Analysis of Naturalistic Driving Data to Assess Distraction and Drowsiness in Drivers of Commercial Motor Vehicles

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

August 2021

FOREWORD

The mission of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce crashes, injuries, and fatalities involving large trucks and motorcoaches. Research on existing datasets supports this mission. The purpose of this study was to analyze naturalistic driving data collected from motorcoach and heavy truck drivers to investigate driver distraction and drowsiness. This study includes more than 3.8 million miles of naturalistic data from 225 vehicles and 245 drivers. The resulting report includes a literature review on the motorcoach and trucking 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 other commercial motor vehicle (CMV) industry stakeholders. There were no previous printings of this document in its entirety.

NOTICE

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16. Abstract

The objective of this study was to reduce and analyze data from previously collected heavy-vehicle naturalistic data to better understand crashes involving heavy-vehicle drivers and the efficiency of Commercial Motor Vehicle (CMV) operations. Two key elements of this study were to investigate driver distraction and the role it plays in CMV operations and to answer critical questions related to hours of service (HOS) regulations and fatigue.

More than 3.8 million miles of naturalistic data were collected from seven fleets and 10 locations under the original Onboard Monitoring System Field Operational Test (OBMS FOT) study. A total of 43 motorcoaches, 73 motorcoach drivers, 182 trucks and 172 truck drivers participated in this study. Key findings from the study showed an overall decrease in cell phone used compared to previous research. Hands-free cell phone use was found to be protective as it likely helps drivers alleviate boredom, while hand-held cell phone use was found to be risky as it takes the driver's attention away from driving tasks. Additionally, the 8th driving hour showed the highest rate of safety critical event occurrence. This study provides needed insight into motorcoach and truck operations.

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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
CMV	commercial motor vehicle
DAS	data acquisition system
FMCSA	Federal Motor Carrier Safety Administration
GLMM	generalized linear mixed-effect model
HOS	hours of service
IMU	inertial measurement unit
LCL	lower confidence limit
LOS	level of service
LTCCS	Large Truck Crash Causation Study
NTSC	National Television System Committee (video)
OBMS FOT	Onboard Monitoring System Field Operational Test
OR	odds ratio
ORD	observer rating of drowsiness
PAR	population attributable risk
SCE	safety critical event
TTC	time-to-collision
UCL	upper confidence limit
USDOT	U.S. Department of Transportation
V1	Vehicle 1
VMT	vehicle miles traveled
VORAD	vehicle onboard radar
VTTI	Virginia Tech Transportation Institute

EXECUTIVE SUMMARY

BACKGROUND

The objective of this study was to reduce and analyze previously collected naturalistic data about heavy vehicles (trucks and motorcoaches) to better understand crashes involving heavy vehicle drivers. One element involved investigating driver distraction and the role it plays in commercial motor vehicle operations. Driver distraction can be defined as a diversion of attention away from activities critical for safe driving and toward a competing activity.(1) Analyses of crash databases have indicated that driver distraction is a primary contributing factor in approximately 25–30 percent of crashes.(2) This estimate is based on police accident reports completed at the crash scene. That is, the investigating officer could report distraction or inattention based on observation or driver admission. Because these reports may record inaccurate or incomplete information, it is commonly believed that the actual percentage of distraction-related crashes may be substantially higher.(3) This study also examined SCEs and fatigued driving as a function of driving hour to determine how driver behavior may change across a shift.

PROCESS

More than 3.8 million miles of data were collected from seven fleets and 10 locations under the original Onboard Monitoring System Field Operational Test (OBMS FOT) study.(4) Table ES1 below shows a breakdown of each fleet by operation type, the number of vehicles and drivers, and the duration of data collection.

Table ES1. Participating fleets by location, operation type, vehicle, drivers, and participation time.

Fleet	Location	Operation	Vehicles	Drivers	Participation
A	Baton Rouge, LA	Grocery—reefer	65	58	1 year
B	Escanaba, MI	Dry goods—long-haul and regional, both company and owner-operator drivers	8	9	3 months
C	Selma, NC	Fuel-tanker	35	47	3 weeks
D	Tampa and Taft, FL	Fuel-tanker	42	23	6 months
E	Los Angeles, CA	Motorcoach	22	38	1 year
F	San Antonio, TX	Motorcoach	21	35	2 years
G	Coraopolis, PA	Oil field	14	17	1 month (Coraopolis), 3 weeks (Williamsport)
H	Pembroke, NH	Grocery—reefer	18	18	1 year

The data acquisition system used in the study included five video cameras. The multiplexed image in Figure ES1 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 ES1. Photo. Five camera images multiplexed into a single image.

These study data were processed with a set of sensor trigger values to identify SCEs. Video and data were reviewed manually to ensure SCE validity and group them into one of five categories:

1. Crash.
2. Near crash.
3. Crash-relevant conflict.
4. Unintentional lane deviation.

This process resulted in 4,102 valid events and 14,198 baseline epochs (periods of normative driving). Analyses were conducted to investigate eight research questions, the salient results of which are summarized in Table ES2 below.

STUDY FINDINGS AND CONCLUSIONS

Table ES2. Research question summary table.

Research Question	Study Finding
Research Question 1: What are the types, and what is the frequency of tasks in which drivers engage prior to involvement in SCEs? What are the ORs, and what is the PAR percentage for each task type?	Motorcoach: Dancing showed a reduced risk of being involved in an SCE. In contrast, the following showed an increased risk of being involved in an SCE: reaching for object; adjusting instrumental panel adjusting/monitoring other device integral to vehicle; external distraction; removing/adjusting clothing; and personal hygiene. Truck: Dancing and talking/singing showed a reduced risk of being involved in an SCE. In contrast, the following showed an increased risk of being involved in an SCE: reaching for object; interacting with electronic dispatching device; other electronic device; adjusting/monitoring other device integral to vehicle; external distraction; reaching for food- or drink-related items; and removing/adjusting clothing.
Research Question 2: What is the prevalence, and what are the characteristics of hands-free and hand-held cell phone use? What are the odds, and what is the PAR percentage of being involved in an SCE while talking on a hand-held or hands-free cell phone?	Motorcoach: Overall, cell phone use was lower for motorcoach drivers. Talking/listening on a hand-held phone showed no change in risk while talking/listening on a hands-free device showed a reduced risk of being involved in an SCE. Truck: Talking/listening on a hand-held phone showed no change in risk while talking/listening on a hands-free device showed a reduced risk of being involved in an SCE. Browsing and texting showed an increased risk of being involved in an SCE.
Research Question 3: What are the environmental conditions associated with driver choice of engagement in tasks? What are the odds, and what is the PAR percentage of being in an SCE while engaging in tasks while encountering these conditions?	Motorcoach: The majority of the SCEs occurred in daylight, with no adverse conditions, on non-junction roadways, on divided roadways, and in moderate traffic areas such as airports and business/industrial areas. Truck: The majority of the SCEs occurred in daylight, with no adverse conditions, on non-junction roadways, on divided roadways, and in low traffic such as the interstate.

Research Question	Study Finding
Research Question 4: What are the ORs of eyes off forward roadway? Does eyes off forward roadway significantly affect safety and/or driving performance?	Results for both motorcoach and truck drivers showed that the longer the driver's eyes were off the forward roadway, the greater the risk of being involved in an SCE, with a significant increase once the driver's eyes were off the road for more than 2 seconds. Truck SCEs with a secondary task of browsing had one of the highest mean eyes off roadway time of 4 seconds while texting had the highest mean eyes off roadway time of 5 seconds.
Research Question 5: What is the prevalence of driver drowsiness? What are the odds, and what is the PAR percentage of being in an SCE while drowsy?	Drowsiness was observed more frequently in truck data than in motorcoach data and more frequently in SCEs than in baseline epochs.
Research Question 6: How does driver drowsiness vary when drivers are involved in a secondary task?	Few observations of drowsiness coupled with secondary tasks occurred for motorcoach drivers. Both conducting a hands-free phone call using a headset or earpiece or talking/listening on a hands-free call were associated with lower drowsiness for truck drivers. Other tasks associated with alert driving involved drivers moving their bodies in the vehicle for tasks such as adjusting features of the instrument panel and observing external distractions.
Research Question 7: What is the impact of time on task on the risk of SCEs as a function of driving hour? Is there a significant increase in risk associated with increasing hour of driving?	Overall, it can be inferred that there is a significant increase in risk associated with increasing hour of driving. SCE risk rate can increase to two to three times higher than in the 1st hour, hitting peak value at the 8th hour. The pairwise comparison results show that the first 10 driving hours can be further grouped into three parts: low SCE rate (the 1st hour), moderate SCE rate (the 2nd hour), and high SCE rate (the 3rd through the 10th hour).
Research Question 8: What is the prevalence of driver drowsiness by hour of driving? Is there a significant increase in driver drowsiness by hour of driving for both SCEs and normal driving segments?	Results for SCEs show multiple peaks, including the 2nd, 3rd, and 9th hour. There was no pattern of increasing drowsiness after the 8th or 9th hour. The timing and duration of the drivers' breaks could impact driving behavior, and the time of the day of the trip could also affect drivers' drowsiness.

STUDY LIMITATIONS AND NEW OPPORTUNITIES

As in any research study, and especially with naturalistic driving data, there were some limitations to this study. One noticeable limitation when considering driver drowsiness research is that none of the fleets were dedicated over-the-road operations; therefore, not many drivers drove extended hours. While the Onboard Monitoring System Field Operational Test (OBMS FOT) aimed to collect data from a representative sample of fleets and drivers for 1 year each, 3 of the 10 fleets collected data for less than 3 months and one fleet collected data for less than 6 months.[5] This led to the majority of the data collection occurring from mostly local and regional fleets.

Despite this limitation, more than 3.8 million miles of data were collected that provide valuable information. One of the key findings and takeaways from this study is the reduction of cell phone use among both motorcoach and truck drivers.

Stakeholders and the Federal Motor Carrier Safety Administration (FMCSA) may consider additional research questions that might be answered with this existing dataset or require a more extensive data collection effort. Topics may include research into fatigue measures and the correlation of fatigue and events during a driver's shift. Larger efforts, perhaps similar in scope to other large-scale truck studies, would provide additional data to analyze to gain a better understanding of the safety issues faced by motorcoach drivers.

1. INTRODUCTION

1.1 PROJECT OVERVIEW

The objective of this study was to reduce and analyze data from previously collected heavy-vehicle naturalistic data to better understand crashes involving heavy-vehicle drivers. Naturalistic data collection and reduction has become the gold-standard method for investigating driver distraction as it allows researchers to see what a driver is doing just prior to a safety critical event (SCE) in real-world settings. For a given SCE (e.g., a crash, near-crash, crash-relevant conflict, or unintentional lane deviation), various contributing factors—including environmental, vehicle, and driver—may play a role. Previous studies have found that driver factors are by far the most prominent contributing factor in crashes.(6,7,8)

The Onboard Monitoring System Field Operational Test (OBMS FOT) was funded by the Federal Motor Carrier Safety Administration (FMCSA) to evaluate the effects of driver coaching while using an OBMS.(9) During that study, Virginia Tech Transportation Institute's (VTTI) NextGen data acquisition systems (DASs) were installed to collect continuous, naturalistic data from 44 motorcoach vehicles and 151 heavy trucks. Previously, two-thirds of the motorcoach data had been reduced and analyzed.(10) One-third of the motorcoach data and all truck data remained unanalyzed. The current study involved reducing the remaining data collected during the OBMS FOT, and combining that with the previously reduced OBMS FOT data, to answer the eight high-priority research questions noted in the FMCSA's Request for Proposal. The data reduction methodology used in the recently completed Distraction and Drowsiness in Motorcoach Drivers study(11) and pioneered in previous VTTI naturalistic driving studies(12,13,14) was used to complete the reduction for the remaining data.

This study investigated driver distraction and the role it plays in commercial motor vehicle (CMV) operations. Driver distraction is "the diversion of attention away from activities critical for safe driving and toward a competing activity".(15) Analyses of crash databases have indicated that driver distraction is a primary contributing factor in approximately 25–30 percent of crashes.(16) This estimate is based on police accident reports completed at the crash scene (i.e., the investigating police officer indicated "distraction" or "inattention" if the driver admitted to being distracted or inattentive and/or if distraction or inattentiveness was readily apparent based on eyewitness observation). Because this method has the potential to record inaccurate or incomplete information, it is commonly believed that the actual percentage of distraction-related crashes may be substantially higher.(17) This study also examined safety-critical events (SCEs) and fatigued driving as a function of driving hour to determine how driver behavior may change across a shift.

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2. REVIEW OF THE LITERATURE

2.1 DRIVER ERROR

Various factors can contribute to a vehicle crash or be identified as the critical reason for a crash. In the Large Truck Crash Causation Study (LTCCS), researchers found that of the 963 investigated crashes involving large trucks that crashed with other vehicles, 55 percent of the large trucks involved were assigned the critical reason for the crash.(18) Most factors resulting in a crash fall into one of three main categories: vehicle factors (e.g., brakes and tire condition), environmental factors (e.g., weather and road conditions) or driver factors (e.g., failure to yield, inattention). However, studies have reported that the majority of crashes can be attributed to driver factors.(19,20,21) The LTCCS reported that for all large truck crashes in which the truck was assigned the critical reason for the crash, 87 percent of the crashes were due to driver error (i.e., performance, non-performance, recognition, or decision). The most common type of driver error for large trucks was "driver recognition", including the failure to see or react to another vehicle to avoid a crash. This type of driver error is largely due to inattention or distraction.(22) Performance and non-performance errors refer to actions such as staying in the lane and are often attributed to drowsiness or illness effects.(23) Motorcoach crashes reflect similar driver errors. An investigation of factors in fatal motorcoach crashes demonstrated that failing to yield and inattention comprised the highest percentage of errors.(24)

2.1.1 Driver Distraction

The type of driver distraction prior to a crash is not always known and may be reported as a general distraction. Driver distraction can be classified as visual, biomechanical, auditory, or cognitive.(25) These distractions can be related to driving, such as scanning an environment for landmarks to use in directions or adjusting the seat. They can also be unrelated to the driving task, such as reaching for food or attending to social media on cell phones. Furthermore, distractions can be internal, such as a passenger demanding attention, or external, such as something occurring outside of the vehicle catching the driver's attention. In these scenarios, the distraction takes the driver's attention away from the driving task. Engström et al. defined driver distraction as something that occurs when a "driver allocates resources to a non-safety critical activity while the resources allocated to activities critical for safe driving do not match the demands of these activities."(26) These seemingly short tasks can result in serious crashes, with tasks that are visual in nature posing the greatest risk.(27) One study using naturalistic driving data estimated that if a driver takes their eyes off the forward roadway for over 2 seconds, the risk of a crash doubles.(28) Both large truck and motorcoach drivers engage in these distractions with potentially dire consequences.

2.1.1.1 Commercial Motor Vehicle (CMV) Distraction Research

Studies have attempted to capture the prevalence and dangers of distraction for CMV drivers. Olson et al. used a naturalistic driving dataset of 4,452 SCEs and 19,888 baseline epochs to estimate prevalence and risk of SCEs while driving distracted. The study calculated odds ratios (ORs) for a range of tasks—that is, the odds of being involved in an SCE associated with a given task as compared to the absence of that task. Olson et al. found significantly higher ORs of SCE involvement when drivers were engaged in activities such as texting (23.4), writing (8.98), dialing on a cell phone (5.93), reaching or using an electronic device (6.72), personal grooming (4.48), and reaching for an object (3.09). However, smoking and talking or listening to someone on a hands-free phone resulted in a significantly lower ORs of SCE involvement (0.60 and 0.44 respectively).[29] Though previous light-vehicle simulator research found a significant increased risk of driver error with any type of cell phone use,[30] this research indicates that while some secondary tasks result in a greater chance of SCE involvement, some may offer a "protective factor." Talking or listening on a hand-held phone did not provide the same protective qualities, however, and had no impact on the odds of an SCE (1.04).

In a report for FMCSA, Hickman, Hanowski, and Bocanegra used 1 year of existing epoch data from DriveCam (now called Lytx) to assess prevalence and risk of distractions for CMV and bus operators. Event recorders installed on vehicles saved 8 seconds of video prior to and 4 seconds after criteria for when a possible SCE was met or surpassed. Using baseline data, researchers calculated ORs for different types of distractions. ORs for SCEs were found to be significant if drivers engaged in any of the following tasks: dialing a cell phone (3.51), reaching for a cell phone (3.74), and talking or listening on a hands-free phone (0.65 or 0.44, respectively).[31] These results may be lower than the findings of Olson et al. due to driver knowledge that their supervisors were aware that an event had occurred and had access to the video clips. The DriveCam recorders had a light that flashed, indicating that an event was recorded and stored. Nevertheless, these results support the conclusion that though complex secondary tasks can increase the likelihood of involvement in an SCE by more than three times (when compared to a baseline epoch), talking or listening via a hands-free phone actually decreases the likelihood of involvement in an SCE. Results here also mirrored previous results by Olson et al. that talking or listening on a hand-held phone had no impact on the ORs of an SCE (0.90 and 1.04 respectively).[32,33]

A study by researchers in Sweden conducted observations and interviews with CMV drivers to shed light on what kind of secondary tasks drivers were engaging in and why they were engaging in them. Most of the secondary tasks drivers engaged in were considered environmental-related "necessities" (33.3 percent) such as getting food, adjusting their seat, or removing a coat, followed by manipulating a mobile phone (25.6 percent), using in-truck technology (22 percent), or administration tasks (7.4 percent) such as paperwork.[34] It is important to note that the administrative tasks observed during this study were not necessary and were done by drivers out of curiosity. Drivers explained that they were engaged in these activities primarily to alleviate boredom from the monotonous driving of a familiar or easy route. Boredom is the strongest predictor of driver distraction and strongest predictor of proneness to driver error.[35] Drivers indicated that the more technologies they have in their trucks to help them perform their jobs, the more bored they became. One driver stated that he engaged in the other activities to refresh his mind from the monotony. Drivers feel that switching their focus to something else for even a short time helps to prevent drowsiness and gives them the stimulation they need to continue driving safely.

A study by Fitch and Hanowski found that when driving task demands increase, CMV drivers reduced how much time they conversed on the phone because they made their own assessment of the danger of activities before engaging in them.[36] This decision-making may explain the protective factor seen in previous studies of some activities.[37,38] Drivers also stated that they continued to do multiple tasks while driving not because of pressure from work to get things done, but from personal desires to be home. Boredom and self-inflicted pressures to return home motivates CMV drivers to become distracted while driving and increase their chances of crashing three-fold.[39]

2.1.1.2 *Motorcoach Distraction Research*

Motorcoach driver distraction has also been identified as a significant problem.[40,43,44,45] Due to the nature of their job, motorcoach drivers have inherently different distractions than CMV drivers. Beyond driving, motorcoach drivers must also adhere to predetermined timetables and perform customer service duties such as handling money and inquiries from the public. These duties can interrupt their schedule and concentration, causing stress.[41,42,43] Different types of motorcoaches have different pressures and schedules. Transit and school buses are usually on a predictable and regular schedule and together make up most fatal crashes involving motorcoaches (32.5 percent and 38 percent respectively). Intercity buses usually travel longer and have more traffic to navigate, while charter buses have a very unpredictable schedule and longer hauls. Less research has been conducted on motorcoach operator distraction than on large truck driver distraction, but a few studies have attempted to gain a better picture of motorcoach operator distraction. Griffen, Husingh, and McGwin used trained investigators to observe and record distraction behaviors of transit bus drivers over a period of 3 months. They found that there was a 39 percent prevalence of distracted driving, mainly due to interactions with passengers, but also from handling city traffic.[44]

A study by Hammond et al. examined naturalistic data collected from more than 600,000 driving miles by drivers of 43 motorcoaches to identify the tasks that bus drivers engaged in and determine how these tasks affected the risk of an SCE. Researchers found that 37 percent of SCEs and 89 percent of at-fault crashes involved non-driving related engagement in secondary tasks. Cell phone use was rare. The only tasks that significantly increased SCE risk involved the driver reaching for an object, looking outside, or using the intercom to talk to passengers.[45] These results are specific to conditions of a motorcoach driver and warrant further investigation to fully understand their effects.

2.1.2 Driver Fatigue

Researchers, transportation officials, and FMCSA have all identified driver fatigue as a serious concern for vehicle safety and deemed it to be significantly associated with fatal CMV crashes.[46,47,48] The LTCCS reported that driver fatigue was an associated factor assigned to 13% of CMV crashes.[49] Hours of service (HOS) regulations for CMV and motorcoach drivers are in effect to limit the number of hours a driver may remain behind the wheel without taking a break. Drivers have reported that they become fatigued from insufficient time spent recovering during off-duty times, work overload, not working according to their circadian rhythm, disturbed sleep patterns, and the time sensitivity associated with the nature of their jobs.[50] Drivers are aware of the serious impact that fatigue can have on their safety: 32 percent of long-haul truck drivers reported that they had made a serious error while they were fatigued; 52.1 percent reported having a near-miss traffic incident; and 18.5 percent reported being involved in a crash.[51]

2.1.2.1 *CMV Fatigue Driving Research*

Many factors related to being a CMV operator may contribute to fatigue. A survey of 502 truck drivers at truck stops revealed that longer loading and unloading times are significantly related to fatigue, as are the time and hours of undisturbed sleep.(52) Longer loading and unloading times can cause drivers stress by affecting their future planned rests and loading times. This also encourages them to continue driving when tired to make up time and money potentially lost while waiting for the load/unload. The regularity of the route driven was also significantly related to fatigue, supporting the idea that a low mental workload may be detrimental to the driver's safety performance. A study by Bunn, Slavova, and Rock found that drivers have a difficult time finding places to pull over and rest when needed. Crashes involving fatigue were more likely to be located 20 miles or more from a truck rest area than crashes not involving fatigue.(53)

Another study by Barr, Yang, Hanowski and Olson used naturalistic data to characterize fatigue episodes and their effect on driving behavior. Over the 38,000 miles of recorded driving, 2,745 fatigue events were identified. Researchers concluded that fatigue events were more likely to occur and be more severe in the early morning hours of 6:00 a.m. to 9:00 a.m. or near the beginning or end of a driving shift. Researchers used self-report questionnaire responses regarding sleep quality and quantity as well as data from actigraphs—monitoring tools worn on the wrist to measure sleep/wake patterns through movement—to rate fatigue. The study showed that there was a weak connection between the quantity and quality of sleep and actual fatigue.(54) More recent research analyzing 735,000 miles of driving found a relationship between the time that drivers slept and driving risk, concluding that more sleep time between 1:00 a.m. and 5:00 a.m. lead to a lower driving risk than less sleep during that time frame.(55) Another study of 106 drivers analyzed data from actigraphs and sleepiness and vigilance tests. The results affirmed the importance of nighttime sleep, as drivers experienced greater nighttime fatigue when they only had one nighttime period in their restart break versus more than one.(56)

Driving risk and how it changes over daily driving hours has been studied in several ways using different data sources. A study by Jovanis, Wu, and Chen used carrier-provided driving logs to compare driver schedules prior to a crash to schedules from drivers not involved in a crash. The study included drivers from truck-load and less-than-truckload operations. The less-than-truckload driver schedules showed increased crash odds for longer driving hours—especially hours 5 through 11—although the dataset had very few crashes in hours 9, 10, and 11.(57) Blanco et al. used naturalistic driving data, overlaid with detailed self-report logs of drivers' work and non-work related activities, to assess how risk of SCEs changed over driving hours. The study included 97 drivers and 735,000 miles of continuous driving data. This study found no significant differences in driving hours 8, 9, 10, and 11 in shifts with 11 driving hours, but an increased SCE risk was observed in longer work hours.(58) In both studies, there was lower risk in driving periods that followed breaks. Another study by Liu, Guo, and Hanowski investigated driver fatigue and its relationship with rest before driving and on duty driving hours. The study measured fatigued driving performance using unintentional lane deviations (ULD). Researchers found the ULD rate increased after 8 hours of driving in shifts that followed less than 7 hours of sleep, a pattern not observed in shifts following more than 7 hours of sleep.(59) These studies show that driving hours in a shift may interact with risk from fatigue for commercial drivers.

2.1.2.2 *Motorcoach Fatigue Driving Research*

Motorcoach drivers work under different conditions than truck drivers and therefore face different causes of fatigue. The most significant reasons related to their fatigue are pressures to accept trips, driving even when they are tired in order to make a good income, and starting the week tired.(60) Work-related stress can also lead to fatigue on the road.(61) Bus drivers indicate that they are stressed by the thought of potential assaults, dealing with the exchange of money, harsh weather conditions, traffic congestion, peak running times, and interactions with the public.(62,63) In addition, motorcoach drivers can have long and unpredictable hours, which can cause sleep disturbances and lead to stress and fatigue. What makes things even more difficult for motorcoach and bus drivers is that they rarely have an appropriate in-cab rest facility to use. This may hinder a driver's ability to take adequate rest.(64,65)

A naturalistic motorcoach driving study analyzed video of 1,086 SCEs to determine an observer rating of drowsiness (ORD) of low, moderate or high drowsiness for all drivers.(66) The ORD is "a subjective assessment of how drowsy a naturalistic driving participant is based on his/her physical appearance, behaviors, and mannerisms," (67,68) and is conducted on 60 seconds of video data. Interestingly, most of the data, both SCEs and baseline epoch data, involved a driver with a low drowsiness rating, meaning that they were perceived to be alert. Only about 1 percent of the data had drivers with a high drowsiness rating. SCEs involving highly drowsy drivers occurred twice as often when the driver was not engaged in a secondary activity, supporting the idea that secondary tasks may be used as a protective countermeasure to combat fatigue. However, more research still needs to be conducted on the prevalence of and reasons for fatigue in motorcoach drivers to appropriately support drivers.

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3. METHODS

The current analysis includes all data collected under the OBMS FOT.[69] This analysis is a follow up to the Motorcoach Analysis, which analyzed data from two motorcoach fleets, each of which collected data for 1 year.[70] The current study includes both motorcoach and heavy truck data.

3.1 DATA COLLECTION METHODS

3.1.1 Participants and Setting

More than 3.8 million miles of data were collected from 7 fleets and 10 locations under the original OBMS FOT study.[71] Figure 1 shows the locations of home terminals and the number of vehicles in the dataset. Table 1 shows a breakdown of each fleet by operation type, the number of vehicles and drivers, and the duration of data collection. Data were collected from June 2012 to July 2015.

Figure 1. Graphic. Location of each participating fleet and number of vehicles contributing to dataset.

Table 1. Participating fleets by location, operation type, vehicle, drivers and participation time.

Fleet	Location	Operation	Vehicles	Drivers	Participation
A	Baton Rouge, LA	Grocery—reefer	65	58	1 year
B	Escanaba, MI	Dry goods—long-haul and regional, both company and owner-operator drivers	8	9	3 months
C	Selma, NC	Fuel-tanker	35	47	3 weeks
D	Tampa and Taft, FL	Fuel-tanker	42	23	6 months
E	Los Angeles, CA	Motorcoach	22	38	1 year
F	San Antonio, TX	Motorcoach	21	35	2 years
G	Coraopolis and Williamsport, PA	Oil Field	14	17	1 month (Coraopolis), 3 weeks (Williamsport)
H	Pembroke, NH	Grocery—reefer	18	18	1 year

3.1.2 Data Acquisition System (DAS)

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 when 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—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 vehicle-related measures (e.g., GPS, light level, etc.). The digital video file contained the video data continuously recorded during the trip.

The DAS contained multiple communication ports, including ethernet, serial, universal serial bus, controller area network, and National Television System Committee (NTSC) video. It also contained onboard wireless communication capabilities through cellular, Wi-Fi, and Bluetooth bands. 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 to protect the confidentiality of research participants and overall data collection.

Video Cameras. Real-time H264 encoding digital video cameras were used to continuously record the driver and driving environment. 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, providing good visual coverage of the driving environment inside and outside the cab. By viewing the driver's face, researchers could conduct eye glance and 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 2 shows the camera views for the five cameras used in the study.

Figure 2. Photo. Five camera images multiplexed into a single image.

Vehicle Network. SAE International's J1939 standard defines the format of messages and data collected by heavy vehicles' onboard microprocessors. The exact data network protocols and standards depend upon the vehicle model, year, and manufacturer. A network box interface was developed to access the data from this network and merge it into the DAS dataset. 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. Other driver input measures that were collected with sensors included right and left turn signal use and headlight status (on/off).

Front Vehicle Onboard Radar (VORAD). A vehicle onboard radar (VORAD) unit was installed on the front bumper of each motorcoach (see Figure 3) to measure range to lead vehicles and objects. From the range measure, range rate and time-to-collision (TTC) can also be derived.

Figure 3. 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 roadway painted lines and compute parametric data regarding vehicle position in the lane and state of the lane markings. Once the initial camera offsets were entered (e.g., height and lateral 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.

Inertial Measurement Unit (IMU). The IMU contained yaw rate sensors (three axis gyro) providing a measure of steering instability (i.e., jerky steering movements) and 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.

3.2 DATA REDUCTION METHODS

3.2.1 Characterize SCEs

As in previous naturalistic truck studies, the data for this study were processed with a set of sensor trigger values to identify SCEs.(72,73,74) After manual video review and confirmation that a triggered event was a valid SCE, it was classified as a crash, near-crash, crash-relevant conflict, or unintentional lane deviation as defined below:(75)

- 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.
- Near-crash: Any circumstance that requires a rapid evasive maneuver by the subject vehicle, 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, 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 (e.g., guardrail, steep ditch, vehicle, etc.) or the hazard is never closer than one lane-width to the subject vehicle. If the hazard is closer than one lane-width away, the event should be classified as crash-relevant, near-crash, or crash as appropriate.

3.2.2 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.(76) These triggers are defined in Table 2.

Table 2. Trigger definitions used in the OBMS dataset.

Trigger Type	Definition	Description
Longitudinal Acceleration	Hard braking	Deceleration greater than or equal to ｜0.20g｜. Speed greater than or equal to 3.5 miles per hour (mi/h).
Time-to-Collision (TTC)	The amount of time (in seconds) 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 ｜6°/s｜, and an azimuth of less than or equal to ｜12°｜.
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°/s2. 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 0.1g (either left or right) while traveling greater than 45 mi/h with a lane distance off center greater than 1 meter (m).

3.2.3 Checking the Validity of the Triggered Events

A custom software program scanned the data to identify potential SCEs of interest, resulting in a dataset 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 in which sensor readings were spurious due to a transient spike or 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.

While valid events were further analyzed and classified as conflicts or non-conflicts, invalid events were not further analyzed. Conflicts were valid events that represented a traffic conflict (i.e., crash, near-crash, crash-relevant conflict, or unintentional lane deviation). Non-conflicts were events that were not safety critical even though their trigger values were valid (true trigger). These types of non-conflicts were analogous to nuisance alarms—where the threshold value for an 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.

3.2.4 Applying the Data Dictionary to the Validated Events

An event-coding data dictionary, adapted from the criteria used in Olson et al. and Dingus et al., was used to reduce and analyze all valid SCEs.(77,78) 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, but for a few variables, the data analyst could select up to four applicable codes. For example, analysts could select multiple secondary tasks.

3.2.5 Baseline Epochs

In addition to the SCEs described, baseline epochs were created. The creation of a baseline dataset 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) dataset and the SCE dataset. 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."(79)

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 for that driver were included in the baseline dataset. In addition, all baseline epochs involved the vehicle traveling at a minimum speed of 5 mi/h. More specifically, the proportion of an individual driver's driving mileage (when the vehicle was traveling faster than 5 mi/h) was divided by the total driving mileage across this dataset (when the vehicle was traveling faster than 5 mi/h) and multiplied by 100 percent. This percentage reflected each 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.

3.2.6 Quality Control

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. The supervisor then led the analyst through a data 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 was lowered. The percentage drop of randomly selected events began at 75 percent and continued to fall until it reached 25 percent.

3.2.7 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 to be consistent with previous research.[80,81] 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: [82,83]

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

Each glance location was assigned a different letter, as shown in Figure 4. For example, the data analysts would input an "F" when the driver glanced at the forward roadway.

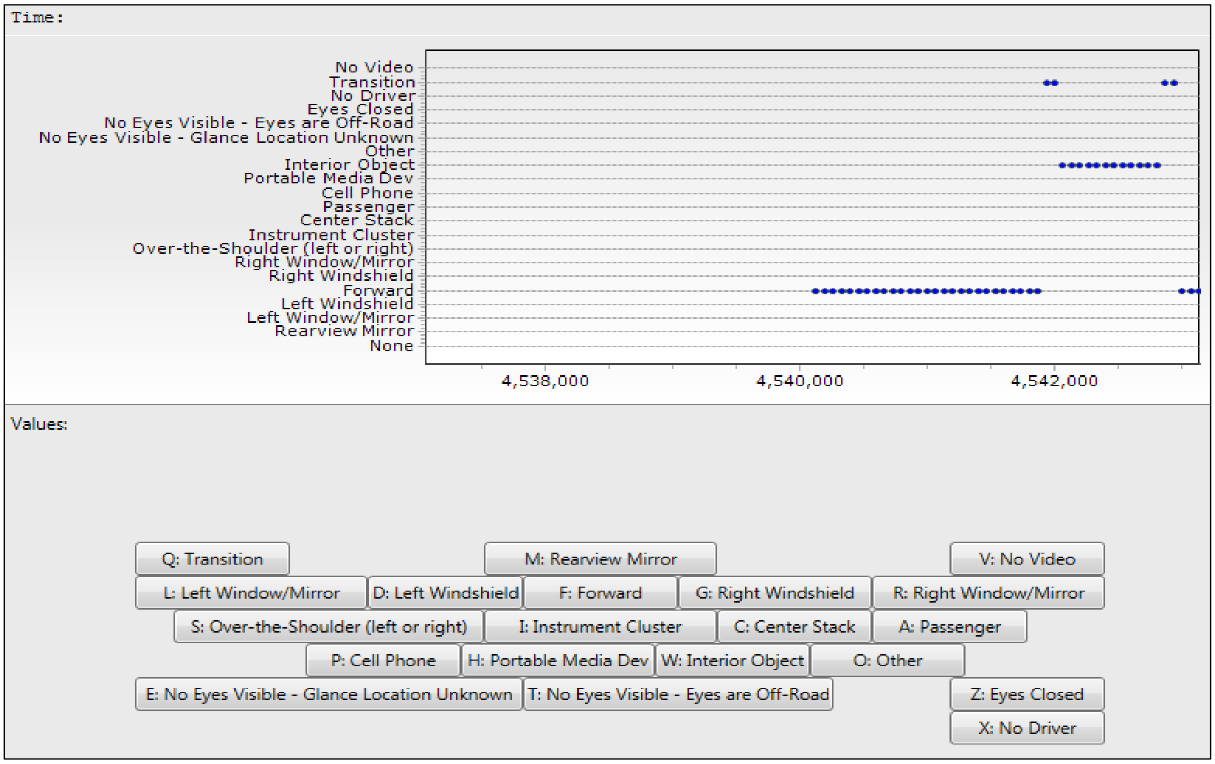

Figure 4. Screen capture. Eye glance location window in data viewing software.

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 of a 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.

3.2.8 ORD

The final step of reduction was to conduct ORD on all SCEs and a large sample of baselines. As noted above, ORD is defined as “a subjective assessment of how drowsy a naturalistic driving participant is based on his/her physical appearance, behaviors, and mannerisms,” [84,85] and was 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.[86] First, analysts participated in a training session in which they reviewed pre-screened 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 5 and the drowsiness category descriptions listed below.

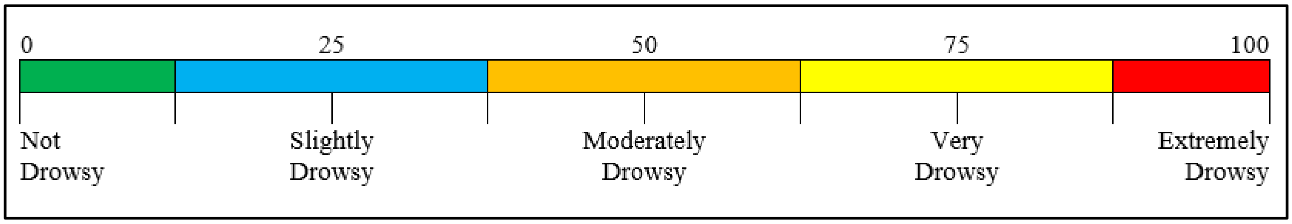

Figure 5. Illustration. ORD scale.

Descriptions for each of the drowsiness categories are provided below:[(87)]

- 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 5; 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 differed by more than 30 points from the "gold standard."

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

3.2.9 Manual Percentage of Eye Closure (PERCLOS)

Manual PERCLOS was conducted on all SCEs and 50 percent of the baseline epochs. PERCLOS is "a mathematically defined proportion of a time interval that the eyes are 80 to 100 percent closed."(88) PERCLOS is a measure of slow eyelid closure (not including blinks) and is a valid indicator of fatigue. Manual PERCLOS was conducted in a similar way to the eye-glance analysis; analysts proceeded through the video and held down a key to indicate whether the driver's eyes were open or closed. Once complete, a single PERCLOS value was calculated over the 3 minutes before the precipitating event (or the random trigger point for baselines).

3.3 DATA ANALYSIS METHODS

The following section details the analysis methods used to answer each of the research questions. Additional details on analysis methods, especially the mixed-effect logistic regression model and Poisson regression model, used to analyze naturalistic driving data can be found in Guo.(89) Analyses looking at risk of driver behaviors or time on task used all SCE types, which is standard in naturalistic driving research methods. The use of near-crashes in risk analysis, and the comparison to crashes in understanding driver safety, has been studied comprehensively in Guo, Klauer, Hankey, and Dingus.(90)

3.3.1 Odds Ratio (ORs)

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 3, an OR is a measure of association commonly employed in the analysis of 2 × 2 contingency tables.(91)

Table 3. 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:

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

Figure 6. Formula. OR 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 to the other. Conversely, ORs of less than 1.0 indicate the odds of an outcome occurring are lower in that same condition when compared to the other. If the categorical variables are not independent, an OR will produce odds both greater than 1.0 and less than1.0, depending on the initial set-up of the table.(92)

ORs analyze the relationship between the two categorical variables, but caution must be used when interpreting the results. Extraneous variables not included in this analysis may explain the relationships between pairs of categorical variables. It is not certain that one categorical variable caused a change in the values of the other categorical variable; one must also consider the situation or environment in which the task(s) 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 4 illustrates how ORs are calculated using contingency tables. 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 4. 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 7:

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

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

$$OR = 2.74$$

Figure 7. Formula. Sample OR calculation using data from Table 4.

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. To determine if the OR of 2.74 is significant, a 95-percent confidence interval (CI) is calculated, including the upper confidence limit (UCL) and lower confidence limit (LCL). The formulas to calculate the UCL and LCL are shown in Figure 8 and Figure 9:

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

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

$$UCL = 5.04$$

Figure 8. Formula. 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 9. Formula. 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.

An alternative method of calculating OR, with LCL and UCL, is to use a mixed-effect logistic regression model from a generalized linear mixed-effect model (GLMM) with logit link function. The GLMM is used to account for potential correlations among multiple observations from the same driver in the calculation of ORs by including a random effect for driver. The random effect for drivers varies in value among drivers, but the values follow a normal distribution. The GLMM method was used primarily in the presented analyses, when applicable to the analysis and data. Few drivers had multiple observations in any one category, so model results were often nearly equivalent to contingency table analysis results.

ORs were also used to assess the distribution of drowsiness during secondary task engagement. For all secondary tasks and individual tasks of interest, SCEs and baselines were labeled as having the task present or not present. The events were then labeled as being above or below the fatigue threshold. The baseline data and SCE data were analyzed separately. For secondary tasks with observations of drowsiness in the dataset, a GLMM was used to calculate the OR and corresponding LCL and UCL. For secondary tasks without observations of drowsiness (therefore having a zero count in the subgroup of task present and drowsiness present), exact logistic regression models were used to calculate OR for drowsiness during secondary task engagement. These models did control for multiple observations from the same driver and had conservative CI calculations, but they allowed estimates to be made for secondary tasks with no observations of drowsiness in the sample.

3.3.2 Population Attributable Risk (PAR)

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)."[(93)] In this context, "disease" refers to SCEs. For each OR with an outcome significantly different than 1.0, the PAR percentage was also calculated. While the OR is measured at the individual level, the PAR is measured at the population level. This analysis assessed the percentage of SCEs that occur in the population and are directly attributable to the specific behavior measured (e.g., 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."[(94)] 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 10):

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

Figure 10. Formula. PAR percentage calculation.

In this formula, P_e is the population exposure estimate (e.g., number of baseline epochs with a secondary task divided by the 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 4, the PAR percentage is calculated in Figure 11.

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

$$OR = 2.74$$

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

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

Figure 11. Formula. Sample PAR percentage calculation, using data from Table 6.

To interpret the PAR percentage, the standard error estimate, UCL, and LCL must first be calculated. Table 5 displays the hypothetical data used in Table 4 in the OR example; these data will be used to explain the calculations shown below.

Table 5. 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 12.

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

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

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

Figure 12. Formula. Standard error calculation.

Next, the 95-percent UCL and LCL are calculated, using the standard error, with the formulas shown in Figure 13 and Figure 14.

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

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

$$UCL = 30.06$$

Figure 13. 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 14. Formula. 95-percent LCL calculation.

Then, it can be reported that 27–30 percent of SCEs are associated with talking on a cell phone while driving. Because crude ORs from the contingency table setup (no control for multiple observations from a single driver) were nearly identical to OR model results, and because of the lack of industry research and support in extending model results to PAR calculations, PAR percentage was calculated using observation counts as described above.

3.3.3 Analysis of Variance (ANOVA) and Post-Hoc Tests

A general linear model was used to perform an unbalanced analysis of variance (ANOVA) to test for significant differences among event types in the total length of time drivers did not look at the forward roadway. For each SCE or baseline epoch with valid eyeglance data, the total length of time that the driver was not looking at the forward roadway in a 6-second interval was calculated. The event types (i.e., crash, near-crash, crash-relevant conflict, unintentional lane deviation, and baseline epochs) were then compared using the model. This analysis was repeated for All and Vehicle 1 (V1; participant vehicle) At-fault events.

ANOVA tests for significant differences in group sample means of a continuous dependent variable for one independent variable. The null hypothesis is that the groups have equal mean values of the continuous variable. The alternative hypothesis is that the group means are not equal. The one-way ANOVA uses the *f*-distribution. The calculation of the *F* statistic uses the following formulas for the between-group mean square ($MS_{between}$) and the within-group mean square (MS_{within}).

$$MS_{between} = \frac{\sum_{j=1}^{k\ groups} n_j \left(\bar{X}_{.j} - \bar{X}_{..}\right)^2}{k-1}$$

$$MS_{within} = \frac{\sum_{j=1}^{k\ groups} \sum_{i=1}^{n_j\ observations} \left(X_{ij} - \bar{X}_{.j}\right)^2}{n-k}$$

$$F = \frac{MS_{between}}{MS_{within}}$$

Figure 15. Formula. Calculation of the F statistic for a one-way ANOVA.

In the formulas above, k is the total number of groups, n_j is the total number of observations within a group, n is the total number of observations across all groups, $\overline{X_{.j}}$ is the mean for group k, $\bar{X}_{..}$ is the mean for all observations, and X_{ij} is the value for a single observation i in group j.

The calculated *F* statistic is then compared to the *f*-distribution and critical value given the number of groups and observations. The conclusion from a one-way ANOVA does not provide information on which specific group means differ. Post-hoc tests are performed following a significant one-way ANOVA result. In post-hoc tests, groups are compared two at a time to determine which groups have significantly different mean values. In this study, Tukey's t-tests were used in post-hoc testing. Results are presented as absolute statistics- reported test statistic values are positive- and indicate whether the variables are significantly different without assigning a direction on the comparison. Tables and plots of the variable means are useful in understanding the direction of differences between two variables.

3.3.4 SCE Rate Calculation

To assess the risk of SCEs by driving hour, the SCE rate was calculated for each of the 11 driving hours allowed in a shift. The SCE rate for a single driving hour was calculated as the number of SCEs occurring within the driving hour divided by the total time driving within the driving hour. The driving hour SCE rate formula is:

SCE Rate for Driving Hour = Number of SCEs in Driving Hour / Total Driving Time Across All Shifts in Driving Hour (SCEs/hours)

For each driver, this formula was used to calculate the Driving Hour SCE Rate for Driving Hour 1, Driving Hour 2, and so on, up to Driving Hour 11.

Figure 16 is used as a reference example to illustrate the calculation of Driving Hour SCE Rate. In Figure 16, the horizontal lines with arrows represent individual shifts (s_i) for a single driver. The driver in the example had nine shifts (s_1, s_2, and so on up to s_9). The length of the line equals the driving hours since the beginning of the shift (t_i) (hours shown on the x-axis). For each shift s_i, SCEs during the shift are marked at the time of occurrence by an orange event bubble.

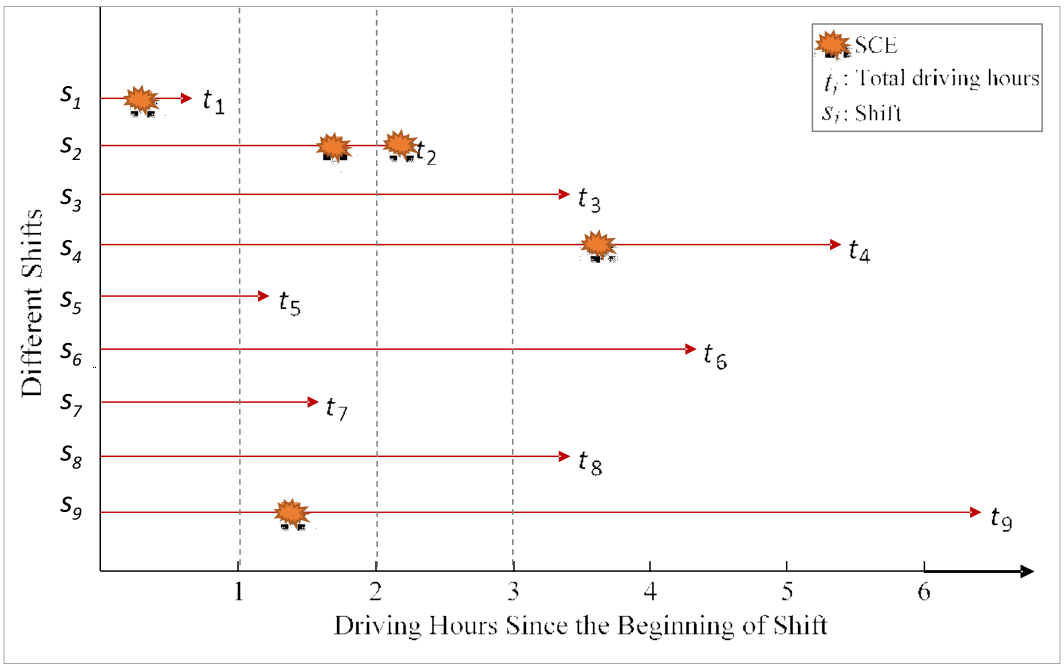

Figure 16. Graph. Plot of SCE rate estimates by driving hour bin.

For each driving hour 1 through 11, the total number of SCEs in that hour can be counted, and the total driving time that occurred in the driving hour can also be calculated.

Taking the first driving hour as an example, Shift s_1 has one SCE (represented by the orange mark) in the first driving hour, while Shifts s_2–s_9 do not have any SCEs in the first hour. In shift s_1, the driver drove less than one full hour (driving time equal to t_1). Shifts s_2–s_9 all had driving for the full first driving hour (with driving times t_2, t_3, etc. that go beyond the first driving hour). The SCE rate for the first driving hour is then calculated as below:

SCE rate for Driving Hour 1 = Number SCEs in Hour 1 / Total Driving Time Across All Shifts in Hour 1

SCE rate for Driving Hour 1 = 1 SCE / (t_1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1)

To calculate the SCE rate in Driving Hour 2, the number of SCEs and total driving time are counted in the second driving hour. Shifts s_2 and s_9 each had an SCE in the second driving hour, for a total of 2 SCEs during Driving Hour 2. Shift s_1 ended in the first driving hour and does not have any driving time in the second driving hour. Shifts s_5 and s_7 drove fully through the first driving hour and only partially in the second hour. The total driving times in the second driving hour for these shifts were t_5-1 and t_7-1. In all remaining shifts, the driving times t_i show the driver drove the entire second hour and then continued driving. For each of these shifts, the driving time in the second driving hour is 1 hour. The SCE rate of the second driving hour is then calculated as below.

SCE rate for Driving Hour 2 = Number SCEs in Hour 2 / Total Driving Time Across All Shifts in Hour 2

SCE rate for Driving Hour 2 = 2 SCEs / (0 + 1 + 1 + 1 + (t_5 - 1) + 1 + (t_7 - 1) + 1 + 1)

These calculations were made for each driver and each driving hour 1 through 11.

3.3.5 Mixed-effect Poisson Model

A mixed-effect Poisson model was used to evaluate the difference in SCE rate by cumulative driving hours in a shift. The model formulation is as follows:

$$\boxed{Y_{it} \sim Poisson(n_{it}\lambda_{it})}$$

Figure 17. Formula. Poisson distribution.

- Where Y_{it} is the number of SCEs for driver i in driving hour t;
- i = 1,2,…,157, is the driver index;
- t = 1,2,…,11, is the driving hour index since the beginning of the shift;
- n_{it} is the total driving hours for driver i and the t^{th} hour;
- λ_{it} is the expected SCE rate for driver i, time t;
- The λ_{it} is linked to explanatory variables through a logarithm link function.

$$\boxed{\log(\lambda_{it}) = \alpha_i + X_t\beta_t,}$$

Figure 18. Formula. Mixed-effect Poisson Model logarithm link function and model explanatory variables.

- where X_t is an indicator variable for driving hour t;
- β_t is a fixed parameter for t^{th} driving hour;
- α_i is a driver specific random term.

3.4 RESEARCH QUESTIONS

This study asked the following research questions, which are described in more detail in Chapter 4.

1. What are the types and frequencies of tasks in which drivers engage prior to involvement in SCEs? What are the ORs, and what is the PAR percentage for each task type?
2. What is the prevalence, and what are the characteristics of hands-free and hand-held cell phone use? What are the ORs, and what is the PAR percentage of being involved in an SCE while talking on a hand-held or hands-free cell phone?
3. What are the environmental conditions associated with driver choice of engagement in tasks? What are the ORs, and what is the PAR percentage of being in an SCE while engaging in tasks while encountering these conditions?
4. What are the ORs of eyes off forward roadway? Does eyes off forward roadway significantly affect safety and/or driving performance?
5. What is the prevalence of driver drowsiness? What are the ORs, and what is the PAR of SCE involvement while drowsy?
6. How does driver drowsiness vary when drivers are involved in a secondary task and/or driving related task?
7. What is the impact of time on task on the risk of SCEs as a function of driving hour? Is there a significant increase in risk associated with increasing hour of driving?
8. What is the prevalence of driver drowsiness by hour of driving? Is there a significant increase in driver drowsiness by hour of driving for both SCEs and normal driving segments?

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4. DATA ANALYSIS AND RESULTS

The analyses described in this section follow those used in Hammond et al., Olson et al., and Klauer et al.[95,96,97] Though the data lends themselves to additional analyses, the current study sought to follow the Hammond et al. and Olson et al. approach as closely as possible.[98,99] ORs were calculated to estimate the risk of being involved in an SCE when the driver was engaged in a secondary task as compared to when the driver was not engaged in this task. PAR calculations were also conducted to generalize the data to a larger population of drivers. 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, such as checking the speedometer and turn signal use, were excluded from the analyses as they were considered part of safe driving practices. It should be noted that crash–tire strike events were also excluded from the analyses. The data were grouped separately for motorcoach drivers and truck drivers.

4.1 DATA SUMMARY

All motorcoach and heavy truck data collected under the OBMS FOT[100] were included for analysis. Table 6 and Table 7 provide a summary of each event type by all SCEs and Vehicle 1 (V1) at-fault SCEs. Plots showing the SCE and baseline counts per driver, for truck and motorcoach drivers, are included in Appendix A and display distribution patterns of data across individual drivers similar to those observed in previous naturalistic driving studies.

Table 6. Frequency of SCEs and baseline epochs by event type for All and V1 At-fault events for motorcoach data.

Event Type	Frequency of All SCEs	Frequency of All SCEs with Secondary Task	Frequency of V1 SCEs	Frequency of V1 SCE with Secondary Task
All SCEs	**1739**	**704**	**876**	**437**
Crash	10	6	3	2
Near Crash	538	198	233	109
Crash-Relevant Conflict	927	315	376	141
Unintentional Lane Deviation	264	185	264	185
Baseline Epochs	6318	1961	6318	1961

Table 7. Frequency of SCEs and baseline epochs by event type for All and V1 At-fault events for truck data.

Event Type	Frequency of All SCEs	Frequency of All SCE with Secondary Task	Frequency of V1 SCEs	Frequency of V1 SCE with Secondary Task
All SCEs	**2363**	**1265**	**1736**	**1080**
Crash	25	12	22	11
Near Crash	328	143	184	98
Crash-Relevant Conflict	1055	416	575	277
Unintentional Lane Deviation	955	694	955	694

Event Type	Frequency of All SCEs	Frequency of All SCE with Secondary Task	Frequency of V1 SCEs	Frequency of V1 SCE with Secondary Task
Baseline Epochs	7880	3729	7880	3729

4.2 RESEARCH QUESTION 1: WHAT ARE THE TYPES AND FREQUENCY OF TASKS IN WHICH DRIVERS ENGAGE PRIOR TO INVOLVEMENT IN SCEs? WHAT ARE THE ORs AND THE PAR PERCENTAGE FOR EACH TASK TYPE?

4.2.1 Frequency of Tasks

As noted previously, only secondary tasks were used in the analysis. Table 8 and Table 9 show a breakdown of each event type and the percentage of each that involved a secondary task. Analysis revealed that 40.5 percent of the 1,739 identified motorcoach SCEs and 53.5 percent of the 2,363 identified truck SCEs had some type of driver distraction (occurring within the 6-second analysis window) listed as a potential contributing factor. Table 8 shows the percentage of any secondary task present in all SCEs and SCEs where the V1 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 leading to the conflict.[101] Driver distraction due to secondary tasks was a contributing factor in 49.9 percent of all motorcoach SCEs and 62.2 percent of all truck SCEs.

Table 8. Frequency and percentage of any secondary tasks in All and V1 At-fault events for motorcoach data.

Event Type	All SCEs with Secondary Task	Frequency of All SCEs	Percent of All SCEs	V1 SCEs with Secondary Task	Frequency of V1 SCEs	Percent of V1 SCEs
All SCEs	40.5%	1,739	100.0%	49.9%	876	100.0%
Crash	60.0%	10	0.6%	66.7%	3	0.3%
Near-crash	36.8%	538	30.9%	46.8%	233	26.6%
Crash-relevant conflict	34.0%	927	53.3%	37.5%	376	42.9%
Unintentional lane deviation	70.1%	264	15.2%	70.1%	264	30.1%
Baseline epochs	31.0%	6,318	100.0%	31.0%	6,318	100.0%

Table 9. Frequency and percentage of any secondary tasks in All and V1 At-fault events for truck data.

Event Type	All SCEs with Secondary Task	Frequency of All SCEs	Percent of All SCEs	V1 SCEs with Secondary Task	Frequency of V1 SCEs	Percent of V1 SCEs
All SCEs	53.5%	2,363	100.0%	62.2%	1,736	100.0%
Crash	48.0%	25	1.1%	50.0%	22	1.3%
Near-crash	43.6%	328	13.9%	53.3%	184	10.6%

Event Type	All SCEs with Secondary Task	Frequency of All SCEs	Percent of All SCEs	V1 SCEs with Secondary Task	Frequency of V1 SCEs	Percent of V1 SCEs
Crash-relevant conflict	39.4%	1,055	44.6%	48.2%	575	33.1%
Unintentional lane deviation	72.7%	955	40.4%	72.7%	955	55.0%
Baseline epochs	47.3%	7,880	100.0%	47.3%	7,880	100.0%

4.2.2 ORs of Secondary Tasks

To approximate SCE risk compared to normal baseline driving, ORs were calculated for the different secondary tasks. ORs for each secondary task category were calculated with the absence and presence of each secondary task. Because of the small sample size for some of these tasks, each task of interest may have occurred 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. Frequency tables corresponding to these OR calculations can be found in Appendix B.

Table 10 and Table 11 show the results of the secondary task analysis for All SCEs and V1 At-fault SCEs for motorcoach and truck data. Secondary tasks with a significant OR are shown in bold. A significant OR value of less than 1.0 indicates that the secondary task was protective or decreased the risk of being involved in an SCE when compared to baseline driving with the same secondary tasks present. A significant OR value of greater than 1.0 indicates that the secondary task increased the driver's risk of being involved in an SCE, when compared to baseline driving with the same secondary tasks present.

Table 10. ORs and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Secondary Task	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Secondary Task (Overall)	**1.56***	1.39	1.75	**2.21***	1.90	2.57
Talking/singing	1.17	0.95	1.46	1.04	0.78	1.40
Dancing	**0.37***	0.16	0.83	-	-	-
Reading	2.04	0.80	5.25	**3.44***	1.26	9.40
Passenger in rear seat	0.97	0.70	1.34	1.22	0.83	1.80
Reaching for object	**2.46***	1.57	3.86	**3.07***	1.83	5.15
Intercom use	**2.74***	1.49	5.03	1.56	0.64	3.79
Other electronic device	1.01	0.49	2.08	1.38	0.62	3.06
Adjusting instrument panel	**1.34***	1.03	1.75	**1.95***	1.43	2.65
Adjusting/monitoring other devices integral to vehicle	**1.59***	1.07	2.38	**1.93***	1.21	3.08
External distraction	**1.57***	1.29	1.93	**2.07***	1.63	2.64
Reaching for food- or drink-related object	0.86	0.43	1.74	1.55	0.76	3.15

Secondary Task	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Eating	1.18	0.77	1.80	1.50	0.92	2.47
Drinking from container	0.90	0.43	1.87	1.45	0.67	3.17
Personal grooming	1.41	0.96	2.07	**2.04***	1.33	3.15
Removing/adjusting clothing	**2.29***	1.27	4.13	**2.79***	1.41	5.54
Other personal hygiene	**2.23***	1.39	3.57	**3.27***	1.95	5.48

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

Table 11. ORs and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Secondary Task	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Secondary Task (Overall)	**1.22***	1.10	1.35	**1.79***	1.59	2.02
Talking/singing	**0.60***	0.47	0.76	**0.62***	0.47	0.81
Dancing	**0.40***	0.24	0.67	**0.46***	0.27	0.81
Reading	**3.27***	1.63	6.59	**4.23***	2.03	8.81
Passenger in adjacent seat	0.90	0.39	2.09	0.75	0.26	2.12
Reaching for object	**4.57***	3.27	6.39	**5.81***	4.09	8.26
Electronic dispatching device	**1.44***	1.05	1.98	**1.80***	1.27	2.55
Other electronic device	**2.87***	1.54	5.36	**3.35***	1.72	6.52
Adjusting instrument panel	0.97	0.78	1.21	1.24	0.97	1.57
Adjusting/monitoring other devices integral to vehicle	**3.31***	2.24	4.89	**4.82***	3.19	7.29
External distraction	**1.21***	1.04	1.41	**1.45***	1.23	1.71
Reaching for food- or drink-related object	**1.67***	1.19	2.33	**2.28***	1.61	3.22
Eating	1.11	0.88	1.40	1.27	0.99	1.62
Drinking from container	0.87	0.57	1.31	1.07	0.69	1.66
Smoking-related: reaching, lighting, extinguishing	1.01	0.39	2.58	1.32	0.50	3.46
Smoking-related: cigarette in hand or mouth	0.72	0.49	1.05	0.70	0.45	1.09
Tobacco use	1.16	0.62	2.17	1.45	0.76	2.76
Personal grooming	0.84	0.60	1.18	1.02	0.71	1.48
Removing/adjusting clothing	**3.01***	1.72	5.27	**3.43***	1.90	6.21
Other personal hygiene	0.90	0.67	1.20	1.07	0.79	1.46

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

4.2.2.1 PAR Percentages

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 than 1.0). The results from these calculations are presented in Table 12 and Table 13.

Table 12. PAR and 95-percent confidence intervals for secondary tasks across All and V1 At-fault events for motorcoach data.

Secondary Task	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Secondary Tasks (Overall)	13.70	13.33	14.06	27.33	26.84	27.83
Reading	-	-	-	0.48	0.42	0.54
Reaching for object	1.23	1.16	1.30	1.85	1.74	1.96
Intercom use	0.87	0.82	0.93	-	-	-
Adjusting instrument panel	0.84	0.73	0.96	2.89	2.71	3.06

Secondary Task	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Adjusting/monitoring other devices integral to vehicle	0.84	0.76	0.91	1.51	1.40	1.63
External distraction	3.21	3.06	3.37	6.30	6.06	6.53
Personal grooming	-	-	-	2.05	1.92	2.18
Removing/adjusting clothing	0.66	0.61	0.72	1.00	0.92	1.08
Other personal hygiene	1.07	1.01	1.14	2.09	1.98	2.21

Table 13. PAR and 95-percent confidence intervals for secondary tasks across All and V1 At-fault events for truck data.

Secondary Task	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Secondary Tasks (Overall)	11.79	11.37	12.22	28.27	27.81	28.72
Reading	0.64	0.60	0.68	0.90	0.85	0.95
Reaching for object	3.31	3.22	3.39	4.31	4.20	4.42
Electronic dispatching device	0.64	0.57	0.71	1.11	1.02	1.20
Other electronic device	0.55	0.51	0.59	0.70	0.65	0.75
Adjusting/monitoring other devices integral to vehicle	1.78	1.71	1.85	2.53	2.44	2.62
External distraction	3.09	2.92	3.26	2.58	5.07	5.48
Reaching for food- or drink-related object	1.05	0.98	1.12	1.88	1.79	1.97
Removing/adjusting clothing	0.87	0.82	0.91	1.15	1.09	1.21

As shown in Table 12, combining all motorcoach secondary tasks (significant OR of 1.56 as reported in Table 10) resulted in a PAR percentage of 13.70, with an LCL of 13.33 and a UCL of 14.06. This indicates that engaging in a secondary task led to 13 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 3.21.

Combining all truck secondary tasks (significant OR of 1.22) resulted in a PAR percentage of 11.79, with an LCL of 11.37 and a UCL of 12.22. This indicates that engaging in a secondary task led to 11 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 3.09.

4.3 RESEARCH QUESTION 2: WHAT ARE THE PREVALENCE AND CHARACTERISTICS OF HANDS-FREE AND HANDHELD CELL PHONE USE? WHAT ARE THE ORs AND THE PAR PERCENTAGE OF BEING INVOLVED IN AN SCE WHILE TALKING ON A HANDHELD OR HANDS-FREE CELL PHONE?

During SCE and baseline epoch reduction, analysts had several hand-held cell phone options to code as secondary tasks. Since it is difficult to determine if a driver is using a hands-free cell phone during the short 6-seconds of video, all SCEs and baseline epochs coded with a secondary task of “talking/singing/dancing audience unknown” were re-reviewed. Reductionists reviewed the video prior to the SCE or baseline epoch to look for the start of a phone call. If they could confirm that the driver was talking on the phone during the event (versus talking to themselves, or singing along with the radio), an additional reduction was completed that provided information on hands-free cell phone use.

Motorcoach Data

Table 14 shows the frequency counts of All SCEs and V1 At-fault SCEs for all cell phone tasks; hand-held cell phone tasks; and hands-free cell phone tasks—a total of 50 SCEs and 135 baseline epochs involved hand-held or hands-free cell phone use. It should be noted that a driver could use both a hand-held device and a hands-free device to make a call. For example, they might pick up a hand-held phone to initiate the phone call, then talk or listen to the call with a Bluetooth device. Therefore, a single event may be counted in both the overall hand-held cell phone tasks and the overall hands-free cell phone tasks in the tables below. Table 15 and Table 16 show the OR calculations and PAR percentages for the three categories.

Table 14. The frequency of cell phone-related secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Cell Phone Task	Frequency of ALL SCE with Task	Frequency of ALL SCE without Task	Frequency of V1 SCE with Task	Frequency of V1 SCE without Task	Frequency of Baseline with Task	Frequency of Baseline without Task
All cell phone tasks	50	1,689	40	836	135	6,183
Hand-held cell phone tasks	42	1,689	36	836	68	6,183
Hands-free cell phone tasks	9	1,696	5	843	71	6,189

Table 15. ORs and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Cell Phone Task	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
All cell phone tasks	**1.41***	1.00	2.00	**2.14***	1.46	3.12
Hand-held cell phone tasks	**2.42***	1.61	3.62	**3.89***	2.52	5.99
Hands-free cell phone tasks	**0.45***	0.22	0.92	0.47	0.19	1.20

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

Table 16. PAR and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Cell Phone Task	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
All cell phone tasks	0.75	0.67	0.84	2.48	2.34	2.63
Hand-held cell phone tasks	1.35	1.28	1.43	3.07	2.94	3.21
Hands-free cell phone tasks	-	-	-	-	-	-

Table 17 and Table 18 show the breakdown of these three categories across event type for All SCEs and V1 At-fault SCEs for motorcoach data.

Table 17. The frequency of cell phone-related secondary tasks during SCEs and baseline epochs by event type across All events for motorcoach data.

Cell Phone Task	Crash	Near-Crash	Crash-Relevant Conflict	Unintentional Lane Deviation	Baseline Epoch
All cell phone tasks	0	9	17	24	135
Hand-held cell phone tasks	0	7	12	23	68
Hands-free cell phone tasks	0	2	5	2	71

Table 18. The frequency of cell phone-related secondary tasks during SCEs and baseline epochs by event type across V1 At-fault events for motorcoach data.

Cell Phone Task	Crash	Near-Crash	Crash-Relevant Conflict	Unintentional Lane Deviation	Baseline Epoch
All cell phone tasks	0	7	9	24	135
Hand-held cell phone tasks	0	5	8	23	68
Hands-free cell phone tasks	0	2	1	2	71

Table 19 shows the frequency counts of All SCEs and V1 At-fault SCEs for all cell phone-related sub tasks. Table 20 shows the OR calculations for the cell phone-related subtasks and Table 21 shows the PAR percentages for the three categories.

Table 19. The frequency of cell phone-related secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Cell Phone Task	Frequency of ALL SCE with Task	Frequency of ALL SCE without Task	Frequency of V1 SCE with Task	Frequency of V1 SCE without Task	Frequency of Baseline with Task	Frequency of Baseline without Task
Hand-held locate/reach/answer	8	1,696	8	843	20	6,189
Hand-held dial	1	1,696	1	843	2	6,189
Hand-held talk/listen	7	1,696	5	843	13	6,189

Cell Phone Task	Frequency of ALL SCE with Task	Frequency of ALL SCE without Task	Frequency of V1 SCE with Task	Frequency of V1 SCE without Task	Frequency of Baseline with Task	Frequency of Baseline without Task
Hand-held holding	7	1,696	5	843	5	6,189
Hand-held browsing	14	1,696	13	843	22	6,189
Hand-held texting	3	1,696	3	843	4	6,189
Hands-free call via headset/earpiece	9	1,696	5	843	65	6,189
Hands-free call via speakerphone	0	1,696	0	843	6	6,189
Hands-free talk/listen	9	1,696	5	843	71	6,189

Table 20. ORs and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data

Cell Phone Task	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Hand-held talk/listen	1.97	0.76	5.10	2.85	0.98	8.35
Hand-held holding	**3.96***	1.18	13.26	**5.72***	1.51	21.64
Hand-held browsing	**2.58***	1.29	5.18	**4.45***	2.15	9.22
Hands-free call via headset/earpiece	0.50	0.24	1.02	0.52	0.20	1.33
Hands-free talk/listen	**0.45***	0.22	0.93	**0.48***	0.19	1.22

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

Table 21. PAR and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Cell Phone Task	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Hand-held holding	0.33	0.30	0.36	0.21	0.19	0.24
Hand-held browsing	0.47	0.42	0.51	1.18	1.10	1.27

Truck Data

Table 22 shows the frequency counts of All SCEs and V1 At-Fault SCEs for all cell phone tasks, hand-held cell phone tasks, and hands-free cell phone tasks. A total of 192 SCEs and 585 baseline epochs had hand-held or hands-free cell phone use. Table 23 and Table 24 show the OR calculations and PAR percentages for the three categories.

Table 22. The frequency of cell phone-related secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Cell Phone Task	Frequency of ALL SCE with Task	Frequency of ALL SCE without Task	Frequency of V1 SCE with Task	Frequency of V1 SCE without Task	Frequency of Baseline with Task	Frequency of Baseline without Task
All cell phone tasks	192	2,171	164	1,572	585	7,295
Hand-held cell phone tasks	132	2,171	127	1,572	178	7,295
Hands-free cell phone tasks	70	2,171	46	1,572	419	7,295

Table 23. ORs and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Cell Phone Task	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
All cell phone tasks	1.14	0.93	1.39	**1.40***	1.13	1.75
Hand-held cell phone tasks	**2.81***	2.16	3.66	**4.00***	3.03	5.27
Hands-free cell phone tasks	**0.51***	0.38	0.69	**0.46***	0.33	0.66

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

Table 24. PAR and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Cell Phone Task	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
All cell phone tasks	-	-	-	2.19	2.02	2.35
Hand-held cell phone tasks	3.43	3.33	3.53	5.22	5.08	5.35
Hands-free cell phone tasks	-	-	-	-	-	-

Table 25 and Table 26 show the breakdown of these three categories across event type for All SCEs and V1 At-Fault SCEs for truck data.

Table 25. The frequency of cell phone-related secondary tasks during SCEs and baseline epochs by event type across All events for truck data.

Cell Phone Task	Crash	Near-Crash	Crash-Relevant Conflict	Unintentional Lane Deviation	Baseline Epoch
All cell phone tasks	2	21	63	106	585
Hand-held cell phone tasks	2	13	22	95	178
Hands-free cell phone tasks	0	9	44	17	419

Table 26. The frequency of cell phone-related secondary tasks during SCEs and baseline epochs by event type across V1 At-fault events for truck data.

Cell Phone Task	Crash	Near-Crash	Crash-Relevant Conflict	Unintentional Lane Deviation	Baseline Epoch
All cell phone tasks	2	14	42	106	585
Hand-held cell phone tasks	2	10	20	95	178
Hands-free cell phone tasks	0	5	24	17	419

Table 27 shows the frequency counts of All SCEs and V1 At-fault SCEs for all cell phone-related sub tasks. Table 28 shows the OR calculations for the cell phone-related subtasks. Table 29 shows the PAR percentages calculated for sub tasks found to be significant and risky in the OR calculations.

Table 27. The frequency of cell phone-related secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Cell Phone Task	Frequency of ALL SCE with Task	Frequency of ALL SCE without Task	Frequency of V1 SCE with Task	Frequency of V1 SCE without Task	Frequency of Baseline with Task	Frequency of Baseline without Task
Hand-held locate/reach/answer	13	2,171	13	1,572	27	7,295
Hand-held dial	3	2,171	3	1,572	5	7,295
Hand-held talk/listen	7	2,171	6	1,572	46	7,295
Hand-held holding	16	2,171	15	1,572	26	7,295
Hand-held browsing	92	2,171	90	1,572	73	7,295
Hand-held texting	6	2,171	6	1,572	10	7,295
Hands-free call via headset/earpiece	66	2,171	42	1,572	403	7,295
Hands-free call via speakerphone	4	2,171	4	1,572	15	7,295
Hands-free talk/listen	70	2,171	46	1,572	418	7,295

Table 28. ORs and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for truck data

Cell Phone Task	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Hand-held locate/reach/answer	1.90	0.93	3.87	**2.71***	1.31	5.61
Hand-held talk/listen	0.71	0.30	1.67	0.95	0.38	2.40
Hand-held holding	**2.26***	1.11	4.61	**3.04***	1.43	6.46
Hand-held browsing	**4.35***	3.08	6.17	**6.14***	4.26	8.85
Hand-held texting	**3.07***	1.03	9.15	**4.33***	1.42	13.26
Hands-free call via headset/earpiece	**0.50***	0.37	0.68	**0.44***	0.31	0.63
Hands-free talk/listen	**0.51***	0.38	0.69	**0.46***	0.33	0.66

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

Table 29. PAR and 95-percent confidence interval of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Cell Phone Task	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Hand-held locate/reach/answer	-	-	-	0.45	0.41	0.50
Hand-held holding	0.38	0.34	0.42	0.47	0.42	0.51
Hand-held browsing	3.11	3.02	3.19	4.47	4.36	4.58
Hand-held texting	0.14	0.12	0.16	0.24	0.21	0.28

4.4 RESEARCH QUESTION 3: WHAT ARE THE ENVIRONMENTAL CONDITIONS ASSOCIATED WITH DRIVER CHOICE OF ENGAGEMENT IN TASKS? WHAT ARE THE ORs AND PAR PERCENTAGE OF BEING IN AN SCE WHILE ENGAGING IN TASKS WHILE ENCOUNTERING THESE CONDITIONS?

Research Question 3 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
- Roadway surface conditions
- Traffic flow
- Locality

- Weather conditions
- Relation to junction
- Traffic density

Reductionists 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.[102]

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.

ORs were calculated with the absence or presence of each task category. The data were parsed for analysis in two ways: All events and V1 At-fault events. Each of the environmental conditions was considered, as described below. The data were again analyzed separately for motorcoach drivers and truck drivers. All frequency tables for the OR calculations can be found in Appendix C.

4.4.1 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 (e.g., street lights).
- Dawn.
- Dusk.

To clarify, "darkness, lighted" indicates the atmospheric lighting was dark although the road had active artificial lighting.

Table 30 and Table 31 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for motorcoach data.

Table 30. ORs and 95-percent confidence intervals for the interaction of any secondary task by lighting level across All and V1 At-fault events for motorcoach data.

Lighting Levels	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Daylight	**1.46***	1.29	1.65	**2.06***	1.76	2.42

Lighting Levels	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Darkness, not lighted	**3.13***	1.75	5.60	**4.92***	2.45	9.87
Darkness, lighted	1.29	0.96	1.75	**1.99***	1.32	3.01
Dawn	1.29	0.47	3.57	-	-	-

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

Table 31. PAR and 95-percent confidence intervals for any secondary task by lighting level across All and V1 At-fault events for motorcoach data.

Lighting Levels	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Daylight	13.09	12.66	13.51	25.81	25.25	26.38
Darkness, not lighted	36.75	34.83	38.67	51.69	49.56	53.82
Darkness, lighted	-	-	-	21.27	19.93	22.61

Table 32 and Table 33 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for truck data.

Table 32. ORs and 95-percent confidence intervals for the interaction of any secondary task by lighting level across All and V1 At-fault events for truck data.

Lighting Levels	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Daylight	1.08	0.97	1.21	**1.69***	1.48	1.93
Darkness, not lighted	**1.91***	1.54	2.38	**1.99***	1.59	2.49
Darkness, lighted	**1.61***	1.16	2.23	**2.26***	1.53	3.34
Dawn	1.28	0.78	2.10	1.67	0.97	2.86

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

Table 33. PAR and 95-percent confidence intervals for any secondary task by lighting level across All and V1 At-fault events for truck data.

Lighting Levels	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Daylight	-	-	-	25.76	25.16	26.36
Darkness, not lighted	28.45	27.56	29.34	30.08	29.17	30.99
Darkness, lighted	19.13	17.83	20.42	32.86	31.36	34.36

4.4.2 Weather Conditions

"Weather conditions" indicates 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.
- Fog.

- Snow.
- Rain and fog.
- Wind gusts.
- Rain.
- Sleet.
- Snow/sleet and fog.

Table 34 and Table 35 show the results of the OR calculations for each weather condition analysis and PAR percentage for each of the significant OR calculations for motorcoach data.

Table 34. ORs and 95-percent confidence intervals for the interaction of any secondary task by weather condition for motorcoach data.

Weather Conditions	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
No adverse conditions	**1.52***	1.36	1.70	**2.23***	1.93	2.58
Rain	1.32	0.63	2.77	2.19	0.87	5.51

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

Table 35. PAR and 95-percent confidence intervals for the interaction of any secondary task by weather condition for motorcoach data.

Weather Conditions	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
No adverse conditions	13.93	13.56	14.30	27.52	27.02	28.02

Table 36 and Table 37 show the results of the OR calculations for each weather condition analysis and PAR percentage for each of the significant OR calculations for truck data.

Table 36. ORs and 95-percent confidence intervals for the interaction of any secondary task by weather condition for truck data.

Weather Conditions	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
No adverse conditions	**1.28***	1.16	1.41	**1.82***	1.62	2.03
Rain	1.18	0.82	1.69	**1.78***	1.17	2.73

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

Table 37. PAR and 95-percent confidence intervals for the interaction of any secondary task by weather condition for truck data.

Weather Conditions	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
No adverse conditions	11.61	11.17	12.05	27.75	27.28	28.23
Rain	-	-	-	27.96	26.07	29.84

4.4.3 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. Reductionists selected one of the following relation-to-junction options:

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

Table 38 and Table 39 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for motorcoach data.

Table 38. ORs and 95-percent confidence intervals for the interaction of any secondary task by relation to junction for motorcoach data.

Relation to Junction	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Non-junction	**1.48***	1.27	1.73	**2.33***	1.90	2.87
Intersection	0.99	0.69	1.42	1.47	0.96	2.27
Intersection-related	1.42	0.93	2.16	1.48	0.76	2.89
Entrance/exit ramp	**2.70***	1.49	4.88	**3.93***	1.97	7.86
Interchange area	**1.69***	1.31	2.19	**2.62***	1.90	3.60
Parking lot entrance/exit	1.37	0.84	2.24	1.40	0.76	2.57
Parking lot, within boundary	1.56	0.54	4.48	1.04	0.29	3.77
Driveway, alley access, etc.	1.61	0.68	3.81	-	-	-
Other	0.88	0.24	3.19	-	-	-

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

Table 39. PAR and 95-percent confidence intervals for the interaction of any secondary task by relation to junction for motorcoach data.

Relation to Junction	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Non-junction	13.38	12.85	13.91	29.95	29.23	30.68
Entrance/exit ramp	32.54	30.65	34.42	45.47	43.33	47.60
Interchange area	15.30	14.52	16.07	29.62	28.58	30.65

Table 40 and Table 41 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for truck data.

Table 40. ORs and 95-percent confidence intervals for the interaction of any secondary task by relation to junction for truck data.

Relation to Junction	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Non-junction	**1.61***	1.42	1.83	**2.04***	1.77	2.34
Intersection	0.84	0.60	1.19	1.17	0.78	1.74
Intersection-related	0.63	0.40	0.99	0.97	0.56	1.70
Entrance/exit ramp	1.80	0.95	3.41	**3.39***	1.55	7.43
Interchange area	0.94	0.73	1.20	**1.53***	1.14	2.07
Parking lot entrance/exit	1.07	0.77	1.47	**1.59***	1.05	2.40
Parking lot, within boundary	0.73	0.31	1.70	1.06	0.40	2.84
Driveway, alley access, etc.	1.40	0.94	2.08	**2.37***	1.48	3.81

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

Table 41. PAR and 95-percent confidence intervals for the interaction of any secondary task by relation to junction for truck data.

Relation to Junction	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Non-junction	22.83	22.26	23.39	33.42	32.83	34.01
Entrance/exit ramp	-	-	-	48.95	46.35	51.56
Interchange area	-	-	-	18.74	17.46	20.01
Parking lot entrance/exit	-	-	-	22.91	20.99	24.83
Driveway, alley access, etc.	-	-	-	42.43	40.51	44.36

4.4.4 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). It also indicates whether a roadway 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 42 and Table 43 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for motorcoach data.

Table 42. ORs and 95-percent confidence intervals for the interaction of any secondary task by traffic flow for motorcoach data.

Traffic Flow	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Not divided: two-way traffic	**1.36***	1.05	1.76	**1.43***	1.04	1.98
Not divided: center turn lane	1.42	0.74	2.73	2.23	0.82	6.08
Divided: median strip/barrier	**1.63***	1.39	1.90	**2.62***	2.15	3.20
One-way traffic	1.19	0.94	1.52	**1.85***	1.36	2.52
No lanes	1.65	0.64	4.21	1.39	0.47	4.16

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

Table 43. PAR and 95-percent confidence intervals for the interaction of any secondary task by traffic flow for motorcoach data.

Traffic Flow	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Not divided: two-way traffic	12.24	11.23	13.24	14.39	13.10	15.67
Divided: median strip/barrier	15.35	14.84	15.86	32.03	31.35	32.71
One-way traffic	-	-	-	21.99	20.94	23.05

Table 44 and Table 45 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for truck data.

Table 44. ORs and 95-percent confidence intervals for the interaction of any secondary task by traffic flow for truck data.

Traffic Flow	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Not divided: two-way traffic	**1.41***	1.18	1.68	**1.90***	1.56	2.32
Not divided: center turn lane	0.64	0.39	1.06	1.05	0.53	2.09
Divided: median strip/barrier	**1.28***	1.14	1.44	**1.84***	1.61	2.11
One-way traffic	1.10	0.66	1.82	1.78	0.98	3.24
No lanes	0.82	0.38	1.79	1.04	0.43	2.54

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

Table 45. PAR and 95-percent confidence intervals for the interaction of any secondary task by traffic flow for truck data.

Traffic Flow	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
Not divided: two-way traffic	17.13	16.31	17.95	31.29	30.42	32.16
Divided: median strip/barrier	11.68	11.14	12.21	28.15	27.58	28.72

4.4.5 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.[103] LOS A includes 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 impact to 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 guaranteed. In LOS D, speeds are somewhat reduced, and motorists are closed in by other cars and trucks. In LOS E, flow becomes irregular. Speed varies rapidly but rarely reaches the posted limit. There is a forced flow in LOS F, the lowest measurement of efficiency for a road's performance. Every vehicle moves in lockstep with the vehicle in front of it, with frequent drops in speed to nearly 0 mi/h.(104) Data analysts were instructed to use the video data to assist in determining the appropriate LOS. Reductionists 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 below normal capacity; queues form in particular locations.

Table 46 and Table 47 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for motorcoach data.

Table 46. ORs and 95-percent confidence intervals for the interaction of any secondary task by traffic density for motorcoach data.

Traffic Density	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
LOS A1	**2.45***	1.77	3.39	**2.92***	2.01	4.24
LOS A2	**2.22***	1.67	2.95	**3.86***	2.66	5.62
LOS B	**1.48***	1.24	1.77	**2.14***	1.69	2.71
LOS C	**1.91***	1.36	2.69	**2.35***	1.54	3.59
LOS D	**1.89***	1.14	3.14	**1.95***	1.05	3.63
LOS E	1.26	0.72	2.23	**2.53***	1.31	4.87
LOS F	**3.83***	1.19	12.29	**-**	-	-

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

Table 47. PAR and 95-percent confidence intervals for the interaction of any secondary task by traffic density for motorcoach data.

Traffic Density	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
LOS A1	34.92	33.73	36.12	41.45	40.11	42.79
LOS A2	29.00	27.96	30.04	49.03	47.79	50.26
LOS B	11.93	11.40	12.47	24.18	23.41	24.94
LOS C	17.96	17.09	18.83	24.52	23.34	25.71
LOS D	14.48	13.37	15.59	15.29	13.83	16.76
LOS E	**-**	-	-	24.44	22.60	26.28
LOS F	38.88	35.81	41.95	**-**	-	-

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

Table 48 and Table 49 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for truck data.

Table 48. ORs and 95-percent confidence intervals for the interaction of any secondary task by traffic density for truck data.

Traffic Density	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
LOS A1	**1.75***	1.50	2.04	**2.05***	1.74	2.42
LOS A2	**2.57***	2.01	3.29	3.37	2.55	4.45
LOS B	0.98	0.84	1.15	**1.42***	1.17	1.73
LOS C	0.59	0.37	0.94	0.70	0.40	1.25
LOS D	0.46	0.15	1.41	0.88	0.27	2.89
LOS E	0.30	0.09	1.02	-	-	-

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

Table 49. PAR and 95-percent confidence intervals for the interaction of any secondary task by traffic density for truck data.

Traffic Density	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
LOS A1	27.41	26.72	28.10	34.52	33.82	35.22
LOS A2	42.73	41.79	43.68	-	-	-
LOS B	-	-	-	15.97	15.11	16.83

4.4.6 Locality

"Locality" denotes 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.
- Business/industrial.
- Playground.
- Urban.
- Interstate.
- Residential.
- Church.
- School.
- Airport.

Table 50 and Table 51 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for motorcoach data.

Table 50. ORs and 95-percent confidence intervals for the interaction of any secondary task by locality for motorcoach data.

Locality	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Open country	2.21	0.95	5.12	**2.96***	1.17	7.49
Residential	**1.91***	1.12	3.25	**2.06***	1.13	3.79
Business/industrial	1.16	0.91	1.47	1.36	0.98	1.87
School	1.52	0.71	3.25	1.85	0.64	5.31
Urban	0.80	0.48	1.31	1.26	0.66	2.41
Airport	1.07	0.81	1.43	**1.53***	1.06	2.20
Interstate	**1.79***	1.50	2.13	**2.89***	2.33	3.59

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

Table 51. PAR and 95-percent confidence intervals for the interaction of any secondary task by locality for motorcoach data.

Locality	PAR OR	ALL LCL	ALL UCL	PAR OR	V1 LCL	V1 UCL
Open country	-	-	-	39.12	35.98	42.27
Residential	27.53	25.42	29.63	30.73	28.33	33.13
Airport	-	-	-	15.58	14.30	16.87
Interstate	18.31	17.74	18.88	34.93	34.20	35.65

Table 52 and Table 53 show the results of the OR calculations for each lighting level analysis and PAR percentage for each of the significant OR calculations for truck data.

Table 52. ORs and 95-percent confidence intervals for the interaction of any secondary task by locality for truck data.

Locality	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
Open country	1.18	0.68	2.07	1.40	0.77	2.54
Residential	**1.74***	1.34	2.26	**2.09***	1.57	2.80
Business/industrial	0.89	0.75	1.05	**1.36***	1.10	1.69
School	2.34	0.76	7.21	-	-	-
Urban	0.39	0.11	1.39	-	-	-
Interstate	**1.46***	1.28	1.66	**2.02***	1.75	2.33

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

Table 53. PAR and 95-percent confidence intervals for the interaction of any secondary task by locality for truck data.

Locality	PAR OR	ALL LCL	ALL UCL	PAR OR	V1 LCL	V1 UCL
Residential	27.13	25.97	28.30	35.54	34.33	36.74
Business/industrial	-	-	-	15.10	14.09	16.10
Interstate	17.48	16.91	18.05	31.98	31.39	32.58

4.5 RESEARCH QUESTION 4: WHAT ARE THE ORs OF EYES OFF FORWARD ROADWAY? DOES EYES OFF FORWARD ROADWAY SIGNIFICANTLY AFFECT SAFETY AND/OR DRIVING PERFORMANCE?

This research question intended to measure visual distraction using eye glance analysis. Answers are based on all SCEs and baseline epochs with valid eye glance data. Eye glance location data were collected frame-by-frame for up to 30 seconds per event, as discussed in Chapter 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.[105,106] The entire 6 seconds was analyzed for all baseline epochs. Valid eye glance data meant that eye glance analysis on the entire 6-second window around the event was possible (i.e., no shadows, camera malfunctions, or other issues blocked the view of the driver's eyes).

4.5.1 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., non-forward eye glance locations) were combined to determine the total eyes off forward roadway time for each 6-second interval (i.e., the total time 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 54 illustrates the 2×2 contingency table used to calculate the ORs for the eyes off forward roadway time analysis.

Table 54. 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 55 shows the frequency of SCEs and baseline epochs across All and V1 At-fault events for each (total) eyes off forward roadway duration grouping for motorcoach data.

Table 55. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for total eyes off forward roadway for motorcoach data.

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	31	120	21	120
Greater than 0.5 seconds but less than or equal to 1.0 second	78	327	46	327
Greater than 1.0 second but less than or equal to 1.5 seconds	85	295	57	295
Greater than 1.5 seconds but less than or equal to 2.0 seconds	59	156	35	156
Greater than 2.0 seconds	191	384	146	384

Table 56 displays the results of the OR calculations for each of the five eyes off forward roadway time bins across All events and V1 At-fault events for the motorcoach data. The results indicate that a total eyes off forward roadway duration time of 2.0 seconds or greater had a significant OR for All events. There is a total eyes off forward roadway duration time of 1.5 seconds or greater for V1 At-fault events. These data were compared to events with complete forward eyeglance.

Table 56. ORs and 95-percent confidence intervals to assess likelihood of an SCE while eyes were off the forward roadway across All and V1 At-fault events for motorcoach data.

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	0.86	0.54	1.35	1.30	0.74	2.28
Greater than 0.5 seconds but less than or equal to 1.0 second	0.75	0.54	1.05	1.07	0.69	1.65
Greater than 1.0 second but less than or equal to 1.5 seconds	0.95	0.69	1.31	1.44	0.95	2.19
Greater than 1.5 seconds but less than or equal to 2.0 seconds	1.24	0.85	1.81	**1.69***	1.04	2.74
Greater than 2.0 seconds	**1.50***	1.13	1.98	**2.77***	1.94	3.96

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

Table 57 shows the frequency of SCEs and baseline epochs across All and V1 At-fault events for each total eyes off forward roadway duration grouping for truck data.

Table 57. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for total eyes off forward roadway for truck data.

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	55	236	42	236
Greater than 0.5 seconds but less than or equal to 1.0 second	124	592	90	592
Greater than 1.0 second but less than or equal to 1.5 seconds	139	527	118	527
Greater than 1.5 seconds but less than or equal to 2.0 seconds	105	350	88	350
Greater than 2.0 seconds	543	942	659	1,299

Table 58 displays the results of the OR calculations for each of the five eyes off forward roadway time bins across All events and V1 At-fault events for the truck data. The results indicate that a total eyes off forward roadway duration time 1.5 seconds or greater had a significant OR for All events, and a total eyes off forward roadway duration time of 1.0 seconds or greater for V1 At-fault events compared to events with complete forward eyeglance.

Table 58. ORs and 95-percent confidence intervals to assess likelihood of an SCE while eyes were off the forward roadway across All and V1 At-fault events for truck data.

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	1.17	0.82	1.66	1.43	0.95	2.15
Greater than 0.5 seconds but less than or equal to 1.0 second	0.99	0.75	1.29	1.10	0.80	1.51
Greater than 1.0 second but less than or equal to 1.5 seconds	1.28	0.98	1.67	**1.72***	1.27	2.33
Greater than 1.5 seconds but less than or equal to 2.0 seconds	**1.45***	1.07	1.95	**1.94***	1.39	2.73
Greater than 2.0 seconds	**2.73***	2.21	3.37	**4.05***	3.18	5.17

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

4.5.2 Duration of Eyes Off Forward Roadway

"Duration of eyes off forward roadway" was 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, near-crash, crash-relevant conflict, unintentional lane deviation, and baseline epochs) across All and V1 At-fault events.

Figure 19 shows the mean eyes off forward roadway duration for each event type across All and V1 At-fault events for secondary tasks for motorcoach data. A one-way ANOVA found a significant difference in the mean eyes off forward roadway duration between the five event types across All events and V1 At-fault events.

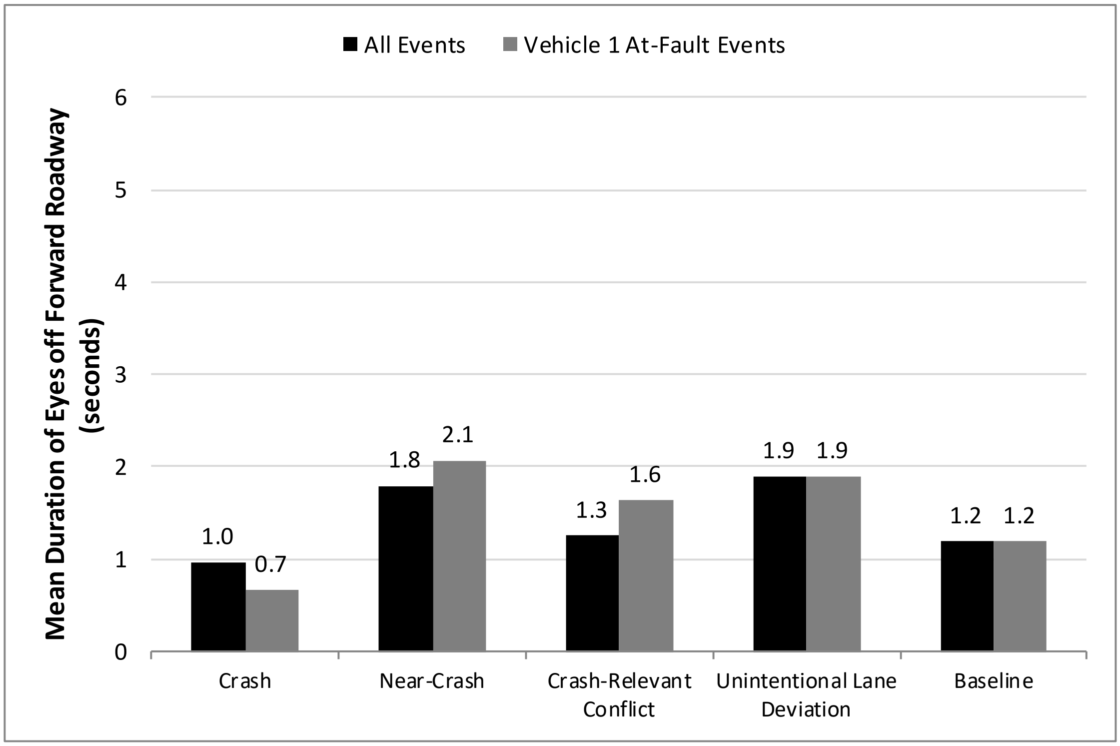

Figure 19. Graph. Mean eyes off forward roadway duration by event type for secondary tasks for motorcoach data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations of event types to determine simple effects. The results of the Tukey *t* tests are shown in Table 59 below.

Table 59. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for secondary tasks for motorcoach data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Crash and Near Crash	1.656	0.462	1.630	0.478
Crash and Crash-Relevant Conflict	0.575	0.979	1.133	0.789
Crash and Unintentional Lane Deviation	1.859	0.340	1.437	0.604
Crash and Baseline	0.457	0.991	0.617	0.972
Near Crash and Crash-Relevant Conflict	4.371	**0.0001***	2.491	0.093
Near Crash and Unintentional Lane Deviation	0.727	0.950	1.067	0.824
Near Crash and Baseline	5.830	**< 0.0001***	6.528	**< 0.0001***
Crash-Relevant Conflict and Unintentional Lane Deviation	5.327	**< 0.0001***	1.749	0.404
Crash-Relevant Conflict and Baseline	0.756	0.943	3.840	**0.001***
Unintentional Lane Deviation and Baseline	7.087	**< 0.0001***	7.086	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Figure 20 shows the mean eyes off forward roadway duration for each event type across All and V1 At-fault events for secondary tasks for truck data. A one-way ANOVA found a significant difference in the mean eyes off forward roadway duration between the five event types across All events and V1 At-fault events.

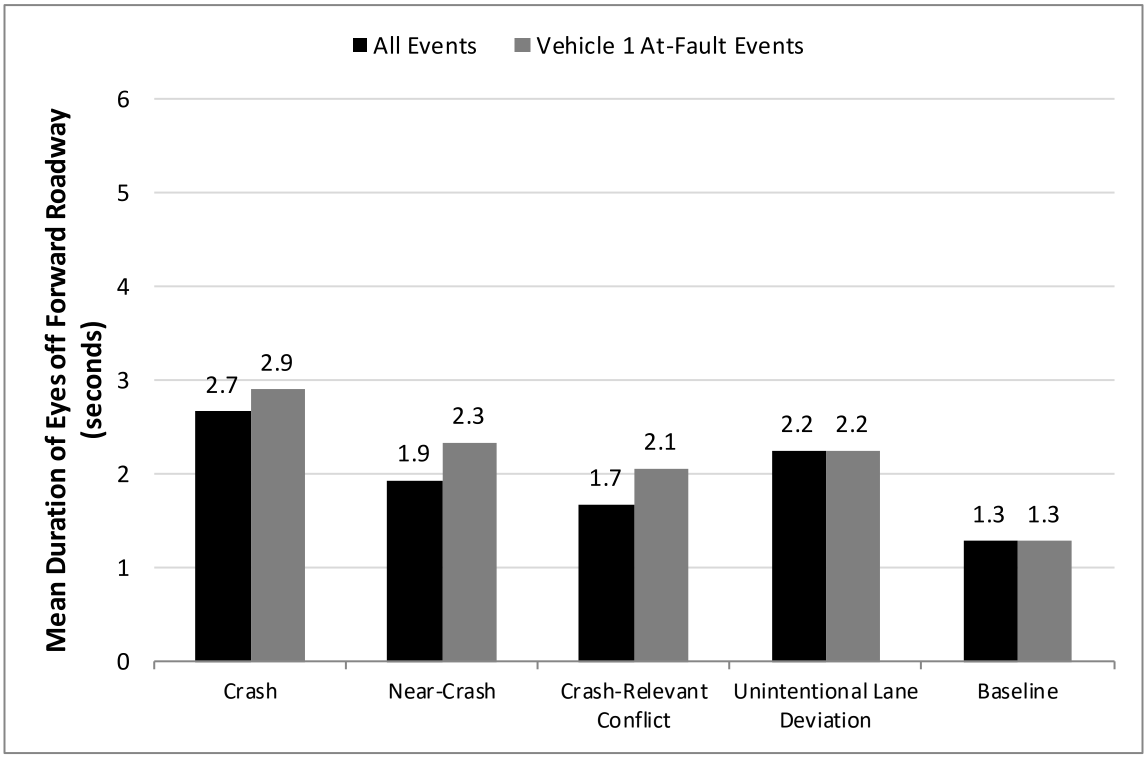

Figure 20. Graph. Mean eyes off forward roadway duration by event type for secondary tasks for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations of event types to determine simple effects. The results of the Tukey *t* tests are shown in Table 60 below.

Table 60. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for secondary tasks for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Crash and Near Crash	1.728	0.417	1.262	0.715
Crash and Crash-Relevant Conflict	2.405	0.114	1.940	0.296
Crash and Unintentional Lane Deviation	1.018	0.847	1.522	0.548
Crash and Baseline	3.388	**0.006***	3.784	**0.002***
Near Crash and Crash-Relevant Conflict	1.992	0.270	1.731	0.415
Near Crash and Unintentional Lane Deviation	2.505	0.090	0.598	0.976
Near Crash and Baseline	5.619	**< 0.0001***	7.520	**< 0.0001***
Crash-Relevant Conflict and Unintentional Lane Deviation	6.917	**< 0.0001***	1.985	**< 0.0001***
Crash-Relevant Conflict and Baseline	5.671	**< 0.0001***	9.362	**< 0.0001***
Unintentional Lane Deviation and Baseline	17.285	**< 0.0001***	17.365	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

4.5.2.1 Secondary Task Breakout Analyses

Additional ANOVAs were calculated on secondary tasks of interest that were shown to be significant in Research Questions 1 and 2. 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).

Motorcoach Data

Reach for Object: "Reach for object" was coded when drivers were observed reaching for objects such as clipboards, pens, personal bags, and pieces of paper. Figure 21 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

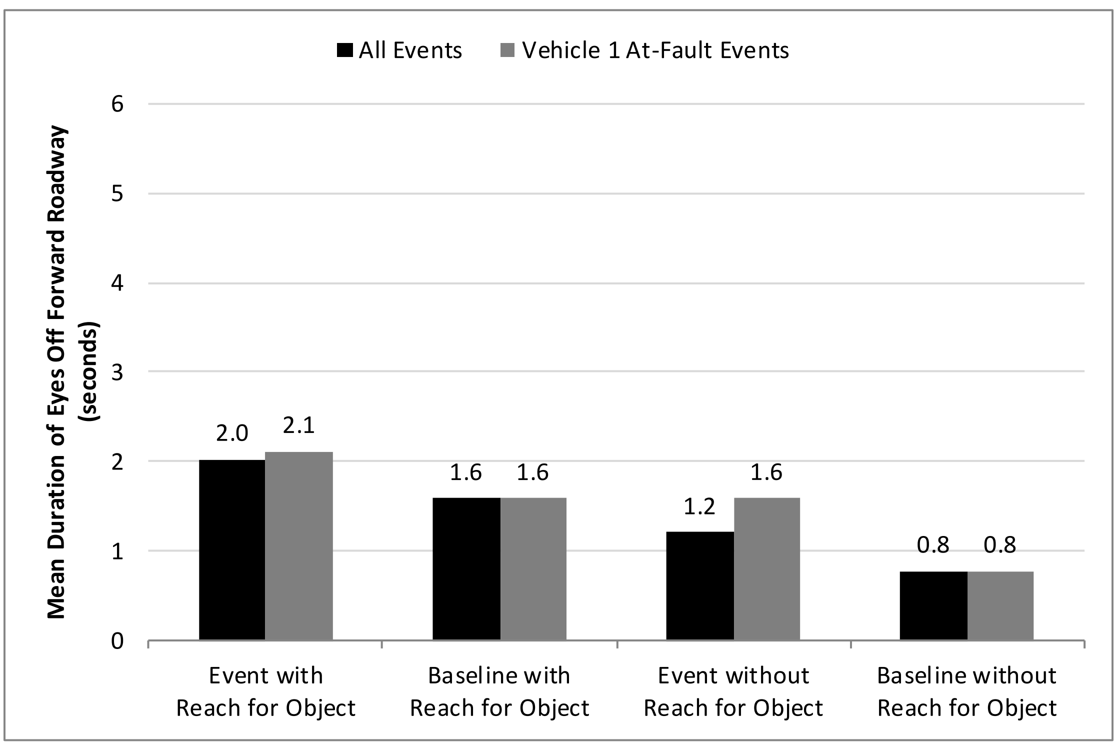

Figure 21. Graph. Mean eyes off forward roadway duration for "reach for object" for motorcoach data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 61 below.

Table 61. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "reach for object" for motorcoach data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with Reach for Object and Baseline with Reach for Object	1.727	0.310	1.892	0.232
Event with Reach for Object and Event without Reach for Object	4.339	**< 0.0001***	2.339	0.089
Event with Reach for Object and Baseline without Reach for Object	6.668	**< 0.0001***	6.049	**< 0.0001***
Event without Reach for Object and Baseline with Reach for Object	2.192	0.125	0.008	1.000
Event without Reach for Object and Baseline without Reach for Object	13.197	**< 0.0001***	18.799	**< 0.0001***
Baseline with Reach for Object and Baseline without Reach for Object	4.704	**< 0.0001***	4.770	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Intercom Use: "Intercom Use" was coded when data analysts observed the driver using the intercom system to communicate with vehicle passengers. Figure 22 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

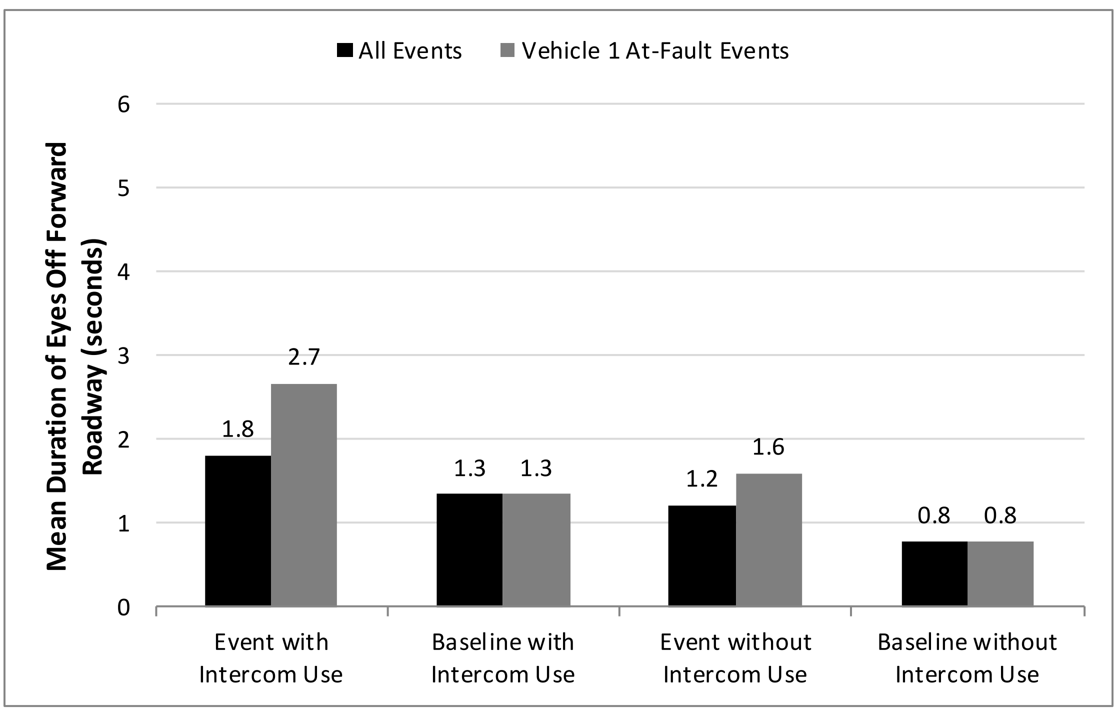

Figure 22. Graph. Mean eyes off forward roadway duration for "intercom use" for motorcoach data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 62 below.

Table 62. Results of Tukey *t* tests for mean eyes-off-forward roadway duration by event type for "intercom use" for motorcoach data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with Intercom Use and Baseline with Intercom Use	1.340	0.537	2.508	0.059
Event with Intercom Use and Event without Intercom Use	2.327	0.092	2.256	0.109
Event with Intercom Use and Baseline without Intercom Use	4.060	**0.0003***	3.989	**0.0004***
Event without Intercom Use and Baseline with Intercom Use	0.517	0.955	1.065	0.711
Event without Intercom Use and Baseline without Intercom Use	13.480	**< 0.0001***	19.137	**< 0.0001***
Baseline with Intercom Use and Baseline without Intercom Use	2.335	0.090	2.369	0.083

*Asterisk indicates a significant result. These p-values are also shown in bold.

Adjust Instrument Panel: "Adjust Instrument Panel" was coded when data analysts observed the driver adjusting the instrument panel. This may include adjusting the heating and/or cooling system; adjusting the radio; or adjusting anything else on the front dash of the motorcoach. Figure 23 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

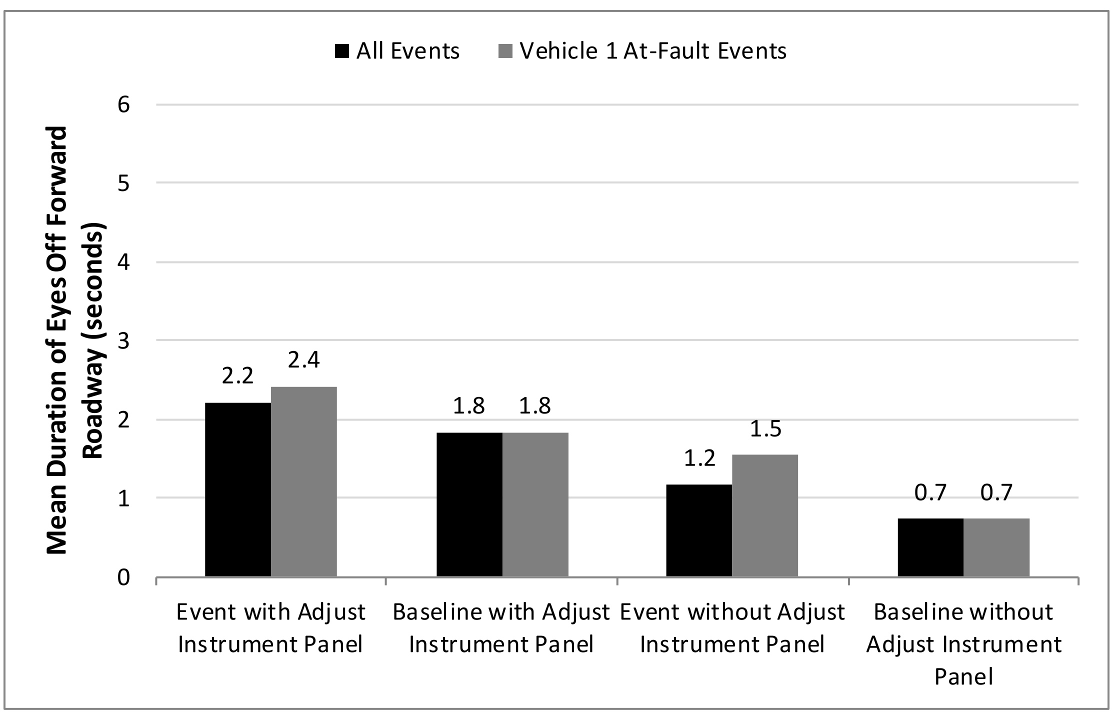

Figure 23. Graph. Mean eyes off forward roadway duration for "adjust instrument panel" for motorcoach data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 63 below.

Table 63. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "adjust instrument panel" for motorcoach data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with Adjust Instrument Panel and Baseline with Adjust Instrument Panel	2.587	**0.048***	3.468	**0.003***
Event with Adjust Instrument Panel and Event without Adjust Instrument Panel	7.875	**< 0.0001***	5.522	**< 0.0001***
Event with Adjust Instrument Panel and Baseline without Adjust Instrument Panel	11.366	**< 0.0001***	3.468	**0.003***
Event without Adjust Instrument Panel and Baseline with Adjust Instrument Panel	8.655	**< 0.0001***	3.593	**0.002***
Event without Adjust Instrument Panel and Baseline without Adjust Instrument Panel	13.502	**< 0.0001***	18.773	**< 0.0001***
Baseline with Adjust Instrument Panel and Baseline without Adjust Instrument Panel	15.182	**< 0.0001***	15.412	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

External Distraction: Observed "external distraction" 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 24 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

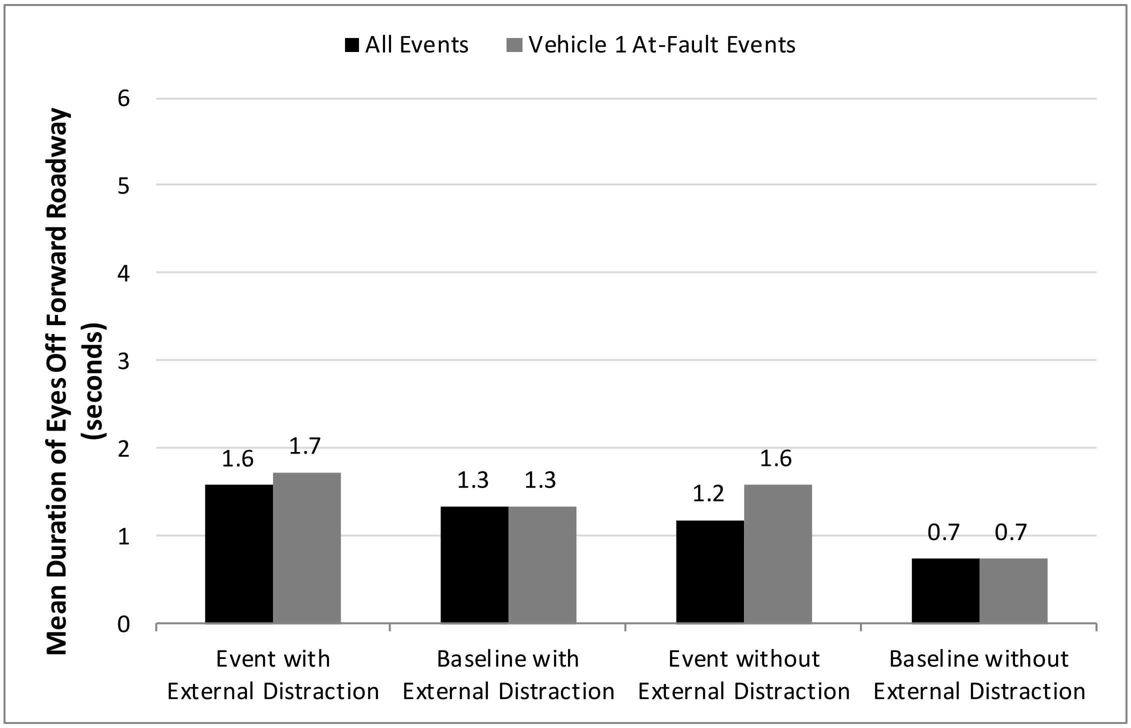

Figure 24. Graph. Mean eyes off forward roadway duration for "external distraction" for motorcoach data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 64 below.

Table 64. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "external distraction" for motorcoach data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with External Distraction and Baseline with External Distraction	2.202	0.123	3.043	**0.013***
Event with External Distraction and Event without External Distraction	4.012	**0.0004***	1.158	0.653
Event with External Distraction and Baseline without External Distraction	8.796	**< 0.0001***	8.559	**< 0.0001***
Event without External Distraction and Baseline with External Distraction	2.349	0.087	3.470	**0.003***
Event without External Distraction and Baseline without External Distraction	13.227	**< 0.0001***	18.748	**< 0.0001***
Baseline with External Distraction and Baseline without External Distraction	9.964	**< 0.0001***	10.111	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Truck Data

Reading: "Reading" was coded when drivers were observed reading materials such as paperwork, magazines, newspapers, or books. Figure 25 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

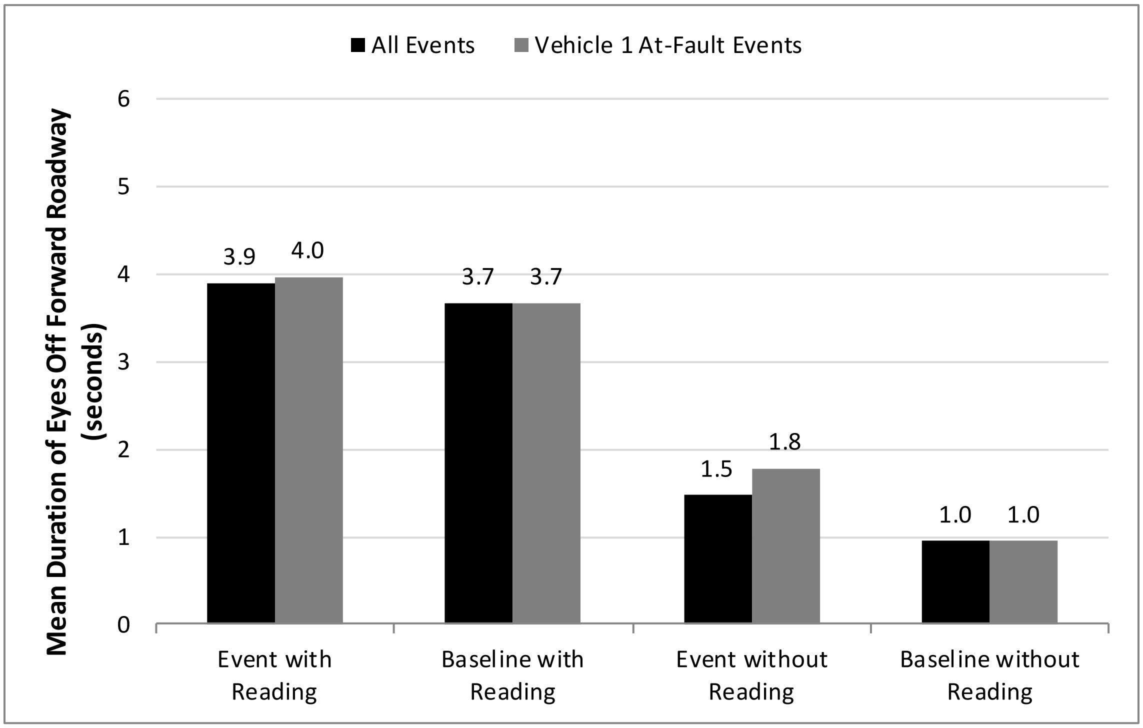

Figure 25. Graph. Mean eyes off forward roadway duration for "reading" for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 65 below.

Table 65. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "reading" for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with Reading and Baseline with Reading	0.514	0.956	0.804	0.853
Event with Reading and Event without Reading	7.743	**< 0.0001***	0.325	0.988
Event with Reading and Baseline without Reading	9.437	**< 0.0001***	2.367	0.084
Event without Reading and Baseline with Reading	7.018	**< 0.0001***	1.035	0.729
Event without Reading and Baseline without Reading	17.747	**< 0.0001***	16.175	**< 0.0001***
Baseline with Reading and Baseline without Reading	8.711	**< 0.0001***	6.033	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Reach for Object: "Reach for object" was coded when drivers were observed reaching for objects such as clipboards, pens, personal bags, and pieces of paper. Figure 21 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

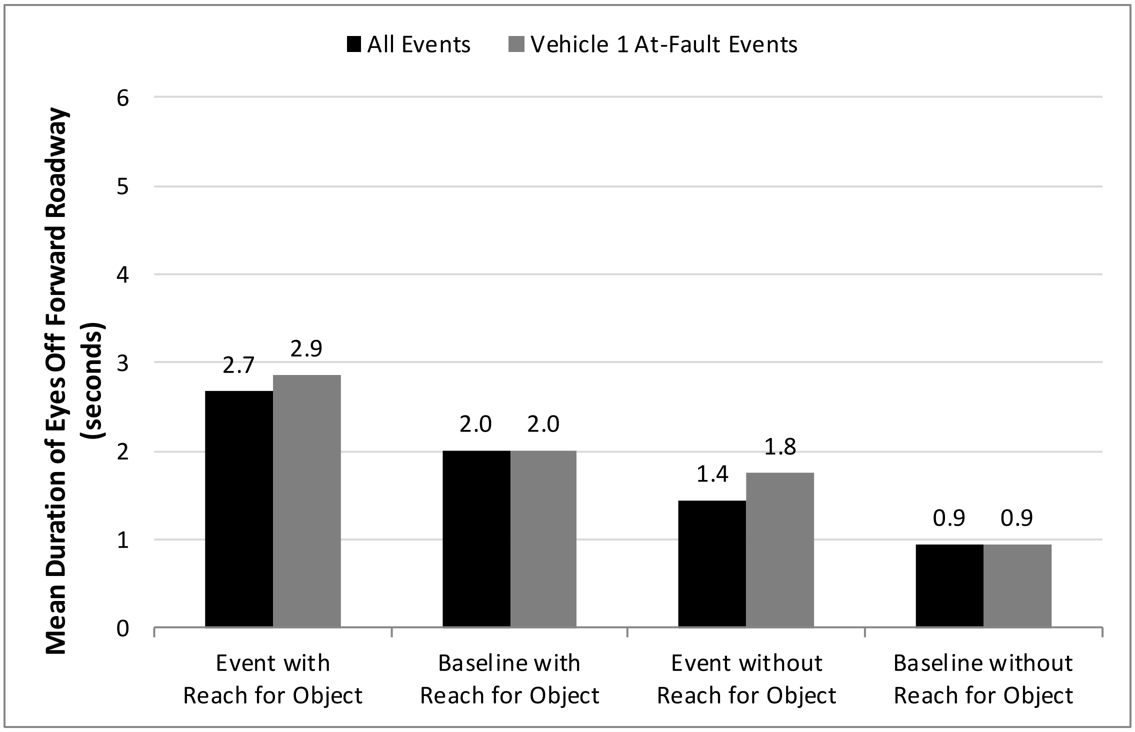

Figure 26. Graph. Mean eyes off forward roadway duration for "reach for object" for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 66 below.

Table 66. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "reach for object" for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with Reach for Object and Baseline with Reach for Object	3.236	**0.007***	4.053	**0.0003***
Event with Reach for Object and Event without Reach for Object	8.793	**< 0.0001***	7.471	**< 0.0001***
Event with Reach for Object and Baseline without Reach for Object	12.515	**< 0.0001***	13.136	**< 0.0001***
Event without Reach for Object and Baseline with Reach for Object	3.631	**0.002***	1.654	0.348
Event without Reach for Object and Baseline without Reach for Object	16.741	**< 0.0001***	23.909	**< 0.0001***
Baseline with Reach for Object and Baseline without Reach for Object	6.911	**< 0.0001***	6.967	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Electronic Dispatching Device: "Electronic Dispatching Device" was coded when drivers were observed interacting with the electronic dispatching device, which was typically mounted to their right, between the two seats. Figure 27 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

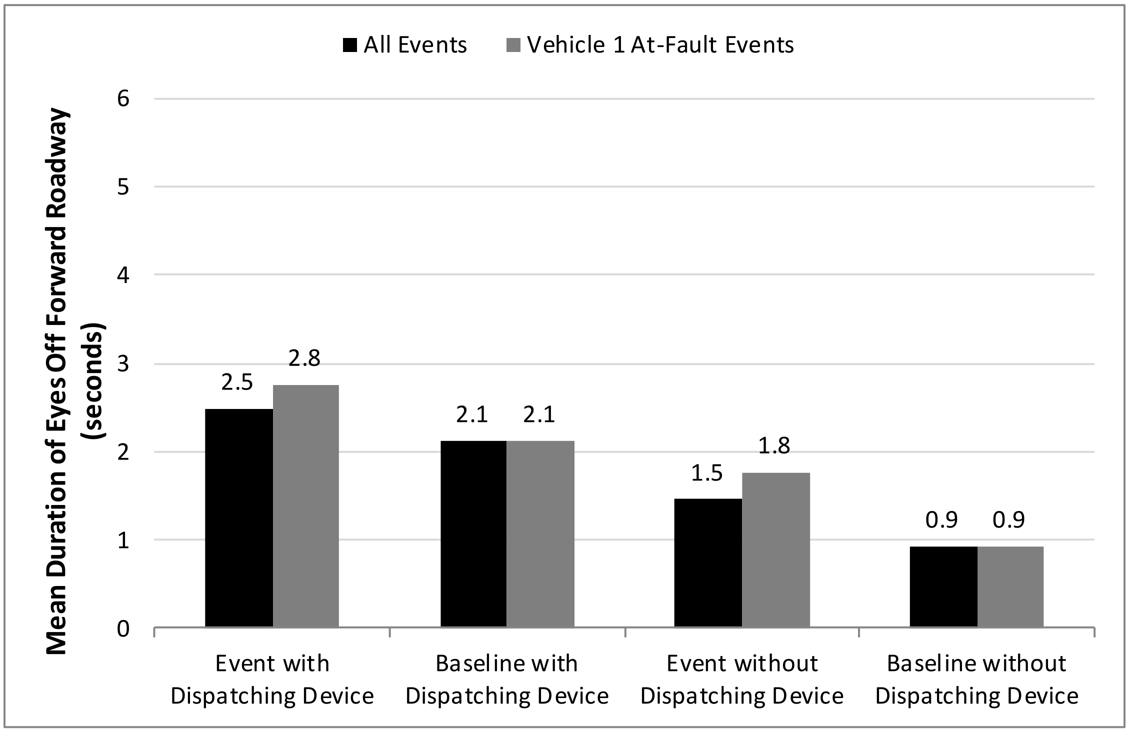

Figure 27. Graph. Mean eyes off forward roadway duration for "electronic dispatching device" for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 67 below.

Table 67. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "electronic dispatching device" for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with Electronic Dispatching Device and Baseline with Electronic Dispatching Device	1.997	0.189	3.296	**0.005***
Event with Electronic Dispatching Device and Event without Electronic Dispatching Device	6.476	**< 0.0001***	5.779	**< 0.0001***
Event with Electronic Dispatching Device and Baseline without Electronic Dispatching Device	9.919	**< 0.0001***	3.296	**0.005***
Event without Electronic Dispatching Device and Baseline with Electronic Dispatching Device	6.693	**< 0.0001***	3.555	**0.002***
Event without Electronic Dispatching Device and Baseline without Electronic Dispatching Device	17.918	**< 0.0001***	25.094	**< 0.0001***
Baseline with Electronic Dispatching Device and Baseline without Electronic Dispatching Device	12.375	**< 0.0001***	12.488	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

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 28 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

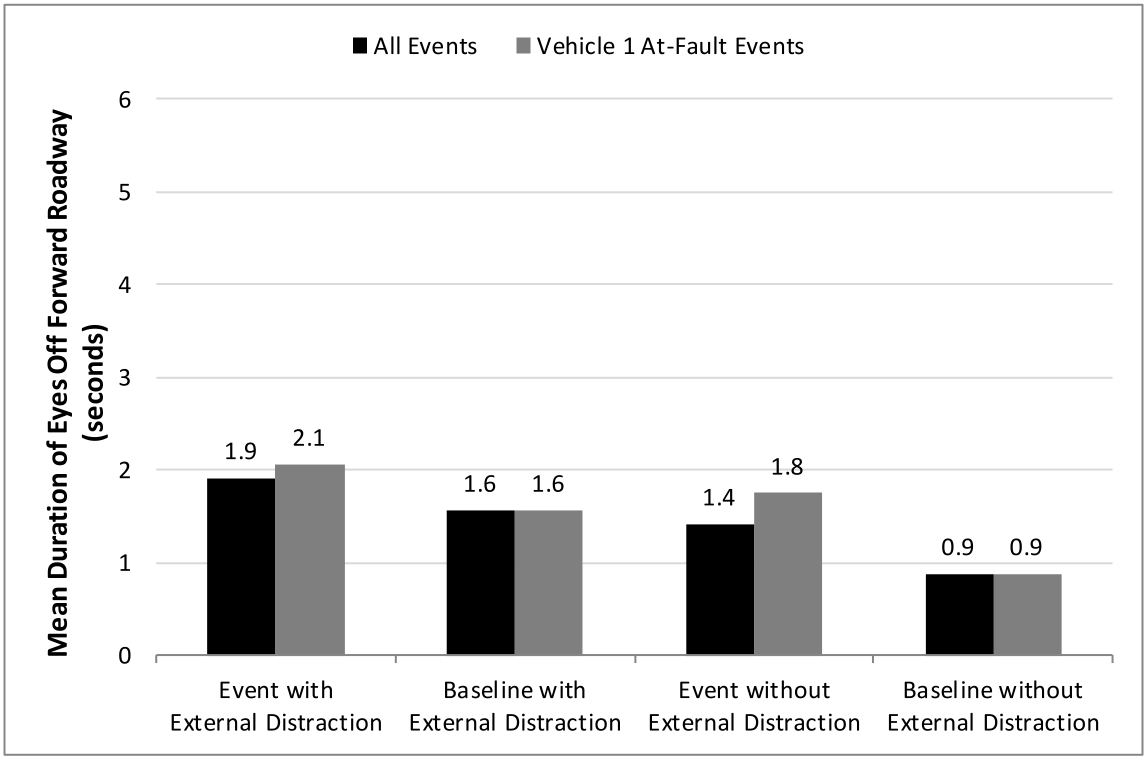

Figure 28. Graph. Mean eyes off forward roadway duration for "external distraction" for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 68 below.

Table 68. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "external distraction" for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with External Distraction and Baseline with External Distraction	4.410	**< 0.0001***	5.880	**< 0.0001***
Event with External Distraction and Event without External Distraction	6.818	**< 0.0001***	3.878	**0.001***
Event with External Distraction and Baseline without External Distraction	14.933	**< 0.0001***	15.779	**< 0.0001***
Event without External Distraction and Baseline with External Distraction	2.929	**0.018***	3.487	**0.003***
Event without External Distraction and Baseline without External Distraction	17.124	**< 0.0001***	24.286	**< 0.0001***

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Baseline with External Distraction and Baseline without External Distraction	15.359	**< 0.0001***	15.486	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Cell Phone Browsing: "Browsing" was coded when drivers were observed looking at and interacting with their cell phones in a manner that appeared to be browsing only and not dialing or texting. Figure 29 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

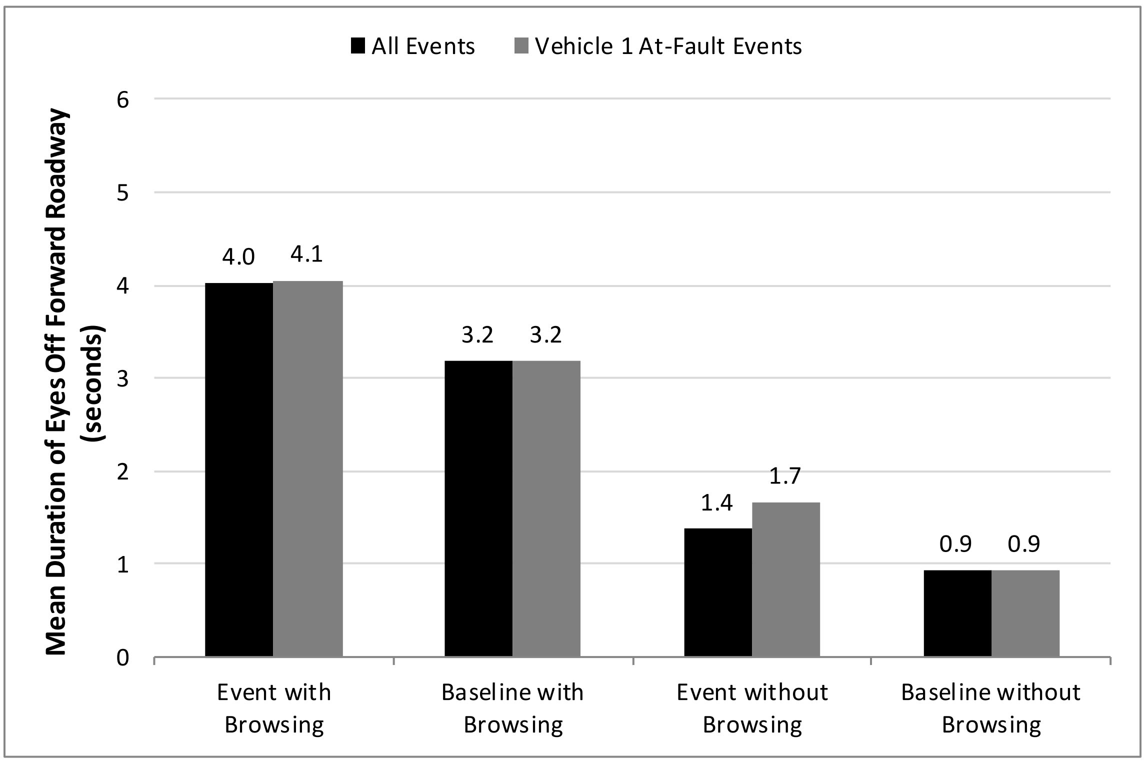

Figure 29. Graph. Mean eyes off forward roadway duration for "browsing" for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 69 below.

Table 69. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "browsing" for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with Browsing and Baseline with Browsing	4.460	**< 0.0001***	4.630	**< 0.0001***
Event with Browsing and Event without Browsing	21.052	**< 0.0001***	10.501	**< 0.0001***
Event with Browsing and Baseline without Browsing	24.959	**< 0.0001***	4.630	**< 0.0001***
Event without Browsing and Baseline with Browsing	12.492	**< 0.0001***	10.501	**< 0.0001***

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event without Browsing and Baseline without Browsing	15.273	**< 0.0001***	22.142	**< 0.0001***
Baseline with Browsing and Baseline without Browsing	15.741	**< 0.0001***	15.843	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Cell Phone Texting: "Texting" was coded when drivers were observed texting on their cell phones in a manner that appeared to be texting only and not dialing or browsing. Figure 30 shows the mean duration of eyes off forward roadway across All and V1 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 and V1 At-fault events.

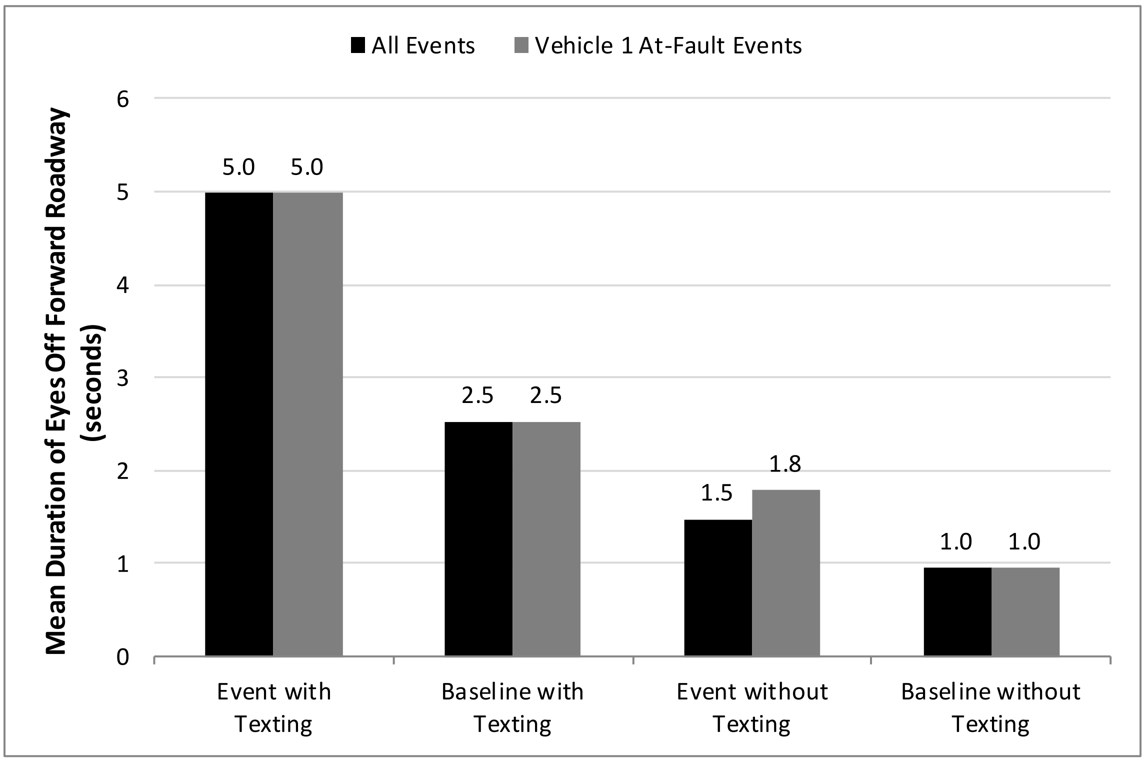

Figure 30. Graph. Mean eyes off forward roadway duration for "texting" for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations. The results of the Tukey *t* tests are shown in Table 70 below.

Table 70. Results of Tukey *t* tests for mean eyes off forward roadway duration by event type for "texting" for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event with Texting and Baseline with Texting	3.926	**0.001***	3.960	**0.0004***
Event with Texting and Event without Texting	7.078	**< 0.0001***	6.505	**< 0.0001***
Event with Texting and Baseline without Texting	8.149	**< 0.0001***	8.220	**< 0.0001***
Event without Texting and Baseline with Texting	2.734	**0.032***	1.942	0.211

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Event without Texting and Baseline without Texting	17.839	**< 0.0001***	25.129	**< 0.0001***
Baseline with Texting and Baseline without Texting	4.112	**0.0002***	4.147	**0.0002***

*Asterisk indicates a significant result. These p-values are also shown in bold.

4.5.3 Number of Glances Away From Forward Roadway

"Number of glances away from forward roadway" was defined as the number of glances away from the forward roadway during the 6-second interval or epoch period sampled for SCEs and baselines. This may include partial glances captured at either the beginning or end of the 6-second interval. A glance was operationally defined as any time a driver took their eyes off the forward roadway, regardless of where they 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, near-crash, crash-relevant conflict, unintentional lane deviation, and baseline epochs) across All and V1 At-fault events.

Figure 31 shows the mean number of glances away from the forward roadway for each event type across All and V1 At-fault events for secondary tasks for motorcoach data. A one-way ANOVA found a significant difference in the mean eyes off forward roadway duration between the five event types across All events and V1 At-fault events.

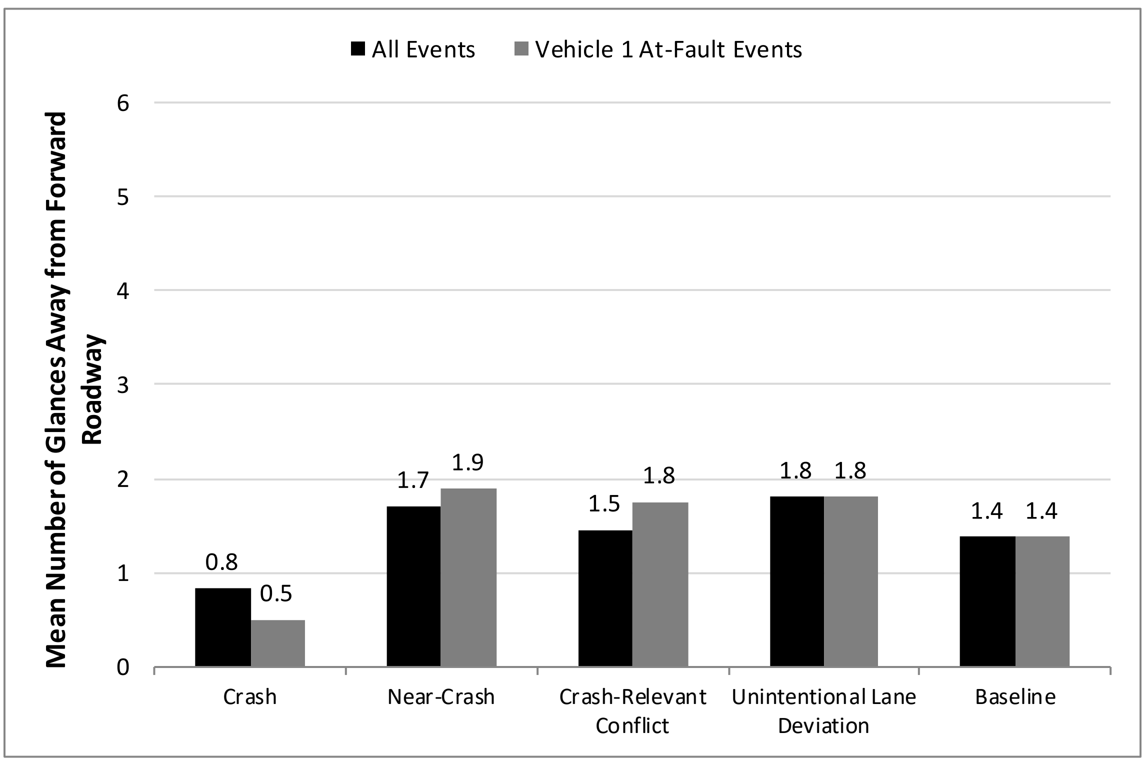

Figure 31. Graph. Mean number of glances away from the forward roadway by event type for secondary tasks for motorcoach data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations of event types to determine simple effects. The results of the Tukey *t* tests are shown in Table 71 below.

Table 71. Results of Tukey *t* tests for mean number of glances away from the forward roadway by event type for secondary tasks for motorcoach data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Crash and Near Crash	1.810	0.368	1.696	0.437
Crash and Crash-Relevant Conflict	1.303	0.690	1.532	0.542
Crash and Unintentional Lane Deviation	2.023	0.255	1.599	0.498
Crash and Baseline	1.150	0.780	1.080	0.817
Near Crash and Crash-Relevant Conflict	2.088	0.226	0.839	0.919
Near Crash and Unintentional Lane Deviation	0.761	0.942	0.560	0.981
Near Crash and Baseline	3.290	**0.009***	4.018	**0.001***
Crash-Relevant Conflict and Unintentional Lane Deviation	3.015	**0.022***	0.369	0.996
Crash-Relevant Conflict and Baseline	1.014	0.849	3.395	**0.006***
Unintentional Lane Deviation and Baseline	4.485	**< 0.0001***	4.519	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Figure 32 shows the mean number of glances away from the forward roadway for each event type across All and V1 At-fault events for secondary tasks for truck data. A one-way ANOVA found a significant difference in the mean eyes off forward roadway duration between the five event types across All events and V1 At-fault events.

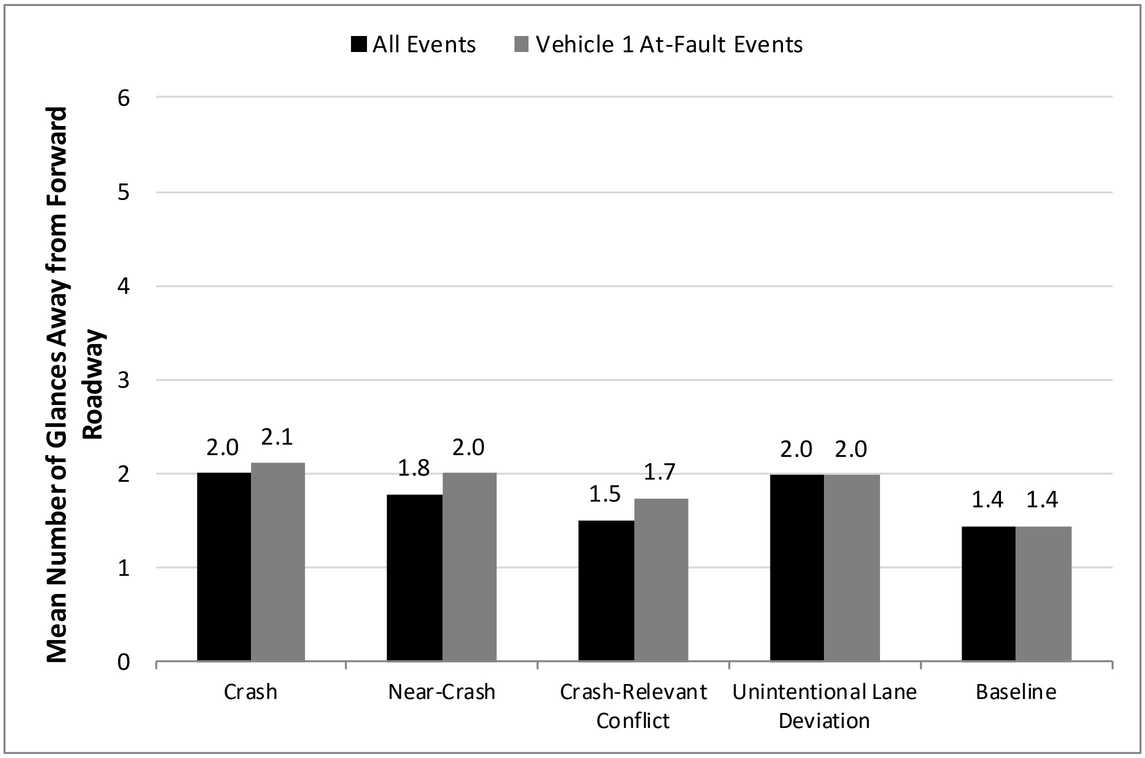

Figure 32. Graph. Mean number of glances away from the forward roadway by event type for secondary tasks for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations of event types to determine simple effects. The results of the Tukey *t* tests are shown in Table 72 below.

Table 72. Results of Tukey *t* tests for mean number of glances away from the forward roadway by event type for secondary tasks for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Crash and Near Crash	0.562	0.981	0.268	0.999
Crash and Crash-Relevant Conflict	1.303	0.689	0.925	0.887
Crash and Unintentional Lane Deviation	0.050	1.000	0.327	0.998
Crash and Baseline	1.479	0.576	1.685	0.443
Near Crash and Crash-Relevant Conflict	2.286	0.150	1.766	0.394
Near Crash and Unintentional Lane Deviation	1.737	0.411	0.140	1.000
Near Crash and Baseline	3.154	**0.014***	4.294	**0.0002***
Crash-Relevant Conflict and Unintentional Lane Deviation	6.226	**< 0.0001***	2.755	**0.047***
Crash-Relevant Conflict and Baseline	0.955	0.875	3.847	**0.001***
Unintentional Lane Deviation and Baseline	10.442	**< 0.0001***	10.450	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

4.5.4 Length of Longest Glance Away From Forward Roadway

"Length of longest glance away from forward roadway" was defined as the longest single glance during which the driver was not looking forward during the 6-second SCE or baseline epoch. As in the previous analysis, this may include glances that fall partially outside the 6-second interval. The analyses in this section were grouped by event type (i.e., crash, near-crash, crash-relevant conflict, unintentional lane deviations) across All and V1 At-fault events.

Figure 33 shows the mean length of longest glance away from forward roadway for each event type across All and V1 At-fault events for secondary tasks for motorcoach data. A one-way ANOVA found a significant difference in the mean eyes off forward roadway duration between the five event types across All events and V1 At-fault events.

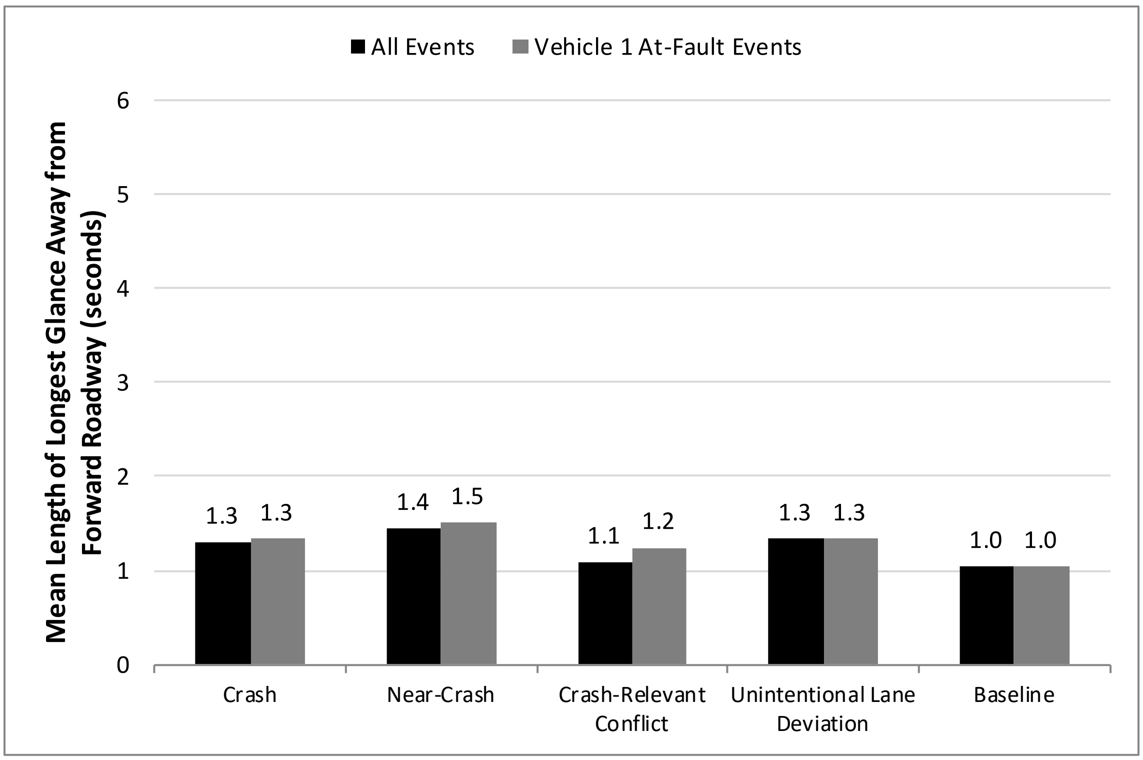

Figure 33. Graph. Mean length of longest glance away from the forward roadway by event type for secondary tasks for motorcoach data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations of event types to determine simple effects. The results of the Tukey *t* tests are shown in Table 73 below.

Table 73. Results of Tukey *t* tests for mean length of longest glance away from the forward roadway by event type for secondary tasks for motorcoach data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Crash and Near Crash	0.453	0.991	0.270	0.999
Crash and Crash-Relevant Conflict	0.658	0.965	0.140	1.000

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Crash and Unintentional Lane Deviation	0.107	1.000	0.002	1.000
Crash and Baseline	0.811	0.928	0.455	0.991
Near Crash and Crash-Relevant Conflict	4.796	**< 0.0001***	2.662	0.060
Near Crash and Unintentional Lane Deviation	1.398	0.629	1.874	0.332
Near Crash and Baseline	6.638	**< 0.0001***	6.121	**< 0.0001***
Crash-Relevant Conflict and Unintentional Lane Deviation	3.424	**0.006***	1.059	0.828
Crash-Relevant Conflict and Baseline	0.933	0.884	2.948	**0.027***
Unintentional Lane Deviation and Baseline	5.088	**< 0.0001***	5.053	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

Figure 34 shows the mean length of longest glance away from forward roadway for each event type across All and V1 At-fault events for secondary tasks for truck data. A one-way ANOVA found a significant difference in the mean eyes off forward roadway duration between the five event types across All events and V1 At-fault events.

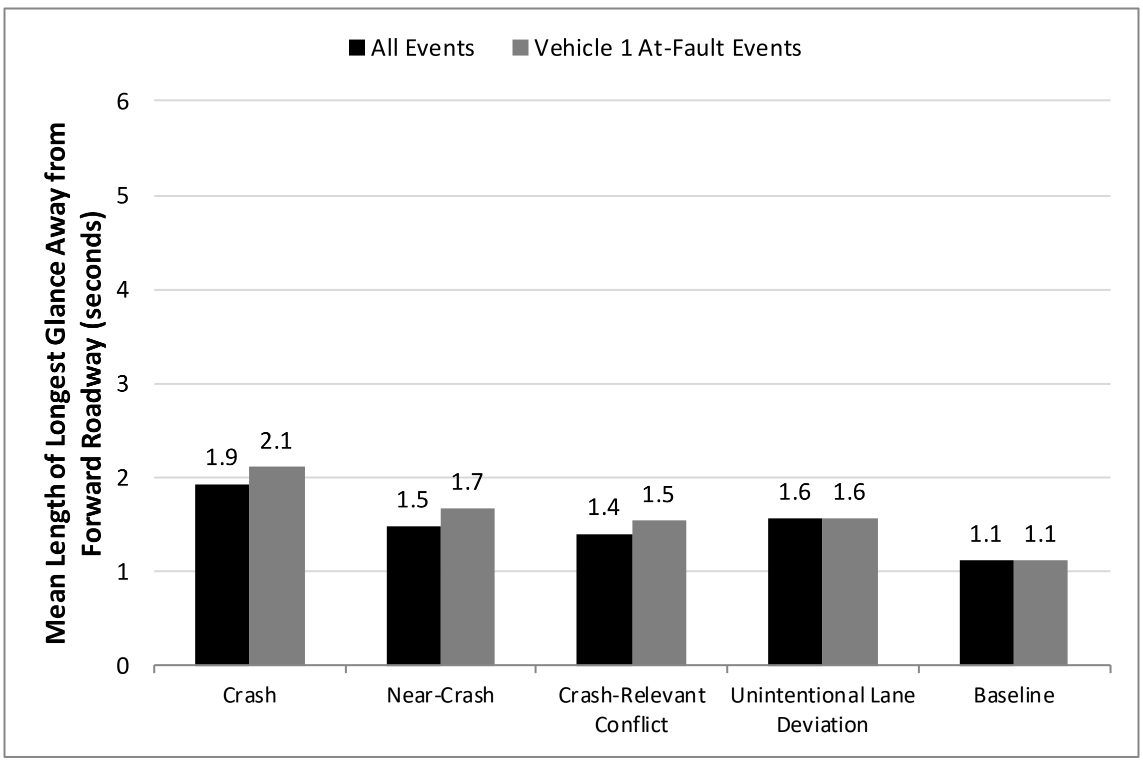

Figure 34. Graph. Mean length of longest glance away from the forward roadway by event type for secondary tasks for truck data.

As the ANOVA was significant, post-hoc Tukey *t* tests were conducted on all pair-wise combinations of event types to determine simple effects. The results of the Tukey *t* tests are shown in Table 74 below.

Table 74. Results of Tukey *t* tests for mean length of longest glance away from the forward roadway by event type for secondary tasks for truck data. Results are reported as absolute statistics for consistency.

Event Type	ALL t-value	ALL p-value	V1 t-value	V1 p-value
Crash and Near Crash	1.860	0.339	1.688	0.441
Crash and Crash-Relevant Conflict	2.246	0.163	2.278	0.152
Crash and Unintentional Lane Deviation	1.568	0.518	2.191	0.183
Crash and Baseline	3.501	**0.004***	4.021	**0.001***
Near Crash and Crash-Relevant Conflict	1.006	0.853	1.451	0.595
Near Crash and Unintentional Lane Deviation	1.115	0.799	1.247	0.724
Near Crash and Baseline	5.255	**< 0.0001***	6.845	**< 0.0001***
Crash-Relevant Conflict and Unintentional Lane Deviation	3.272	**0.010***	0.497	0.988
Crash-Relevant Conflict and Baseline	6.860	**< 0.0001***	8.774	**< 0.0001***
Unintentional Lane Deviation and Baseline	13.572	**< 0.0001***	13.608	**< 0.0001***

*Asterisk indicates a significant result. These p-values are also shown in bold.

4.6 RESEARCH QUESTION 5: WHAT IS THE PREVALENCE OF DRIVER DROWSINESS? WHAT ARE THE ORs AND PAR OF BEING IN AN SCE WHILE DROWSY?

4.6.1 Prevalence of Driver Drowsiness

Driver drowsiness was rated using two methods of fatigue measurement: ORD and PERCLOS. The baseline data for each vehicle type were used to assess prevalence of driver drowsiness. In the motorcoach data, 5,305 baseline events with ORD scores were used to assess driver drowsiness. Of these baselines, 24.60 percent (1,305 epochs) had scores in the “very drowsy” range, and 1.96 percent (104 epochs) had scores in the “extremely drowsy” range, with average scores of 62.50 or higher. Valid PERCLOS data were available for 2,288 motorcoach baseline epochs and 0.39 percent (9) of these epochs were above the PERCLOS fatigue threshold (score greater than 12 percent).

In the truck data, 1,962 baselines had a valid ORD score. “Moderate” drowsiness was observed in 48.67 percent (955) of these epochs and an additional 10.91 percent (214) of these epochs had scores in the “very” or “extremely” drowsy range. Valid PERCLOS data was available for 2,564 truck baseline epochs and 2.89 percent (74) of these epochs were above the PERCLOS fatigue threshold.

The prevalence of driver drowsiness in the motorcoach and truck data for both fatigue measurement methods is presented in Figure 35. In the figure below, ORD scores of “very” and “extremely” are rated as above the drowsiness threshold. For both the motorcoach and truck data, a larger percentage of baselines were over the fatigue threshold when using the ORD method as compared to the PERCLOS method.

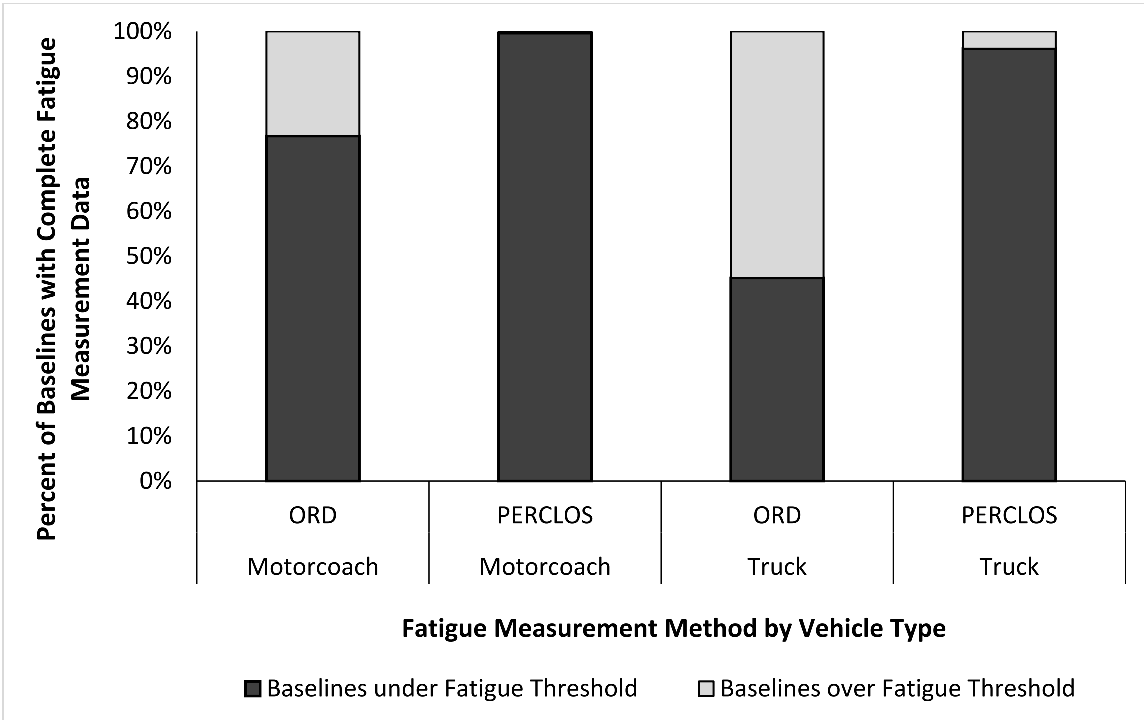

Figure 35. Graph. Drowsiness prevalence in motorcoach and truck data, measured by percent of baselines scored under or over a fatigue threshold using ORD and PERCLOS fatigue measurement methods.

4.6.2 ORs and PAR Percentage of Being in an SCE while Drowsy

In the following analysis, the odds of being in an SCE while drowsy were calculated using individual models for events with ORD data and those with PERCLOS data. The calculations were also performed using All SCEs and V1 At-fault SCEs. For ORD data, the epochs were compared in categories of "no," "low," or "moderate" drowsiness to "very" or "extremely" drowsy.

Motorcoach Data

Table 75 shows the number of truck baselines and SCEs with ORD or PERCLOS data and the average score for each fatigue measurement method. The average ORD score was 27.28 for baselines and 23.18 for SCEs. The average PERCLOS score was similar for both event types at 2.07 percent for baselines and 2.46 percent for SCEs.

Table 75. Summary statistics for ORD and PERCLOS values in the motorcoach data.

Fatigue Measurement Method	Number of Baselines with Data	Percent of Baselines Over Fatigue Threshold	Average Score for Baselines (SD)	Number of SCEs with Data	Percent of SCEs Over Fatigue Threshold	Average Score for SCEs (SD)
ORD	5,305	1.96%	27.28 (16.24)	1,576	2.73%	23.18 (16.79)
PERCLOS	2,288	0.39%	2.07 (2.46)	1,203	1.41%	2.46 (2.51)

In the motorcoach data, the association of drowsiness and SCEs show different results for the two fatigue measurement methods. Using ORD, the odds of observed drowsiness levels of "very" or "extreme" were significantly higher in the SCE data than the baseline data for V1 At-fault events (OR of 1.58). However, for All events, the findings showed no significant difference. The odds of observed drowsiness using PERCLOS are significantly higher in the SCE data than the baseline data for All events (OR of 2.68) and V1 At-fault events (OR of 3.48). The OR and CI are listed in Table *76*. The PAR calculations for comparisons with significant OR findings follow in Table 77.

Table 76. ORs and 95-percent confidence interval of drowsiness during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Fatigue Measurement Method	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
ORD	1.01	0.69	1.48	**1.58***	1.05	2.39
PERCLOS	**2.68***	1.14	6.31	**3.48***	1.39	8.73

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

Table 77. PARs and 95-percent confidence interval of drowsiness during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Fatigue Measurement Method	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
PERCLOS	0.86	0.79	0.92	1.51	1.40	1.62

Truck Data

Table 78 shows the number of truck baselines and SCEs with ORD or PERCLOS data and the average score for each fatigue measurement method. The average ORD scores are similar for baselines and SCEs at 42.06 and 42.43, respectively. The average PERCLOS score was 4.50 percent for baselines and 5.80 percent for SCEs.

Table 78. Summary statistics for ORD and PERCLOS values in the truck data.

Fatigue Measurement Method	Number of Baselines with Data	Percent of Baselines Over Fatigue Threshold	Average Score for Baselines (SD)	Number of SCEs with Data	Percent of SCEs Over Fatigue Threshold	Average Score for SCEs (SD)
ORD	1,962	10.91%	42.06 (16.25)	2,298	19.06%	42.43 (21.31)
PERCLOS	2,564	2.89%	4.50 (3.27)	1,748	15.64%	5.80 (7.08)

In the truck data, the odds of observed drowsiness using ORD were significantly higher in the SCE data than the baseline data for All events (OR of 1.31) and V1 At-fault events (OR of 1.74). Using PERCLOS fatigue measures, observed drowsiness was associated with a significant OR of 2.88 for All events and 3.70 for V1 At-fault events. The OR and CI calculations are listed in Table 79. The PAR calculations are in Table 80.

Table 79. ORs and 95-percent confidence interval of drowsiness during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Fatigue Measurement Method	ALL OR	ALL LCL	ALL UCL	V1 OR	V1 LCL	V1 UCL
ORD	**1.31***	1.07	1.63	**1.74***	1.39	2.18
PERCLOS	**2.88***	2.10	3.94	**3.70***	2.67	5.12

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

Table 80. PARs and 95-percent confidence interval of drowsiness during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Fatigue Measurement Method	ALL PAR	ALL LCL	ALL UCL	V1 PAR	V1 LCL	V1 UCL
ORD	9.15	8.92	9.38	15.73	15.47	16.00
PERCLOS	8.93	8.76	9.09	13.13	12.92	13.35

4.7 RESEARCH QUESTION 6: HOW DOES DRIVER DROWSINESS VARY WHEN DRIVERS ARE INVOLVED IN A SECONDARY TASK?

To assess how driver drowsiness varies when drivers are involved in a secondary task, all SCEs and baselines with valid drowsiness scores were investigated separately for motorcoach and truck data. The events were grouped by the presence or absence of an observed secondary task. Significant differences in the distribution of drowsiness between the two groups (task present vs. task not present) were identified using chi-squared tests of independence. This analysis was conducted once with ORD as the fatigue measurement method, then with PERCLOS as the fatigue measurement method.

Motorcoach Data

Table 81 shows the percent of all motorcoach SCEs and

Table 82 shows the percent of all motorcoach baselines scored as “very” or “extremely” drowsy in ORD for those with a secondary task and those without a secondary task. The results of the logistic regression models assessing drowsiness between the two groups (with and without a secondary task) are also included in the table as OR and 95 percent CI. Secondary tasks marked as significant had significantly different distributions of drowsiness depending on whether the task was observed.

For motorcoach drivers with low counts of drowsiness overall, only secondary task overall showed any association with drowsiness levels. Secondary task overall showed fewer drowsy observations in both the SCE and baseline data sets. The displayed percent of drowsiness in SCEs or baselines with drowsiness show how infrequently drowsiness was observed during secondary task engagement for motorcoach drivers. During cell phone use, no observations of “very” or “extreme” drowsiness were found. Actual counts of drowsiness in the secondary tasks are included in Appendix D for reference. Due to the low counts of drowsiness using the PERCLOS fatigue measurement method, this analysis was not suitable for the PERCLOS fatigue threshold and has thus been excluded from the report.

Table 81. Distribution of drowsiness during secondary task involvement with OR and 95 percent CI results, using ORD fatigue measurement method for motorcoach SCE data.

Secondary Task	Percent of All SCEs Task Not Present with Drowsiness	Percent of All SCEs Task Present with Drowsiness	OR	LCL	UCL
Secondary Task (Overall)	3.42%	1.72%	**2.22***	**1.09**	**4.50**
Talking/singing	2.89%	0.81%	3.87	0.51	29.30
Dancing	2.68%	14.29%	-	-	-
Reading	2.74%	0.00%	-	-	-
Passenger in rear seat	2.82%	0.00%	2.02	0.44	infinity
Reaching for object	2.65%	6.67%	0.45	0.10	2.09
Intercom use	2.76%	0.00%	0.64	0.13	infinity
Other electronic device	2.75%	0.00%	0.39	0.08	infinity
Adjusting instrument panel	2.79%	1.41%	2.44	0.32	18.66
Adjusting/monitoring other devices integral to vehicle	2.72%	3.13%	0.72	0.09	5.67
External distraction	2.87%	1.36%	2.28	0.54	9.68
Reaching for food- or drink-related object	2.75%	0.00%	0.39	0.08	infinity
Eating	2.78%	0.00%	1.21	0.26	infinity
Drinking from container	2.74%	0.00%	-	-	-
Personal grooming	2.73%	2.70%	1.09	0.14	8.69
Removing/adjusting clothing	2.70%	5.56%	0.40	0.05	3.34
Other personal hygiene	2.78%	0.00%	1.30	0.28	infinity
Hand-held locate/reach/answer	2.74%	0.00%	-	-	-
Hand-held dial	2.73%	0.00%	-	-	-
Hand-held talk/listen	2.74%	0.00%	-	-	-
Hand-held holding	2.74%	0.00%	-	-	-
Hand-held browsing	2.75%	0.00%	0.55	0.12	infinity
Hand-held texting	2.73%	0.00%	-	-	-
Hands-free call via headset/earpiece	2.74%	0.00%	-	-	-
Hands-free call via speakerphone	2.73%	0.00%	-	-	-
Hands-free talk/listen	2.74%	0.00%	-	-	-

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

Table 82. Distribution of drowsiness during secondary task involvement with OR and 95 percent CI results, using ORD fatigue measurement method for motorcoach baseline data.

Secondary Task	Percent of All SCEs Task Not Present with Drowsiness	Percent of All SCEs Task Present with Drowsiness	OR	LCL	UCL
Secondary Task (Overall)	2.18%	1.45%	**1.72***	**1.07**	**2.78**
Talking/singing	2.05%	0.80%	2.95	0.92	9.50
Dancing	1.98%	0.00%	1.79	0.40	infinity
Reading	1.96%	0.00%	0.31	0.06	infinity
Passenger in rear seat	1.99%	0.74%	3.78	0.52	27.68
Reaching for object	1.96%	2.13%	0.85	0.11	6.37
Intercom use	1.97%	0.00%	0.71	0.16	infinity
Other electronic device	1.97%	0.00%	0.80	0.18	infinity
Adjusting instrument panel	1.98%	1.55%	1.23	0.38	3.96
Adjusting/monitoring other devices integral to vehicle	1.96%	1.69%	1.09	0.15	8.20
External distraction	2.00%	1.28%	1.69	0.61	4.67
Reaching for food- or drink-related object	1.98%	0.00%	1.15	0.26	infinity
Eating	1.93%	3.90%	0.67	0.20	2.24
Drinking from container	1.96%	2.50%	0.79	0.11	5.94
Personal grooming	1.97%	1.45%	1.19	0.16	8.93
Removing/adjusting clothing	1.97%	0.00%	0.74	0.16	infinity
Other personal hygiene	1.97%	0.00%	1.06	0.24	infinity
Hand-held locate/reach/answer	1.97%	0.00%	0.39	0.08	infinity
Hand-held dial	1.96%	0.00%	-	-	-
Hand-held talk/listen	1.96%	0.00%	0.31	0.06	infinity
Hand-held holding	1.96%	0.00%	-	-	
Hand-held browsing	1.97%	0.00%	0.39	0.08	infinity
Hand-held texting	1.96%	0.00%	-	-	
Hands-free call via headset/earpiece	1.98%	0.00%	1.21	0.27	infinity
Hands-free call via speakerphone	1.96%	0.00%	-	-	
Hands-free talk/listen	1.98%	0.00%	1.266	0.282	infinity

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

Truck Data

Table 83 shows the percent of all truck SCEs and

Table 84 shows the percent of all truck baselines scored as above the ORD fatigue threshold for those with a secondary task and those without a secondary task. The results of the logistic regression models for distribution of drowsiness between the two groups (with and without a secondary task) are also included in the table, in ORs and 95 percent CI. Secondary tasks marked as significant had significantly different distributions of drowsiness for those with or without the task observed. For truck drivers, secondary tasks associated with significantly fewer observations of drowsiness in SCEs included secondary tasks overall; talking/singing; adjusting the instrument panel; external distractions; browsing on a hand-held phone; conducting a phone call on a hands-free headset or earpiece; and talking/listening in a hands-free call. Removing or adjusting clothing was associated with significantly higher observations of drowsiness in SCEs. Secondary tasks associated with fewer observations of drowsiness in baselines included secondary task overall, conducting a phone call on a hands-free headset or earpiece, and talking/listening in a hands-free call.

Table 85 and

Table 86 show the results for SCEs and baselines, respectively, using the PERCLOS fatigue threshold. For SCEs, interacting with the electronic dispatching device; external distractions; conducting a phone call on a hands-free headset or earpiece; and talking/listening in a hands-free call were associated with significantly fewer observations of drowsiness. Again, removing/adjusting clothing was associated with higher observations of drowsiness. In the baseline dataset, the only significant findings were fewer observations of drowsiness when conducting a phone call on a hands-free headset or earpiece and talking/listening in a hands-free call. Actual counts of drowsiness in the secondary tasks are included in Appendix D for reference.

Table 83. Distribution of drowsiness during secondary task involvement with OR and 95 percent CI results, using ORD fatigue measurement method for truck SCE data.

Secondary Task	Percent of All SCEs Task Not Present with Drowsiness	Percent of All SCEs Task Present with Drowsiness	OR	LCL	UCL
Secondary Task (Overall)	25.84%	13.13%	**2.13***	**1.64**	**2.78**
Talking/singing	19.47%	8.89%	**2.61***	**1.16**	**5.84**
Dancing	18.90%	38.89%	0.38	0.13	1.11
Reading	19.18%	5.00%	2.41	0.29	19.81
Passenger in adjacent seat	19.13%	0.00%	-	-	-
Reaching for object	19.26%	14.58%	1.15	0.61	2.19
Electronic dispatching device	19.19%	14.52%	1.06	0.48	2.53
Other electronic device	15.30%	16.67%	0.94	0.39	2.25
Adjusting instrument panel	19.32%	14.29%	**2.25***	**1.22**	**4.13**
Adjusting/monitoring other devices integral to vehicle	19.32%	8.77%	1.63	0.58	4.56
External distraction	20.32%	10.97%	**2.02***	**1.31**	**3.14**
Reaching for food- or drink-related object	19.21%	13.56%	1.24	0.55	2.79
Eating	19.58%	9.84%	**3.00***	**1.52**	**5.89**
Drinking from container	19.21%	9.09%	2.23	0.62	8.00
Smoking-related: reaching, lighting, extinguishing	19.03%	28.57%	-	-	-
Smoking-related: cigarette in hand or mouth	19.24%	8.11%	2.54	0.60	10.71
Tobacco use	19.03%	23.53%	0.51	0.12	1.69
Personal grooming	19.17%	14.55%	1.05	0.45	2.46
Removing/adjusting clothing	18.69%	46.67%	**0.33***	**0.14**	**0.81**
Other personal hygiene	18.79%	27.94%	0.61	0.32	1.17
Hand-held locate/reach/answer	19.17%	0.00%	4.32	0.91	infinity
Hand-held dial	19.08%	0.00%	-	-	-
Hand-held talk/listen	19.07%	14.29%	-	-	-
Hand-held holding	19.15%	6.25%	5.20	0.52	51.57
Hand-held browsing	19.58%	6.52%	**2.95***	**1.17**	**7.42**
Hand-held texting	19.11%	0.00%	-	-	-
Hands-free call via headset/earpiece	19.61%	0.00%	**22.73***	**5.15**	**infinity**
Hands-free call via speakerphone	19.09%	0.00%	-	-	-
Hands-free talk/listen	19.65%	0.00%	**24.19***	**5.49**	**infinity**

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

Table 84. Distribution of drowsiness during secondary task involvement with OR and 95 percent CI results, using ORD fatigue measurement method for truck baseline data.

Secondary Task	Percent of All SCEs Task Not Present with Drowsiness	Percent of All SCEs Task Present with Drowsiness	OR	LCL	UCL
Secondary Task (Overall)	13.21%	8.40%	**1.79***	**1.31**	**2.44**
Talking/singing	11.14%	7.38%	1.59	0.77	3.26
Dancing	10.83%	15.63%	0.38	0.13	1.11
Reading	10.92%	0.00%	-	-	-
Passenger in adjacent seat	10.97%	0.00%	2.07	0.43	infinity
Reaching for object	10.96%	5.56%	1.54	0.19	12.15
Electronic dispatching device	11.05%	4.65%	2.34	0.55	10.01
Other electronic device	10.91%	10.00%	1.10	0.14	8.76
Adjusting instrument panel	10.89%	11.21%	0.92	0.50	1.71
Adjusting/monitoring other devices integral to vehicle	11.00%	0.00%	2.96	0.64	infinity
External distraction	11.30%	8.27%	1.58	0.96	2.58
Reaching for food- or drink-related object	10.76%	20.69%	0.53	0.20	1.39
Eating	11.13%	5.88%	2.16	0.84	5.55
Drinking from container	10.96%	7.41%	2.23	0.62	8.00
Smoking-related: reaching, lighting, extinguishing	10.88%	20.00%	-	-	-
Smoking-related: cigarette in hand or mouth	10.85%	13.33%	0.60	0.23	1.56
Tobacco use	10.92%	8.33%	1.08	0.13	9.13
Personal grooming	10.86%	13.51%	0.67	0.24	1.88
Removing/adjusting clothing	10.82%	25.00%	0.37	0.09	1.52
Other personal hygiene	10.88%	12.00%	1.05	0.42	2.61
Hand-held locate/reach/answer	10.84%	28.57%	-	-	-
Hand-held dial	10.91%	0.00%	-	-	-
Hand-held talk/listen	10.96%	0.00%	1.71	0.35	infinity
Hand-held holding	10.89%	16.67%	-	-	-
Hand-held browsing	10.83%	21.43%	0.46	0.12	1.79
Hand-held texting	10.92%	0.00%	-	-	-
Hands-free call via headset/earpiece	11.45%	0.99%	**15.14***	**2.05**	**111.92**
Hands-free call via speakerphone	10.92%	0.00%	-	-	-
Hands-free talk/listen	11.46%	0.96%	**15.61***	**2.11**	**115.40**

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

Table 85. Distribution of drowsiness during secondary task involvement with OR and 95 percent CI results, using PERCLOS fatigue measurement method for truck SCE data.

Secondary Task	Percent of All SCEs Task Not Present with Drowsiness	Percent of All SCEs Task Present with Drowsiness	OR	LCL	UCL
Secondary Task (Overall)	13.36%	10.52%	1.20	0.84	1.71
Talking/singing	11.66%	16.00%	1.02	0.49	2.10
Dancing	6.33%	11.11%	0.36	0.10	1.25
Reading	11.89%	6.67%	2.12	0.24	19.11
Passenger in adjacent seat	11.88%	0.00%	-	-	-
Reaching for object	11.64%	16.05%	0.63	0.31	1.31
Electronic dispatching device	12.16%	0.00%	**9.10***	**2.04**	**infinity**
Other electronic device	11.91%	5.26%	1.70	0.20	14.18
Adjusting instrument panel	11.76%	13.33%	0.82	0.41	1.65
Adjusting/monitoring other devices integral to vehicle	11.96%	7.14%	1.46	0.40	5.30
External distraction	12.89%	4.82%	**2.58***	**1.31**	**5.07**
Reaching for food- or drink-related object	12.04%	4.44%	3.48	0.77	15.60
Eating	11.80%	12.64%	1.05	0.50	2.17
Drinking from container	11.95%	4.17%	2.74	0.34	22.21
Smoking-related: reaching, lighting, extinguishing	11.77%	33.33%	0.70	0.06	8.94
Smoking-related: cigarette in hand or mouth	11.83%	12.50%	0.66	0.16	2.65
Tobacco use	11.84%	12.50%	-	-	-
Personal grooming	11.77%	15.00%	0.42	0.16	1.15
Removing/adjusting clothing	11.54%	33.33%	**0.33***	**0.11**	**0.96**
Other personal hygiene	11.26%	31.37%	0.50	0.23	1.06
Hand-held locate/reach/answer	11.92%	0.00%	-	-	-
Hand-held dial	11.86%	0.00%	-	-	-
Hand-held talk/listen	11.88%	0.00%	-	-	-
Hand-held holding	11.89%	6.67%	1.68	0.12	23.12
Hand-held browsing	12.20%	3.95%	2.20	0.60	8.04
Hand-held texting	11.88%	0.00%	-	-	-
Hands-free call via headset/earpiece	12.21%	0.00%	**10.54***	**2.37**	**infinity**
Hands-free call via speakerphone	11.86%	0.00%	-	-	-
Hands-free talk/listen	6.68%	0.00%	**10.96***	**2.47**	**infinity**

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

Table 86. Distribution of drowsiness during secondary task involvement with OR and 95 percent CI results, using PERCLOS fatigue measurement method for truck baseline data.

Secondary Task	Percent of All SCEs Task Not Present with Drowsiness	Percent of All SCEs Task Present with Drowsiness	OR	LCL	UCL
Secondary Task (Overall)	3.65%	3.12%	1.23	0.78	1.93
Talking/singing	3.25%	5.49%	0.72	0.34	1.54
Dancing	11.61%	37.50%	0.59	0.16	2.10
Reading	3.40%	0.00%	-	-	-
Passenger in adjacent seat	3.41%	0.00%	0.80	0.17	infinity
Reaching for object	3.43%	0.00%	1.26	0.27	infinity
Electronic dispatching device	3.43%	1.75%	1.83	0.24	13.88
Other electronic device	3.41%	0.00%	0.59	0.12	infinity
Adjusting instrument panel	3.24%	5.81%	0.58	0.27	1.23
Adjusting/monitoring other devices integral to vehicle	3.42%	0.00%	1.00	0.22	infinity
External distraction	3.32%	3.92%	0.86	0.46	1.61
Reaching for food- or drink-related object	3.35%	6.67%	0.53	0.12	2.46
Eating	3.49%	0.97%	4.11	0.55	30.58
Drinking from container	3.44%	0.00%	1.72	0.38	infinity
Smoking-related: reaching, lighting, extinguishing	3.40%	0.00%	0.34	0.07	infinity
Smoking-related: cigarette in hand or mouth	3.37%	4.11%	0.49	0.14	1.72
Tobacco use	3.41%	0.00%	0.64	0.13	infinity
Personal grooming	3.44%	1.64%	1.95	0.26	14.87
Removing/adjusting clothing	3.41%	0.00%	0.69	0.15	infinity
Other personal hygiene	3.44%	1.54%	3.43	0.45	26.36
Hand-held locate/reach/answer	3.40%	0.00%	0.39	0.08	infinity
Hand-held dial	3.39%	0.00%	-	-	-
Hand-held talk/listen	3.42%	0.00%	0.85	0.18	infinity
Hand-held holding	3.41%	0.00%	0.54	0.11	infinity
Hand-held browsing	3.43%	0.00%	1.26	0.27	infinity
Hand-held texting	3.40%	0.00%	-	-	-
Hands-free call via headset/earpiece	3.57%	0.00%	**6.57***	**1.49**	**infinity**
Hands-free call via speakerphone	3.40%	0.00%	-	-	-
Hands-free talk/listen	3.57%	0.00%	**6.73***	**1.52**	**infinity**

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

4.8 RESEARCH QUESTION 7: WHAT IS THE IMPACT OF TIME ON TASK ON THE RISK OF SCEs AS A FUNCTION OF DRIVING HOUR? IS THERE A SIGNIFICANT INCREASE IN RISK ASSOCIATED WITH INCREASING HOUR OF DRIVING?

4.8.1 Individual and Overall SCE Rate Result

To determine time on task, driving shifts were identified and shift driving hours were calculated from the naturalistic data. To do this, the driving files were linked together chronologically by driver. It was assumed that after a break in driving greater than 8 hours, driving hours were reset to zero and a new shift started at the driving period immediately following. The break value was chosen using knowledge of the participant companies' specific industries and their typical work day. In each shift, all instances of driving (i.e., vehicle speed greater than 5 mi/h) were used to calculate the cumulative driving time. It is important to note that there was no information on non-driving time, so it was not possible to determine what the driver did prior to their shift or during breaks from driving. It should also be noted that it was not possible to perform these calculations on the motorcoach data as malfunctions of the DAS led to potentially missing files. The following results are all from the truck data.

The SCE rate by driving hours for truck data is shown in Table 87 and Figure 36. Similar to the individual driver's SCE rate distribution, the aggregated SCE rate also shows the increase pattern and hits the peak value at the eighth hour.

Table 87. Overall SCE rate by driving hours for truck data.

Driving Hour Relative to the Beginning of the Shift	Number of SCEs	Total Driving Hours	SCE rate (SCEs per 100 driving hours)
1	247	12,351	2.00
2	364	11,990	3.04
3	440	11,479	3.83
4	428	10,182	4.20
5	330	7,554	4.37
6	252	4,838	5.21
7	135	2,859	4.72
8	98	1,611	6.08
9	36	807	4.46
10	20	363	5.51
11	2	157	1.27

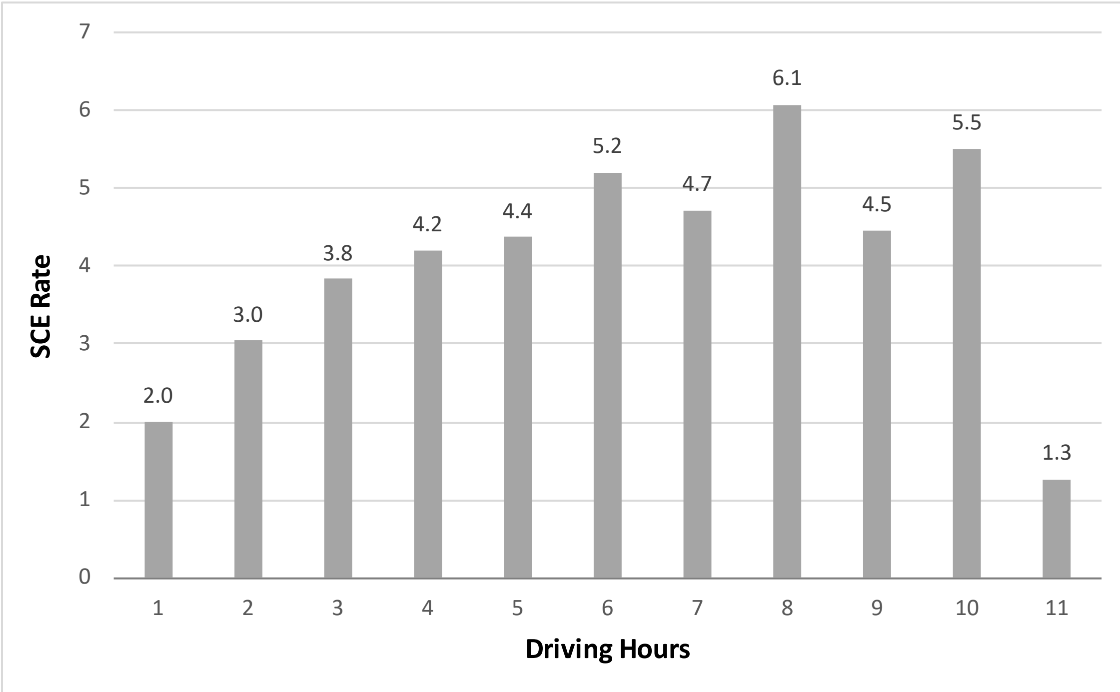

Figure 36. Graph. Overall SCE rate by driving hours since the beginning of the shift for truck data.

4.8.2 Results of Mixed-Effect Poisson Model

Results from the Poisson Model show that all driving hours have a significantly higher SCE rate when compared to the first driving hour—except for the 11th hour, which has a small sample size (two SCEs for the entire hour). The SCE rate ratio indicates that the risk rate can increase 1.5–2.8 times compared to the first hour, as shown in Table 88.

Table 88. Results of mixed-effect Poisson regression for SCE rate for truck data.

Hour	Estimate	Standard Error	SCE Rate Ratio	Pr > |t|
Intercept	-4.55	0.12	0.01	**<.0001***
2nd hour vs. 1st hour	0.42	0.08	1.52	**<.0001***
3rd hour vs. 1st hour	0.65	0.08	1.92	**<.0001***
4th hour vs. 1st hour	0.76	0.08	2.14	**<.0001***
5th hour vs. 1st hour	0.81	0.08	2.25	**<.0001***
6th hour vs. 1st hour	0.94	0.09	2.56	**<.0001***
7th hour vs. 1st hour	0.81	0.11	2.25	**<.0001***
8th hour vs. 1st hour	1.03	0.12	2.80	**<.0001***
9th hour vs. 1st hour	0.76	0.18	2.14	**<.0001***
10th hour vs. 1st hour	0.96	0.24	2.61	**<.0001***
11th hour vs. 1st hour	-0.13	0.71	0.88	0.8575

*Asterisk indicates a significant result. These p-values are also shown in bold.

To determine whether there were significant differences between each hour combination, Tukey adjustments were calculated among all 11 groups, and the results show that the SCE rate in the second driving hour is significantly higher than that of the first hour. The SCE rates from the third driving hour to the eleventh driving hour are significantly higher than that of the second hour. There is no significant difference in SCE rate from the third to the tenth driving hours. The sample size in the eleventh driving hour is very small, and no significant results were found. The results of the pair-wise comparisons can be found in Appendix E.

To further explore the pattern of SCE risk during the driving shift, breaks in driving of 30 minutes or longer (that did not restart a shift) were identified in all driving shifts. The total shift driving time that occurred up to the break start was calculated. This data was used to calculate the average number of breaks per a single shift at each driving hour; for all shifts (Figure 37); and shifts that went into the 11th driving hour (Figure 38). For shifts of any total driving time, the average number of breaks is highest at driving hour 3. For shifts with more than 10 driving hours, the average number of breaks is highest at driving hour 6. Although this analysis does not identify the impact of breaks on SCE risk, it does illuminate the differences in break patterns among different shift lengths and the need to study breaks and their immediate and long-term impact on SCE risk in a driving shift.

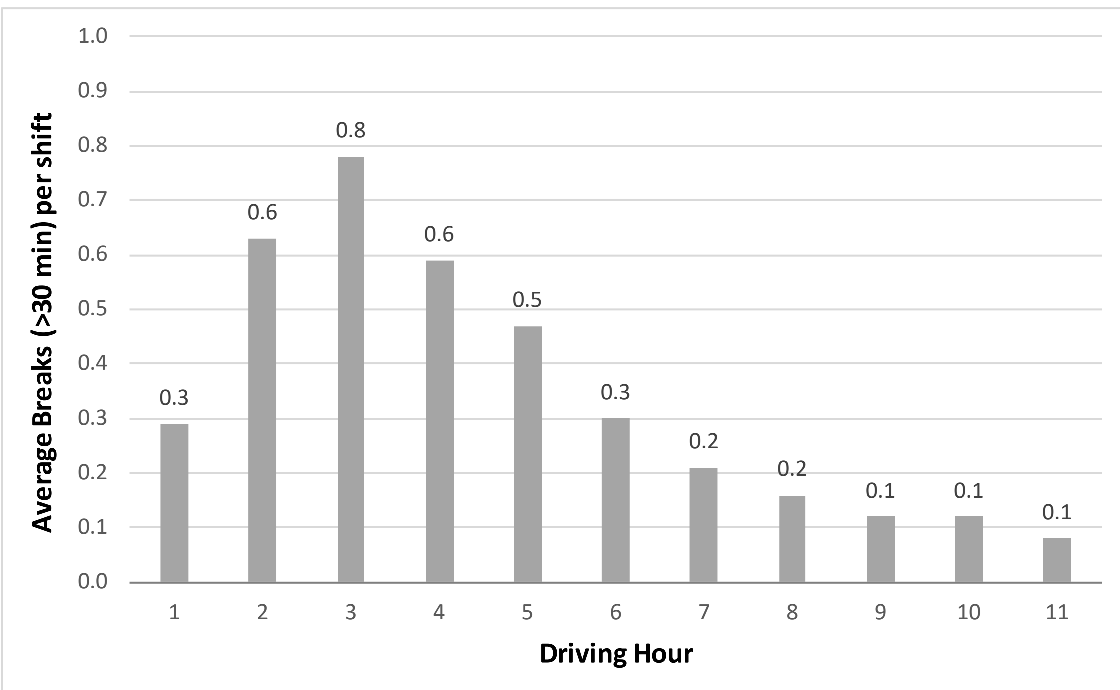

Figure 37. Graph. Average number of non-restart breaks (>30 min) per shift for all shifts.

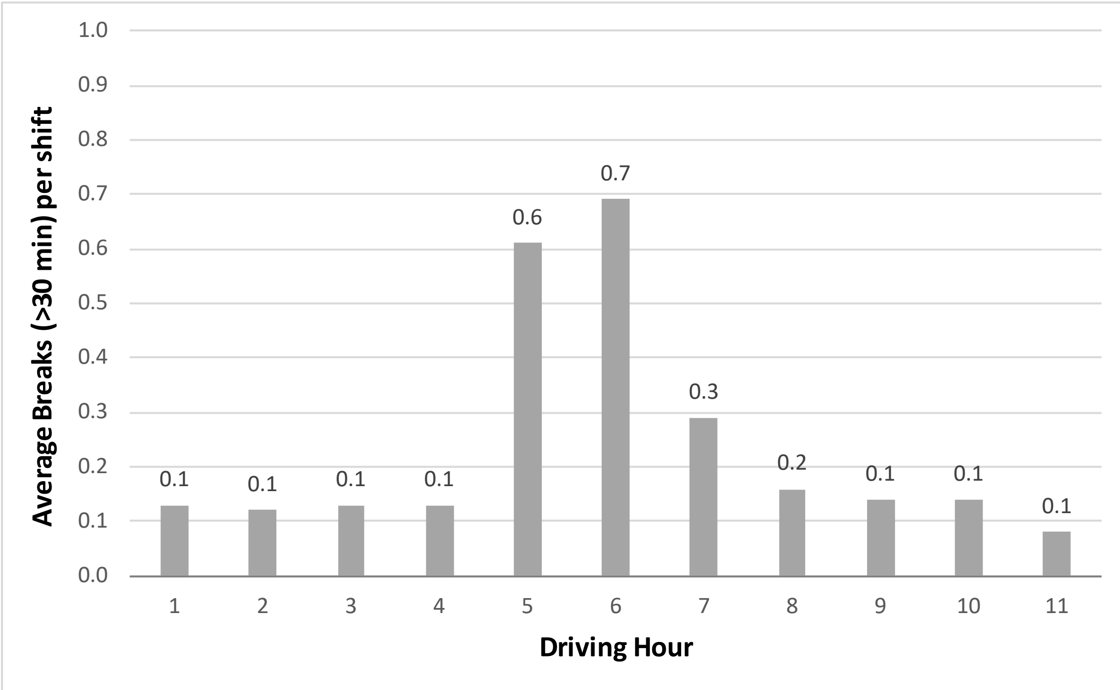

Figure 38. Graph. Average number of non-restart breaks (>30 min) per shift for shifts that went into the 11th hour for truck data.

4.9 RESEARCH QUESTION 8: WHAT IS THE PREVALENCE OF DROWSY DRIVING BY HOUR OF DRIVING? IS THERE A SIGNIFICANT INCREASE IN DROWSY DRIVING BY HOUR OF DRIVING FOR BOTH SCEs AND NORMAL DRIVING SEGMENTS?

To evaluate drowsy driving by hour of driving, baselines were systematically sampled to represent as many driving hours as possible. The driving time calculations (as described above) were used to identify hours of driving. From there, data analysts attempted to identify baseline epochs from driving hours 1, 3, 5, 7, 8, 9, 10, and 11. It was not always possible to obtain samples from each driving hour, usually due to poor visibility of the drivers face (which was required to complete manual PERCLOS) or a lack of sufficient video prior to the baseline epoch (manual PERCLOS requires a minimum of 3 minutes of video at moving speeds). Approximately 200 driving shifts were identified with a total driving time of more than 10 hours (i.e., the driver drove into the 11th hour). Of those, it was possible to obtain valid samples from 162 shifts for use in this analysis.

To eliminate low quality data, an SCE or baseline needed to have 80 percent valid PERCLOS data to be included in the analysis (i.e., the percentage of unknown eye status should be less than 20 percent for the 3-minute duration). This resulted in 925 valid systematic baselines out of a total of 932 and 2,325 valid SCEs out of a total of 2,353 SCEs. The driver is considered fatigued if the PERCLOS value is greater than 12 percent. It was not possible to calculate driving time for the motorcoach data, so the following results pertain only to the truck data.

4.9.1 PERCLOS by Driving Hour for Systematic Baselines

The PERCLOS value by driver ranged from 0–0.30, and the median PERCLOS value was less than 0.05 for all 11 driving hours. This indicated that overall, drivers were not very drowsy. The percentage of drowsy driving (i.e., PERCLOS value greater than 12 percent) by driving hour is shown in Figure 39 and Table 89. The third hour has the highest percentage of drowsy driving while the seventh hour has the lowest.

Table 89. Aggregated PERCLOS fatigue percentage of systematic baselines by driving hours for truck data.

Driving Hour	PERCLOS Fatigued Baselines	Total Number of Systematic Baselines	PERCLOS Fatigue Percentage in Systematic Baselines
1	5	114	4.4%
3	11	112	9.8%
5	4	115	3.5%
7	1	117	0.9%
8	3	113	2.7%
9	3	117	2.6%
10	3	118	2.5%
11	0	119	0.0%
Total	**30**	**925**	**3.2%**

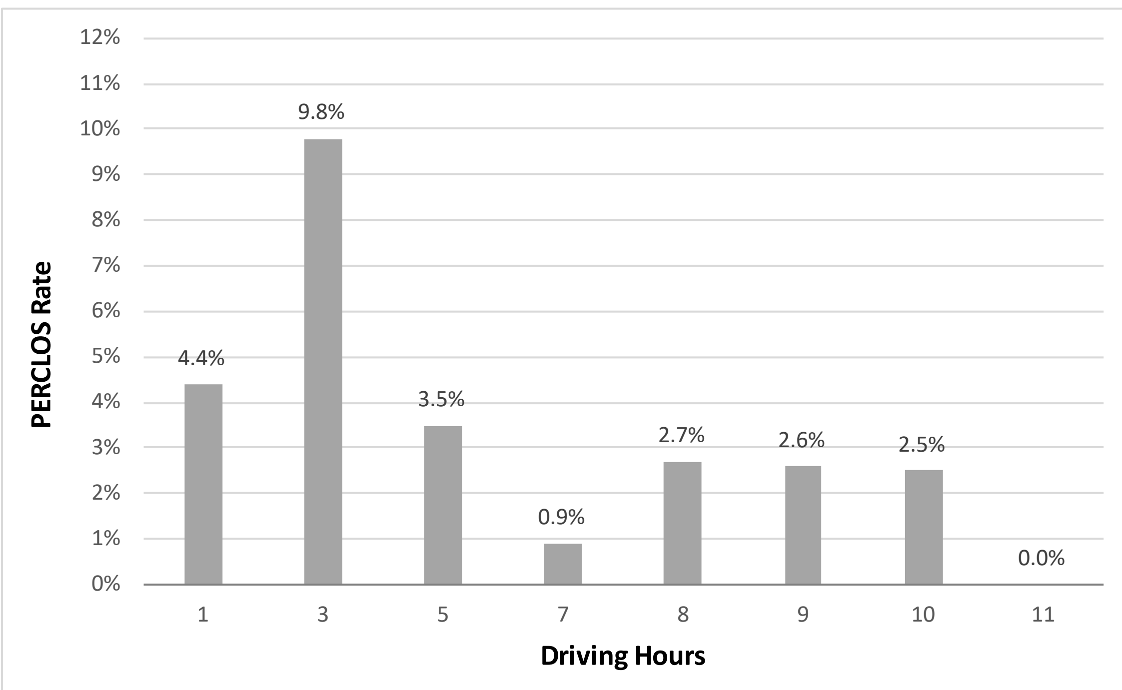

Figure 39. Graph. Aggregated PERCLOS percentage of systematic baselines by driving hours for truck data.

A mixed-effect logistic regression model was conducted to evaluate the impact of time on drowsy driving, and the results show that the PERCLOS fatigue rate ratio is almost 3 times in the second hour as that in the first hour with p-value 0.0726. All other hours have smaller PERCLOS fatigue percentages compared with the first hour; however, the differences are not statistically significant. The comparison of the 11th and 1st hours using the model did not yield a meaningful result as there were no fatigue samples found in the 11th hour.

Table 90. Mixed-effect logistic regression model fit result for PERCLOS fatigue in systematic baselines for truck data.

Hour	Estimate	Standard Error	PERCLOS Fatigue Percentage Ratio	Pr > |t|
Intercept	-3.80	0.73	0.02	**<.0001***
3rd hour vs. 1st hour	1.09	0.60	2.96	0.0726
5th hour vs. 1st hour	-0.27	0.72	0.76	0.7095
7th hour vs. 1st hour	-1.79	1.13	0.17	0.1132
8th hour vs. 1st hour	-0.60	0.78	0.55	0.4440
9th hour vs. 1st hour	-0.60	0.78	0.55	0.4395
10th hour vs. 1st hour	-0.66	0.78	0.52	0.3974
11th hour vs. 1st hour	-	-	-	-

*Asterisk indicates a significant result. These p-values are also shown in bold.

Tukey multiple comparison adjustment confirms the above conclusions and shows no significant difference among all pairs comparison, as shown in Appendix F.

To further investigate the increased PERCLOS percentage at driving hour 3 for the systematic baselines, the time of day was calculated. Figure 40 shows the percentage of fatigued systematic baselines by time of day. The highest percent of fatigued baselines fall between 1 a.m. and 6 a.m. Figure 41 shows the distribution of all systematic baselines across the time of day. The majority of the baseline samples occurred between 10 a.m. and 2 p.m. Finally, Figure 42 shows the hour of the day in which the driver started driving. For most shifts that included systematic baselines, drivers started driving between 1 a.m. and 2 a.m.

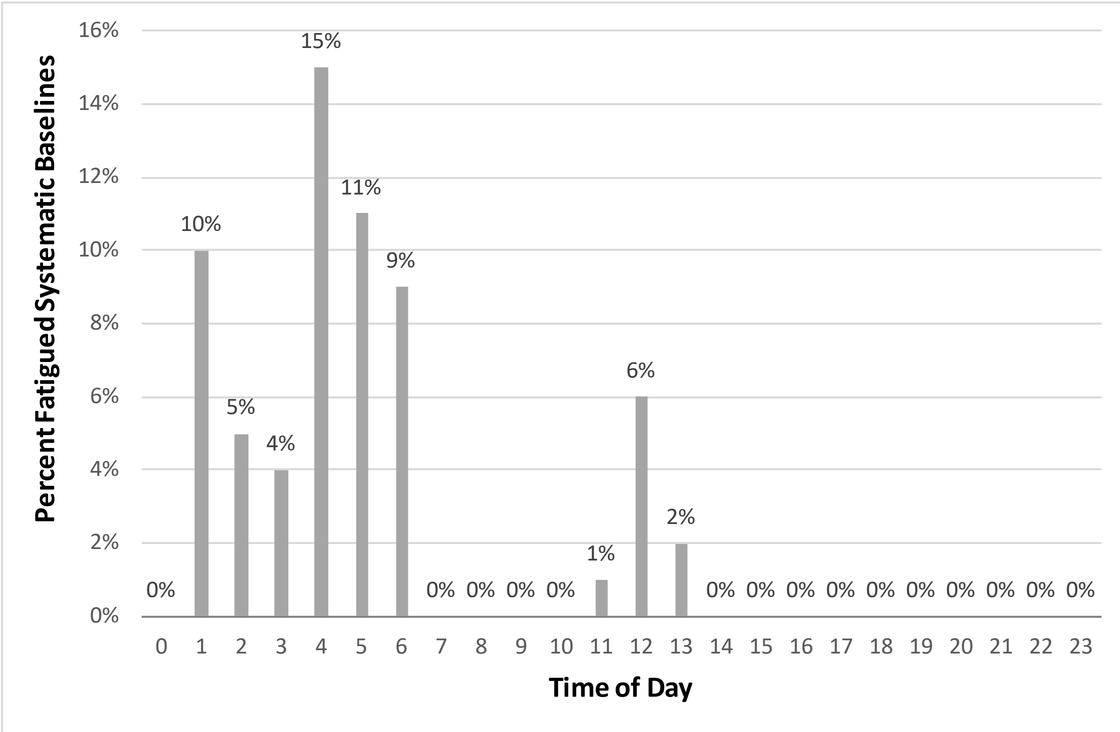

Figure 40. Graph. Percent fatigued systematic baselines by time of day for truck data.

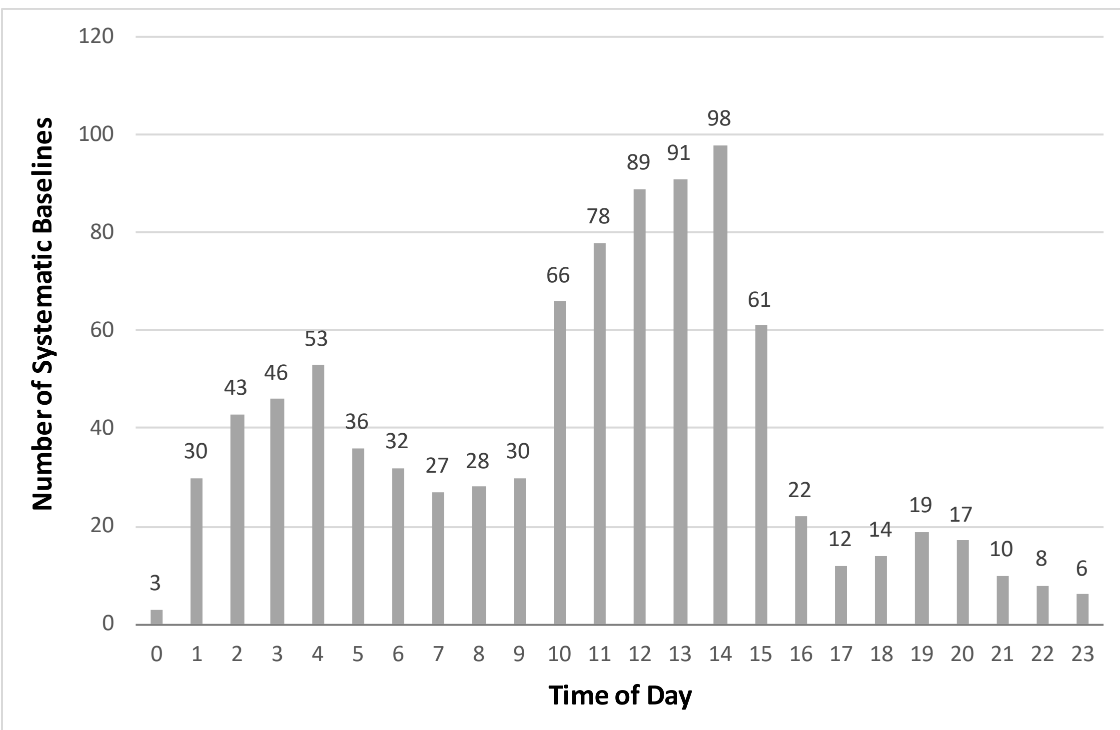

Figure 41. Graph. Sample size of systematic baselines by time of day for truck data.

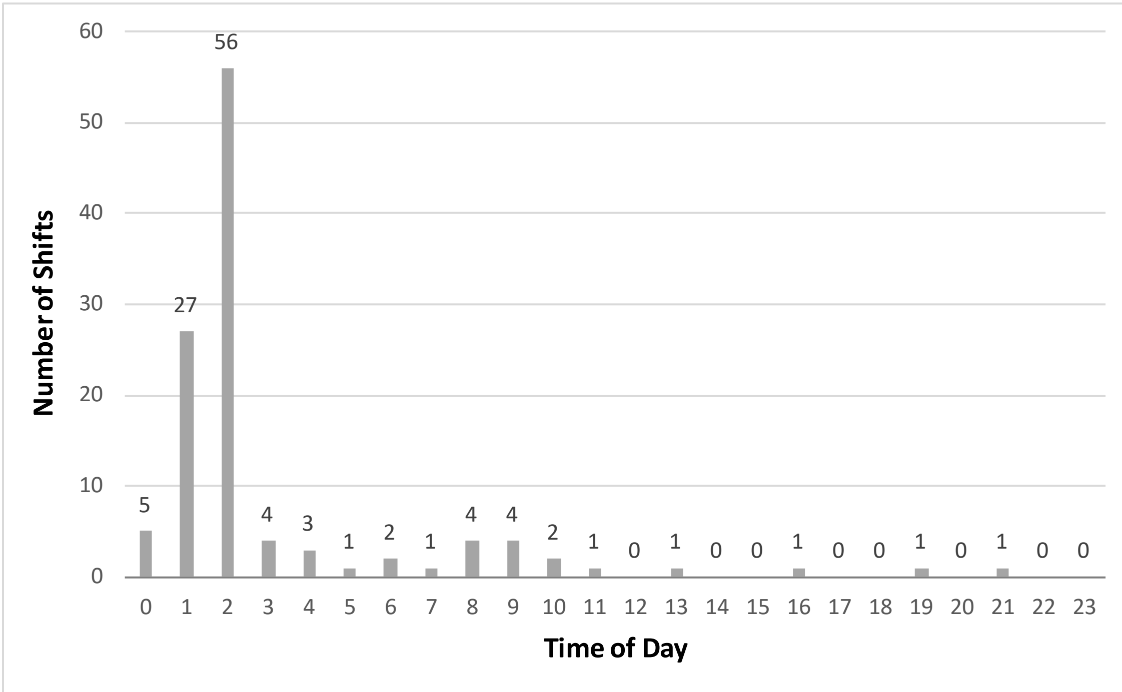

Figure 42. Graph. Shift start for systematic baselines by time of day for truck data.

4.9.2 PERCLOS by Driving Hour for SCEs

The range of percent of SCEs with PERCLOS fatigue is from 0 to 0.50, and the median values of all 11 driving hours are less than 0.05. This indicated that overall, drivers were not very drowsy. The percentage of drowsy driving is shown in Figure 43 and

Table 91. The 9^{th} hour has the highest percentage of drowsy driving and the 2^{nd} hour has the second highest. The lowest PERCLOS fatigue percentages appear at the 4^{th} hour and 10^{th} hour. The sample size for the 11^{th} hour is too small to provide any meaningful data.

Table 91. Aggregated PERCLOS fatigue percentage of SCEs by driving hours.

Driving Hour	PERCLOS Fatigued SCEs	Total Number of SCEs	PERCLOS Fatigue Percentage in SCEs
1	24	200	12.0%
2	43	248	17.3%
3	47	322	14.6%
4	22	331	6.6%
5	20	247	8.1%
6	24	188	12.8%
7	8	88	9.1%
8	6	72	8.3%
9	7	31	22.6%
10	1	14	7.1%
11	0	1	0.0%
Total	**202**	**1742**	**11.6%**

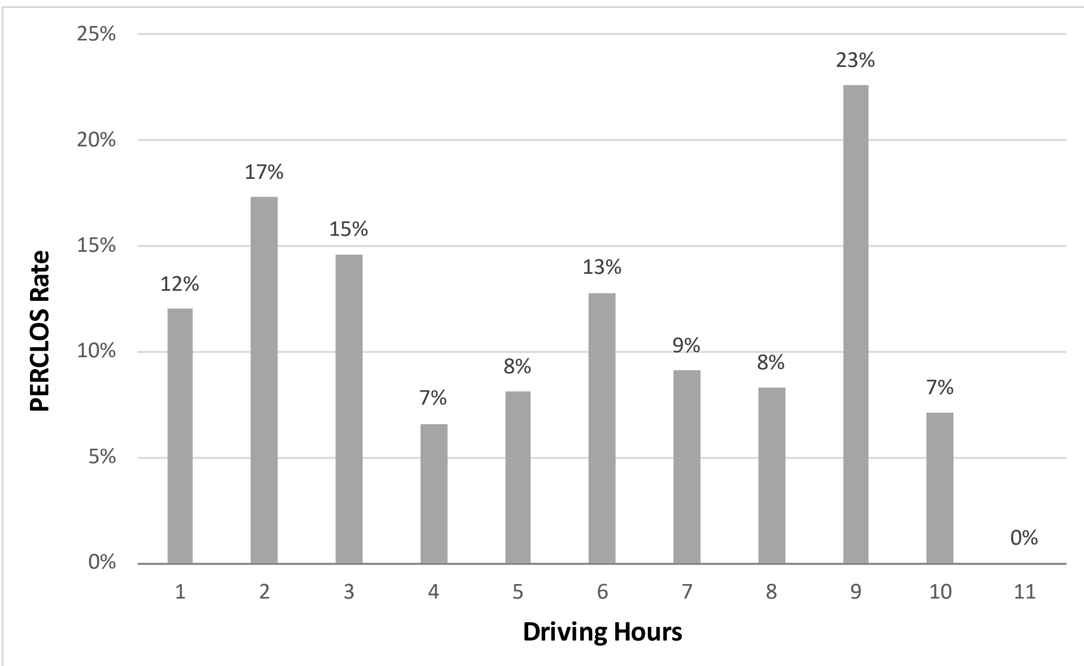

Figure 43. Graph. Aggregated PERCLOS percentage of SCEs by driving hours for truck data.

A mixed-effect logistic model was conducted to evaluate the impact of time on drowsy driving, and the result shows that there is a statistically significant difference between the 1st hour and the 2nd and 3rd hours. The PERCLOS fatigue rate ratios for the 2nd (2.18) and 3rd (1.91) hours compared to the 1st hour show approximately two times the rate of fatigue. All other hours are not significantly different than the 1st hour, and there is no clear trend of PERCLOS fatigue percentage for SCEs.

Table 92. Mixed-effect logistic regression model fit result for PERCLOS fatigue in SCEs for truck data.

Hour	Estimate	Standard Error	PERCLOS Percentage Ratio	Pr > |t|
Intercept	-5.62	0.95	0.00	**<.0001***
Hour 2 vs. Hour 1	0.78	0.33	2.18	**0.0179***
Hour 3 vs. Hour 1	0.65	0.32	1.91	**0.0437***
Hour 4 vs. Hour 1	-0.20	0.36	0.82	0.5768
Hour 5 vs. Hour 1	0.06	0.38	1.06	0.8697
Hour 6 vs. Hour 1	0.07	0.42	1.07	0.8690
Hour 7 vs. Hour 1	-0.18	0.51	0.83	0.7201
Hour 8 vs. Hour 1	-0.70	0.55	0.50	0.1991
Hour 9 vs. Hour 1	0.90	0.59	2.45	0.1256
Hour 10 vs. Hour 1	0.16	1.21	1.17	0.8977
Hour 11 vs. Hour 1	-4.57	46.86	0.01	0.9223

*Asterisk indicates a significant result. These p-values are also shown in bold.

The Tukey multiple comparison adjustment shows no significant difference among all paired comparisons, as shown in Appendix F.

To further investigate the increased PERCLOS percentage at driving hour 9 for the SCEs, the time of day was calculated. Figure 44 shows the percentage of fatigued SCEs by time of day. The highest percent of fatigued SCEs fall between 1 a.m. and 6 a.m. Figure 45 shows the distribution of all SCEs across time of day. Most of the SCE samples occurred between 3 a.m. and 2 p.m. Finally, Figure 46 shows the hour of the day in which the driver started driving. For most shifts that included SCEs, drivers started driving between 1 a.m. and 3 a.m.

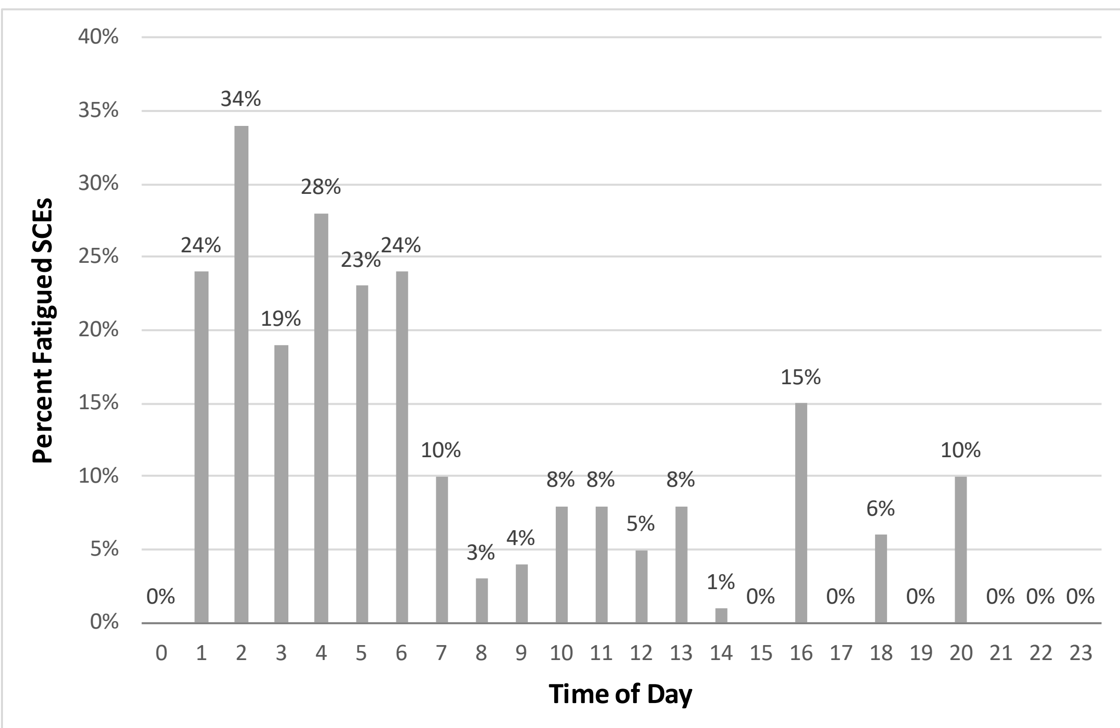

Figure 44. Graph. Percent fatigued SCEs by time of day for truck data.

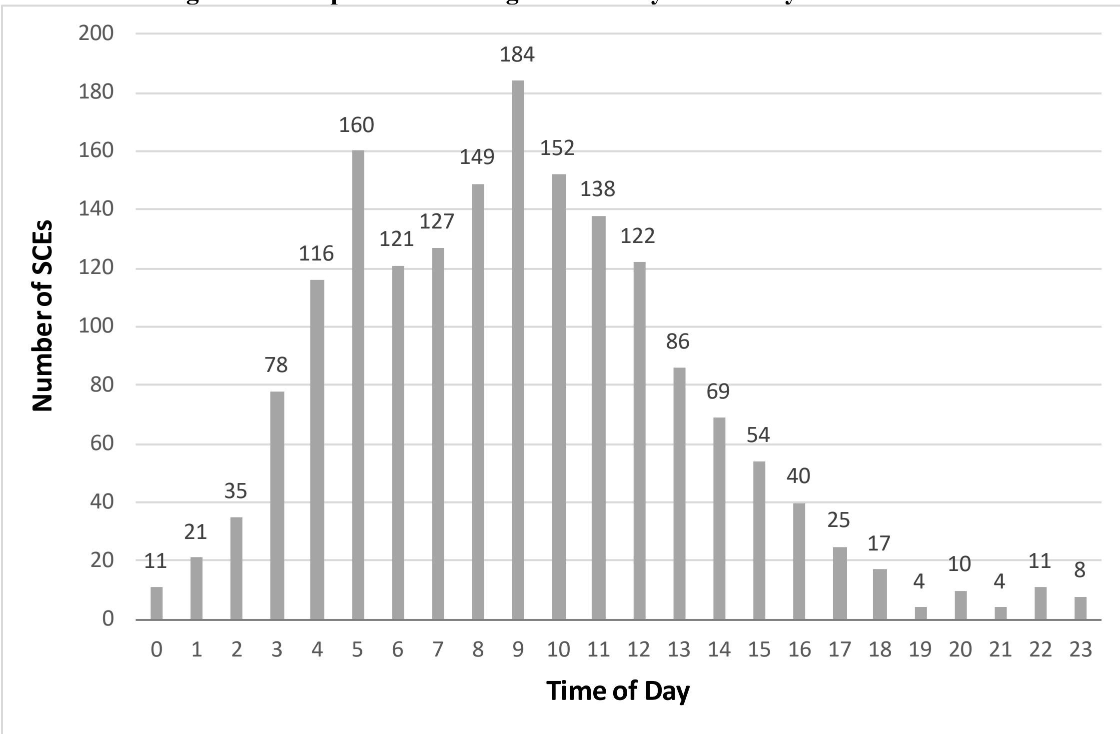

Figure 45. Graph. Sample size of SCEs by time of day for truck data.

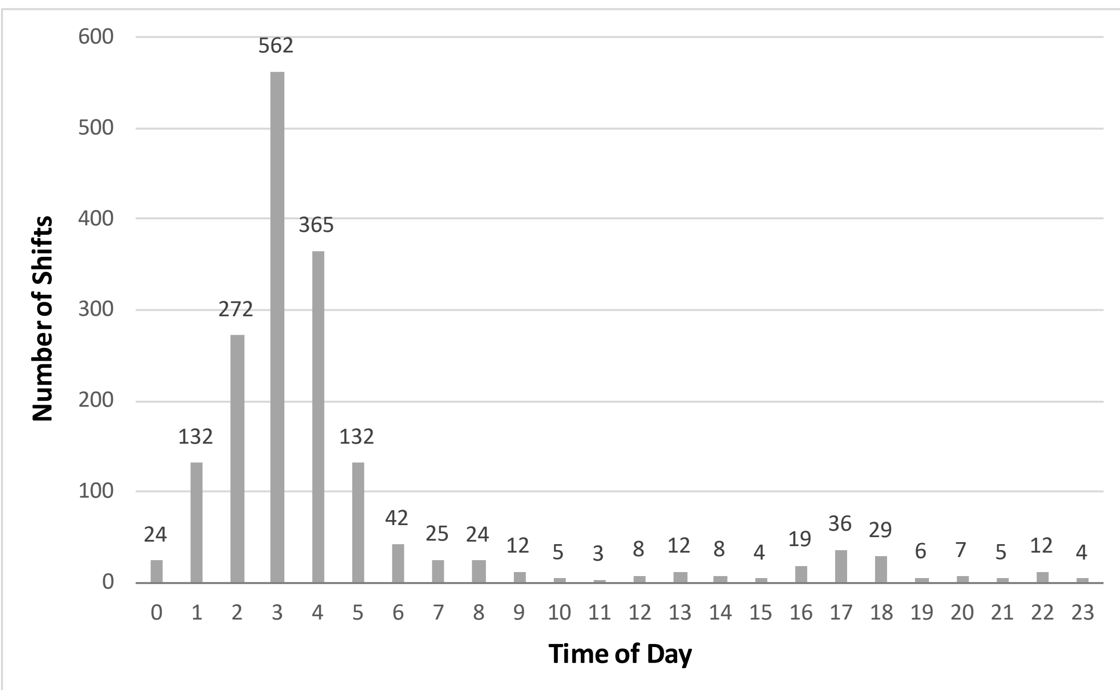

Figure 46. Graph. Shift start for SCEs by time of day for truck data.

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5. CONCLUSIONS

The goal of this study was to investigate the impact of driver distraction and drowsiness on heavy vehicle drivers. More than 3.8 million miles of data were collected from seven fleets and 10 locations under the original OBMS FOT study.[107] A total of 43 motorcoaches, 73 motorcoach drivers, 182 trucks and 172 truck drivers participated in the study.

As of 2016, there were 12,474,722 registered large trucks and motorcoaches in the US. Heavy vehicle fatal crashes have decreased over the last 20 years. However, the ratio of large trucks and motorcoaches involved in fatal crashes per 100 million VMT remains higher than that of passenger vehicles. Crashes involving large trucks and motorcoaches go beyond occupants of the vehicles. In 2016, 83.3 percent of the fatalities involving large trucks and 84.9 percent of the fatalities involving motorcoaches were not occupants of those vehicles.[108] These data suggest a need for a better understanding of factors contributing to large truck and motorcoach crashes to create better safety standards and mitigate the number of fatalities and injuries.

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

5.1 RESEARCH QUESTION 1: WHAT ARE THE TYPES AND FREQUENCY OF TASKS IN WHICH DRIVERS ENGAGE PRIOR TO INVOLVEMENT IN SCEs? WHAT ARE THE ORs AND THE PAR PERCENTAGE FOR EACH TASK TYPE?

There were several significant findings for this research question. The results show that dancing is protective for both motorcoach and truck drivers. Talking/singing was also found to be protective for truck drivers. This could have been talking/singing to the radio, themselves, or surrounding traffic. Neither talking nor singing requires a high visual load, so these results are not surprising.

Reaching for object; intercom use; adjusting instrument panel; adjusting/monitoring other device integral to vehicle (e.g., adjusting seatbelt, adjusting seat height, or adjusting mirrors); external distraction; removing/adjusting clothing; and other personal hygiene all showed a significant increased risk of being involved in an SCE when compared to baseline driving for motorcoach drivers.

Reading; reaching for object; interacting with electronic dispatching device; other electronic device (e.g., GPS, satellite radio); adjusting/monitoring other device integral to vehicle (e.g., adjusting seatbelt, adjusting seat height, or adjusting mirrors); external distraction; reaching for food- or drink-related item; and removing/adjusting clothing all showed a significant increased risk of being involved in an SCE when compared to baseline driving for truck drivers. These findings are similar to previous heavy vehicle research.[109,110]

5.2 RESEARCH QUESTION 2: WHAT ARE THE PREVALENCE AND CHARACTERISTICS OF HANDS-FREE AND HANDHELD CELL PHONE USE? WHAT ARE THE ORs AND THE PAR PERCENTAGE OF BEING INVOLVED IN AN SCE WHILE TALKING ON A HANDHELD OR HANDS-FREE CELL PHONE?

Talking and/or listening to a phone call continues to show no risk or reduced risk in naturalistic driving studies. Talking or listening to a call on a hands-free device was associated with a reduced risk for motorcoach (OR of 0.45) and truck (OR of 0.51) drivers. Talking or listening to a call on a hand-held cell phone was associated with no change in risk for motorcoach and truck drivers.

Cell phone use is lower overall in the motorcoach data than in the truck data. Motorcoach drivers often have passengers who can observe their behavior while driving, which may be why their cell phone use is less frequent.

Visual-manual intensive tasks on a hand-held cell phone showed increased risk. These tasks include browsing and texting, which were both associated with increased risk in the truck data (OR of 4.35 and 3.07, respectively). However, it is important to note that texting occurred infrequently in the data—0.28 percent of SCEs and 0.14 percent of baselines in trucks, and 0.18 percent of SCEs and 0.06 percent of baselines in motorcoaches. Low rates of texting in the data may indicate that information campaigns, local and national legislation changes, and individual carrier policies have had a positive impact on safe behavioral changes.

5.3 RESEARCH QUESTION 3: WHAT ARE THE ENVIRONMENTAL CONDITIONS ASSOCIATED WITH DRIVER CHOICE OF ENGAGEMENT IN TASKS? WHAT ARE THE ORs AND PAR PERCENTAGE OF BEING IN AN SCE WHILE ENGAGING IN TASKS WHILE ENCOUNTERING THESE CONDITIONS?

The environmental analysis yielded similar results as previous studies.[(111)] The majority of SCEs (for both motorcoaches and trucks) occurred during the daylight, in non-adverse conditions, on non-junction roadways, and on divided roadways. Most motorcoach SCEs took place in moderate traffic areas, such as the airport and business/industrial areas, whereas most truck SCEs took place in low-traffic areas, such as the interstate. The results from these analyses may help characterize motorcoach and heavy truck operations with respect to environmental and other roadway-related conditions.

5.4 RESEARCH QUESTION 4: WHAT ARE THE ORs OF EYES OFF FORWARD ROADWAY? DOES EYES OFF FORWARD ROADWAY SIGNIFICANTLY AFFECT SAFETY AND/OR DRIVING PERFORMANCE?

The eyeglance analysis again showed results similar to previous studies.[(112)] When total eyes off forward roadway time was binned into five categories, the results showed that the longer the driver's eyes were off the forward roadway, the greater the risk of being involved in an SCE, with a significant increase once the driver's eyes were off the road for more than 2 seconds.

ANOVAs were calculated on secondary tasks of interest that were shown to be significant in Research Questions 1 and 2. For truck data, events with a secondary task of browsing had one of the highest mean eyes off roadway time of 4 seconds while events with a secondary task of texting had the highest mean eyes off roadway time of 5 seconds.

5.5 RESEARCH QUESTION 5: WHAT IS THE PREVALENCE OF DRIVER DROWSINESS? WHAT ARE THE ORs AND PAR OF BEING IN AN SCE WHILE DROWSY?

Drowsiness was observed more frequently in truck data than in motorcoach data. This may be due to several factors. Most notably, the driving schedule for motorcoach drivers was likely more consistent with the typical sleep/wake schedule, while many of the truck drivers in this study drove at night. Also, motorcoach drivers often had passengers in their vehicle, which may have provided interaction as a counter to drowsiness.

ORD drowsiness and PERCLOS drowsiness were observed more frequently in the SCE data than the baseline data for both motorcoach and truck drivers. This finding supports previous research, which has shown drowsiness and decreased alertness can cause safety consequences including involvement in SCEs, especially unintended lane deviations.(113) Further research could explore how drowsiness changes in the different event types.

ORD drowsiness was observed more frequently than PERCLOS drowsiness in both the motorcoach and truck data. One possible explanation may be that ORD drowsiness ratings capture even moderate signs of drowsiness, as analysts are trained to look at all aspects of the driver's fatigue such as sagging cheeks and yawning, whereas PERCLOS drowsiness captures more severe drowsy events via eye closures. Additional research comparing ORD ratings and PERCLOS scores for the same events might better identify the individual strengths of ORD and PERCLOS methods or how the methods can be used together to best assess true drowsiness and risk.

5.6 RESEARCH QUESTION 6: HOW DOES DRIVER DROWSINESS VARY WHEN DRIVERS ARE INVOLVED IN A SECONDARY TASK?

Results from this research question showed that conducting a hands-free phone call using a headset or earpiece or talking/listening on a hands-free call were associated with lower drowsiness for truck drivers in SCEs and baselines. Additional research could determine if the interactions were performed to reduce drowsiness or if more alert drivers tend to have more interactions.

Other tasks found to be associated with alert driving involve drivers moving their bodies in the vehicle in tasks such as adjusting features of the instrument panel and observing external distractions. Tasks found to be associated with higher drowsiness support behaviors used in ORD to identify drowsiness (such as fidgeting with clothes or other personal hygiene tasks).

Motorcoach drivers had very few observations of drowsiness. The occurrence of drowsiness and secondary tasks together further reduced the available sample in this analysis, leading to limited findings for the motorcoach drivers.

5.7 RESEARCH QUESTION 7: WHAT IS THE IMPACT OF TIME ON TASK ON THE RISK OF SCEs AS A FUNCTION OF DRIVING HOUR? IS THERE A SIGNIFICANT INCREASE IN RISK ASSOCIATED WITH INCREASING HOUR OF DRIVING?

Overall, it can be inferred that there is a significant increase in risk associated with increasing hour of driving. The SCE risk rate can increase to be two to three times higher than in the first hour, hitting the peak value at the eighth hour. The HOS regulations at the time of data collection required drivers to take a break of at least 30 minutes after a maximum of 8 hours of being on duty before they could continue driving.

The pairwise comparison results show that the first 10 driving hours can be further grouped into three parts: low SCE rate (the 1st hour); moderate SCE rate (the 2nd hour); and high SCE rate (the 3rd though the 10th hour).

5.8 RESEARCH QUESTION 8: WHAT IS THE PREVALENCE OF DROWSY DRIVING BY HOUR OF DRIVING? IS THERE A SIGNIFICANT INCREASE IN DROWSY DRIVING BY HOUR OF DRIVING FOR BOTH SCEs AND NORMAL DRIVING SEGMENTS?

PERCLOS was used to assess the prevalence of drowsy driving by hour of driving. Systematic samples were taken at hours 1, 3, 5, 7, 8, 9, 10, and 11 for normal driving conditions, and the fatigue status of the driver prior to each SCE was identified with PERCLOS (>12 percent). The results show that there is no pattern of increasing drowsiness with driving hours. For systematic baselines, the peak of drowsy driving appears at the third hour. Results for the SCEs show multiple peaks, including the second, third and ninth hour. There was no pattern of increasing drowsiness after the eighth or ninth hour. The timing and duration of the driver's breaks could impact driving behavior, and the time-of-the-day of the trip could also affect drivers' drowsiness.

A deeper investigation of the drowsiness data revealed that although most truck drivers with long shifts begin their shift in the very early morning hours, fatigue is highest in systematic baselines and SCEs from 1 a.m. to 6 a.m. While there was not a statistically significant difference in the third driving hour for systematic baselines and ninth driving hour for SCEs, it appears that time of day and the driver's natural circadian rhythm may play a role in their drowsiness.

5.9 STUDY LIMITATIONS AND NEW OPPORTUNITIES

As in any research study, and especially with naturalistic driving data, there were some limitations to this study. One noticeable limitation when considering driver drowsiness research is that none of the fleets were dedicated over-the-road operations, and therefore not many of the drivers drove extended hours. While the OBMS FOT aimed to collect data from a representative sample of fleets and drivers for 1 year each, three of the fleets collected data for less than 3 months, and one fleet collected data for less than 6 months.[114] This led to the majority of the data collection occurring from mostly local and regional fleets.

Despite this limitation, more than 3.8 million miles of data were collected that provide valuable information. One of the key findings and takeaways from this study is the reduction of cell phone use among both motorcoach and truck drivers.

Stakeholders and FMCSA may consider additional research questions that might be answered with this existing dataset or require a more extensive data collection effort. Topics may include research into fatigue measures and the correlation of fatigue and events during a driver's shift. Larger efforts, perhaps similar in scope to other large-scale truck studies, would provide additional data to analyze to gain a better understanding of the safety issues faced by motorcoach drivers.

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APPENDIX A: DISTRIBUTION OF SCEs AND BASELINES FOR ALL DRIVERS

Motorcoach

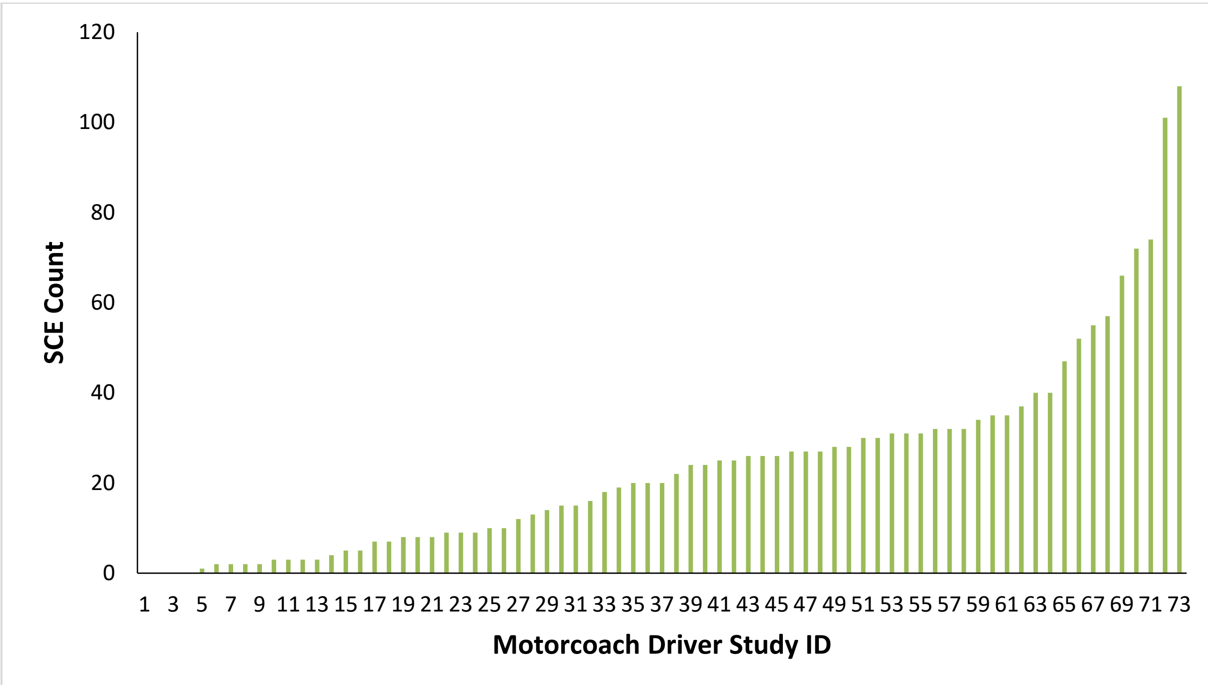

Figure 47. Graph. Number of verified SCEs reduced for analysis per motorcoach driver.

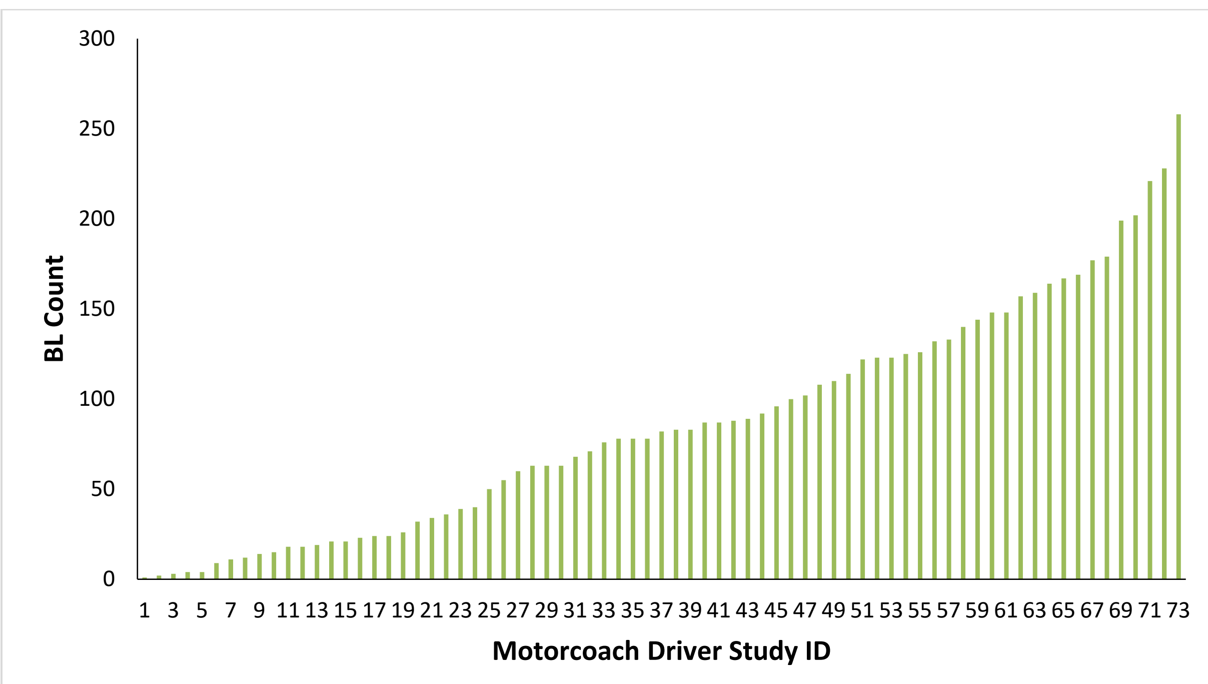

Figure 48. Graph. Number of verified baselines reduced for analysis per motorcoach driver.

Truck

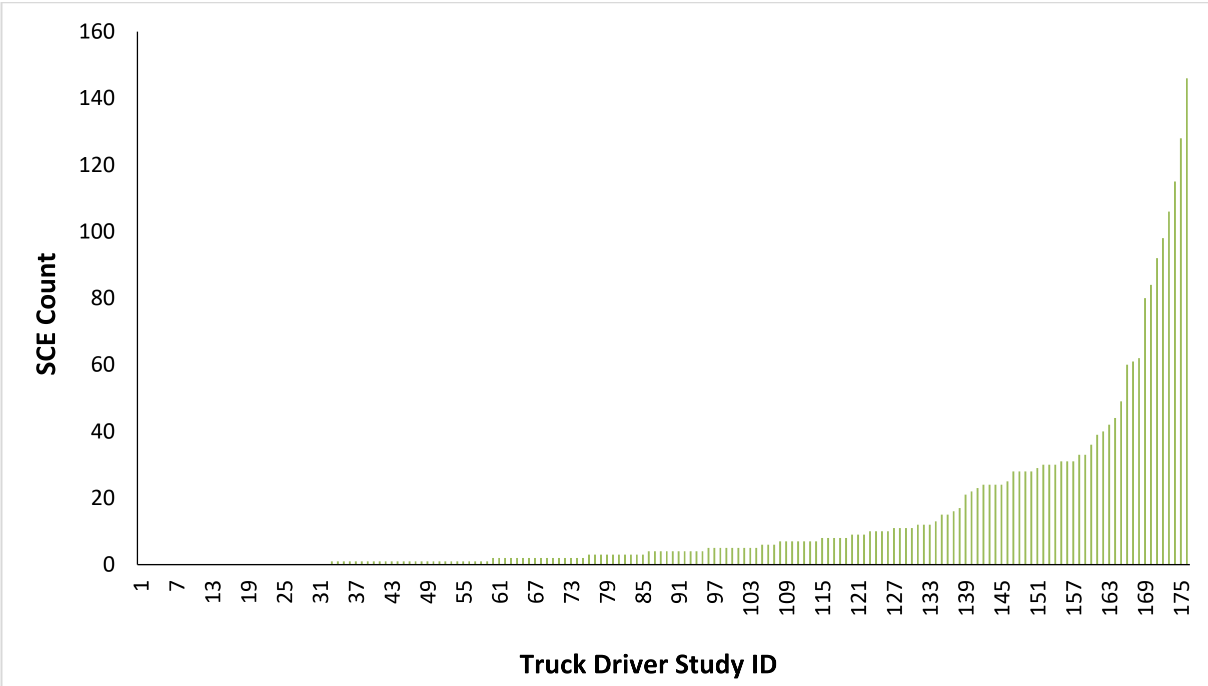

Figure 49. Graph. Number of verified SCEs reduced for analysis per truck driver.

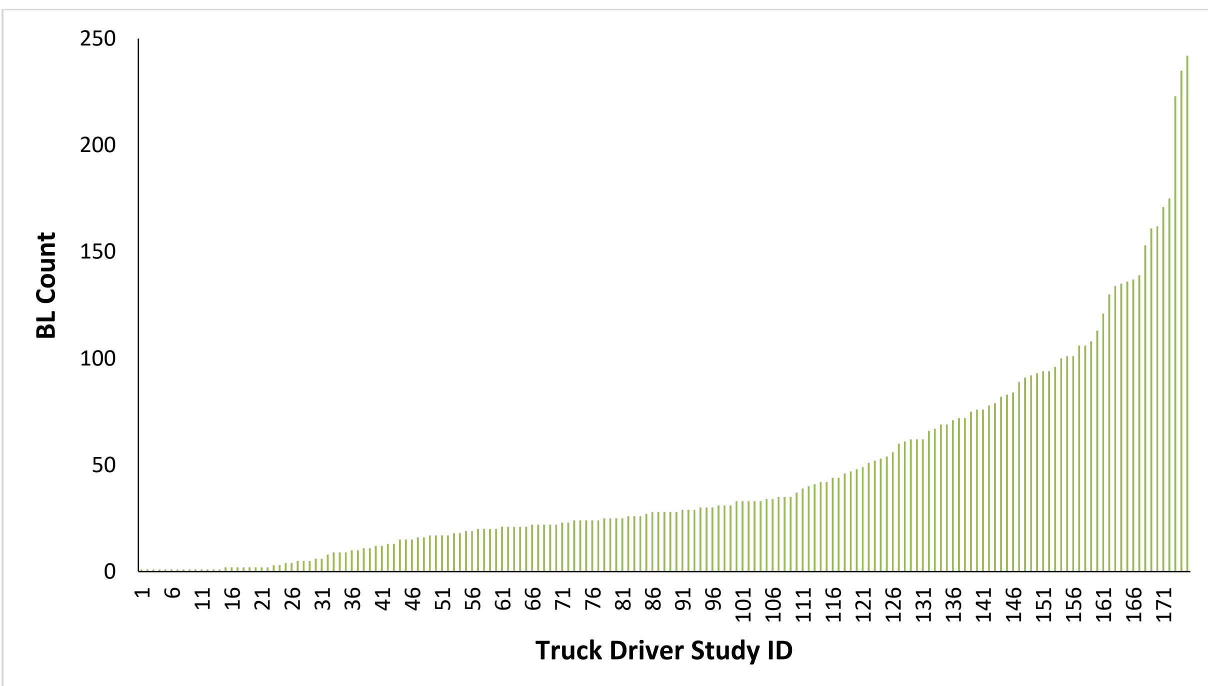

Figure 50. Graph. Number of verified baselines reduced for analysis per truck driver.

APPENDIX B: FREQUENCY TABLES FOR RESEARCH QUESTION 1

Table 93. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for motorcoach data.

Secondary Task	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Secondary Task (Overall)	704	1,035	437	439	1961	4,357
Talking/singing	134	1,605	62	814	413	5,905
Dancing	7	1,732	2	874	71	6,247
Reading	7	1,732	6	870	13	6,305
Writing	2	1,737	1	875	3	6,315
Passenger in rear seat	52	1,687	34	842	201	6,117
Reaching for object	35	1,704	23	853	50	6,268
Object in vehicle, other	66	1,673	43	833	76	6,242
Intercom use	22	1,717	7	869	25	6,293
Other electronic device	10	1,729	8	868	35	6,283
Adjusting instrument panel	81	1,658	58	818	243	6,075
Adjusting/monitoring other devices integral to vehicle	38	1,701	25	851	86	6,232
Looking at outside, vehicle, animal, object, etc.	156	1,583	104	772	376	5,942
Reaching for food- or drink-related object	10	1,729	10	866	46	6,272
Eating	31	1,708	21	855	98	6,220
Drinking from container	9	1,730	8	868	42	6,276
Personal grooming	42	1,697	31	845	96	6,222
Removing/adjusting clothing	20	1,719	13	863	31	6,287
Other personal hygiene	32	1,707	25	851	49	6,269

Table 94. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for truck data.

Secondary Task	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Secondary Task (Overall)	1,265	1,098	1,080	656	3,729	4,151
Talking/singing	92	2,271	72	1,664	483	7,397
Dancing	18	2,345	16	1,720	123	7,757
Reading	21	2,342	20	1,716	20	7,860
Writing	5	2,358	5	1,731	3	7,877
Passenger in adjacent seat	8	2,355	5	1,731	40	7,840
Reaching for object	99	2,264	90	1,646	72	7,808
Object in vehicle, other	202	2,161	185	1,551	186	7,694
Interact with electronic dispatching device	64	2,299	55	1,681	164	7,716
Other electronic device	21	2,342	18	1,718	27	7,853
Interact with CB	3	2,360	2	1,738	8	7,872
Adjusting instrument panel	123	2,240	111	1,625	424	7,456
Adjusting/monitoring other devices integral to vehicle	60	2,303	57	1,679	61	7,819
Looking at outside, vehicle, animal, object, etc.	320	2,043	269	1,467	850	7,030
Reaching for food- or drink-related object	61	2,302	59	1,677	122	7,758
Eating	214	2,239	108	1,628	320	7,560
Drinking from container	33	2,330	30	1,706	133	7,747
Smoking-related: reaching, lighting, extinguishing	7	2,356	7	1,729	24	7,856
Smoking-related: cigarette in hand or mouth	41	2,322	30	1,706	214	7,666
Tobacco use	17	2,346	17	1,719	39	7,841
Personal grooming	55	2,308	47	1,689	194	7,686
Removing/adjusting clothing	30	2,333	27	1,709	32	7,848
Other personal hygiene	72	2,219	65	1,671	228	7,652

APPENDIX C: FREQUENCY TABLES FOR RESEARCH QUESTION 3

Lighting Level

Table 95. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each lighting level for motorcoach data.

Lighting Levels	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Daylight	588	826	362	360	1,402	2,874
Darkness, not lighted	27	23	24	13	183	488
Darkness, lighted	78	161	44	59	313	836
Dawn	7	13	5	3	28	67
Dusk	4	12	2	4	35	92

Table 96. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each lighting level for truck data.

Lighting Levels	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Daylight	883	806	732	428	2,414	2,385
Darkness, not lighted	242	164	230	150	823	1,067
Darkness, lighted	87	85	69	48	359	564
Dawn	47	39	44	28	114	121
Dusk	5	4	4	2	19	12

Weather Conditions

Table 97. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each weather condition for motorcoach data.

Weather Conditions	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
No adverse conditions	687	1,010	424	426	1,868	4,187
Wind gusts	0	1	0	0	1	0
Fog	2	5	1	4	8	22
Rain	14	19	11	9	82	147
Snow	0	0	0	0	0	0
Sleet	0	0	0	0	0	0
Rain and fog	1	0	1	0	1	1
Snow/sleet and fog	0	0	0	0	0	0

Table 98. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each weather condition for truck data.

Weather Conditions	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
No adverse conditions	1,158	1,016	987	610	3,349	3,757
Wind gusts	0	0	0	0	0	0
Fog	6	4	6	2	45	45
Rain	82	71	70	40	261	266
Snow	9	4	7	2	28	22
Sleet	0	0	0	0	0	0
Rain and fog	0	0	0	0	5	6
Snow/sleet and fog	0	0	0	0	2	0

Relation to Junction

Table 99. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each relation to junction for motorcoach data.

Relation to Junction	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Non-junction	345	493	1,052	2,227	1,052	2,227
Intersection	73	153	49	69	107	222
Intersection-related	54	76	17	23	105	210
Entrance/exit ramp	30	28	25	16	62	156
Rail grade crossing	1	1	1	1	4	6
Interchange area	112	188	81	88	467	1,328
Parking lot entrance/exit	50	49	27	26	81	109
Parking lot, within boundary	10	8	5	6	28	35
Driveway, alley access, etc.	17	11	46	48	46	48
Crossover-related	2	3	2	2	3	3
Other	10	25	4	8	5	11

Table 100. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each relation to junction for truck data.

Relation to Junction	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Non-junction	759	503	685	359	2,363	2,524
Intersection	78	126	59	69	170	232
Intersection-related	41	70	29	32	121	130
Entrance/exit ramp	29	24	25	11	57	85
Rail grade crossing	1	1	0	1	8	12
Interchange area	137	192	111	95	455	597
Parking lot entrance/exit	110	100	72	44	256	248
Parking lot, within boundary	10	20	8	11	46	67
Driveway, alley access, etc.	86	53	77	28	219	189
Crossover-related	6	3	6	2	7	9
Other	1	1	1	1	2	1

Traffic Flow

Table 101. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each traffic flow for motorcoach data.

Traffic Flow	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Not divided: two-way traffic	150	173	85	93	341	534
Not divided: center turn lane	20	28	9	8	58	115
Divided: median strip/barrier	312	470	223	208	1,336	3,271
One-way traffic	209	353	112	122	197	397
No lanes	13	11	8	8	28	39

Table 102. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each traffic flow for truck data.

Traffic Flow	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Not divided: two-way traffic	418	290	350	180	1,014	991
Not divided: center turn lane	33	51	19	18	130	129
Divided: median strip/barrier	759	679	667	416	2,448	2,812
One-way traffic	39	53	31	26	75	112
No lanes	13	23	10	14	46	67

Traffic Density

Table 103. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each traffic density for motorcoach data.

Traffic Density	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
LOS A1	102	71	82	48	451	770
LOS A2	111	99	86	44	718	1,419
LOS B	280	486	152	183	539	1,389
LOS C	116	192	58	78	79	250
LOS D	44	99	22	48	36	153
LOS E	22	65	19	28	55	205
LOS F	10	9	7	0	9	31

Table 104. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each traffic density for truck data.

Traffic Density	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
LOS A1	561	317	528	255	1,541	1,525
LOS A2	246	106	225	74	862	956
LOS B	362	453	261	225	1,040	1,276
LOS C	43	131	23	59	61	110
LOS D	11	36	10	17	8	12
LOS E	7	21	4	8	11	10
LOS F	3	2	2	1	1	0

Locality

Table 105. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each locality for motorcoach data.

Locality	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Open country	14	13	13	9	41	84
Residential	41	30	31	21	108	151
Business/industrial	169	245	84	104	311	522
School	15	16	8	7	73	118
Urban	35	75	20	27	71	121
Airport	170	297	80	98	128	240
Interstate	251	354	197	172	1212	3,060

Table 106. The frequency of secondary tasks during SCEs and baseline epochs across All and V1 At-fault events for each locality for truck data.

Locality	ALL SCE Did Occur	ALL SCE Did Not Occur	V1 SCE Did Occur	V1 SCE Did Not Occur	Baseline Did Occur	Baseline Did Not Occur
Open country	32	29	30	23	122	131
Residential	205	116	183	86	434	427
Business/industrial	336	398	238	183	877	920
School	13	5	9	2	40	36
Urban	7	10	4	6	16	9
Airport	0	0	0	0	1	3
Interstate	649	518	598	345	2,152	2,505

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APPENDIX D: DROWSINESS IN SECONDARY TASKS RESEARCH QUESTION 6

Table 107. Drowsiness during secondary task involvement, using ORD fatigue measurement method for motorcoach data.

Secondary Task	Number of All Events Task Not Present with Drowsiness	Number of All Events Task Present with Drowsiness
Secondary Task (Overall)	113	34
Talking/singing	143	4
Dancing	146	1
Reading	147	0
Passenger in rear seat	146	1
Reaching for object	144	3
Intercom use	147	0
Other electronic device	147	0
Adjusting instrument panel	143	4
Adjusting/monitoring other devices integral to vehicle	145	2
External distraction	141	6
Reaching for food- or drink-related object	147	0
Eating	144	3
Drinking from container	146	1
Personal grooming	145	2
Removing/adjusting clothing	146	1
Other personal hygiene	147	0
Hand-held locate/reach/answer	147	0
Hand-held dial	147	0
Hand-held talk/listen	147	0
Hand-held holding	147	0
Hand-held browsing	147	0
Hand-held texting	147	0
Hands-free call via headset/earpiece	147	0
Hands-free call via speakerphone	147	0
Hands-free talk/listen	147	0

Table 108. Drowsiness during secondary task involvement, using PERCLOS fatigue measurement method for motorcoach data.

Secondary Task	Number of All Events Task Not Present with Drowsiness	Number of All Events Task Present with Drowsiness
Secondary Task (Overall)	18	8
Talking/singing	24	2
Dancing	26	0
Reading	26	0
Passenger in rear seat	25	1
Reaching for object	24	2
Intercom use	25	1
Other electronic device	26	0
Adjusting instrument panel	26	0
Adjusting/monitoring other devices integral to vehicle	26	0
External distraction	26	0
Reaching for food- or drink-related object	26	0
Eating	26	0
Drinking from container	25	1
Personal grooming	26	0
Removing/adjusting clothing	26	0
Other personal hygiene	25	1
Hand-held locate/reach/answer	26	0
Hand-held dial	26	0
Hand-held talk/listen	26	0
Hand-held holding	26	0
Hand-held browsing	26	0
Hand-held texting	26	0
Hands-free call via headset/earpiece	26	0
Hands-free call via speakerphone	26	0
Hands-free talk/listen	26	0

Table 109. Drowsiness during secondary task involvement, using ORD fatigue measurement method for truck data.

Secondary Task	Number of All Events Task Not Present with Drowsiness	Number of All Events Task Present with Drowsiness
Secondary Task (Overall)	412	240
Talking/singing	635	17
Dancing	640	12
Reading	651	1
Passenger in adjacent seat	652	0
Reaching for object	637	15
Electronic dispatching device	641	11
Other electronic device	647	5
Adjusting instrument panel	622	30
Adjusting/monitoring other devices integral to vehicle	647	5
External distraction	597	55
Reaching for food- or drink-related object	638	14
Eating	635	17
Drinking from container	647	5
Smoking-related: reaching, lighting, extinguishing	649	3
Smoking-related: cigarette in hand or mouth	643	9
Tobacco use	647	5
Personal grooming	639	13
Removing/adjusting clothing	635	17
Other personal hygiene	627	25
Hand-held locate/reach/answer	650	2
Hand-held dial	652	0
Hand-held talk/listen	651	1
Hand-held holding	650	2
Hand-held browsing	643	9
Hand-held texting	652	0
Hands-free call via headset/earpiece	651	1
Hands-free call via speakerphone	652	0
Hands-free talk/listen	651	1

Table 110. Drowsiness during secondary task involvement, using PERCLOS fatigue measurement method for truck data.

Secondary Task	Number of All Events Task Not Present with Drowsiness	Number of All Events Task Present with Drowsiness
Secondary Task (Overall)	157	137
Talking/singing	273	21
Dancing	285	9
Reading	293	1
Passenger in adjacent seat	294	0
Reaching for object	281	13
Electronic dispatching device	293	1
Other electronic device	293	1
Adjusting instrument panel	273	21
Adjusting/monitoring other devices integral to vehicle	291	3
External distraction	270	24
Reaching for food- or drink-related object	290	4
Eating	282	12
Drinking from container	293	1
Smoking-related: reaching, lighting, extinguishing	292	2
Smoking-related: cigarette in hand or mouth	287	7
Tobacco use	293	1
Personal grooming	287	7
Removing/adjusting clothing	286	8
Other personal hygiene	277	17
Hand-held locate/reach/answer	294	0
Hand-held dial	294	0
Hand-held talk/listen	294	0
Hand-held holding	293	1
Hand-held browsing	291	3
Hand-held texting	294	0
Hands-free call via headset/earpiece	294	0
Hands-free call via speakerphone	294	0
Hands-free talk/listen	294	0

APPENDIX E: PAIRWISE COMPARISON RESULTS FOR RESEARCH QUESTION 7

Table 111. Differences of Hour Least Squares Means Adjustment for Multiple Comparisons—SCE rate.

Hour	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Hour 2 vs. hour 1	0.42	0.08	1329	5.05	<.0001	<.0001
Hour 3 vs. hour 1	0.65	0.08	1329	8.22	<.0001	<.0001
Hour 3 vs. hour 2	0.24	0.07	1329	3.35	0.0008	0.0338
Hour 4 vs. hour 1	0.76	0.08	1329	9.53	<.0001	<.0001
Hour 4 vs. hour 2	0.35	0.07	1329	4.85	<.0001	<.0001
Hour 4 vs. hour 3	0.11	0.07	1329	1.6	0.1094	0.8816
Hour 5 vs. hour 1	0.81	0.08	1329	9.57	<.0001	<.0001
Hour 5 vs. hour 2	0.39	0.08	1329	5.14	<.0001	<.0001
Hour 5 vs. hour 3	0.15	0.07	1329	2.12	0.0345	0.5656
Hour 5 vs. hour 4	0.05	0.07	1329	0.63	0.5316	0.9999
Hour 6 vs. hour 1	0.94	0.09	1329	10.41	<.0001	<.0001
Hour 6 vs. hour 2	0.53	0.08	1329	6.33	<.0001	<.0001
Hour 6 vs. hour 3	0.29	0.08	1329	3.6	0.0003	0.0146
Hour 6 vs. hour 4	0.18	0.08	1329	2.23	0.0257	0.4815
Hour 6 vs. hour 5	0.13	0.08	1329	1.58	0.1133	0.8889
Hour 7 vs. hour 1	0.81	0.11	1329	7.46	<.0001	<.0001
Hour 7 vs. hour 2	0.39	0.10	1329	3.84	0.0001	0.006
Hour 7 vs. hour 3	0.16	0.10	1329	1.56	0.1194	0.8993
Hour 7 vs. hour 4	0.05	0.10	1329	0.47	0.6404	1
Hour 7 vs. hour 5	0.00	0.10	1329	0.01	0.9943	1
Hour 7 vs. hour 6	-0.13	0.11	1329	-1.24	0.2162	0.9782
Hour 8 vs. hour 1	1.03	0.12	1329	8.45	<.0001	<.0001
Hour 8 vs. hour 2	0.61	0.12	1329	5.27	<.0001	<.0001
Hour 8 vs. hour 3	0.37	0.11	1329	3.28	0.0011	0.0423
Hour 8 vs. hour 4	0.26	0.11	1329	2.32	0.0204	0.4196
Hour 8 vs. hour 5	0.22	0.12	1329	1.88	0.0607	0.7323
Hour 8 vs. hour 6	0.09	0.12	1329	0.71	0.4751	0.9998
Hour 8 vs. hour 7	0.22	0.13	1329	1.64	0.1017	0.866
Hour 9 vs. hour 1	0.76	0.18	1329	4.22	<.0001	0.0013
Hour 9 vs. hour 2	0.35	0.18	1329	1.95	0.0508	0.6807
Hour 9 vs. hour 3	0.11	0.18	1329	0.62	0.5373	0.9999
Hour 9 vs. hour 4	0.00	0.18	1329	0	0.9975	1
Hour 9 vs. hour 5	-0.05	0.18	1329	-0.26	0.7931	1
Hour 9 vs. hour 6	-0.18	0.18	1329	-1	0.3175	0.9958
Hour 9 vs. hour 7	-0.05	0.19	1329	-0.25	0.8022	1

Hour	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Hour 9 vs. hour 8	-0.27	0.20	1329	-1.36	0.1752	0.9583
Hour 10 vs. hour 1	0.96	0.24	1329	4.06	<.0001	0.0025
Hour 10 vs. hour 2	0.54	0.23	1329	2.32	0.0204	0.4194
Hour 10 vs. hour 3	0.30	0.23	1329	1.31	0.1909	0.9675
Hour 10 vs. hour 4	0.19	0.23	1329	0.84	0.4016	0.999
Hour 10 vs. hour 5	0.15	0.23	1329	0.64	0.524	0.9999
Hour 10 vs. hour 6	0.02	0.23	1329	0.07	0.9467	1
Hour 10 vs. hour 7	0.15	0.24	1329	0.61	0.5408	0.9999
Hour 10 vs. hour 8	-0.07	0.25	1329	-0.28	0.7773	1
Hour 10 vs. hour 9	0.20	0.28	1329	0.7	0.4852	0.9998
Hour 11 vs. hour 1	-0.13	0.71	1329	-0.18	0.8575	1
Hour 11 vs. hour 2	-0.54	0.71	1329	-0.77	0.444	0.9996
Hour 11 vs. hour 3	-0.78	0.71	1329	-1.1	0.2714	0.991
Hour 11 vs. hour 4	-0.89	0.71	1329	-1.25	0.2103	0.976
Hour 11 vs. hour 5	-0.94	0.71	1329	-1.32	0.1879	0.9659
Hour 11 vs. hour 6	-1.07	0.71	1329	-1.5	0.133	0.9189
Hour 11 vs. hour 7	-0.94	0.71	1329	-1.31	0.1894	0.9667
Hour 11 vs. hour 8	-1.15	0.72	1329	-1.61	0.1067	0.8764
Hour 11 vs. hour 9	-0.89	0.73	1329	-1.22	0.2214	0.9799
Hour 11 vs. hour 10	-1.09	0.74	1329	-1.46	0.1441	0.932

APPENDIX F: PAIRWISE COMPARISON RESULTS FOR RESEARCH QUESTION 8

Table 112. Tukey-Kramer multiple comparison results for PERCLOS percentage (systematic baselines).

Hour	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Hour 3 vs. Hour 1	1.09	0.60	885	1.80	0.07	0.74
Hour 3 vs. Hour 5	1.35	0.65	885	2.10	0.04	0.53
Hour 3 vs. Hour 7	2.87	1.08	885	2.65	0.01	0.20
Hour 3 vs. Hour 8	1.68	0.71	885	2.36	0.02	0.35
Hour 3 vs. Hour 9	1.69	0.71	885	2.38	0.02	0.34
Hour 3 vs. Hour 10	1.74	0.71	885	2.45	0.01	0.30
Hour 3 vs. Hour 11	779.11	0.60	885	1290.62	<.0001	<.0001
Hour 5 vs. Hour 1	-0.27	0.72	885	-0.37	0.71	1.00
Hour 5 vs. Hour 7	1.52	1.15	885	1.32	0.19	0.95
Hour 5 vs. Hour 8	0.33	0.81	885	0.40	0.69	1.00
Hour 5 vs. Hour 9	0.33	0.81	885	0.41	0.68	1.00
Hour 5 vs. Hour 10	0.39	0.81	885	0.48	0.63	1.00
Hour 5 vs. Hour 11	777.76	0.72	885	1078.75	<.0001	<.0001
Hour 7 vs. Hour 1	-1.79	1.13	885	-1.59	0.11	0.86
Hour 7 vs. Hour 8	-1.19	1.19	885	-1.01	0.31	0.99
Hour 7 vs. Hour 9	-1.19	1.19	885	-1.00	0.32	0.99
Hour 7 vs. Hour 10	-1.13	1.18	885	-0.95	0.34	0.99
Hour 7 vs. Hour 11	776.24	1.13	885	688.26	<.0001	<.0001
Hour 8 vs. Hour 1	-0.60	0.78	885	-0.77	0.44	1.00
Hour 8 vs. Hour 9	0.01	0.86	885	-0.01	1.00	1.00
Hour 8 vs. Hour 10	0.06	0.86	885	-0.07	0.94	1.00
Hour 8 vs. Hour 11	777.43	0.78	885	-999.35	<.0001	<.0001
Hour 9 vs. Hour 1	-0.60	0.78	885	-0.77	0.44	1.00
Hour 9 vs. Hour 10	0.06	0.86	885	0.07	0.95	1.00
Hour 9 vs. Hour 11	777.43	0.78	885	1000.64	<.0001	<.0001
Hour 10 vs. Hour 1	-0.66	0.78	885	-0.85	0.40	1.00
Hour 10 vs. Hour 11	777.37	0.78	885	1000.72	<.0001	<.0001
Hour 11 vs. Hour 1	-778.03	0.00	885	-Infty	<.0001	.

Table 113. Tukey-Kramer multiple comparison results for PERCLOS percentage (SCEs).

Hour	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Hour 2 vs. Hour 1	0.78	0.33	1600	2.37	0.02	0.39
Hour 2 vs. Hour 3	0.13	0.28	1600	0.48	0.63	1.00
Hour 2 vs. Hour 4	0.98	0.32	1600	3.07	0.00	0.08
Hour 2 vs. Hour 5	0.72	0.33	1600	2.17	0.03	0.53
Hour 2 vs. Hour 6	0.71	0.40	1600	1.79	0.07	0.79
Hour 2 vs. Hour 7	0.96	0.49	1600	1.98	0.05	0.67
Hour 2 vs. Hour 8	1.48	0.53	1600	2.79	0.01	0.16
Hour 2 vs. Hour 9	-0.12	0.57	1600	-0.21	0.83	1.00
Hour 2 vs. Hour 10	0.62	1.20	1600	0.52	0.61	1.00
Hour 2 vs. Hour 11	5.35	46.86	1600	0.11	0.91	1.00
Hour 3 vs. Hour 1	0.65	0.32	1600	2.02	0.04	0.64
Hour 3 vs. Hour 4	0.85	0.31	1600	2.75	0.01	0.18
Hour 3 vs. Hour 5	0.58	0.32	1600	1.81	0.07	0.77
Hour 3 vs. Hour 6	0.58	0.39	1600	1.48	0.14	0.93
Hour 3 vs. Hour 7	0.83	0.48	1600	1.74	0.08	0.82
Hour 3 vs. Hour 8	1.35	0.52	1600	2.59	0.01	0.26
Hour 3 vs. Hour 9	-0.25	0.56	1600	-0.45	0.66	1.00
Hour 3 vs. Hour 10	0.49	1.20	1600	0.41	0.68	1.00
Hour 3 vs. Hour 11	5.22	46.86	1600	0.11	0.91	1.00
Hour 4 vs. Hour 1	-0.20	0.36	1600	-0.56	0.58	1.00
Hour 4 vs. Hour5	-0.26	0.36	1600	-0.74	0.46	1.00
Hour 4 vs. Hour6	-0.27	0.41	1600	-0.66	0.51	1.00
Hour 4 vs. Hour7	-0.02	0.50	1600	-0.04	0.97	1.00
Hour 4 vs. Hour8	0.50	0.54	1600	0.92	0.36	1.00
Hour 4 vs. Hour9	-1.10	0.59	1600	-1.88	0.06	0.73
Hour 4 vs. Hour10	-0.36	1.21	1600	-0.3	0.77	1.00
Hour 4 vs. Hour11	4.37	46.86	1600	0.09	0.93	1.00
Hour 5 vs. Hour 1	0.06	0.38	1600	0.16	0.87	1.00
Hour 5 vs. Hour 6	-0.01	0.42	1600	-0.02	0.98	1.00
Hour 5 vs. Hour 7	0.24	0.51	1600	0.48	0.63	1.00
Hour 5 vs. Hour 8	0.76	0.55	1600	1.39	0.17	0.95
Hour 5 vs. Hour 9	-0.83	0.59	1600	-1.41	0.16	0.95
Hour 5 vs. Hour 10	-0.09	1.21	1600	-0.08	0.94	1.00
Hour 5 vs. Hour 11	4.64	46.86	1600	0.1	0.92	1.00
Hour 6 vs. Hour 1	0.07	0.42	1600	0.16	0.87	1.00
Hour 6 vs. Hour 7	0.25	0.53	1600	0.47	0.64	1.00
Hour 6 vs. Hour 8	0.77	0.57	1600	1.36	0.18	0.96
Hour 6 vs. Hour 9	-0.83	0.62	1600	-1.34	0.18	0.96
Hour 6 vs. Hour 10	-0.09	1.23	1600	-0.07	0.94	1.00

Hour	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Hour 6 vs. Hour 11	4.64	46.86	1600	0.1	0.92	1.00
Hour 7 vs. Hour 1	-0.18	0.51	1600	-0.36	0.72	1.00
Hour 7 vs. Hour 8	0.52	0.64	1600	0.81	0.42	1.00
Hour 7 vs. Hour 9	-1.08	0.68	1600	-1.59	0.11	0.89
Hour 7 vs. Hour 10	-0.34	1.26	1600	-0.27	0.79	1.00
Hour 7 vs. Hour 11	4.39	46.86	1600	0.09	0.93	1.00
Hour 8 vs. Hour 1	-0.70	0.55	1600	-1.28	0.20	0.97
Hour 8 vs. Hour 9	-1.60	0.71	1600	-2.27	0.02	0.46
Hour 8 vs. Hour 10	-0.86	1.27	1600	-0.68	0.50	1.00
Hour 8 vs. Hour 11	3.87	46.86	1600	0.08	0.93	1.00
Hour 9 vs. Hour 1	0.90	0.59	1600	1.53	0.13	0.91
Hour 9 vs. Hour 10	0.74	1.29	1600	0.57	0.57	1.00
Hour 9 vs. Hour 11	5.47	46.86	1600	0.12	0.91	1.00
Hour 10 vs. Hour 1	0.16	1.21	1600	0.13	0.90	1.00
Hour 10 vs. Hour 11	4.73	46.87	1600	0.1	0.92	1.00
Hour 11 vs. Hour 1	-4.57	46.86	1600	-0.1	0.92	1.00

Table 114. Tukey-Kramer multiple comparison results for ORD percentage (SCEs).

Hour	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Hour 2 vs. Hour 1	1.08	0.26	2142	4.11	<.0001	0.00
Hour 2 vs. Hour 3	0.48	0.21	2142	2.29	0.02	0.44
Hour 2 vs. Hour 4	1.33	0.23	2142	5.73	<.0001	<.0001
Hour 2 vs. Hour 5	1.33	0.25	2142	5.34	<.0001	<.0001
Hour 2 vs. Hour 6	1.72	0.30	2142	5.75	<.0001	<.0001
Hour 2 vs. Hour 7	1.80	0.35	2142	5.16	<.0001	<.0001
Hour 2 vs. Hour 8	1.94	0.40	2142	4.84	<.0001	<.0001
Hour 2 vs. Hour 9	0.92	0.50	2142	1.82	0.07	0.77
Hour 2 vs. Hour 10	2.64	1.10	2142	2.40	0.02	0.37
Hour 2 vs. Hour 11	6.04	17.38	2142	0.35	0.73	1.00
Hour 3 vs. Hour 1	0.60	0.26	2142	2.31	0.02	0.42
Hour 3 vs. Hour 4	0.85	0.23	2142	3.77	0.00	0.01
Hour 3 vs. Hour 5	0.85	0.24	2142	3.47	0.00	0.02
Hour 3 vs. Hour 6	1.24	0.29	2142	4.21	<.0001	0.00
Hour 3 vs. Hour 7	1.32	0.34	2142	3.84	0.00	0.01
Hour 3 vs. Hour 8	1.46	0.39	2142	3.70	0.00	0.01
Hour 3 vs. Hour 9	0.44	0.50	2142	0.87	0.38	1.00
Hour 3 vs. Hour 10	2.16	1.10	2142	1.96	0.05	0.68
Hour 3 vs. Hour 11	5.56	17.38	2142	0.32	0.75	1.00
Hour 4 vs. Hour 1	-0.25	0.28	2142	-0.90	0.37	1.00
Hour 4 vs. Hour5	0.00	0.26	2142	0.00	1.00	1.00
Hour 4 vs. Hour6	0.39	0.31	2142	1.28	0.20	0.97
Hour 4 vs. Hour7	0.47	0.35	2142	1.33	0.18	0.96
Hour 4 vs. Hour8	0.61	0.41	2142	1.51	0.13	0.92
Hour 4 vs. Hour9	-0.41	0.51	2142	-0.81	0.42	1.00
Hour 4 vs. Hour10	1.31	1.10	2142	1.19	0.24	0.98
Hour 4 vs. Hour11	4.71	17.38	2142	0.27	0.79	1.00
Hour 5 vs. Hour 1	-0.25	0.29	2142	-0.86	0.39	1.00
Hour 5 vs. Hour 6	0.39	0.32	2142	1.24	0.22	0.98
Hour 5 vs. Hour 7	0.47	0.37	2142	1.28	0.20	0.97
Hour 5 vs. Hour 8	0.61	0.41	2142	1.48	0.14	0.93
Hour 5 vs. Hour 9	-0.41	0.52	2142	-0.79	0.43	1.00
Hour 5 vs. Hour 10	1.31	1.11	2142	1.18	0.24	0.98
Hour 5 vs. Hour 11	4.71	17.38	2142	0.27	0.79	1.00
Hour 6 vs. Hour 1	-0.64	0.33	2142	-1.95	0.05	0.68
Hour 6 vs. Hour 7	0.08	0.39	2142	0.20	0.84	1.00
Hour 6 vs. Hour 8	0.22	0.43	2142	0.51	0.61	1.00
Hour 6 vs. Hour 9	-0.81	0.54	2142	-1.50	0.13	0.92
Hour 6 vs. Hour 10	0.92	1.11	2142	0.82	0.41	1.00

Hour	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
Hour 6 vs. Hour 11	4.32	17.38	2142	0.25	0.80	1.00
Hour 7 vs. Hour 1	-0.72	0.38	2142	-1.92	0.06	0.71
Hour 7 vs. Hour 8	0.14	0.47	2142	0.30	0.76	1.00
Hour 7 vs. Hour 9	-0.88	0.57	2142	-1.56	0.12	0.90
Hour 7 vs. Hour 10	0.84	1.13	2142	0.74	0.46	1.00
Hour 7 vs. Hour 11	4.24	17.38	2142	0.24	0.81	1.00
Hour 8 vs. Hour 1	-0.86	0.42	2142	-2.05	0.04	0.62
Hour 8 vs. Hour 9	-1.03	0.59	2142	-1.72	0.09	0.82
Hour 8 vs. Hour 10	0.70	1.14	2142	0.61	0.54	1.00
Hour 8 vs. Hour 11	4.10	17.39	2142	0.24	0.81	1.00
Hour 9 vs. Hour 1	0.16	0.52	2142	0.31	0.76	1.00
Hour 9 vs. Hour 10	1.72	1.19	2142	1.45	0.15	0.94
Hour 9 vs. Hour 11	5.13	17.39	2142	0.29	0.77	1.00
Hour 10 vs. Hour 1	-1.56	1.11	2142	-1.41	0.16	0.95
Hour 10 vs. Hour 11	3.40	17.42	2142	0.20	0.85	1.00
Hour 11 vs. Hour 1	-4.96	17.38	2142	-0.29	0.78	1.00

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