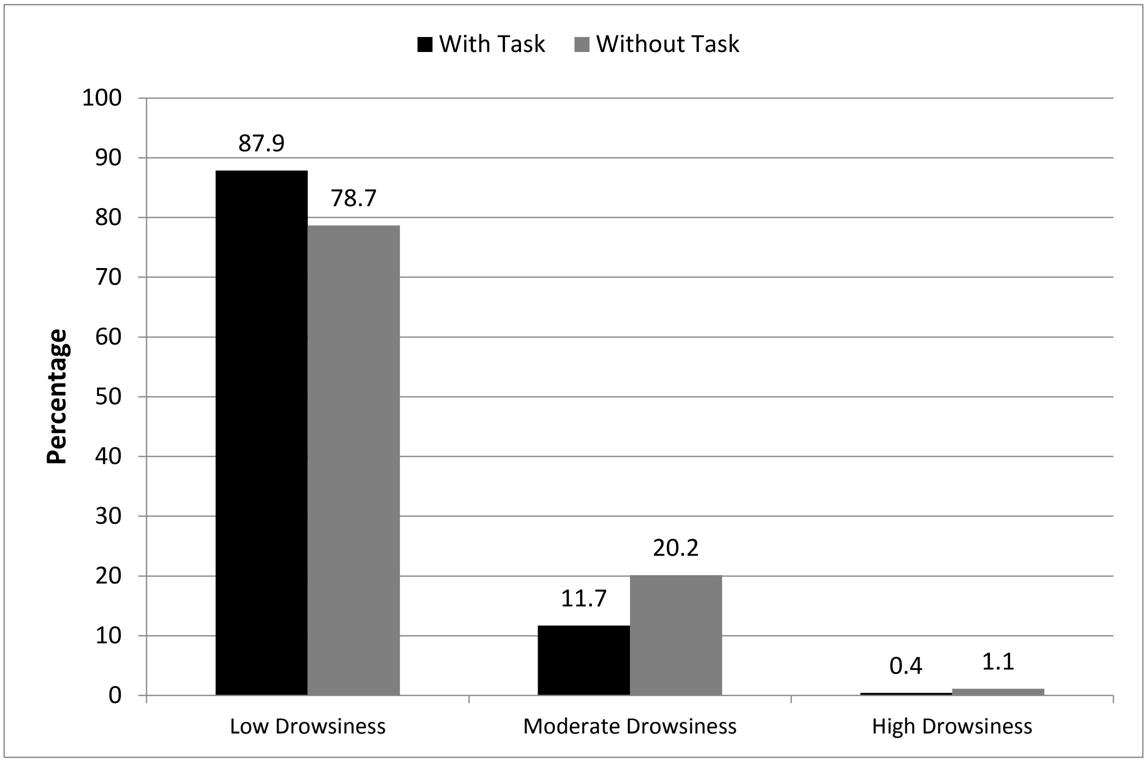

Figure 41. Graph. Percentage of data with and without secondary tasks for "All" events.

A chi-square test comparing the distribution of ORD ratings in events with a secondary task and events without a secondary task was significant (χ^2=65.01, $p < 0.0001$). Events with a secondary task had more frequent observations of low drowsiness and less frequent observations of moderate or high drowsiness.

The data were also grouped by "Vehicle 1 At-fault." Figure 42 shows the percentage of SCEs and/or baseline epochs that included a secondary task for "Vehicle 1 At-fault" data. It can be seen that:

- 87.4 percent of the data that included a secondary task showed low drowsiness.
- 12.2 percent of the data that included a secondary task showed moderate drowsiness.
- 0.5 percent of that data that included a secondary task showed high drowsiness.

Events without a secondary task showed:

- Low drowsiness in 77.4 percent of the data.
- Moderate drowsiness in 21.4 percent of the data.
- High drowsiness in 1.2 percent of the data.

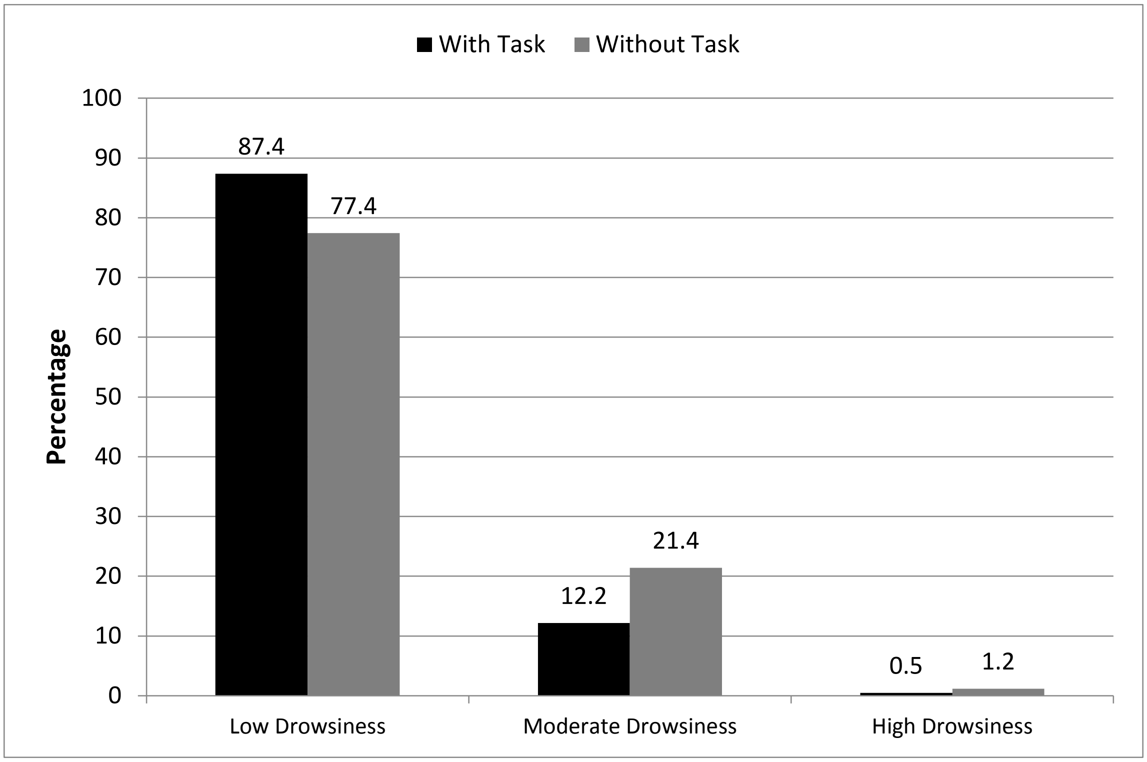

Figure 42. Graph. Percentage of data with and without secondary tasks for “Vehicle 1 At-fault” events.

A chi-square test comparing the distribution of ORD ratings in events with a secondary task and events without a secondary task was significant (χ^2=65.52, $p < 0.0001$). Events with a secondary task had more frequent observations of low drowsiness and less frequent observations of moderate or high drowsiness.

4.5.3 Driving-related Tasks

Figure 43 shows the percentage of SCEs and/or baseline epochs that include a driving-related task for “All” data. It can be seen that:

- 82.7 percent of the data that included a driving-related showed low drowsiness.
- 16.1 percent of the data that included a driving-related showed moderate drowsiness.
- 1.2 percent of the data that included a driving-related showed high drowsiness.

Events without a driving-related task showed:

- Low drowsiness in 81.2 percent of the data.
- Moderate drowsiness in 17.9 percent of the data.
- High drowsiness in 0.9 percent of the data.

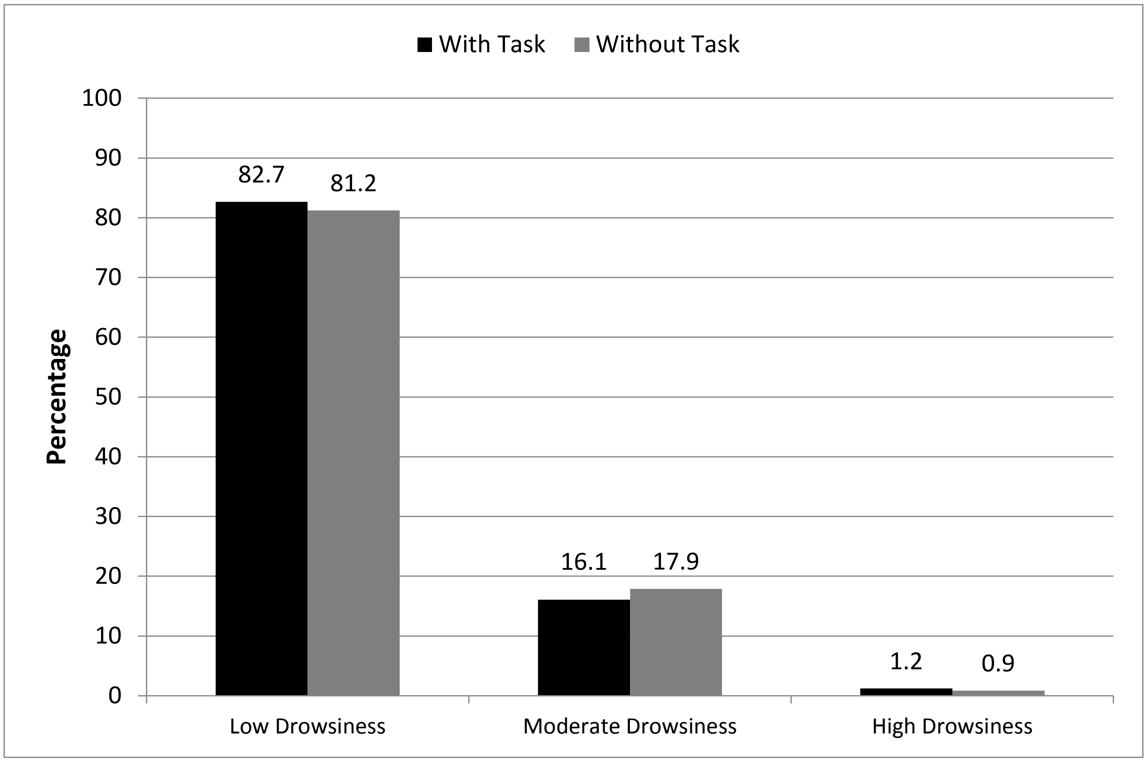

Figure 43. Graph. Percentage of data with and without driving-related tasks for "All" events.

A chi-square test comparing the distribution of ORD ratings in events with a driving-related task and events without a driving-related task was not significant (χ^2=2.67, p = 0.263). Events with a driving-related task had more frequent observations of low drowsiness and less frequent observations of moderate or high drowsiness.

The data were also grouped by "Vehicle 1 At-fault." Figure 44 shows the percentage of SCEs and/or baseline epochs that included a driving-related task for "Vehicle 1 At-fault" data. It can be seen that:

- 80.9 percent of the data that included a driving-related task showed low drowsiness.
- 17.8 percent of the data that included a driving-related task showed moderate drowsiness.
- 1.2 percent of the data that included a driving-related task showed high drowsiness.

Events without a driving-related task showed:

- Low drowsiness in 80.4 percent of the data.
- Moderate drowsiness in 18.7 percent of the data.
- High drowsiness in 0.9 percent of the data.

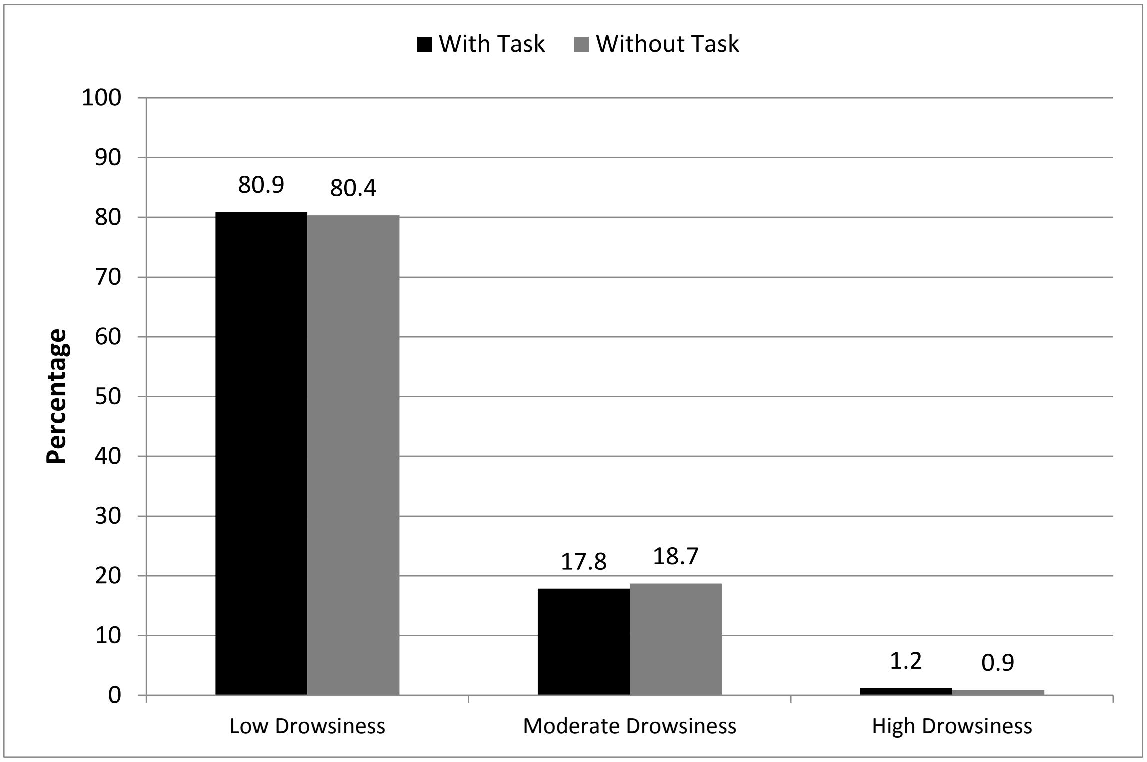

Figure 44. Graph. Percentage of data with and without driving-related tasks for "Vehicle 1 At-fault" events.

A chi-square test comparing the distribution of ORD ratings in events with a driving-related task and events without a driving-related task was significant (χ^2=0.98, p = 0.613). Events with a driving-related task had more frequent observations of low drowsiness and less frequent observations of moderate or high drowsiness.

4.5.4 Summary

ORD is a tool that has been used in many studies as a way to capture the level of drowsiness observed in video. Trained analysts in this study reviewed up to 60 seconds of video data prior to the event to determine an ORD score. Once these scores were determined, categories were collapsed resulting in three ORD categories: low, moderate, and high drowsiness. Because these data were non-parametric, chi-square analyses were conducted. A key finding from the analyses was that most of the data, including both SCEs and baselines, involved a driver with low drowsiness (i.e., an alert driver). A very small percentage of the SCEs and baselines involved a driver judged to have a high ORD rating; that is, about 1 percent of the data involved motorcoach drivers that were judged to be in the high drowsiness category.

A second interesting takeaway from the analyses was with respect to engagement in secondary and driving-related tasks during SCEs. As noted in Hanowski and in Hanowski et al., studies with truck drivers have suggested that secondary task interaction may be a countermeasure to drowsiness.[148,149] This finding is supported by the current data on motorcoach drivers. Drivers engaged in non-driving secondary tasks were judged to have significantly less drowsiness, when considering both moderately and highly drowsy categories. Focusing on at-fault SCEs and the "moderately drowsy" category, approximately 12 percent of SCEs and baselines occurred when drivers were engaged in a secondary task, but 21 percent occurred when drivers were not engaged in a secondary task. Considering the high drowsiness category, 0.5 percent of the SCEs were observed when drivers were engaged in a secondary task; that percentage jumped to 1.2 percent when they were not engaged. However, when considering the low drowsiness category where most SCEs occurred, the potential stimulating benefit from secondary task engagement would not be expected and was not found in these data. Furthermore, when considering the relationship between driving-related tasks and drowsiness levels, the same type of pattern does not appear. So, as previously noted in Hanowski and in Hanowski et al., commercial drivers may utilize secondary task engagement selectively as a drowsiness countermeasure.[150,151]

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5. SUMMARY AND CONCLUSIONS

The primary aim of this study was to investigate the impact that driver distraction and drowsiness have on motorcoach operations. Following the methods outlined in Olson et al., the current study analyzed naturalistic driving data that were collected over a 1-year period, beginning in May 2013.[152] Two bus fleets and 43 buses were instrumented with naturalistic driving study equipment that included video cameras and other sensors. The study resulted in the collection of more than 600,000 miles of continuous, naturalistic driving data. Sixty-five motorcoach drivers participated in the study, 48 of whom were male. The average age of the 65 drivers was 49 years (range: 23 to 79 years).

Despite the large number of buses registered in the United States, there has been very limited research conducted on motorcoach operations. With more than 15 billion miles traveled per year involving the transport of millions of people, crashes, when they occur, can involve multiple injuries and deaths.[153] When motorcoach crashes do occur, driver error factors are often cited.[154] Two prominent driver error categories are distraction and drowsiness. When compared to truck crashes, bus fatalities occur at a rate that is more than one-third higher than large truck fatalities per 100 million VMT.[155] Given the large number of miles that buses travel each year and the resulting fatality rates, the motorcoach transport domain should be the focus of more research attention than it actually receives. The current study aimed to provide some insight on the topic; additional studies are warranted.

The current study used data from the recently completed OBMS FOT.[156] The OBMS FOT research project tested and evaluated an OBMS installed on multiple truck and bus fleets. As part of the OBMS FOT research project, the research team also installed a DAS in each vehicle and collected continuous, naturalistic data. The collected DAS data were analyzed in the current study. Additionally, the analysis method used in Olson et al., which focused on assessing driver distraction and drowsiness in truck drivers, was replicated in the current study.[157]

Though many research questions can be addressed using this very rich data set, the current study focused on four research questions. A summary of the key findings for each research question is included below.

5.1 RESEARCH QUESTION 1: UNDERSTANDING THE TYPE AND FREQUENCY OF TASKS IN WHICH MOTORCOACH DRIVERS ENGAGED PRIOR TO SCE INVOLVEMENT

The focus of the first research question was to understand the tasks that motorcoach drivers engage in and to determine the relationship of these different tasks with SCE involvement. Video data were reviewed within a 6-second window—5 seconds prior to the precipitating event and 1 second after.[158,159] Several analyses were conducted and reported in the Section 4. Some of the key findings for this research question are as follows:

- Secondary and driving-related task engagement was prevalent in recorded SCEs. Approximately 59 percent of all SCEs involved said task engagement. When only at-fault crashes were considered, that percentage jumped to 89 percent.

- Secondary task engagement, which involved non-driving related tasks, was identified in 37 percent of SCEs. In 56 percent of at-fault crashes, the driver was engaged in a secondary task.

- Specific types of secondary tasks associated with a significant OR included reaching for an object and looking outside (external distraction). Novel to motorcoach drivers, intercom use was also identified as a secondary task with an associated significant OR.

- Motorcoach drivers rarely used cell phones and none of the cell phone subtasks observed were associated with an increase in risk.

An analysis of SCEs and baseline (normative) driving found that motorcoach drivers can be impacted by driver distraction. Though some of the secondary tasks that increase risk are common across driver domains (i.e., light vehicle and truck), there were some novel findings for this particular driver group; in particular, interaction with an intercom system to talk to passengers may warrant further investigation.[160,161]

5.2 RESEARCH QUESTION 2: HOW ENVIRONMENTAL CONDITIONS MAY IMPACT SAFETY AND TASK ENGAGEMENT

The second research question addressed in this study focused on understanding the environmental conditions in which motorcoaches operate, and the impact that those different conditions may have on driver choice to engage in secondary and driving-related tasks. The coding of SCEs and baselines was extensive and assessed nine different conditions: lighting level, weather condition, roadway surface condition, relation to junction, roadway alignment, roadway grade, traffic flow, traffic density, and locality. A few of the key findings are as follows:

- Most SCEs occurred in daylight with no adverse weather conditions.
- Most baseline data were identified to have occurred in non-junctions and interchange areas. Similarly, most SCEs occurred in non-junctions. However, a second notable area for SCEs, but not baselines, was intersections.
- Entrance/exit ramps had some of the highest values for OR calculations.

The findings from this analysis may be of interest to roadway engineers, highway designers, or others that may focus on the road use aspects of motorcoach operations. The data seemed to point to many findings that would be expected, though other findings may be more intriguing. For example, a seemingly consistent finding was that roadway conditions and characteristics that involved significant vehicle interaction produced many of the SCES. For example, buses at airports, on entrance/exit ramps, and at intersections were all found to have high ORs. One explanation for this finding relates to the difficulty that motorcoach drivers face when interacting in relatively confined spaces with other vehicles.

5.3 RESEARCH QUESTION 3: CHARACTERIZING RISK AND TASK ENGAGEMENT USING EYE GLANCE ANALYSIS

The third research question focused on the eyes-off-forward-roadway measure to determine the relationship between eyes off forward roadway and SCE involvement. Eye glance analysis was manually calculated, using a frame-by-frame approach, for the 6-second window of the event—5 seconds before the precipitating event and 1 second after. Bins of 0.5 seconds were constructed to determine the frequency of SCEs as a function of bin time. Several important findings were determined through the various analyses conducted, as follows:

- The distribution of ORs was nearly linear from less than or equal to 0.05 seconds through 1.5–2.0 seconds. However, the risk jumped significantly and exponentially when the driver's eyes were off the forward roadway for more than 2 seconds.
- The eyes-off-forward-roadway times across the different SCE types were similar, ranging from 1.7 to 1.9 seconds for at-fault events.
- Baseline data were shown to have mean eye glance times that were 0.5 seconds less than any of the SCE times.
- The intercom task (a novel task for bus drivers), had one of the highest mean eyes-off-forward-roadway durations of any secondary task.
- The high mean eyes-off-forward-roadway duration for the turn signal task was surprising, though it is expected this has more to do with the drivers' need to look in multiple directions when changing lanes or changing direction of travel.

Collectively, the results from the eye glance analyses show a pattern consistent with similar analyses conducted on light vehicle and truck drivers.[162,163] The longer the eyes-off-forward-roadway time, the more likely an SCE is to occur. Furthermore, this study validates the 2.0-second demarcation as the threshold in which risk of an SCE will exponentially increase.

5.4 RESEARCH QUESTION 4: MEASURING DROWSY DRIVING WITH ORD AND CONSIDERATION OF DROWSINESS AS A FUNCTION OF TASK INVOLVEMENT

The fourth research question focused on the relationship of task engagement and observed drowsiness. Each event and baseline was reviewed for up to 60 seconds and analysts assessed the drivers' level of drowsiness using the ORD scale. Key findings included the following:

- By far, most of the SCEs and baseline data reviewed involved an alert motorcoach driver. Approximately 1 percent of the data involved a driver who was judged to have been in the high drowsiness category.
- Consistent with research on truck drivers, motorcoach drivers may use secondary task engagement as a countermeasure to drowsiness.[164,165] Both SCEs and baselines with a secondary task tended to have lower drowsiness ratings than SCEs and baselines without a secondary task. Similar results were found when SCEs were limited to at-fault. For driving-related tasks, the results were not as strong, and events/baselines showed similar

distributions of drowsiness levels in the presence and absence of the task. One potential takeaway from these contrasting findings is that drivers may be using secondary tasks as a drowsiness countermeasure, whereas driving-related tasks would be a less likely choice.

Though other analyses on drowsiness are possible with this data set, the current study focused on how drowsiness may influence secondary task engagement. To this end, it appears that motorcoach drivers may engage in secondary tasks to counteract the negative impacts of drowsiness.

5.5 HOW DO THE MOTORCOACH RESULTS COMPARE TO THE OLSON ET AL. (2009) TRUCK RESULTS?

To enable comparison of collected motorcoach driver distraction and drowsiness data with existing truck driver distraction and drowsiness data, this study adopted the methods used in Olson et al., a study focused on driver distraction in trucking operations.(166) It was important to provide a side-by-side comparison of the secondary task and driving-related task results. The left column of Table 72 lists all of the identified tasks from the two studies. The ORs from the current motorcoach study are shown, for both “All” SCEs and “Vehicle 1 At-fault” SCEs, next to the results from the truck study. A few related key findings are as follows:

- There were relatively fewer secondary tasks in the bus data compared to the truck data.
- There was very little cell phone use in the bus data (though the bus study occurred after the FMCSA regulation to limit cell use).
- Only two secondary tasks had comparable ORs (significant and in the same direction). “Reaching for an object” was shown to increase risk in both driver groups, as was “external distraction.”
- Though there were many electronic secondary tasks associated with a significantly high OR for truck drivers, only one such electronic secondary task—intercom use—was significant for the bus drivers.
- Though some basic secondary tasks were shown to lead to distraction in both bus drivers and truck drivers, truck drivers were found to be much more heavily engaged in various tasks, including electronic tasks and work-related activities, as compared to bus drivers.

Table 72. Comparison of motorcoach and truck driver secondary task results.

Task Type	Task Description	ALL Motorcoach Data OR	V1 Motorcoach Data OR	ALL Truck Data OR	V1 Truck Data OR
Secondary	Talking/singing	1.22	1.28	1.05	0.93
Secondary	Dancing	0.40	-	n/a	n/a
Secondary	Reading	-	-	**3.97***	**4.76***
Secondary	Writing	-	-	**8.98***	**11.07***
Secondary	Looking at map	n/a	n/a	**7.02***	**8.67***
Secondary	Passenger in rear seat	0.79	0.71	n/a	n/a
Secondary	Interacting with or look at other occupant(s)	n/a	n/a	**0.35***	**0.36***
Secondary	Moving object in vehicle	-	-	n/a	n/a
Secondary	Insect in vehicle	-	-	n/a	n/a
Secondary	*Reaching for object*	**2.14***	**2.88***	**3.09***	**3.65***
Secondary	Look back in sleeper berth	n/a	n/a	**2.30***	**2.52***
Secondary	Object in vehicle, other	**1.69***	**2.06***	n/a	n/a
Secondary	Cell phone, holding	-	-	n/a	n/a
Secondary	Cell phone, talking/listening hand-held	1.93	-	1.04	1.16
Secondary	Cell phone, talking/listening hands-free	n/a	n/a	**0.44***	**0.40***
Secondary	Cell phone, texting	-	-	**23.24***	**27.71***
Secondary	Cell phone, browsing	-	-	n/a	n/a
Secondary	Cell phone, dialing hand-held	-	-	**5.93***	**7.06***
Secondary	Cell phone, locating/reaching/answering	-	-	n/a	n/a
Secondary	Cell phone, other	-	-	n/a	n/a
Secondary	Intercom use	**3.78***	2.17	n/a	n/a
Secondary	Interacting with dispatch device	n/a	n/a	**9.93***	**11.90***
Secondary	Talking or listening to CB radio	n/a	n/a	**0.55***	**0.46***
Secondary	Using calculator	n/a	n/a	**8.21***	**10.11***
Secondary	Other electronic device	-	-	**6.72***	**7.58***
Secondary	Adjusting instrument panel	0.87	1.39	**1.25***	**1.38***
Secondary	Adjusting/monitoring other devices integral to vehicle	1.64	1.25	**1.25***	**1.38***
Secondary	*Looking at outside, vehicle, animal, object, etc.*	**1.61***	**2.28***	**0.54***	**0.51***
Secondary	Eating	0.90	1.24	1.01	1.16
Secondary	Drinking from container	0.66	-	0.97	1.13
Secondary	Smoking-related: cigarette in hand or mouth	-	-	0.97	0.94

Task Type	Task Description	ALL Motorcoach Data OR	V1 Motorcoach Data OR	ALL Truck Data OR	V1 Truck Data OR
Secondary	Smoking-related: reaching, lighting, extinguishing	n/a	n/a	**0.60***	**0.63***
Secondary	Personal grooming	-	-	**4.48***	**5.05***
Secondary	Biting nails/cuticles	-	-	**0.45***	**0.43***
Secondary	Removing/adjusting clothing	**2.84***	-	n/a	n/a
Secondary	Removing/adjusting jewelry	-	-	1.68	2.06
Secondary	Removing/inserting/adjusting contact lenses or glasses	1.46	1.55	**3.63***	**4.00***
Secondary	Other personal hygiene	**3.47***	**5.96***	**0.67***	**0.73***
Secondary	Other non-specific internal eye glance	1.27	1.51	n/a	n/a
Secondary	Other	**4.06***	**6.97***	n/a	n/a
Driving-related	Checking speed	0.51	0.38	**0.32***	**0.34***
Driving-related	Using turn signal(s)	**4.37***	**5.63***	n/a	n/a

*Asterisk indicates a significant OR. These ratios are also shown in bold.

5.6 STUDY LIMITATIONS AND NEW OPPORTUNITIES

As in any research study, the current effort had some limitations that must be acknowledged and considered. Foremost, this study may be the most extensive research study on motorcoach operations. With that noted, the current study involved only 2 fleets, 43 instrumented buses, and 65 drivers. Though this may be a good start with respect to understanding some of the issues that motorcoach drivers encounter, additional research is needed. Perhaps this study may be considered a first step, with its results providing the impetus for more extensive studies involving more fleets, buses, and drivers.

Despite this primary limitation, the resulting data set is rich and could be mined to answer other research questions. Data mining could be conducted alone with the motorcoach data set or in combination with various truck data sets. In general, much of the cost associated with a large-scale naturalistic study is data collection. However, now that these data have been collected, a unique opportunity exists to conduct a host of follow-on analyses in a cost-effective manner.

Furthermore, as noted earlier in this report, the current analysis utilized only the first year of data collection from the two study fleets. An additional year of data was collected from one of these fleets. Collectively, this initial motorcoach study resulted in approximately 600,000 miles of continuously collected data, of which two-thirds has been analyzed initially in this report.

Stakeholders, including FMCSA, may consider additional research questions that might be answered with this existing data set or that require a more extensive data collection effort. Larger efforts, perhaps similar in scope to other large-scale truck studies, would provide additional data for FMCSA and industry stakeholders to analyze for a better understanding of the safety issues faced by motorcoach drivers.

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APPENDIX A: DATA CODING VARIABLES

The table below contains data coding variables from the data coding dictionary used in the current study. An asterisk denotes that the variable also is coded for baseline epochs. The complete dictionary and individual options for each variable can be found on the Strategic Highway Research Program (SHRP) 2 InSight Web site.(167)

Variable Name	Variable Definition
Subject Number*	All consented drivers (primary and secondary) are assigned a unique numeric ID number that can be used for cross-referencing demographic information, etc. For SHRP2, subject numbers are between 1 and 7 digits.
Conflict Begin	The point in the video when the sequence of events defining the occurrence of the incident, near-crash, or crash begins. Defined as the point at which the Precipitating Event begins (see Precipitating Event [V7]). Value is a timestamp, in milliseconds, after the start of the file. NOTE 1: For road departures with no other associated event types, the conflict begins when the vehicle first starts to move (or drift) towards the edge of the road in "going straight" scenarios OR begins the maneuver that ultimately leads to the road departure (e.g., left or right turn, entering parking space). This maneuver is also the Precipitating Event even though it did not begin until the Conflict Begin time. NOTE 2: For cases in which the origin of the Precipitating Event is not visible in the video (e.g., "Other vehicle ahead - stopped on roadway more than 2 seconds" or "Pedestrian in roadway"), the start point for the Precipitating Event would be when the event is first visible in the forward view of the subject vehicle (SV). NOTE 3: For baseline events, the Conflict Begin is defined as 1 second (1,000 timestamps) prior to the end of the baseline epoch.
Subject Reaction Start	The timestamp, milliseconds after the start of the file, when the driver is first seen to recognize and begin to react to the safety-critical incidents occurring. Defined as the first change in facial expression to one of alarm or surprise or the first movement of a body part in a way that indicates awareness and/or the start of an evasive maneuver, whichever occurs first. In most cases, this occurs before Impact or Proximity Time, but Subject Reaction Start can be coded after the time of impact in low-risk tire strikes if the driver is acting to prevent a worse collision and for certain rear-end, struck (or similar) collisions if the driver is acting to prevent a second (e.g., rear-end, striking) incident.
Conflict End	The timestamp in the video, milliseconds from the start of the file, when the sequence of events defining the occurrence of the incident, near-crash, or crash ends. Defined as the point at which final evasive maneuvers have been completed and all vehicles, objects, pedestrians, animals, etc., involved have either stopped or returned to normal patterns of road use, whichever occurs first.

Variable Name	Variable Definition
Pre-Incident Maneuver*	This represents the last type of action or driving maneuver that the subject vehicle driver engaged in or was engaged in just prior to or at the time of the Precipitating Event, beginning anywhere up to 5 seconds before the Precipitating Event (V7). This variable is independent of the driver's engagement in secondary tasks and the Precipitating Event, but should be determined after the precipitating event is defined. It is a vehicle kinematic measure—based on what the vehicle does (movement and position of the vehicle), not on what the driver is doing inside the vehicle. For baselines, this is the action or driving maneuver that the subject is engaged in immediately before (or up to 5 seconds before) the baseline anchor point (Conflict Begin, V2), which occurs 1 second before the end of the baseline event. NOTE: For road departures, Pre-Incident Maneuver is coded somewhat differently. In these cases, Pre-Incident Maneuver is instead coded as that maneuver that ultimately led to the road departure, even though that maneuver begins at Conflict Begin instead of being in progress before it. This allows the Precipitating Event to be coded as "road departure," while still providing the context of the maneuver.
Maneuver Judgment*	Judgment of the safety and legality of the Pre-Incident Maneuver (V6). This is a vehicle kinematic measure based on what the vehicle does independent of the driver's engagement in secondary tasks and the Precipitating Event (V8) (for example, driving while texting on a cell phone may not be safe or legal, but it is not a consideration in this variable). Although the determination of whether the maneuver is safe or unsafe is situation-dependent, the position of the vehicle itself is the main determinant of this factor. A maneuver may or may not be safe, depending on the vehicle position.
Precipitating Event	The state of environment or action that began the event sequence under analysis. What environmental state or what action by the subject vehicle, another vehicle, person, animal, or non-fixed object was critical to this vehicle becoming involved in the crash or near-crash? This is a vehicle kinematic measure (based on what the vehicle does—an action—not a driver behavior). It does not include factors such as driver distraction, fatigue, or disciplining a child, for example. This is the critical event that made the crash or near-crash possible. It may help to use the "but for" test; "but for this action, would the crash or near-crash have occurred?" This is independent of fault. For example, if Vehicle A is speeding when Vehicle B crosses Vehicle A's path causing a crash, the Precipitating Event would be Vehicle B crossing Vehicle A's path. If two possible Precipitating Events occur simultaneously, choose the event that imparted the greatest effect on the crash or near-crash. If more than one sequential event contributed to the crash or near-crash, determination of which is the Precipitating Event depends upon whether the driver had enough time or vehicular control to avoid the latter event. If the driver avoids one event and immediately encounters another potentially harmful event (with no time or ability to avoid the latter), then the Precipitating Event is the first obstacle or event that was successfully avoided (this is where the critical envelope begins, and is the reference point for the other variables). If the driver had ample time or vehicular control to avoid the latter event, then that latter event would be coded as the Precipitating Event (the critical envelope would begin here, and all other variables would be coded based on this event). Note that a parking lot is considered a roadway; thus, a barrier or light pole in the parking lot would be considered an object in the roadway.
Vehicle 1 (Subject), 2, 3 Configuration	A numerical designation of the role and configuration of the vehicle or other non-motorists or objects at the time of their first involvement in the sequence of events. Configurations are depicted in Figure 1 at the beginning of this dictionary and in the Accident Types chart in the General Estimates System (GES) (2014). Vehicle 1 is the subject vehicle, Vehicle 2 is the first other vehicle involved in the study, and Vehicle 3 is the last vehicle to become involved. If more than three vehicles are involved, code the three vehicles at greatest risk.

Variable Name	Variable Definition
Event Nature 1, 2	Identifies the other object(s) of conflict (e.g., lead vehicle, following vehicle) for the crash, near-crash, or other safety-related incident that occurred. If multiple Event Natures apply, list them in sequential order by time. If more than two apply, select the two most severe (most harmful or potentially most harmful). Determination of the nature of the event and the envelope surrounding it will lead to the determination of other variables such as Pre-Incident Maneuver (V5) and Precipitating Event (V7). (Example 1: Subject vehicle that rear-ends a lead vehicle may then be rear-ended by a following vehicle. 1 = Conflict with lead vehicle; 2 = Conflict with following vehicle. Example 2: Subject vehicle avoids rear-ending a lead vehicle [near crash] by steering off the road into a ditch [a crash]. 1 = Conflict with lead vehicle; 2 = Single-vehicle conflict. Figures 1 and 2 in the Research Dictionary for Video Reduction Data should be referenced when coding this variable.)
Incident Type 1, 2	Identifies the type of conflict(s) that the subject vehicle has with other objects of conflict for the most severe type of crash, near-crash, or safety-related incident that occurred. If multiple incident types apply, list them in sequential order by time, correlating with the Event Natures listed in Variables 11 and 18. If more than two apply, select the two most severe (most harmful or potentially most harmful). For categories not involving pedestrians, pedal cyclists, or animals, the orientation of the vehicle(s) also is indicated. However, unless the subject vehicle is specified, "vehicle" may refer to any vehicle involved in the event. (Example 1: A subject vehicle that rear-ends a lead vehicle may then be rear-ended by a following vehicle. 1 = Rear-end, striking; 2 = Rear-end, struck. Example 2: Subject vehicle avoids rear-ending a lead vehicle [near-crash] by steering off the road into a ditch [a crash]. 1 = Rear-end, striking [the near crash]; 2 = Run-off-road [the crash]. Figures 1 and 2 in the Research Dictionary for Video Reduction Data should be referenced when coding this variable.)
Event Severity 1, 2	General term describing the outcome of the event/incident type(s) listed. Denotes the outcome of each event/incident type as a crash, near-crash, crash-relevant, non-conflict, or non-subject conflict. For baselines, only one variable is listed, and it is coded "Baseline."
Crash Severity 1, 2	A ranking of crash severity for the referenced event/incident type(s) based on the magnitude of vehicle dynamics, the presumed amount of property damage, knowledge of human injuries (often unknown in this data set), and the level of risk posed to the drivers and other road users. This variable is coded only for events that include a crash.
Impact or Proximity Time 1, 2	The timestamp, in milliseconds after the start of the file, when the subject vehicle and other object of conflict first make impact for the portion of the event (1 or 2) in question. In the case of a near-crash, this is the timestamp when the subject vehicle and other object of conflict are at their closest distance to each other. If only one event type occurs, Impact or Proximity Time 2 is left blank. Impact or Proximity Times are always after Conflict Begin, but prior to Conflict End. When Event Severity = Unintentional Lane Deviation, this value is the timestamp of the most severe point in the lane deviation.
V1 Evasive Maneuver 1, 2	The subject driver's reaction or avoidance maneuvers (if any) in response to the event/incident(s) coded in Variables 12–15 and 18–21. This is independent of maneuvers associated with or caused by the resulting crash or near-crash. This is a vehicle kinematic measure based on what the vehicle does.
V1 Post-Maneuver Control 1, 2	Ability of subject vehicle driver to maintain control of the vehicle during evasive maneuver(s), if any. Consider the time between the start of the evasive maneuver and either Conflict End or start of the evasive maneuver for the second incident type (if any), whichever is first. Subject's level of vehicle control prior to the evasive maneuver or after impact should not be considered.

Variable Name	Variable Definition
Airbag Deployment	An indication of whether the driver-side airbag or any other airbag in the vehicle was deployed during the crash. If yes, the event is also classified as a "Level 1 Crash" in Crash Severity.
Vehicle Rollover	An indication of whether the subject vehicle rolled over during the crash. If yes, the event is also classified as a "Level 1 Crash" in Crash Severity.
Driver Behavior 1, 2, 3, 4*	Driver behaviors (those that either occurred within seconds prior to the Precipitating Event or those resulting from the context of the driving environment) that include what the driver did to cause or contribute to the crash or near-crash. Behaviors may be apparent at times other than the time of the Precipitating Event, such as aggressive driving at an earlier moment, which led to retaliatory behavior later. If there are more than four behaviors present, select the most critical or those that most directly impact the event as defined by event outcome or proximity in time to the event occurrence. Populate this variable in numerical order. (If there is only one behavior, name it Behavior 1; if there are two, name them Behaviors 1 and 2.) NOTE: The Driver Behavior category "Distracted" is only used for critical event analysis in cases where a secondary task (V34, V38, V42, or V46) is believed to have contributed to the event. The "Distracted" category is omitted from baseline analysis.
Driver Impairments*	Possible reasons for the observed driver behavior(s), judgment, or driving ability. More than one category may be assigned.
Front Seat Passengers*	The number of human occupants present in the front seat of the subject vehicle at the time of the event, including the driver. Zero passengers means the vehicle has no human occupants in the front seat(s). Number of passengers is observed from the cabin snapshot taken closest in time to the event, if available, and from subjective analysis of the video and driver behaviors if suitable snapshots are not available.
Rear Seat Passengers*	The number of human occupants present in the rear seat(s) of the subject vehicle at the time of the event. Zero passengers means the vehicle has no human occupants in the rear seat(s). Number of passengers is observed from the cabin snapshot taken closest in time to the event, if available, and from subjective analysis of the video and driver behaviors if suitable snapshots are not available.
Secondary Task 1, 2, 3, 4*	Observable driver engagement in any of the listed secondary tasks, beginning at any point during the 5 seconds prior to the Precipitating Event time (Conflict Begin, Variable 2) through the end of the conflict (Conflict End). For baselines, secondary tasks are coded for the last 6 seconds of the baseline epoch, which corresponds to 5 seconds prior to "Conflict Begin" through 1 second after "Conflict Begin" (to the end of the baseline). Distractions include non-driving-related glances away from the direction of vehicle movement. Does not include tasks that are critical to the driving task, such as speedometer checks, mirror/blind spot checks, activating wipers/headlights, or shifting gears. (These are instead coded in the Driving Tasks variable.) Other non-critical tasks are included, i.e., including radio adjustments, seatbelt adjustments, window adjustments, and visor and mirror adjustments. Note that there is no lower limit for task duration. If there are more than 4 secondary tasks present, select the most critical or those that most directly impact the event, as defined by event outcome or proximity in time to the event occurrence. Populate this variable in numerical order. (If there is only one distraction, name it Secondary Task 1; if there are two, name them Secondary Tasks 1 and 2. Enter "No Additional Secondary Tasks" for remaining Secondary Task variables.)

Variable Name	Variable Definition
Secondary Task 1, 2, 3, 4 Start Time*	The time at which the driver began to engage in the secondary task. This is a specific integer value for the video timestamp in milliseconds from the start of the file. Only secondary tasks that occur during or overlap the period of time starting 5 seconds prior to the Precipitating Event through Conflict End are included. If the secondary task began more than 5 seconds before the Precipitating Event, then enter the Conflict Begin (Variable 2) timestamp minus 5 seconds (5,000 timestamps).
Secondary Task 1,2,3,4 End Time*	The time at which the driver disengaged from the secondary task or the driver's attention returned to the driving task or another activity. This is a specific integer value for the video timestamp in milliseconds from the start of the file. Only distractions that occur during or overlap the period of time starting 5 seconds prior to the Precipitating Event through Conflict End are included. If the secondary task continued after the Conflict End, then enter the Conflict End (Variable 4) timestamp.
Secondary Task 1,2,3,4 Outcome	Determination of whether the secondary task contributed to the event sequence and severity (not whether the factor actually caused the event, but contributed to it).
Driving Tasks*	An indication of whether the subject-vehicle driver engaged in any driving-related tasks, beginning at any point during the 5 seconds prior to the Precipitating Event time (Conflict Begin, Variable 2) through the end of the conflict (Conflict End). For baselines, secondary tasks are coded for the last 6 seconds of the baseline epoch, which corresponds to 5 seconds prior to "Conflict Begin" through one second after "Conflict Begin" (to the end of the baseline). Multiple options can be selected.
Hands on the Wheel*	A description of how many and/or which hands the driver had on the steering wheel at the start of the Precipitating Event (some part of the hand or arm must be touching the wheel).
Driver Seatbelt Use*	Driver's use of seatbelt at the time of the start of the Precipitating Event. If video is available, information from the times surrounding the time of the precipitating event may clarify whether seatbelt is in use. If driver is in the process of putting a seatbelt on at the time of the Precipitating Event, this is considered NOT wearing a seatbelt.
Vehicle Contributing Factors	Factors related to the mechanical functioning or flaws in subject vehicle, which may have contributed to the Precipitating Event or to the ability of the subject driver to respond effectively to the Precipitating Event. Only include if factor can be seen as clearly contributing to the severity or presence of an event or is known to have been reported by the driver.
Infrastructure Contributing Factors	Judgment providing a possible environmental reason or contributing factor to the occurrence and severity of the event, wherein some aspect of the roadway design impacted the driver's ability to safely navigate the roadway, recognize potential safety risks, or respond effectively to the Precipitating Event. These categories are not in order of importance or level of effect.
Visual Obstructions	Visual factors relating to sight distance or blind spots in the roadway infrastructure, which may have contributed to the occurrence and severity of the event or impacted the ability of the subject to recognize potential safety risks or respond effectively to the Precipitating Event. Visual obstructions must be clearly present from the video or known to have been reported by the driver.
Lighting*	Lighting condition at the time of the start of the Precipitating Event. If inside a tunnel or parking facility, code the conditions inside the facility, regardless of the lighting conditions outside.
Weather*	Weather condition at the time of the start of the Precipitating Event. If inside a tunnel or parking facility, code the conditions inside the facility, regardless of the weather conditions outside.
Surface Type*	The type of road surface applicable to the subject vehicle at the time of the Precipitating Event. Includes pavement, gravel, etc.

Variable Name	Variable Definition
Surface Condition*	The type of roadway surface condition that would affect the vehicle's coefficient of friction at the start of the Precipitating Event. Includes weather-related surface conditions as well as non-paved surface descriptions. If inside a tunnel or parking facility, code the conditions inside the facility, regardless of the surface conditions outside.
Roadway Alignment*	Description of the roadway curvature in the subject vehicle's direction of travel, which best suits the condition at the time of the start of the Precipitating Event.
Roadway Grade*	Description of the roadway profile (e.g., uphill, downhill) in the subject vehicle's direction of travel, which best suits the condition at the time of the start of the Precipitating Event.
Traffic Flow*	Roadway design, including the presence or lack of a median, present at the start of the Precipitating Event. If the event occurs at an intersection, the traffic flow conditions just prior to the intersection are recorded.
Contiguous Travel Lanes*	The total number of contiguous travel lanes at the time of the Precipitating Event. Includes all lanes that the subject vehicle could easily maneuver into, including any turn lanes, acceleration/deceleration lanes, oncoming lanes, etc., not taking into account any occupants of these lanes. High-occupancy vehicle (HOV) lanes are included in this count, as are lanes of a drive-through station if the subject is in a drive-through lane. All lanes that are separated only by pavement and paint should be counted. For divided trafficways , this is the number of lanes in the subject vehicle's direction of travel. For undivided trafficways, this is the number of lanes in all directions (total). If the event occurs at an intersection, the traffic lanes just prior to the intersection should be recorded. Number of lanes does not include those rendered unusable by restriction of the right-of-way (e.g., closed due to construction, being used for parking).
Through Travel Lanes*	The number of travel through-lanes present in the subject vehicle's direction of travel at the time of the Precipitating Event. This will be a subset of the Contiguous Travel Lanes, and includes only through-lanes in the subject's direction of travel; does NOT include non through-lanes, just as dedicated turn lanes or dedicated acceleration/ deceleration lanes. This number will never be greater than the number of contiguous lanes. HOV lanes are included in this count unless they are also a dedicated deceleration/exit lane. Lanes of a drive-through station are also included if the subject is in a drive-through lane. If the event occurs at an intersection, the traffic lanes just prior to the intersection should be recorded (not including dedicated turn lanes). If the event occurs in an interchange area, only through lanes are included; deceleration and acceleration lanes are NOT included. Number of lanes does not include those rendered unusable by restriction of the right-of-way (e.g., closed due to construction, being used for parking).
V1 Lane Occupied*	A number indicating which lane the subject vehicle is in at the time of the Precipitating Event. Lanes are numbered by starting with the left-most through-lane closest to the median or double yellow line (direction of travel only) and starting with "1," counting out towards the right shoulder of the road, and stopping with the right-most through-lane. Turn lanes and acceleration/deceleration lanes are noted as such and are not included in the lane numbering. HOV lanes are included in this count unless they are also a dedicated deceleration/exit lane. Lanes of a drive-through station are also included if the subject is in a drive-through lane. This number will never be greater than the number of through-lanes.

Variable Name	Variable Definition
Traffic Density*	The level of traffic density at the time of the start of the Precipitating Event. Based entirely on number of vehicles present in the subject's travel lane and other lanes in the subject's direction of travel, and the ability of the subject vehicle driver to maneuver between lanes and select the driving speed. In variable speed zones, consider a reduced speed limit to be an indicator of traffic density (e.g., a variable speed limit of 30 mi/h on an interstate should be interpreted as a 50 percent reduction in travel speeds). Note that this variable is "Not Applicable" in parking lots (except for parking lot entrance/ exit areas that are still influenced by through-traffic) and other non-road situations.
Parking Lot Demand*	A measure of the demand placed on a driver traveling through a parking lot based on a subjective combination of the estimated percent of parking spaces occupied and the level of activity present from other motorists and non-motorists (e.g., into/out of parking spaces, up and down aisles, and across aisles) at the time of the Precipitating Event and in the vicinity of the subject vehicle. Note that this variable is "Not Applicable" outside of parking lot situations. Parking lot entrance/exit areas that are influenced by through-traffic should be coded using the Traffic Density variable.
Traffic Control*	Type of traffic control applicable to the subject vehicle's direction of travel at the time of the start of the Precipitating Event. Applicability of categories is determined by the proximity in space of the subject vehicle to the traffic control. Generally defined by the vehicle in question being no further than three vehicle-lengths away from the specified traffic control or close enough to be directly impacted by the traffic control (distance can vary with the situation). If more than one of the categories applies, code the one that is most relevant to the event.
Relation to Junction*	The spatial (rather than causal) relation of the subject vehicle to a junction at the time of the start of the Precipitating Event. A junction is defined as a point in space where two or more roads or trafficways with different travel speeds or direction of travel meet. If the incident occurs off of the roadway, the relation to junction is determined by the point of departure. Note that this is different than GES in that this database records "Relation to Junction" at the beginning of the Precipitating Event whereas the GES manual will code this variable at the beginning of the First Harmful Event.
Intersection Influence*	A judgment call as to whether the subject vehicle's safe movement, travel path, and travel speed, are under the influence of an intersection at the time of the event (at any time between Conflict Begin through Conflict End). This can include the subject or other involved vehicle(s) accelerating or decelerating in relation to an intersection or intersecting trafficway, accelerating or decelerating prior to a turn onto a new roadway or into a parking lot or driveway, waiting in a queue of traffic, moving between through lanes and turn lanes or through lanes and acceleration/deceleration lanes, yielding to oncoming or cross traffic, etc. Note that a "Yes" option can be coded here even if Relation to Junction is Non-junction if the vehicle(s) are too far from the intersection to code Relation to Junction categories, but are still being influenced in a manner described here by an intersection (e.g., a longer queue of traffic at a signal, or a long process of deceleration prior to a turn).
Roadway Feature*	Description of any special roadway feature that may be influencing the vehicle's direction of travel at time of the Precipitating Event. Includes features that are not captured by other variables, such as traffic circles, toll booths, bridges, tunnels, etc.

Variable Name	Variable Definition
Locality*	Best description of the surroundings that influence or may influence the flow of traffic at the time of the start of the precipitating event. If there are ANY commercial buildings, indicate as business/industrial or urban area as appropriate (these categories take precedence over others except for church, school, and playground). Indicate school, church, or playground if the driver passes one of these areas (or is imminently approaching one) at the same time as the beginning of the Precipitating Event (these categories take precedence over any other categories except urban and divided highway).
Construction Zone*	An indication of whether the Precipitating Event occurs in or in relation to a construction zone.
"Number of Other Motorists/Non-Motorists"	This is the number of motorists or non-motorists (any vehicle involving a human occupant, including pedestrians), other than the subject vehicle, involved in the crash or near-crash; or that restrict the subject vehicle's ability to maneuver at the time of the start of the Precipitating Event (Vehicle 1 is subject vehicle). This number includes not only those vehicles directly involved in the crash (those with physical contact), but also other vehicles that may have been involved in precipitating the event or affected by the evasive maneuvers of the event. It therefore, may include vehicles that were both part of the "crash" and part of any "near crash(es)" that may have occurred at the same time. Parked vehicles with occupants would be included in this category, whereas parked vehicles with no occupants would be included in the category "Number of Objects/Animals." Note: animals and objects are not included in this category.
"Number of Objects/Animals"	Number of objects or animals involved in the crash or near-crash, or that restrict the subject vehicle's ability to maneuver at the time of the start of the Precipitating Event. Includes curbs, medians, barriers, as well as other fixed and non-fixed objects. Also includes animals, both dead and alive. Note: motorists and non-motorists are not included in this category.
Fault	Indicates which driver or non-motorist (if any) committed an error that led to the event. If another motorist or non-motorist (other than the subject) committed the error leading to the event, label that other vehicle or non-motorist as Driver 2 or 3, in accordance with the Vehicle Configurations (V8, V9, and V10). Only code a fault if there is observable evidence. Note: Objects and animals cannot be assigned fault. Such events are always coded as either Driver Fault or No Fault.
"Motorist/Non-Motorist 2, 3 Type"	Specification of other vehicle, pedestrian, cyclist, or other person or person-operated vehicle that is involved in the event or that restricts the subject vehicle's ability to maneuver at the time of the start of the Precipitating Event.
Object/Animal 2, 3 Type	Specification of other animal or object that is involved in the event or that restricts the subject vehicle's ability to maneuver at the time of the start of the Precipitating Event.
Motorist/Non-Motorist/Object/Animal 2, 3 Location	Position of other vehicle, pedestrian, animal, or object that is involved in the event or that restricts the subject vehicle's ability to maneuver at the time of the start of the Precipitating Event. (Vehicle 1 is subject vehicle and is coded in earlier questions.) Exception: medians, barriers, and curbs are not considered to be objects in this category. Refer to Figure 5 in the beginning of this dictionary for location definitions.
Motorist/Non-Motorist 2, 3 Pre-Incident Maneuver	Ongoing actions of the other motorist(s) or non-motorist(s) immediately prior to the start of the Precipitating Event. Only vehicles in clear view of a subject-vehicle camera are included. If the other vehicle(s) initiated the Precipitating Event (e.g., by encroaching into the subject vehicle's lane during lane change), the Vehicle 2 maneuver would be the maneuver that initiated that action (e.g., changing lanes). Note: If coding for "Pedestrian," use one of the four options for pedestrians; if coding for "Animal or Object," use the option "Not Applicable".

Variable Name	Variable Definition
"Motorist/Non-Motorist 2, 3 Evasive Maneuver"	The other motorist(s) or non-motorist(s)' reaction or avoidance maneuvers (if any) in response to the Precipitating Event. Only reactions that are clearly evident in the video are included. If Vehicle 2/3 initiated the Precipitating Event, this category would be the immediate reaction to the result(s) of the Precipitating Event. This is a vehicle kinematic measure, based on what the vehicle does. Note: If coding for "Pedestrian," use one of the two options for pedestrians; if coding for "Animal or Object," use the option ""Not Applicable"".
Motorist/Non-Motorist 2, 3 Behavior 1, 2, 3	Driver behaviors (those that either occurred within seconds prior to the Precipitating Event or those resulting from the context of the driving environment), which include what Motorist or Non-Motorist 2 or 3 did to cause or contribute to the crash or near-crash. Behaviors may be apparent at times other than the time of the Precipitating Event, such as aggressive driving at an earlier moment, which led to retaliatory behavior later. If there are more than three behaviors present, select the most critical or those that most directly impact the event as defined by event outcome or proximity in time to the event occurrence. Populate this variable in numerical order. (If there is only one behavior, name it Behavior 1; if there are two, name them Behaviors 1 and 2.) NOTE: Several of the Driver Behavior categories coded for the subject vehicle are not included in this category due to a lack of context in the video to make such determinations. Categories not included here are ""Distracted,"" ""Drowsy, sleepy, asleep, fatigued,"" ""Did not see other vehicle,"" and ""Use of cruise control.""
Final Narrative/ Additional Notes	For critical event reduction. This is a final narrative or a short, open-ended description of the event. This variable provides context and descriptions in sufficient detail so as to fill any gaps in reconstructing the event if video were not available. The written narrative should always be clear about which vehicle is the subject vehicle (SV, Vehicle 1, V1, or ""subject vehicle""), and which are the other vehicle(s) (privately owned vehicle [POV] or Vehicle 2/3).

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