Driver Distraction: Eye Glance Analysis and Conversation Workload

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

November 2015

FOREWORD

The objective of this Federal Motor Carrier Safety Administration (FMCSA) project was to better understand the relationship between secondary tasks, conversation workload (a proxy for cognitive distraction), and visual distraction while the driver is experiencing real-world driving conditions and pressures. The data were collected during a 4-month period from an existing naturalistic database from an onboard monitoring system vendor. These data are intended to provide FMCSA with data about the adverse consequences of performing secondary tasks while driving a commercial motor vehicle (CMV).

NOTICE

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16. Abstract

The objective of this project was to assess the risk of performing a secondary task while driving a commercial motor vehicle (CMV). The risk of conversation workload while driving a CMV was also assessed. Conversation workload is a proxy for cognitive distraction or the amount of mental workload associated with thinking about something other than the driving task. The data were collected from an existing naturalistic driving dataset. Naturalistic driving data records a driver performing his or her normal duties. The data were from 6,379 commercial trucks and buses during a 4-month period. The study found that talking to passenger(s) significantly increased the risk of a safety critical event (SCE). However, talking or listening on an electronic device while driving did not pose a significant risk. Drivers who looked away from the forward roadway close to the trigger point were more likely to be involved in an SCE. Talking time analyses showed that the longer a driver talked while driving, the less likely that driver was to be involved in an SCE. Results from the conversation workload analyses were inconclusive because there were not enough data for an assessment. Finally, the current study compared spurious and random baselines. Spurious baselines are recordings that are triggered by events not related to safety such as a vehicle traveling across railroad tracks. The study found that talking time and visual distraction plots for random and spurious baselines were similar. As a result, spurious baselines are acceptable for use in place of random baselines.

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truck, commercial motor vehicle, distraction, visual distraction, conversation workload, emotion, odds ratio, environment, workload, naturalistic	**No restrictions**

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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
CB	citizens band radio
CI	confidence interval
CMV	commercial motor vehicle
df	degrees of freedom
EOFR	eyes off forward roadway
FMCSA	Federal Motor Carrier Safety Administration
GPS	global positioning system
Hz	hertz
LCL	lower confidence level
OR	odds ratio
OSM	onboard safety monitoring
PAR	population attributable risk
SCE	safety-critical event
SD	standard deviation
SE	standard error
UCL	upper confidence level
VM	visual/manual
VR	voice-related
USDOT	U.S. Department of Transportation

Symbol	Definition
®	registered trademark
™	trademark

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EXECUTIVE SUMMARY

Distraction from the primary task of driving can be serious and potentially deadly. In 2013, there were 2,910 fatal crashes that involved distraction that occurred on the Nation's roadways (or 10 percent of all fatal crashes). These crashes involved 2,959 distracted drivers (some crashes involved more than 1 distracted driver). Distraction was reported for 7 percent (2,959 of 44,574) of the drivers involved in fatal crashes. In these distraction-affected crashes, 3,154 fatalities (10 percent of overall fatalities) and 424,000 injuries (18 percent of total people injured) occurred.[(1)]

BACKGROUND

There are various types of distraction that an individual can experience while driving. This report looks at two specific types of distraction and seeks to understand how they impact driving performance, both individually and collectively:

1. **Cognitive Distraction.** Cognitive distraction is the amount of mental workload associated with thinking about something other than the driving task.[(2)] In this study, the term "conversation workload" is used as a proxy for "cognitive distraction," because voice-related events (i.e., conversation-related events) are being analyzed, specifically. Cognitive distraction is generally not observable, but it can be inferred from video and audio analysis. For example, a driver would have increased conversation workload (and therefore would be experiencing some form of cognitive distraction) while talking to a passenger or even while talking on a mobile device.
2. **Visual Distraction.** Visual distraction occurs any time a driver takes his or her eyes off the forward roadway (EOFR). Specific visual distractions could include looking at a passenger or looking at a mobile phone. Visual distraction is observable.

RESEARCH OBJECTIVES

The objective of this project was to address research gaps related to distracted driving and to obtain a better understanding of the relationship of conversation workload and visual distraction during mobile phone conversations or interactions while the driver is experiencing real-world driving conditions and pressures.

RESEARCH GAPS

More research is needed in the area of cognitive distraction while driving. Further, more research is needed to examine eye glances as they relate to driver distraction. Olson et al. analyzed drivers' eye glances (using naturalistic driving data) in 6-second increments (i.e., a 6-second analysis envelope).[(3)] Recommendations to improve the description of how eye glances were used in the 6-second analysis envelope included:

- Describing whether the glance was the result of poor timing just before the onset of a safety-critical event (SCE).

- Describing whether the glance was a single long glance occurring at some point during the 6-second analysis envelope.
- Explaining if using the total time the driver's eyes were off the forward roadway could be prone to misinterpreting grouped glances as a single glance.

Finally, Hickman et al. used "spurious baselines" when analyzing truck and bus driver distraction.[4] Spurious baselines are recordings that are triggered by events not related to safety, such as a vehicle traveling across train tracks. Because these spurious baselines were not truly random, this increased possible biasing to certain situations that triggered the spurious baselines. For that reason, these baselines did not contain periods during which the driver was driving and nothing occurred on the roadway.

DATA COLLECTION SYSTEM

The data were collected during a 4-month period from an existing naturalistic database maintained by an onboard monitoring systems vendor. The onboard monitoring system platform used in the current study had two camera views (the driver's face and the forward road, as shown in Figure 1), one audio channel, and global positioning system (GPS) data. The system also recorded speed and acceleration and provided driver feedback. A light on the recorder changed colors to provide the driver with immediate feedback regarding his or her historical driving performance. The recorder had three accelerometers (y-, x-, and z-axes) that triggered when a potential SCE was to be recorded. When a certain criterion was met or surpassed, the recorder saved 30 seconds of video (i.e., 15 seconds prior to the criterion being met or surpassed and 15 seconds after). Once potential SCEs were validated and reduced, the SCEs were uploaded to a secure server where fleet safety managers and other fleet personnel with the required permissions could access the data (including video, audio, kinematic, and data analyst comments).

Figure 1. Photograph. Two-camera view from the onboard monitoring system used in the current study.

For the purposes of the current study, the technology vendor added a specific triggering enhancement to its firmware logic that allowed the collection of random baselines. An algorithm in the onboard monitoring system performed periodic checks, each with a random chance of a trigger while the vehicle was in motion. The baseline triggering frequency was approximately once every 200 minutes while the vehicle was in motion.

DATA REVIEW PROCESS

Recording of potential SCEs was triggered in one of three ways: speeding, exceeding the criteria on one or more of the three accelerometers (e.g., hard braking, hard cornering, collision, rough road, etc.), or manual activation (pressing a button). The recorder was active 24 hours per day, 7 days per week. Data relating to potential SCEs were typically transmitted at night across a cellular network from the recorder to the technology vendor. Recordings from potential events included 30 seconds of video, audio, and key kinematic and vehicle data (i.e., serial number, settings, accelerometer data, GPS, speed, date/time stamp of recorded events, and recorder logs). After all data associated with a potential SCE were transmitted to the technology vendor, a data analyst reviewed the information to determine if the event was truly an SCE. Potential events deemed to have no relationship to safety were categorized as spurious baselines (e.g., the vehicle traveled across train tracks or a pothole and exceeded the kinematic threshold; the driver braked in response to no apparent traffic safety situation; etc.). While reviewing the data associated with identified SCEs, data analysts recorded information about each driver's behavior (including secondary tasks, talking time, conversation workload, and visual behavior) and environmental conditions.

Odds ratios (ORs) were used to assess the risk posed from drivers engaged in non-driving tasks while driving. However, the cell counts in most of the individual secondary tasks were fairly low, thereby resulting in unstable ORs that made interpretation difficult. Thus, as shown in Table 1, the secondary tasks were combined into mutually exclusive categories (similar to those used in a Fitch et al. report.[(5)] Secondary tasks in each of these categories shared similar visual, manual, or cognitive demands (or a combination of these demands) on the driver. As shown, the secondary task "Talk to Passengers" was not grouped with any other secondary tasks in a secondary task category. Although previous naturalistic driving truck studies have not aggregated visual/manual (VM) secondary tasks into secondary task categories as in the current study, most of the specific VM secondary tasks in these prior studies have shown a significant increase in the likelihood of involvement in an SCE while performing these tasks while driving.[(6,7)]

Table 1. Categories for each secondary task.

Secondary Task Category	Secondary Task
No Distraction Found	No Distraction Found
Visual	Look at Passengers
Visual	Mobile Phone—Look at Phone
Visual/Manual (VM)	Citizens Band (CB) Radio—Put CB Away
VM	CB—Reach for CB
VM	Interact with Dispatching Device
VM	Mobile Phone—Dial/Answer
VM	Mobile Phone—Put Mobile Phone/Headset/Earpiece Away
VM	Mobile Phone—Reach for and Pick up Headset/Earpiece
VM	Mobile Phone—Reach for and Pick up Phone
VM	Mobile Phone—Text
VM	Push-to-talk—Reach for Push-to-talk Mobile Phone
VM	Push-to-talk—Put Push-to-talk Phone Away
Talk/Listen on an Electronic Device	Mobile Phone—Talk/Listen (handheld)
Talk/Listen on an Electronic Device	Mobile Phone—Talk/Listen (hands-free)
Talk/Listen on an Electronic Device	Talk or Listen on Push-to-talk Phone
Talk/Listen on an Electronic Device	Talk or Listen to CB Microphone
Talk to Passengers	Talk to Passengers

The final data set included 23,280 observations (from 77 different companies at 483 different locations) that were reduced by data analysts. Of these, there were:

- 1,121 SCEs.
- 11,562 random baselines.
- 10,597 spurious baselines.

DISCUSSION OF RESULTS

The objective of this study was to better understand the risk associated with secondary task activity (with a specific focus on voice-related secondary tasks) while driving a truck or bus under real-world driving conditions and pressure. Unfortunately, the small sample size of specific secondary tasks prohibited an analysis at this level of the data. To increase statistical power, the current analysis focused on secondary task categories, such as visual, VM, talk/listen on an electronic device, and talk to passengers. The results were consistent regardless of the approach used. For example, the secondary task category of talk/listen on an electronic device was consistently found to have no significant impact on the risk of involvement in an SCE compared to spurious baselines and random baselines. This result is consistent with other naturalistic truck driving research which found that talking/listening on a handheld device did not increase the risk of involvement in an SCE, and talking on a hands-free phone or CB decreased the risk of involvement in an SCE.[8,9]

There were two interesting findings related to the visual, VM, and "Talk to Passenger" secondary task categories. In this study, visual and VM secondary task categories were consistently found to have no impact on the risk of involvement in an SCE compared to spurious and random baselines. However, given the small sample size and grouping into secondary task categories, it is premature to indicate that visual or VM secondary tasks are safe to perform while driving a truck or bus.

The only significant secondary task category was "Talk to Passengers." Talking to passengers while driving significantly increased the likelihood of involvement in an SCE compared to spurious baselines and random baselines. Research about the risk of talking to a passenger while driving is mixed. Some studies have found a decrease in risk[10] or no increase in risk.[11] Studies that have found a decrease in risk suggest that an extra pair of eyes on the road to warn the driver of upcoming threats and/or the passenger's ability to modulate the conversation can benefit the driver. Other studies have found this secondary task increases risk,[12,13] suggesting the conversation itself and/or the propensity for drivers to look at the passenger to whom they are talking creates a safety deficit. However, this study does not address why talking to a passenger while driving is more likely to result in an SCE compared to talking/listening on an electronic device while driving.

During the current study, conversation workload was measured via the expression and intensity of emotion during a conversation (on a mobile phone or with a passenger). What data analysts did find during this study was that CMV drivers rarely have emotional conversations while driving, and coding emotion using a brief clip of audio and video was difficult (as indicated by the high number of "unsure" ratings). Of course, data analysts only had brief video clips and audio recordings to review; thus, it is possible that a driver may have experienced an emotion, but did not overtly display this emotion. A naturalistic study by Fitch et al.[14] supports these findings. Using video and mobile phone records, Fitch et al.[15] found that only 3.8 percent of the video clips that occurred while drivers drove a passenger car were deemed to show some type of emotion (it should be noted that no audio was available for analysis in the Fitch et al. study). Taken together, these two naturalistic studies suggest that emotional conversations while driving are rare.

The current study assessed risk as a function of 0.25-second intervals. None of the talking intervals during any of the analyses resulted in a significant increase in the likelihood of a voice-related SCE. In fact, the majority of intervals were significantly less likely to result in a voice-related SCE, especially those intervals from 0–4.0 seconds. This suggests that the amount of talking time (or the interval) during which a driver was talking on an electronic device did not increase the likelihood of a voice-related SCE.

Most of the significant ORs for time intervals of EOFR glances occurred close to and after the trigger points. This suggests the timing of the glance away from the forward roadway is important. However, this does not invalidate the importance of mean EOFR glance times or total EOFR glance times, as it is difficult to predict when something unexpected will occur. If anything, greater mean and total EOFR glance times should be predictive of increased risk, as the longer a driver looks away from the forward roadway, the greater the probability a driver will be looking away from the forward roadway when something unexpected occurs. What is clear from this study is that drivers were associated with fewer EOFR glance counts when they were talking.

1. BACKGROUND AND SIGNIFICANCE

Distraction from the primary task of driving can be serious and potentially deadly. In 2013, there were 2,910 fatal crashes that involved distraction that occurred on the Nation's roadways (or 10 percent of all fatal crashes). These crashes involved 2,959 distracted drivers (some crashes involved more than 1 distracted driver). Distraction was reported for 7 percent (2,959 of 44,574) of the drivers involved in fatal crashes. In these distraction-affected crashes, 3,154 fatalities (10 percent of overall fatalities) and 424,000 injuries (18 percent of total people injured) occurred.[16]

1.1 FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION (FMCSA) RESEARCH ABOUT TRUCK DRIVER DISTRACTION

In the past 3 years, the Federal Motor Carrier Safety Administration (FMCSA) completed two studies about truck driver distraction. The purpose of the study entitled, "Driver Distraction in Commercial Vehicle Operations," (completed by Olson et. al) was to investigate the prevalence of driver distraction in commercial motor vehicle (CMV) drivers as recorded in a naturalistic driving data set. The data set included more than 200 instrumented trucks and data from 3 million miles of driving during normal, revenue-producing deliveries.[17] Naturalistic driving studies involve the use of video and kinematic sensors to record drivers in actual driving situations under real-world pressures. During the study, 4,452 safety-critical events (SCEs) were reported. SCEs include crashes, near-crashes, crash-relevant conflicts, and unintentional lane deviations. Of the SCEs reported in the above-referenced data set, 60 percent had some type of non-driving-related task listed as a potential contributing factor.

The Olson et al. study[18] calculated odds ratios (ORs) to determine the "risk" of being involved in an SCE while engaging in a non-driving task while driving. The odds of being involved in an SCE were three times greater when the driver was reaching for an object compared to when the driver was not reaching for an object while driving. The odds of being involved in an SCE were six times greater when the truck driver was dialing on a mobile phone compared to when the truck driver was not dialing while driving. However, the odds of being involved in an SCE while talking or listening to a handheld or hands-free mobile phone did not show an increased risk of being involved in an SCE. The last finding regarding talking and listening on a handheld or hands-free mobile phone is noteworthy, as simulator and epidemiological studies have found that talking/listening on a mobile phone while driving does increase risk (see references 19, 20, 21, 22, 23, and 24).

In addition, Olson et al.[25] calculated the population attributable risk (PAR) percentage, or the proportion of SCEs that would be eliminated if the risk were removed. If a large population of truck drivers performs a task more frequently, it will have a greater PAR percentage. The PAR percentage for reaching for an object was the highest in the study at 7.6 percent. Thus, there would be 7.6 percent fewer SCEs if reaching for an object were eliminated. By contrast, the PAR percentage for talking/listening on a handheld mobile phone was low (0.2 percent); the PAR percentage was not calculated for talking/listening on a hands-free mobile phone.

The second driver distraction study completed by FMCSA was "Distraction in Commercial Trucks and Buses: Assessing Prevalence and Risk in Conjunction with Crashes and Near-

Crashes."[26] The purpose of this research was to conduct an analysis of naturalistic data collected by a video event data recorder. In this study, Hickman et al.[27] documented the prevalence of distractions while driving a CMV, including trucks and buses, using an existing naturalistic driving data set. The data set included 183 different truck and bus fleets comprising 13,306 vehicles (8,509 buses and 4,797 trucks) traveling during a 90-day period. The data set did not include continuous data; instead, it included recorded events that met or exceeded a kinematic threshold (e.g., a minimum g-force setting that triggered the recorded event). These recorded events included SCEs (e.g., hard braking in response to another vehicle) and spurious baselines (e.g., an event that was not related to safety, such as a vehicle traveling over a pothole and exceeding the kinematic threshold). A total of 1,085 crashes, 8,375 near-crashes, 30,661 crash-relevant conflicts, and 211,171 baselines were captured in the data set.

Hickman et al.[28] calculated ORs to show a measure of association between involvement in an SCE and performing a non-driving task while driving. The odds of involvement in an SCE increased significantly when truck and bus drivers performed certain non-driving tasks while driving a truck or bus, including reaching for a mobile phone while driving (OR = 3.7), dialing a phone while driving (OR = 3.5), and reaching for a headset/earpiece (OR = 3.4). Drivers decreased the odds of being involved in an SCE by 0.65 times while talking/listening on a hands-free phone while driving a truck or bus. Consuming food/drink and talking/listening on a handheld phone (ORs = 1.11 and 0.89, respectively) had a statistically non-significant OR, meaning there was no increase or decrease in risk. However, the OR for talking/listening on a handheld phone should not preclude the fact that a person usually has to reach for and/or dial a mobile phone to talk/listen.

1.2 OTHER DRIVER DISTRACTION STUDIES

Numerous research studies have addressed driver distraction. Most of these studies address issues relating to the distraction effects of mobile phones. The relevant literature has grown to the point that several comprehensive reviews have been published.[29,30] Despite the preponderance of experimental evidence that consistently reveals driving performance degradation associated with mobile phone use while driving (see references 31, 32, 33, 34, and 35), a study by McCartt et al.[36] questioned the usefulness of the experimental data for assessing the safety implications of mobile phone use while driving. McCartt et al.[37] referred to a lack of "operational clarity," which refers to the difficulties involved in comparing results from studies that used different methods. This raises concerns about the reliability of the findings and their ecological validity, which refers to how well the experiments re-create the real-world challenges of mobile phone use while driving. This area of research has been criticized for using artificial mobile phone tasks and has resulted in considerable difficulty characterizing the content and level of driver involvement in mobile phone conversations.[38] However, recent studies have attempted to address these shortcomings. For example, Fitch et al.[39] evaluated driver workload (e.g., lighting condition, weather, traffic density, etc.) during naturalistic passenger and truck driver mobile phone conversations while driving, and Funkhouser and Sayer[40] conducted a naturalistic census of mobile phone use while driving a passenger car.

1.3 RESEARCH GAPS

More research is needed in the area of cognitive distraction while driving. In the context of this study, cognitive distraction involves tasks that are defined by the mental workload associated with an activity that includes thinking about something other than the driving task.[41] Cognitive distraction is generally not observable but can be inferred from video and audio analyses.

The level of distraction and the corresponding primary driving task degradation is likely to be greater when a driver is heavily engaged in a meaningful, serious, or emotional conversation than when engaged in a superficial or non-emotional conversation.[42,43] The same is true for a complex versus a simple conversation (e.g., such as receiving and processing directions versus discussing what items to get at the store).[44,45,46] These two dimensions (the level of driver engagement and conversation complexity) combine to influence the amount of mental workload or effort a driver devotes to a mobile phone conversation while driving (i.e., cognitive distraction). However, these studies have only been conducted in a simulated environment; thus, there is no published research that characterizes the dynamics of naturalistic mobile phone conversations. This has raised concerns about the ecological validity of simulator research with regard to mobile phone conversation complexity and engagement.[47]

In addition, more research is needed to examine eye glances as they relate to driver distraction. Olson et al.[48] assessed visual distraction via the time that drivers' eyes were off the forward roadway. However, data from this study could be re-analyzed to refine the eye-glance results. As the glances were reduced individually, it is possible to perform a more glance-specific type of analysis. In the Olson et al.[49] peer review report, Dr. Trent Victor recommended a more detailed description of how glances were used within the 6-second analysis envelope, including:

- Whether the glance was the result of poor timing just before the onset of SCEs.
- Whether the glance was a single long glance occurring at some point during the 6-second analysis envelope.
- Whether using the total time the driver's eyes were off the forward roadway could be prone to misinterpreting grouped glances as a single glance.

Rather than examining total eyes off forward roadway (EOFR) glance times, the finding of a statistically-significant association between EOFR glance times of < 1 second and involvement in an SCE[50] may suggest that shorter glances performed just prior to the SCE can be problematic. These short glances may also be regarded as "check" glances and are best understood by examining the changes in these shorter glances in baselines and comparing them to tasks performed during SCEs. More complex tasks are likely to require more check glances.[51] Thus, glances of < 1 second could be the result of engaging in more complex tasks and should be evident in glance histograms along with longer glances.

Olson et al.[52] showed a statistically-significant "gaze concentration" effect for talk/listen on a citizens band (CB) radio and talk/listen on a hands-free phone. Both tasks showed a statistically-significant gaze concentration effect when talking/listening in comparison with baseline driving. This finding is in line with other research about the effect of gaze concentration, which shows that some cognitive tasks do have an effect on driver performance.[53,54] Based on Olson et al.,[55] it appears that talking tasks may cause the driver to look more at the road, and visual/manual (VM) tasks, such as texting and dialing, may cause the driver to look away from the road.

Finally, Hickman et al.[56] used spurious baselines (e.g., the vehicle traveled across train tracks or a pothole and exceeded the kinematic threshold, or the driver braked in response to no apparent traffic safety situation, etc.) during their analysis of truck and bus driver distraction. Although the spurious baselines collected in Hickman et al. were not randomly selected, they were used to evaluate the risk in performing various non-driving tasks while driving. The lack of continuous data collection or randomly collected video segments means that there was no “true” baseline or control data. The authors argue this had little effect on the results because:

- The similarity in the ORs with the Olson et al. study,[57] which did use true baseline events, suggests the lack of random baselines likely had little or no influence on the findings.
- Dingus et al.[58] found that randomly-selected baseline events in the 100-Car Study had a similar kinematic profile as did the crash-relevant conflicts (the lowest-severity SCE).

However, the non-random baselines that Hickman et al.[59] used were not truly random, thus increasing possible biasing to certain situations that triggered the baselines (e.g., potholes, train tracks, etc.). For that reason, these baselines did not contain periods of driving during which the driver was driving, and nothing occurred on the roadway. There are still concerns regarding whether this approach was appropriate. The current study will address some of these limitations by including an analysis of spurious baselines and random baselines, conversation workload (a proxy for cognitive distraction), visual distraction (longest glance, mean EOFR glance time, 0.5-second intervals), and talking time.

1.4 RESEARCH OBJECTIVES

The objective of this FMCSA-funded project was to obtain a better understanding of the relationship of conversation workload and visual distraction during mobile phone conversations or interactions while a driver is experiencing real-world driving conditions and pressures. The data were collected during a 4-month period from an existing naturalistic database maintained by an onboard monitoring systems vendor. Research objectives were as follows:

- **Research Objective 1**: Assess the risk of mobile phone subtasks (e.g., dialing, talking, listening, etc.) for hands-free, handheld, CB radio, and push-to-talk devices, as well as other electronic devices (such as a dispatching device).
- **Research Objective 2**: Determine if conversation workload is related to voice-related (VR) SCE risk (e.g., any SCEs during which the driver and/or passenger are talking, such as talking to a passenger, talking on a mobile phone, etc.).
- **Research Objective 3**: Assess the risk of talking behavior as it relates to involvement in a VR SCE.
- **Research Objective 4**: Assess the risk of eye-glance behavior as it relates to involvement in a VR SCE.

- **Research Objective 5**: Assess the difference between spurious baselines and random baselines. There is no section devoted to this research objective; research objectives 1–4 include analyses for spurious and random baselines. The results from these analyses are described in Section 5.

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2. OVERVIEW OF THE SUBJECT ONBOARD SAFETY MONITORING SYSTEM

The onboard safety monitoring (OSM) system used in this study aims to reduce risky driving behaviors by using in-vehicle video technology. The technology vendor who provided the system used in this study serves a variety of industries and delivers solutions that make it easy for fleet managers to advance driver safety and operational savings. The technology vendor records comprehensive video-based data from the road, thoroughly reviews operational and safety performance, and provides recommendations and tools that allow fleet managers to respond easily and deliver coaching cost savings. Video, audio, and kinematic data snippets (recorded with a kinematic trigger, such as a hard brake at a preset threshold) were made available for analysis during this study. The research team did not receive any raw video or audio data from the technology vendor; the team only received anonymous, de-identified categorical data formulated from the reduction of videos performed by the technology vendor staff.

2.1 DATA COLLECTION SYSTEM

The onboard monitoring system platform used in the current study has two camera views (a 160-degree view of the cab centered on the driver's face and a 120-degree view of the forward road), one audio channel, and global positioning system (GPS) data. The system also records speed and acceleration and provides driver feedback. Figure 2 shows the two camera views captured by the onboard monitoring system. A light on the recorder changes colors to provide the driver with immediate feedback regarding his or her historical driving performance. The recorder has three accelerometers (y-, x-, and z-axes) that trigger when a potential SCE is to be recorded. When a certain criterion is met or surpassed (e.g., greater than or equal to $|0.5\ g|$), the recorder saves 30 seconds of video (i.e., 15 seconds prior to the criterion being met or surpassed and 15 seconds after). Once potential SCEs have been validated and reduced, the SCEs are uploaded to a secure server where fleet safety managers and other fleet personnel with the required permissions can access the video, audio, and kinematic data (and the data analyst's comments). Figure 3 illustrates the secure interface where fleet safety managers can access recorded SCEs. Fleet personnel use these videos and associated data from the SCEs to coach drivers to reduce risky driving behaviors and to praise appropriate responses to safety situations.

It is important to note the current study was an observational study that evaluated associations between various secondary tasks and SCE occurrence. The current study did not evaluate cause and effect (e.g., texting on a mobile phone caused an SCE), but rather showed which secondary tasks increased a commercial vehicle operator's odds of being involved in an SCE if he or she engaged in those secondary tasks while driving. The current data set does not reflect the actual prevalence of secondary tasks given the presence of the technology vendor's OSM device. However, the presence of an OSM device does not change the riskiness of engaging in secondary tasks while driving; it only affects the prevalence of drivers who engage in this those tasks while driving. Thus, the ORs presented in the analyses below reflect the actual risk of engaging in those secondary tasks while driving.

Figure 2. Photograph. Two-camera view from the onboard monitoring system used in the current study.

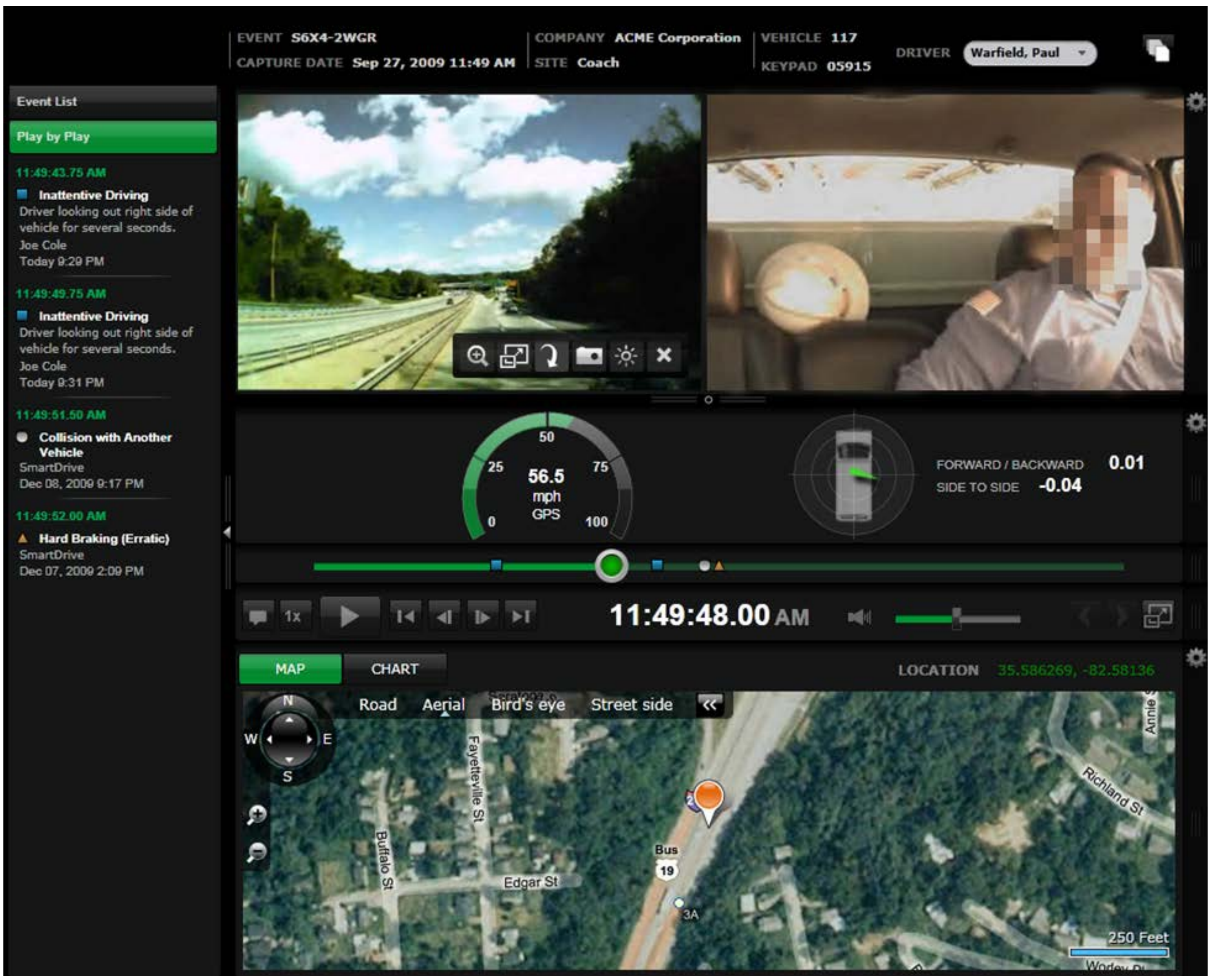

Figure 3. Screenshot. Secure interface where fleet safety managers can access recorded SCEs.

For the purposes of the current study, the technology vendor added a specific triggering enhancement to its firmware logic that allowed the collection of random baselines. An algorithm in the onboard monitoring system performed period checks, each with a random chance of a trigger while the vehicle was in motion (e.g., generating a number from 1–100 once every 10 minutes). If the generated number was less than or equal to 5, then a baseline collection of 30 seconds of video, audio, and associated data began. Thus, the baseline triggering frequency was approximately once every 200 minutes while the vehicle was in motion.

2.2 DATA REVIEW PROCESS

Recording of potential SCEs was triggered in one of three ways: speeding, exceeding the criteria on one or more of the three accelerometers (e.g., hard braking, hard cornering, collision, rough road, etc.), or manual activation (e.g., pressing a button). The recorder was active 24 hours per day, 7 days per week. However, potential SCEs and other safety-related behaviors would not be captured unless the criteria for speeding or the three accelerometers were exceeded or manually activated. Data relating to potential SCEs were typically transmitted at night across a cellular network from the recorder to the technology vendor. Recordings from potential events included 30 seconds of video, audio, and key kinematic and vehicle data (i.e., serial number, settings, accelerometer data, GPS, speed, date/time stamp of recorded events, and recorder logs). After all data associated with a potential SCE were transmitted to the technology vendor, a data analyst reviewed the information to determine if the event was truly an SCE. Potential events deemed to have no relationship to safety were called spurious baselines (e.g., the vehicle traveled across train tracks or a pothole and exceeded the kinematic threshold; the driver braked in response to no apparent traffic safety situation; etc.). While reviewing the data associated with identified SCEs, data analysts recorded information about the drivers' behavior and environmental conditions according to more than 70 operational standards developed by the vendor (as shown in Figure 4).

Fundamental Driving Errors

Unprofessional Driving

Unsafe Backing
Unsafe Braking
Unsafe Lane Change
Unsafe Merging
Unsafe Passing
Unsafe Railroad Crossing
Unsafe Turning
Lane Departure/Straddling Lanes
Competitive/Aggressive Driving
Driving the Wrong Way - On Roadway
Driving the Wrong Way - Off Roadway
False Start
Curb Check/Jumped Curb

Vehicle Control

Driving with Two Hands off Wheel
Unattended Moving Vehicle

Stopping

Incomplete Stop at Light
Incomplete Stop at Stop Sign
Failure to Attempt to Stop at Light
Failure to Attempt to Stop at Stop Sign
Failure to Yield to Pedestrian(s)
Failure to Yield to Vehicle(s)

Speeding

Moderate Speeding (≤ 10 mph Over Limit)
Excessive Speeding (> 10 mph Over Limit)
Exceeded Maximum Fleet Speed

Situational Awareness

Unsafe Following (≤ 1 second)
Unsafe Following (1.25 - 2 seconds)
Unsafe Following (2.25 - 3 seconds)
Unsafe Following (3.25 - 4 seconds)
Not Checking Mirrors
Not Scanning Road Ahead
Not Scanning Intersection

Distracted & Inattentive Driving

Distraction

Mobile Phone - Texting/Dialing
Mobile Phone - Talking (Handheld)
Mobile Phone - Talking (Hands-free)
Operating Other Mobile Device
Reading Paperwork
Grooming/Personal Hygiene
Food
Beverage
Smoking
Passenger(s)
Other Task

Fatigue

Drowsy/Falling Asleep
Yawning

Other Unsafe Driving

Seatbelts
Driver Seatbelt Unfastened (≤ 20 mph)
Driver Seatbelt Unfastened (> 20 mph)
Passenger Seatbelt Unfastened

Outcomes

Collision
Collision with Pedestrian
Collision with Vehicle in Transport
Collision with Parked Vehicle
Collision with Train
Collision with Pedalcycle
Collision with Animal
Collision with Fixed Object
Collision with Work Zone Equipment
Collision with Other Movable Object
Overturn (Rollover)

Outcomes

Near Collision
Near Collision with Pedestrian
Near Collision with Vehicle in Transport
Near Collision with Parked Vehicle
Near Collision with Train
Near Collision with Pedalcycle
Near Collision with Animal
Near Collision with Fixed Object
Near Collision with Work Zone Equipment
Near Collision with Other Movable Object
Other Outcomes
Ran off Road
Crossed Median/Centerline

Non-Driving Observations

Unprofessional Conduct
Rude Gesture
Raised Voice
Event of Interest
Captured Passenger Incident
Captured Roadway Incident

SmartDrive Equipment

Obstructed View
Obstructed View of Driver
Obstructed Exterior View
Tampering
Tampering/Abusing Equipment

Figure 4. Image. Fundamental driving errors coded by data analysts during the review process.

Figure 4 shows the standard data variables coded by data analysts. However, the current study required use of additional data variables and reduction techniques to answer the research objectives. In addition to the non-driving tasks listed in Figure 4 (see the “Distraction” section in the second column), data analysts were required to code the following mobile phone subtasks during an SCE, baseline, or spurious baseline:

- Manually dialing a mobile phone.
- Voice dialing a mobile phone.
- Reaching for a mobile phone.
- Reaching for a headset/earpiece.
- Talking/listening on a mobile phone.
- Texting/e-mailing/accessing the Internet on a mobile phone.

These mobile phone subtasks were coded by the type of voice communication device, including a handheld or hands-free mobile phone, push-to-talk mobile phone, and a CB radio. Additional communication devices (e.g., dispatching devices) were coded by data analysts. Data analysts were also responsible for calculating the amount of time each driver’s eyes were off the forward roadway, the amount of time the driver was talking, and the conversation workload for all VR SCEs, baselines, and spurious baselines. Section 3 provides a detailed description of the operational definitions for the non-driving tasks and the protocols for calculating visual distraction, time spent talking, and conversation workload.

2.3 DATA ANALYST TRAINING

Data analysts undergo a 4–6-week training program prior to achieving tenure to process events for the clients of the technology vendor. Training begins with 2 weeks of detailed classroom instruction about driving rules according to government regulations, the proprietary observation definitions of the technology vendor, and how to use the software tools of the technology vendor to analyze a video event and complete a review. After training, trainees are tested to ensure mastery of the concepts and are required to achieve a minimum passing score of 95 percent to continue with the training program. After passing the first test, trainees practice reviewing events in a simulated production environment during the next 2–4 weeks, drawing from thousands of example events that have been selected to challenge trainees on an extensive variety of driving scenarios. At the end of each training day, the trainees’ completed reviews are checked for accuracy and coaching/feedback is conducted to correct any mistakes. Trainees must achieve and maintain a minimum accuracy of 95 percent during the final 3 consecutive days of the practice review stage to pass the training program and join the live production team.

2.4 DATA ANALYST QUALITY CONTROL

As part of the standard review process of the technology vendor, each data analyst experiences statistical quality assurance sampling. As shown in Figure 5, the technology vendor has a tool that randomly selects 2 percent of the total video clips (SCEs, baselines, and spurious baselines) from each data analyst. Quality assurance was completed on a daily basis on the SCEs, spurious baselines, and random baselines reviewed by each data analyst. If the initial quality assurance review revealed no discrepancies, a discrepancy report was not generated, and the coding was saved as it was originally entered. However, if a discrepancy was found between the data analyst's coding and the quality assurance coding, a discrepancy report was created and a second quality assurance review was conducted. The second quality assurance review identified the error (group consensus [i.e., two out of three reviewers] essentially determined agreement) and generated a report about the cause and solution to the error. Each day, data analysts received a list of the reviewed SCEs, spurious baselines, and random baselines with their associated errors and successes. Data analysts attended weekly meetings with their manager(s) and quality assurance team to review their overall quality and to determine areas where refresher training may be needed. The technology vendor also tracked the most common mistakes made by all data analysts. This information was used to improve training guidelines and behavioral definitions.

As the additional data reduction planned during the current project involved subjective interpretations made by data analysts, reliability estimates were critical to ensure that data analysts followed the operational definitions described in Section 3. Thus, approximately 33 percent of the SCEs, spurious baselines, and random baselines were subjected to an inter-rater reliability check.

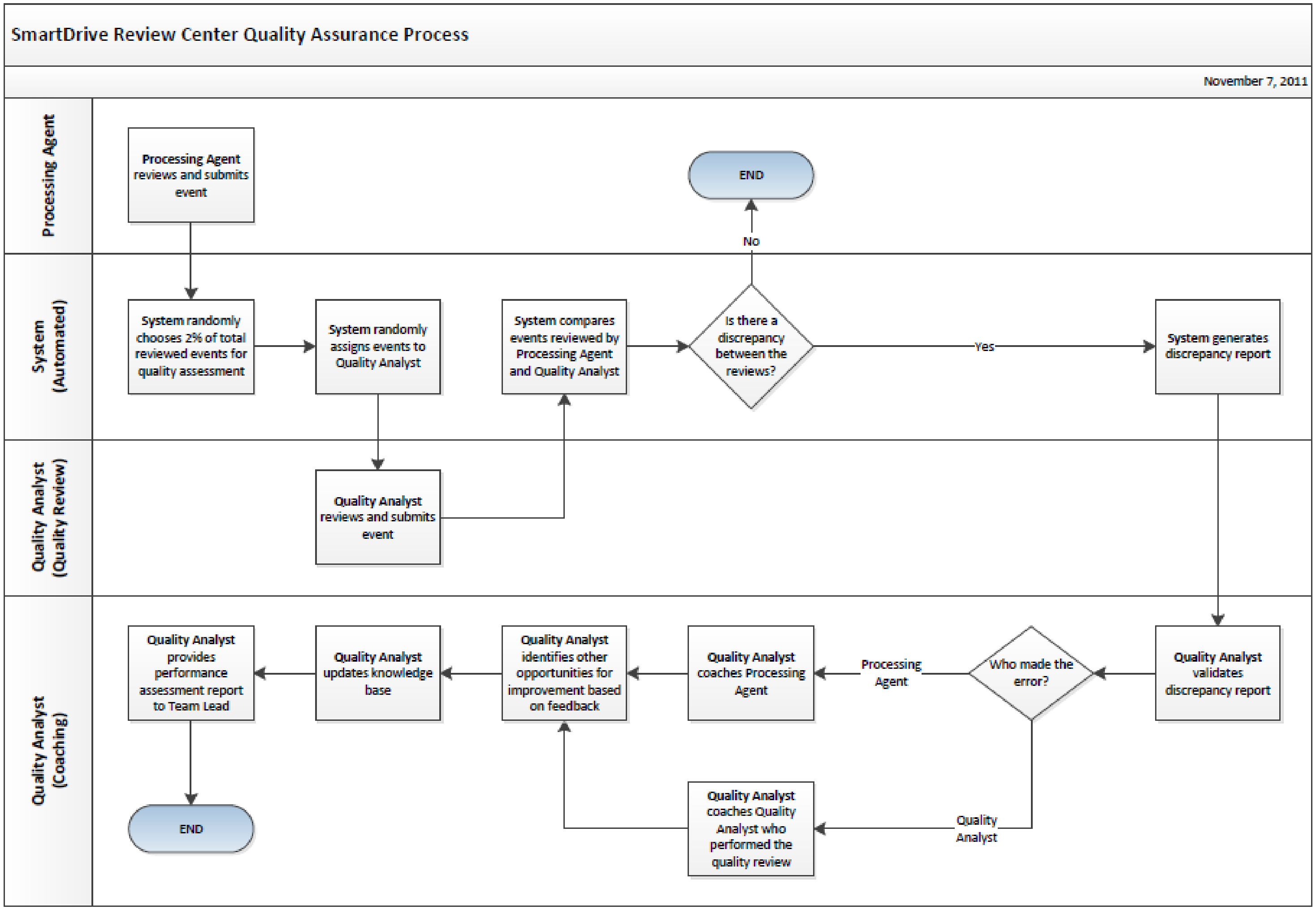

Figure 5. Flowchart. Quality control process used by the technology vendor.

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3. REDUCTION AND ANALYSIS APPROACH

3.1 REDUCTION PROTOCOL FOR TECHNOLOGY-RELATED TASKS AND SUBTASKS

As described above, the technology vendor currently has an established reduction protocol to assess whether drivers are engaged in technology-related tasks. However, further detail was required to distinguish between subtasks. For example, "use a mobile phone" was segmented into subtasks such as reaching, dialing, texting, etc. The technology-related tasks and subtasks protocol identifies additional technology-related tasks and subtasks that were coded by data analysts in SCEs, spurious baselines, and random baselines. In addition, data analysts recorded several environmental variables.

To be consistent with the 6-second observation envelope identified by Olson et al. in a previous study,[60] data analysts were instructed to code all of the non-driving behaviors (shown in Appendix A) that occurred within the 5 seconds prior to and 1 second after the trigger during SCEs and spurious baselines. Similarly, data analysts were instructed to code all the non-driving behaviors (also shown in Appendix A) that occurred within the 6-second analysis envelope during random baselines, as there were no triggers in those instances. For example, if a driver looked at a mobile phone and then entered text into the phone during the 6-second observation envelope, the data analyst recorded both "Mobile Phone—Look at Phone" and "Mobile Phone—Text."

Data analysts reduced a total of 20,411 SCEs and baseline epochs for non-driving behaviors. A single data analyst viewed the 6-second recordings in 70.14 percent (14,317) of the total observations. Two different data analysts reduced the same 6-second recordings in 29.86 percent (6,094) of the total observations (for inter-rater reliability). Overall agreement between the two data analysts on the same observation was 93.52 percent. Data analysts were instructed to list all observed non-driving behaviors, so it was possible that two data analysts viewing the same 6-second recording could agree on at least one non-driving behavior and disagree on at least one non-driving behavior (or more).

The speed of the vehicle was automatically determined with a special batch script that analyzed the speed data stream of the vehicle during each SCE, spurious baseline, or random baseline. Speed was measured at the beginning of the operational envelope (i.e., 5 seconds prior to the trigger in SCEs and spurious baselines and at the beginning of the data file for random baselines), as a driver's avoidance response to an SCE may have included acceleration or deceleration. Therefore, the beginning of the file provided the most accurate measure of the vehicle speed prior to any potential avoidance responses.

3.1.1 Environmental Variables

Rather than using the video stream, data analysts examined a still image taken at the trigger point during SCEs and spurious baselines to increase throughput of the environmental variables. In random baselines, an image taken at the beginning of the data file, as there was no trigger value. Below is a description of the environmental variables coded by data analysts in SCEs, spurious baselines, and random baselines.

3.1.1.1 Light Condition

- Day (includes dawn and dusk).
- Night (darkness; includes lighted roads at night).
- Unknown.

3.1.1.2 Weather

- Clear.
- Inclement—rain/snow/sleet/fog/other (smog, smoke, sand/dust, crosswind, hail).
- Unknown.

3.1.1.3 Relation to Junction

- In, or close to, an intersection.
- Entrance/exit ramp.
- Parking lot.
- Not intersection-related, entrance/exit ramp-related, or parking lot-related.
- Unknown.

3.1.1.4 Traffic Density

- No cars in view.
- One car ahead (in adjacent lane[s]).
- One car ahead (in same lane).
- Multiple cars ahead (in same lane).
- Multiple cars ahead (in same lane and adjacent lane).
- Heavy traffic congestion (includes traffic deadlock or stopped at intersection).
- Unknown.

Data analysis reduced 23,271 observations for environmental variables. Of these, 29.93 percent had inter-rater reliability. Overall agreement between the two data analysts on the same observation was 82.45 percent.

3.2 REDUCTION PROTOCOL FOR EYE-GLANCE ANALYSIS OF VOICE-RELATED ACTIVITIES

An eye-glance data reduction protocol was developed to assess the visual distraction in VR secondary tasks during SCEs, spurious baselines, and random baselines. The protocol was based on eye-glance reduction protocols developed by the research team and used during other

FMCSA-funded studies.[61,62] However, consideration must be given to camera placement and the recording rate of the onboard monitoring system. As the onboard monitoring system only has one camera facing the driver, data analysts were only able to code if the driver was looking at the forward roadway or away from the forward roadway rather than at specific glance locations. In addition, the eye glance analyses need to be viewed with caution given that video data were collected at 4–5 hertz (Hz). Human blinking behavior lasts 0.10–0.40 seconds;[63] thus, the video images in the current study would miss many blinks. Moreover, saccades (small, rapid movements of both eyes) last between 0.02–0.20 seconds; thus, a driver could have made a glance (or several) away from the forward roadway that would not be revealed in the video data.[64] Because of this limitation, the types of possible eye glance analyses are limited, especially those calculating the specific location and duration of glances.

Data analysts calculated the amount of time the driver was looking away from the forward road (i.e., EOFR glance time) during the 6-second operational envelope (5 seconds before the trigger and 1 second after the trigger during SCEs and spurious baselines and the entire 6-second operational envelope during random baselines). This was the same approach used in Olson et al.[65] and Klauer et al.[66] Appendix B describes the protocol that was used by data analysts to calculate the EOFR glance time for VR-related activities during SCEs, spurious baselines, and random baselines.

A total of 3,480 observations were reduced for eye-glance location by data analysts (27.84 percent of these had inter-rater reliability). In each 6-second observation, data analysts recorded an eye-glance location (e.g., forward roadway or non-forward roadway) at each 0.25-second interval for a total of 25 intervals per observation. Inter-rater reliability was calculated as the number of 0.25-second intervals with agreement on eye-glance location divided by the total number of 0.25-second observations. The inter-rater reliability for eye-glance location reduction was 79.47 percent.

3.3 TALKING TIME AND CONVERSATION WORKLOAD PROTOCOL FOR VOICE-RELATED ACTIVITIES

Using the literature as a guide,[67] a data reduction protocol was developed to assess the conversation workload associated with VR SCEs, spurious baselines, and random baselines in the data set. An analogy to this reduction is the researcher's development of the observer rating of drowsiness (ORD) scale, which has been used during several FMCSA studies to subjectively assess the level of drowsiness captured via video.[68,69] The protocol was developed to be easy to implement by the technology vendor data analysts. In addition to conversation workload, data analysts recorded the amount of time the driver was talking during the 6-second operational envelope (5 seconds before the trigger and 1 second after the trigger during SCEs and spurious baselines and the entire 6-second operational envelope during random baselines). Appendix C describes the protocol that was used by data analysts to calculate the amount of time spent talking and the conversation workload during a VR SCE, VR spurious baseline, or VR random baseline.

Data analysts reduced 1,188 observations for talking time. Of these, 21.13 percent of these had inter-rater reliability. For each 6-second observation, data analysts noted start and end times for all talking segments. They also identified the speaker in each instance (i.e., driver or passenger). Data analysts agreed on the number of talking segments in 75 percent of the observations. The percent agreement for segment start time and end time within 0.25-seconds was 57.09 and 50.20 percent, respectively. The percent agreement on the identified speaker was 93.22 percent.

Data analysts reduced emotion and emotion intensity in 1,797 observations. A single data analyst reviewed the 6-second recording in 71.79 percent (1,290) of the total observations. Two data analysts reviewed the same 6-second recording in 28.21 percent (507) of the total observations. For each 6-second observation, data analysts noted one emotion and one emotion intensity. Data analysts agreed on the emotion and emotion intensity in 378 observations (74.56 percent) and 380 observations (74.95 percent), respectively.

3.4 ANALYSIS PLAN

It was important to have a sample data set representative of the population with large enough data to conduct sound analyses. Although the number of SCEs experienced during the current study was bound by the 4-month data collection period (August–November 2012), the technology vendor could control how many random and spurious baselines data analysts reduced. Drawing from studies on myocardial infarctions, Maclure and Mittleman[(70)] found that the CI width was reduced by 36 percent when using a 4:1 ratio of control periods (i.e., baselines) to myocardial infarction; the CI width was reduced by 40 percent when the ratio was increased to 100:1. Thus, using a ratio greater than 4:1 did not produce an increase in the precision of the CI and did not justify the addition of more baselines. Based on project resources and informed by Maclure and Mittleman,[(71)] the research team selected a 4:1 ratio of spurious and random baselines to SCEs.

3.4.1 Risk Associated with Non-driving Tasks and Subtasks

ORs were used to assess the risk posed from drivers engaged in non-driving tasks while driving. However, the cell counts in most of the individual secondary tasks were fairly low (thereby resulting in unstable ORs, which makes the ORs difficult to interpret). Thus, as shown in Table 2, the secondary tasks were combined into mutually exclusive categories similar to Fitch et al.[(72)] Secondary tasks in each of these categories shared similar visual, manual, cognitive, or a combination of these demands on the driver. The secondary task “Talk to Passengers” was not grouped with any other secondary tasks in a secondary task category.

Table 2. Secondary task categories for each secondary task.

Secondary Task Category	Secondary Task
No Distraction Found	No Distraction Found
Visual	Look at Passengers
Visual	Mobile Phone—Look at Phone
VM	CB—Put CB Away
VM	CB—Reach for CB
VM	Interact with Dispatching Device
VM	Mobile Phone—Dial/Answer
VM	Mobile Phone—Put Mobile Phone/Headset/Earpiece Away
VM	Mobile Phone—Reach for and Pick up Headset/Earpiece
VM	Mobile Phone—Reach for and Pick up Phone
VM	Mobile Phone—Text
VM	Push-to-talk—Reach for Push-to-talk Mobile Phone
VM	Push-to-talk—Put Push-to-talk Phone Away
Talk/Listen on an Electronic Device	Mobile Phone—Talk/Listen (handheld)
Talk/Listen on an Electronic Device	Mobile Phone—Talk/Listen (hands-free)
Talk/Listen on an Electronic Device	Talk or Listen on Push-to-talk Phone
Talk/Listen on an Electronic Device	Talk or Listen to CB Microphone
Talk to Passengers	Talk to Passengers

To determine if non-driving tasks were related to involvement in an SCE, a contingency table (see Table 3 for an example) was created and analyzed using an OR and respective 95-percent CI. The risk associated with a secondary task category was calculated two ways. The first analysis compared a secondary task category to all other secondary task categories, a method used in the Olson et al. study.[73] In this analysis, the risk of a secondary task category was calculated with respect to other secondary task categories that may have their own risk. The rows in Table 3 (Visual, No Visual) represent the format of the first analysis. The second analysis compared a secondary task category to driving with no secondary tasks (i.e., no distraction found), a method used by Klauer et al.[74] In this analysis, the OR represents how the secondary task category changes the risk of driving when not performing a non-driving task. In this second analysis, the rows in Table 3 would read Visual, No Distraction Found.

Table 3. Example of a contingency table for texting while driving.

Secondary Task Category	SCEs	Random Baselines	Total
Visual	n_{11}	n_{12}	$n_{1.}$
No Visual	n_{21}	n_{22}	$n_{2.}$
• **Total**	$\mathbf{n_{.1}}$	$\mathbf{n_{.2}}$	$\mathbf{n_{..}}$

The formula for calculating the OR is the cross product:[75] $(n_{11} * n_{22}) / (n_{12} * n_{21})$

where n_{11} is the number of SCEs where the driver is performing a visual secondary task while driving, n_{12} is the number of random baselines where the driver is performing a visual secondary task while driving, n_{21} is the number of SCEs where the driver is not performing a visual secondary task while driving, and n_{22} is the number of random baselines where the driver is not performing a secondary task while driving.

The formula for calculating the CI is:[76] $OR * e^{\pm z * SE_{OR}}$

where e is a constant and the base of natural logarithms, OR is the odds ratio, z is the z-score value corresponding to the chosen alpha (1.96 for a 95-percent CI), and SE is the standard error of the natural logarithm of the OR.

The interpretation of the OR and 95-percent CI was similar for all analyses performed using different secondary task categories. An OR is considered statistically significant if the 95-percent CI does not include "1." If the OR for the contingency table is greater than 1.0, the presence of the secondary task category is associated with a statistically significant greater likelihood of involvement in an SCE than when the secondary task category is not present. If the OR for the contingency table is less than 1.0, the presence of the secondary task category is associated with a statistically significant lower likelihood of involvement in an SCE than when the secondary task category is not present. If the OR is equal to 1.0 or if the CI includes 1.0, the presence of the secondary task category is not associated with any different risk than when the secondary task category task is not present.

For example, if the OR for the contingency table is greater than 1 and statistically significant, a visual secondary task is associated with greater risk than driving without a visual secondary task. If the OR for the contingency table is lower than 1 and statistically significant, performing a visual secondary task while driving is associated with a lower risk than driving without a visual secondary task. If the OR is equal to 1 or if the CI includes 1, performing a visual secondary task while driving is not associated with any different risk than occurs when the driver is not performing a visual secondary task. The strength and direction of ORs for different secondary task categories were compared to determine the risk association with each secondary task category.

3.4.2 Risk Associated with Conversation Workload

To determine if conversation workload was related to involvement in a VR SCE, a contingency table (see Table 4 for an example) was created and analyzed with an OR and respective CI.

Table 4. Example of a contingency table for the emotion "Angry."

Emotion	VR SCEs	VR Baselines	Total
Angry	n_{11}	n_{12}	$n_{1.}$
No Emotion Present	n_{21}	n_{22}	$n_{2.}$
Total	**n.1**	**n.2**	**n..**

The subsets of SCEs and random baselines with conversation were used to analyze the risk associated with conversation workload, as defined by the emotion and its intensity. A chi-square test was conducted to assess if at least one row was statistically different from the other rows. If the chi-square test was statistically significant, follow-up analyses compared only two rows (or values of "Category of Emotion") at a time using an OR and CI. To assess how the intensity of emotion related to the number of SCEs and random baselines for each emotion, a contingency table was created with “Intensity of Emotion” replacing the “Emotion” column. The cross product of these variables (i.e., Emotion × Intensity of Emotion) was analyzed in a similar fashion, using a chi-square test to assess if at least one row was significantly different from the other rows. The calculation and interpretation of ORs and CIs made during this analysis were consistent with the description in the analysis for non-driving tasks (where the 95-percent CI does not include “1” to be statistically significant).

3.4.3 Talking Time Analyses

The risk of talking time on the likelihood of an SCE was assessed across multiple measures: the total time the driver was talking in 6-second and 5-second intervals, and the total time the passenger was talking in 6-second and 5-second intervals. To assess if the total talking time affected the likelihood of involvement in a VR SCE, a logistic regression model was used. A logistic regression model uses variables to estimate the likelihood of a particular outcome. In this analysis, the predictor will be the talking time under one of four conditions (driver talking, passenger talking, 6-second interval, or 5-second interval). The model uses total talking time to predict the likelihood of a VR SCE. The model coefficient for total talking time was tested for statistical significance (difference from zero [0]).

To assess if the risk associated with talking time changes across the time interval, an OR and CI were calculated based on a contingency table similar to Table 5. The reduced data did not come in categorical form. For each observation, the talking segments were broken down into 0.25-second intervals across the 6-second window. If an observation had talking between two 0.25-second intervals, the earlier 0.25-second interval was marked with “Talking.” If an observation did not have talking during a 0.25-second interval, the earlier 0.25-second interval was marked with “No Talking.” For each interval, an OR and CI was calculated and the OR was compared across each of the time intervals. This analysis was performed for driver talking segments only, using spurious and random baselines.

Table 5. Example of a contingency table for talking times using 0.25-second intervals.

Interval	VR SCEs	VR Baselines	Total
Driver Talking	n11	n12	n1.
Driver Not Talking	n21	n22	n2.
Total	**n.1**	**n.2**	**n..**

3.4.4 Eye-glance Analyses

The face camera recorded at 4–5 Hz, which allowed data analysts to record eye-glance behavior at 0.25-second intervals. The categorical data was analyzed using contingency table analyses, such as chi-square tests and ORs with CIs. A chi-square test at each time interval was used to examine if VR events had different EOFR glance behavior than non-VR events. This method was used to compare VR and non-VR events by event type (SCE, spurious baseline, or random baseline).

To assess if the risk associated with EOFR glances changed across the time intervals, an OR and CI were calculated based on a contingency table similar to Table 6. Statistically-significant ORs and CIs indicate that the risk associated with EOFR glances is different at certain points in time from the trigger point in a VR SCE.

Table 6.Example of a contingency table for EOFR glance times using 0.25-second intervals.

Interval	VR SCEs	VR Baselines	Total
EOFR from 0.75–1.0 seconds	n_{11}	n_{12}	$n_{1.}$
No EOFR from 0.75–1.0 seconds	n_{21}	n_{22}	$n_{2.}$
• **Total**	**n.1**	**n.2**	**n..**

The relationship between eye glance behavior and talking time in different event types was analyzed using chi-square tests calculated on a contingency table similar to Table 7. The following counts of events were calculated at each 0.25-second time interval:

- Talking and EOFR glances.
- Talking and eyes toward forward roadway.
- No talking and EOFR glances.
- No talking and eyes toward forward roadway.

If talking and EOFR glances are not related at a time interval, the chi-square test should not find a statistically-significant result.

Table 7. Example of a contingency table for EOFR glances and talking times using 0.25-second intervals.

Interval	Events with Driver Talking	Events without Driver Talking	Total
EOFR	n_{11}	n_{12}	$n_{1.}$
Eyes Toward Forward Roadway	n_{21}	n_{22}	$n_{2.}$
• **Total**	**n.1**	**n.2**	**n..**

4. RESULTS

Section 4 outlines the results from the data analysis performed by the research team.

4.1 OVERVIEW OF DATA SET

The final data set included 23,280 observations that were reduced by data analysts. Table 8 lists the number of SCEs, random baselines, and spurious baselines in the data set. SCEs accounted for 1,121 observations. Random baselines and spurious baselines accounted for 11,562 and 10,597 observations, respectively. The data set included observations from 77 different companies at 483 different terminal locations.

Table 8. Number of recording types in data set.

Recording Type	Number of Observations
SCE	1,121
Random Baseline	11,562
Spurious Baseline	10,597

Table 9 shows the number of power units for each vehicle represented in the data set. Tractor-trailers accounted for the largest percentage of the vehicles (44.11 percent), and 3-axle or more trucks accounted for the smallest percentage of vehicles (1.02 percent).

Table 9. Vehicle type frequencies in data set.

Vehicle Type	Count	Percent of Total Data Set
2-axle Truck	814	12.77%
3-axle or More Truck	65	1.02%
Bus	1,986	31.13%
Passenger Van less than 10,000 lbs	700	10.97%
Tractor Trailer	2,814	44.11%
Total	**6,379**	**100.00%**

The frequency counts of environmental variables, including light condition, weather condition, relation to junction, traffic density, and driver task workload (a combination of environmental variables meant to reflect the workload experienced by the driver), can be found in Appendix D.

4.2 RESEARCH OBJECTIVE 1: RISK OF SECONDARY TASKS

Table 10 shows the total number of SCEs, random baselines, and spurious baselines for each secondary task. The row and column totals in this and other tables may vary due to:

- The assembly line data reduction process (some audio and video were lost during the reduction process due to server malfunction at the technology vendor).
- Malfunction of forward and/or driver-facing camera.
- Malfunction of microphone.

Table 10. Number of SCEs, random baselines, and spurious baselines for each secondary task.

Secondary Task Category	Secondary Task	SCEs	Random Baselines	Spurious Baselines	Total
No Distraction Found	No Distraction Found	653	10,433	7,337	18,423
Visual	Look at Passengers	4	56	11	71
Visual	Mobile Phone—Look at Mobile Phone	2	31	20	53
VM	CB—Put CB Away	1	17	2	20
VM	CB—Reach for CB	2	23	8	33
VM	Interact with Dispatching Device	0	2	2	4
VM	Mobile Phone—Dial/Answer	1	2	4	7
VM	Mobile Phone—Put Mobile Phone Phone/Headset/Earpiece Away	2	5	5	12
VM	Mobile Phone—Reach for and Pick up Headset/Earpiece	0	3	3	6
VM	Mobile Phone—Reach for and Pick up Mobile Phone	1	11	18	30
VM	Mobile Phone—Text	4	32	27	63
VM	Push-to-talk—Reach for Push-to-talk Mobile Phone	0	1	2	3
VM	Push-to-talk—Put Push-to-talk Phone Away	0	4	0	4
Talk/Listen on an Electronic Device	Mobile Phone—Talk/Listen (handheld)	11	82	51	144
Talk/Listen on an Electronic Device	Mobile Phone—Talk/Listen (hands-free)	5	214	89	308
Talk/Listen on an Electronic Device	Talk or Listen on Push-to-talk Phone	1	16	9	26
Talk/Listen on an Electronic Device	Talk or Listen to CB Microphone	4	160	41	205
Talk to Passengers	Talk to Passengers	79	448	272	799
	Total	**770**	**11,540**	**7,901**	**20,211**

4.2.1 Secondary Tasks Compared to Spurious Baselines

Table 11 shows the ORs and CIs for each secondary task category compared to counts of “Any Other Secondary Task Category” (not a pure non-event) in the spurious baselines. The research team compared the risk of a particular secondary task category with any secondary task category other than the secondary task category in question. For example, the OR calculation for “Talk to Passengers” included all instances where the driver was coded as “Talk to Passengers” and was compared to any secondary task category that did not include “Talk to Passengers.” Thus, the driver could have been performing another secondary task category in the “Not Talking to Passengers” condition. This was the method employed in other naturalistic distraction studies involving large trucks.[77,78] As shown in Table 11, the secondary task category “Talk to Passengers” significantly elevated the likelihood of involvement in an SCE (OR = 2.75). The ORs for all other secondary task categories were found to be statistically non-significant.

Table 11. ORs for secondary task categories compared to spurious baselines (any other secondary task).

Secondary Task Category	SCEs with Secondary Task Category	SCEs with Any Other Secondary Task	Spurious Baselines with Secondary Task Category	Spurious Baselines with Any Other Secondary Task	OR	LCL	UCL
Visual	6	754	29	7,821	2.15	0.89	5.19
VM	8	752	59	7,791	1.40	0.67	2.95
Talk/Listen on an Electronic Device	21	739	188	7,662	1.16	0.73	1.83
Talk to Passengers	79	681	272	7,578	3.23*	2.49	4.20

*Statistically-significant OR

Table 12 shows the ORs and CIs for each secondary task category compared to counts of “No Other Secondary Task Observed” (a pure non-event) in spurious baselines. The research team compared the risk of a particular secondary task category with no other secondary task (i.e., coded the driver with “No Distraction Found”). For example, the OR calculation for “Talk to Passengers” included all instances where the driver was coded as “Talk to Passengers” and compared with all instances where the driver was coded with “No Distraction Found.” Thus, the driver was not performing another secondary task category in the “No Look at Passenger” condition. As shown in Table 12, the secondary task category “Talk to Passengers” significantly elevated the likelihood of involvement in an SCE (OR = 3.26). The ORs for all other secondary tasks categories were found to be statistically non-significant.

Table 12. ORs for secondary task categories compared to spurious baselines (no other secondary task).

Secondary Task Category	SCEs with Secondary Task Category	SCEs with No Other Secondary Task	Spurious Baselines with Secondary Task Category	Spurious Baselines with No Other Secondary Task	OR	LCL	UCL
Visual	6	653	29	7,337	2.32	0.96	5.62
VM	8	653	59	7,337	1.52	0.72	3.20
Talk/Listen on an Electronic Device	21	653	188	7,337	1.26	0.79	1.98
Talk to Passengers	79	653	272	7,337	3.26*	2.51	4.25

*Statistically-significant OR

4.2.2 Secondary Tasks Compared to Random Baselines

Table 13 shows the ORs and CIs for each secondary task category compared to counts of “Any Other Secondary Task Category” (not a pure non-event) in random baselines. As shown in Table 13, the secondary task category “Talk to Passengers” significantly elevated the likelihood of involvement in an SCE (OR = 3.26). The ORs for all other secondary task categories were found to be statistically non-significant.

Table 13. ORs for secondary task categories compared to random baselines (any other secondary task).

VR Secondary Task Category	SCEs with Secondary Task Category	SCEs with Any Other Secondary Task	Random Baselines with Secondary Task Category	Random Baselines with Any Other Secondary Task	OR	LCL	UCL
Visual	6	754	82	11,363	1.10	0.48	2.53
VM	8	752	84	11,361	1.44	0.69	2.98
Talk/Listen on an Electronic Device	21	739	469	10,976	0.67	0.43	1.04
Talk to Passengers	79	681	448	10,997	2.85*	2.21	3.66

*Statistically-significant OR

Table 14 shows the ORs and CIs for each secondary task category compared to counts of “No Other Secondary Task” (a pure non-event) in random baselines. As shown in Table 14, the secondary task category “Talk to Passengers” significantly elevated the likelihood of involvement in an SCE (OR = 2.79). The ORs for all other secondary task categories were found to be statistically non-significant.

Table 14. ORs for secondary task categories compared to random baselines (no other secondary task).

VR Secondary Task Category	SCEs with Secondary Task Category	SCEs with No Other Secondary Task	Random Baselines with Secondary Task Category	Random Baselines with No Other Secondary Task	OR	LCL	UCL
Visual	6	653	82	10,433	1.17	0.51	2.69
VM	8	653	84	10,433	1.52	0.73	3.16
Talk/Listen on an Electronic Device	21	653	469	10,433	0.72	0.46	1.12
Talk to Passengers	79	653	453	10,433	2.79*	2.17	3.58

*OR significantly different from “1.”

Table 15 shows the number of SCEs, random baselines, and spurious baselines by workload condition. The univariate analyses for weather, relation to junction, traffic density, and light condition make it difficult to form a complete picture of how environmental variables influence risk (see Appendix D for the univariate environmental variables). A more useful analysis combines the environmental variables and how these variables influence driver workload. Workload refers to the amount of perceived effort by the driver in the face of various task demands (e.g., environmental conditions, such as driving in severe weather conditions, being one aspect of perceived effort). Using naturalistic driving data, Fitch and Hanowski[(79)] grouped various environmental variables into low, medium, and high workload conditions. The current study used the groupings from Fitch and Hanowski[(80)] to define two workload conditions: high and low. High workload was defined using the following environmental variables:

- Inclement weather.
- In, or close to, an intersection.
- On an entrance/exit ramp.
- Traveling in stop-and-go traffic.
- Traveling with multiple cars ahead (in any lane).

High workload could occur during the day (includes dawn and dusk) or at night (includes lighted roads at night). Low workload was defined using the following environmental variables:

- Day (includes dawn and dusk).
- Clear weather.
- Traveling in a junction not related to an intersection, entrance/exit ramp, or parking lot.
- No cars in view.

Table 15. Number of SCEs, random baselines, and spurious baselines by workload condition.

Secondary Task Category	High Workload SCEs	High Workload Spurious Baselines	High Workload Random Baselines	High Workload Total	Low Workload SCEs	Low Workload Spurious Baselines	Low Workload Random Baselines	Low Workload Total
No Distraction Found	536	4,763	8,459	13,758	24	1,041	1,019	2,084
Visual	4	19	66	89	0	3	5	8
VM	8	35	66	109	0	11	10	21
Talk/Listen on an Electronic Device	17	138	386	541	2	17	46	65
Talk to Passengers	65	161	376	602	2	46	30	78
Total	**630**	**5,116**	**9,353**	**15,099**	**28**	**1,118**	**1,110**	**2,256**

Table 16 shows the ORs for each workload condition using spurious baselines. Table 16 shows that truck and bus drivers were 2.40 times significantly more likely to be involved in an SCE during high workload conditions while engaged in a secondary task.

Table 16. ORs for workload condition using spurious baselines.

Workload Condition	SCEs with Secondary Task	SCEs with No Secondary Task	Spurious Baselines with Secondary Task	Spurious Baselines with No Secondary Task	OR	LCL	UCL
High	89	536	329	4,763	2.40*	1.87	3.09
Low	4	24	73	1,041	2.38	0.80	7.03

*Statistically-significant OR.

Table 17 shows the ORs for each workload condition using random baselines. Table 17 shows that truck and bus drivers were 1.68 times significantly more likely to be involved in an SCE during high workload conditions while engaged in a secondary task.

Table 17. ORs for workload condition using random baselines.

Workload Condition	SCEs with Secondary Task	SCEs with No Secondary Task	Spurious Baselines with Secondary Task	Spurious Baselines with No Secondary Task	OR	LCL	UCL
High	89	536	837	8,459	1.68*	1.33	2.12
Low	4	24	83	1,019	2.05	0.69	6.04

*Statistically-significant OR

4.3 RESEARCH OBJECTIVE 2: CONVERSATION WORKLOAD

4.3.1 Emotion Type

Table 18 shows the emotion types observed in VR SCEs, VR random baselines, and VR spurious baselines for each secondary task category. As noted above, VR SCEs are a subset of SCEs where the driver and/or passenger were talking. All secondary tasks categories are shown as data analysts coded all that apply. Thus, if “CB—put away” was coded (a non-VR secondary task), it means the driver engaged in that secondary task while the driver and/or passenger talked during the VR SCE, VR spurious baseline, or VR random baseline.

Table 18. Number of VR SCEs, random baselines, and spurious baselines for each emotion type.

Secondary Task Category	*Happy	*Neutral/ No Emotion Shown	*Shock	*Unsure	†Happy	†Neutral/ No Emotion Shown	†Shock	†Unsure	‡Happy	‡Neutral/ No Emotion Shown	‡Shock	‡Unsure
Visual	0	3	1	0	0	11	0	2	0	32	0	6
VM	0	1	0	1	0	3	0	1	0	25	0	3
Talk/Listen on an Electronic Device	0	15	0	3	1	134	0	38	0	374	0	81
Talk to Passengers	0	63	2	10	2	210	0	42	0	362	0	72
Total	**0**	**82**	**3**	**14**	**3**	**358**	**0**	**83**	**0**	**793**	**0**	**162**

*VR SCEs

†VR spurious baselines

‡VR random baselines

As shown in Table 19, the most commonly observed emotion type was “Neutral/No Emotion Shown.” The cell counts for non-neutral emotions were low; thus, Table 19 lists the cell counts for any emotion shown (combining happy and shock). This still did not provide enough data to analyze the risk of emotion while driving. Due to the low cell counts for any emotion shown, OR analyses were not conducted on this data.

Table 19. Number of VR SCEs, VR random baselines, and VR spurious baselines for each emotion type (any emotion shown).

Secondary Task Category	*Emotion Shown	*Neutral/ No Emotion Shown	*Unsure	†Emotion Shown	†Neutral/ No Emotion Shown	†Unsure	‡Emotion Shown	‡Neutral/ No Emotion Shown	‡Unsure
Visual	1	3	0	0	11	2	0	32	6
VM	0	1	0	0	3	1	0	25	3
Talk/Listen on an Electronic Device	0	15	3	1	134	38	0	374	81
Talk to Passengers	2	63	10	2	210	42	0	362	72
Total	**3**	**82**	**13**	**3**	**358**	**83**	**0**	**793**	**162**

*VR SCEs

†VR spurious baselines

‡VR random baselines

4.3.2 Emotion Intensity

Table 20 shows the emotion intensity observed for the total number of VR SCEs, VR random baselines, and VR spurious baselines for each VR secondary task category. Similar to emotion type results, the most commonly observed emotion intensity was "Neutral/No Emotion Shown." The emotion intensity "Neutral/No Emotion Shown" was observed in 82.82 percent of VR SCEs, 81.08 percent of VR spurious baselines, and 82.93 percent of VR random baselines. Due to the small number of observations of emotion intensities "somewhat shown" or "very much shown," the data were not analyzed using ORs or statistical tests.

Table 20. Number of VR SCEs, VR random baselines, and VR spurious baselines for each emotion intensity.

Secondary Task Category	*Neutral/ No Emotion Shown	*Some-what Shown	*Very Much Shown	*Unsure	†Neutral/ No Emotion Shown	†Some-what Shown	†Very Much Shown	†Unsure	‡Neutral/ No Emotion Shown	‡Some-what Shown	‡Very Much Shown	‡Unsure
Visual	3	1	0	0	11	0	0	2	32	0	0	6
VM	1	0	0	1	3	0	0	1	25	0	0	3
Talk/Listen on an Electronic Device	15	0	0	3	136	0	1	36	373	0	0	82
Talk to Passengers	63	2	0	10	210	1	0	43	362	0	0	72
Total	**82**	**3**	**0**	**14**	**360**	**1**	**1**	**82**	**792**	**0**	**0**	**163**

*VR SCEs

†VR spurious baselines

‡VR random baselines

As shown in Table 21, the cell counts for emotion intensity were low; thus, Table 21 shows the cell counts for high emotion (which combines the emotion intensities of “Very Much Shown” and “Somewhat Shown”). Due to the small number of observations for high emotion, the data were not analyzed using ORs or statistical tests.

Table 21. Number of VR SCEs, VR random baselines, and VR spurious baselines for each emotion intensity (high/low).

Secondary Task Category	*High Emotion Intensity Shown	*Low or No Emotion Intensity Shown	*Unsure	†High Emotion Intensity Shown	†Low or No Emotion Intensity Shown	†Unsure	‡High Emotion Intensity Shown	‡Low or No Emotion Intensity Shown	‡Unsure
Visual	0	4	0	0	11	2	0	32	6
VM	0	1	1	0	3	1	0	25	3
Talk/Listen on an Electronic Device	0	15	3	1	136	36	0	373	82
Talk to Passengers	0	65	10	0	211	43	0	362	72
Total	**0**	**85**	**14**	**1**	**361**	**82**	**0**	**792**	**163**

*VR SCEs

†VR spurious baselines

‡VR random baselines

4.4 RESEARCH OBJECTIVE 3: TALKING TIME

4.4.1 Mean Duration of Driver Talking

Table 22 shows the mean duration of driver talking time during VR SCEs, VR spurious baselines, and VR random baselines (6-second intervals).

Table 22. Mean durations of driver talking times during VR SCEs, VR spurious baselines, and VR random baselines (6-second intervals).

Secondary Task Category	*Count	*Average Duration(s)	†Count	†Average Duration(s)	‡Count	‡Average Duration(s)
Visual	2	2.06	8	2.21	22	3.09
VM	1	4.62	1	4.38	21	1.80
Talk/Listen on an Electronic Device	12	2.11	87	2.94	305	3.13
Talk to Passengers	50	1.83	153	2.29	302	2.97

*VR SCEs

†VR spurious baselines

‡VR random baselines

Table 23 shows the logistic regression output for the mean driver talking time using VR spurious baselines (6-second intervals). The mean durations of driver talking times for a VR SCE and VR spurious baseline were 1.64 seconds (standard deviation [SD] = 0.95) and 2.37 seconds (SD = 1.70), respectively. The first column in Table 23 shows the response variable (VR SCE), the second column shows the predictor (mean driver talking time), the third column shows the degrees of freedom (df), the fourth column shows point estimate, the fifth column shows the standard error (SE), the sixth column shows the chi-square value, and the last column shows the *p* value. The results of the logistic regression were statistically significant (chi-square = 20.00, $p < 0.0001$). Thus, there was a relationship between mean driver talking time and the probability of a VR SCE. For every one-unit change (i.e., 1 second) in driver talking duration, the log odds of a VR SCE (versus VR spurious baseline) significantly decreased by 0.36. Or, the longer the driver was talking, the less probability of his or her involvement in a VR SCE.

Table 23. Logistic regression output for mean driver talking time using VR spurious baselines (6-second intervals).

Response Variable	Predictor Variable	df	Estimate	SE	Chi-square	p-value
Probability of VR SCE	Intercept	1	-0.16	0.20	0.67	0.41
Probability of VR SCE	Mean Driver Talking Time in 6-second Interval	1	-0.36	0.09	16.59	< 0.0001

As the logistic regression in Table 23 was significant, the point estimate was transformed into an OR for easier interpretation. As shown in Table 24, the OR was statistically significant. For a one-unit increase in driver talking duration, the odds of a VR SCE (versus VR spurious baseline) significantly decreased by a factor of .69 (31 percent).

Table 24. OR for mean driver talking time using VR spurious baselines (6-second intervals).

Effect	OR	95% Wald Confidence Limit-Lower	95% Wald Confidence Limit-Upper
Mean Driver Talking Time (in 6-second Intervals)	0.69	0.58	0.82

Table 25 shows the logistic regression output for the mean driver talking time using VR random baselines (6-second intervals). The mean durations of driver talking times for VR SCEs and random baselines were 1.64 seconds (SD = 0.95) and 2.59 seconds (SD = 1.56), respectively. The results of the logistic regression were statistically significant (chi-square = 70.81, $p < 0.0001$). Thus, there was a relationship between mean driver talking time and the probability of a VR SCE. For every one-unit change (i.e., 1 second) in driver talking duration, the log odds of a VR SCE (versus random baseline) significantly decreased by a factor of 0.62 (38 percent).

Table 25. Logistic regression output for mean driver talking time using VR random baselines (6-second intervals).

Response Variable	Predictor Variable	df	Estimate	SE	Chi-square	p-value
Probability of VR SCE	Intercept	1	-0.37	0.19	4.05	0.04
Probability of VR SCE	Mean Driver Talking Time in 6-second Interval	1	-0.62	0.09	48.48	< 0.0001

Again, as the logistic regression was significant, the point estimate was transformed into an OR for easier interpretation. The OR in Table 26 was statistically significant. For a one-unit increase in driver talking duration, the odds of a VR SCE (versus VR random baseline) significantly decreased by a factor of .54 (46 percent).

Table 26. OR for mean driver talking time using VR random baselines (6-second intervals).

Effect	OR	95% Wald Confidence Limit–Lower	95% Wald Confidence Limit-Upper
Mean Driver Talking Time (in 6-second Intervals)	0.54	0.45	0.64

Table 27 shows the mean durations of driver talking times during VR SCEs, VR spurious baselines, and VR random baselines (5-second intervals). The 5-second interval is the time period before the VR SCE occurred and does not include any talking behavior after the VR SCE begins.

Table 27. Mean durations of driver talking times during VR SCEs, VR spurious baselines, and VR random baselines (5-second intervals).

Secondary Task Category	*Count	*Average Duration(s)	†Count	†Average Duration(s)	‡Count	‡Average Duration(s)
Visual	2	2.06	8	1.84	22	2.54
VM	1	4.62	1	3.38	21	1.46
Talk/Listen on an Electronic Device	12	1.89	86	2.53	298	2.68
Talk to Passengers	44	1.68	138	2.09	294	2.57

*VR SCEs

†VR spurious baselines

‡VR random baselines

Table 28 shows the logistic regression output for mean driver talking time using VR spurious baselines (5-second intervals). The mean durations of driver talking times for VR SCEs and VR spurious baselines were 1.42 seconds (SD = 0.89) and 2.13 seconds (SD = 1.49), respectively. The results of the logistic regression were statistically significant (chi-square = 21.24, $p < 0.0001$). Thus, there was a relationship between mean driver talking time and the probability of a VR SCE. For every one-unit change in driver talking duration, the log odds of a VR SCE (versus spurious baseline) significantly decreased by a factor of 0.44 (56 percent).

Table 28. Logistic regression output for mean driver talking time using VR spurious baselines. (5-second intervals).

Response Variable	Predictor Variable	df	Estimate	SE	Chi-square	p-value
Probability of VR SCE	Intercept	1	-0.13	0.20	0.41	0.52
Probability of VR SCE	Mean Driver Talking Time (in 5-second Intervals)	1	-0.44	0.11	17.64	<.0001

The OR in Table 29 was statistically significant. For a one-unit increase in driver talking duration, the odds of a VR SCE (versus VR spurious baseline) significantly decreased by a factor of 0.64 (36 percent).

Table 29. OR for mean driver talking time using VR spurious baselines (5-second interval).

Effect	OR	95% Wald Confidence Limit-Lower	95% Wald Confidence Limit-Upper
Mean Driver Talking Time (in 5-second Intervals)	0.64	0.52	0.79

Table 30 shows the logistic regression output for mean driver talking time using VR random baselines (in 5-second intervals). The mean durations of driver talking times for VR SCEs and VR random baselines were 1.42 seconds (SD = 0.89) and 2.59 seconds (SD = 1.56), respectively. The results of the logistic regression were statistically significant (chi-square = 59.86, $p < 0.0001$). Thus, there was a relationship between mean driver talking time and the probability of a VR SCE. For every one-unit change in driver talking duration, the log odds of a VR SCE (versus VR random baseline) significantly decreased by a factor of 0.65 (35 percent).

Table 30. Logistic regression output for mean driver talking time using VR random baselines (5-second intervals).

Response Variable	Predictor Variable	df	Estimate	SE	Chi-square	p-value
Probability of VR SCE	Intercept	1	-0.57	0.19	9.35	0.0022
Probability of VR SCE	Mean Driver Talking Time (in 5-second Intervals)	1	-0.65	0.10	43.42	<.0001

The OR in Table 31 was statistically significant. For a one-unit increase in driver talking duration, the odds of a VR SCE (versus VR spurious baseline) significantly decreased by a factor of 0.52 (48 percent).

Table 31. OR for mean driver talking time using VR random baselines (5-second interval).

Effect	OR	95% Wald Confidence Limit—Lower	95% Wald Confidence Limit—Upper
Mean Driver Talking Time in 5-second Interval	0.52	0.43	0.63

4.4.2 Mean Duration of Passenger Talking

Table 32 shows the mean durations of passenger talking times during VR SCEs, VR spurious baselines, and VR random baselines (6-second intervals). Passenger talking reflects talking by another passenger in the vehicle (not the driver). Due to the very low frequencies of passenger talking in VR SCEs, a significance test comparing the average durations of VR SCEs to VR baselines was not performed.

Table 32. Mean durations of passenger talking times during VR SCEs, VR spurious baselines, and VR random baselines (6-second intervals).

Secondary Task Category	*Count	*Average Duration(s)	†Count	†Average Duration(s)	‡Count	‡Average Duration(s)
Visual	0	.	0	.	4	2.45
VM	0	.	0	.	0	.
Talk/Listen on an Electronic Device	0	.	1	0.83	1	1.42
Talk to Passengers	5	1.99	13	2.67	39	2.78

*VR SCEs

†VR spurious baselines

‡VR random baselines

Table 33 shows the mean durations of passenger talking times during VR SCEs, VR spurious baselines, and VR random baselines (5-second intervals).

Table 33. Mean durations of passenger talking times during VR SCEs, VR spurious baselines, and VR random baselines (5-second intervals).

Secondary Task Category	*Count	*Average Duration(s)	†Count	†Average Duration(s)	‡Count	‡Average Duration(s)
Visual	0	.	0	.	4	2.20
VM	0	.	0	.	0	.
Talk/Listen on an Electronic Device	0	.	1	0.83	1	1.42
Talk to Passengers	5	1.77	12	2.49	37	2.48

*VR SCEs

†VR spurious baselines

‡VR random baselines

4.4.3 Driver Talking Time in 0.25-second Intervals

Figure 6 shows the distribution of driver talking time during the 6-second interval (displayed in 0.25-second intervals). The number “0” represents the start of the VR SCE, VR spurious baseline, and VR random baseline, and “5” represents the beginning of the trigger in the VR SCE and VR spurious baseline; thus, “6” is 1 second after the trigger during the VR SCE and VR spurious baseline. Although the distribution of intervals during which the driver was talking in the VR spurious baselines and VR random baselines is evenly dispersed, the percentage of intervals during which the driver was talking in VR SCEs increases (and peaks) approaching the trigger at 5 seconds.

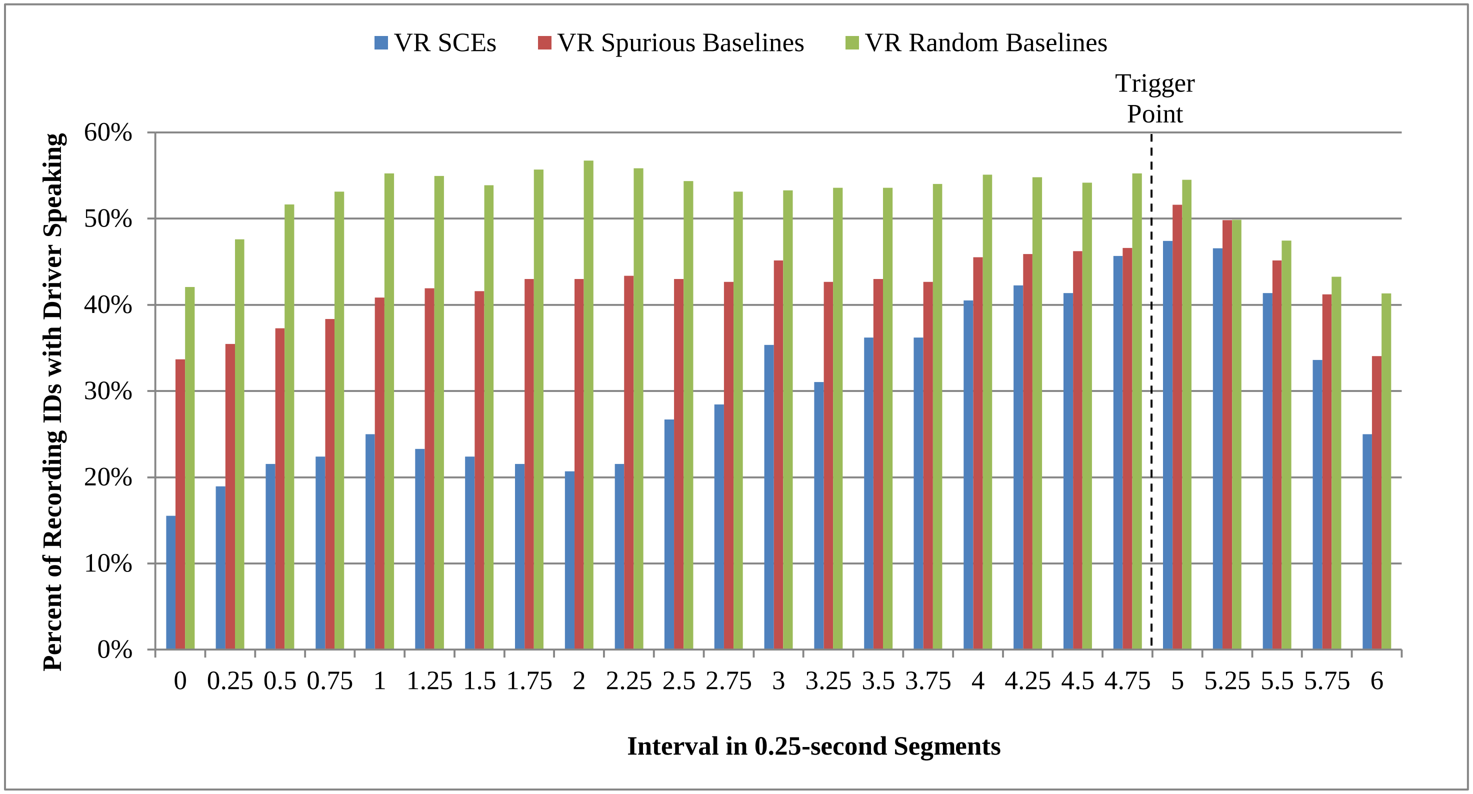

Figure 6. Chart. Distribution of driver talking time during the 6-second interval (displayed in 0.25-second intervals).

Table 34 shows the ORs for driver talking times in 0.25-second intervals (during the 6-second interval) using VR spurious baselines. "Driver Not Talking" means the driver was not talking during the 0.25-second interval. There were 14 statistically-significant ORs that showed a decreased likelihood of involvement in a VR SCE. Truck and bus drivers that were talking at intervals 0–3.25 were less likely to be involved in a VR SCE (compared to a VR spurious baseline) than truck and bus drivers that were not talking while driving.

Table 34. ORs for driver talking times in 0.25-second intervals using VR spurious baselines.

Time Interval	VR SCE with Driver Talking	VR SCE with Driver Not Talking	VR Spurious Baseline with Driver Talking	VR Spurious Baseline with Driver Not Talking	OR	LCL	UCL
0	18	98	94	185	0.36*	0.21	0.63
0.25	22	94	99	180	0.43*	0.25	0.72
0.5	25	91	104	175	0.46*	0.28	0.77
0.75	26	90	107	172	0.46*	0.28	0.76
1	29	87	114	165	0.48*	0.30	0.78
1.25	27	89	117	162	0.42*	0.26	0.69
1.5	26	90	116	163	0.41*	0.25	0.67
1.75	25	91	120	159	0.36*	0.22	0.60
2	24	92	120	159	0.35*	0.21	0.57
2.25	25	91	121	158	0.36*	0.27	0.59
2.5	31	85	120	159	0.48*	0.20	0.78
2.75	33	83	119	160	0.53*	0.33	0.85
3	41	75	126	153	0.66*	0.42	1.04
3.25	36	80	119	160	0.61*	0.38	0.96
3.5	42	74	120	159	0.75	0.48	1.18
3.75	42	74	119	160	0.76	0.49	1.19
4	47	69	127	152	0.82	0.53	1.26
4.25	49	67	128	151	0.86	0.56	1.34
4.5	48	68	129	150	0.82	0.53	1.27
4.75	53	63	130	149	0.96	0.62	1.49
5	55	61	144	135	0.85	0.55	1.30
5.25	54	62	139	140	0.88	0.57	1.35
5.5	48	68	126	153	0.86	0.55	1.33
5.75	39	77	115	164	0.72	0.46	1.14
6	29	87	95	184	0.65	0.40	1.05

*Statistically-significant OR

Table 35 shows the ORs for driver talking times in 0.25-second intervals (during the 6-second interval) using VR random baselines. There were 20 statistically-significant ORs that decreased the likelihood of involvement in a VR SCE (19 of these ORs were in consecutive time intervals). Truck and bus drivers who were talking at intervals 0–4.5 were less likely to be involved in a VR SCE (compared to a random baseline) than truck and bus drivers who were not talking while driving. A significant OR at interval 6 indicates that truck and bus drivers talking at interval 6 were less likely to be involved in a VR SCE (compared to a VR random baseline).

Table 35. ORs for driver talking times in 0.25-second intervals using VR random baselines.

Time Interval	VR SCE with Driver Talking	VR SCE with Driver Not Talking	VR Random Baseline with Driver Talking	VR Random Baseline with Driver Not Talking	OR	LCL	UCL
0	18	98	281	387	0.25*	0.15	0.43
0.25	22	94	318	350	0.26*	0.16	0.42
0.5	25	91	345	323	0.26*	0.16	0.41
0.75	26	90	355	313	0.25*	0.16	0.40
1	29	87	369	299	0.27*	0.17	0.42
1.25	27	89	367	301	0.25*	0.16	0.39
1.5	26	90	360	308	0.25*	0.16	0.39
1.75	25	91	372	296	0.22*	0.14	0.35
2	24	92	379	289	0.20*	0.12	0.32
2.25	25	91	373	295	0.22*	0.14	0.35
2.5	31	85	363	305	0.31*	0.20	0.48
2.75	33	83	355	313	0.35*	0.23	0.54
3	41	75	356	312	0.48*	0.32	0.72
3.25	36	80	358	310	0.39*	0.26	0.59
3.5	42	74	358	310	0.49*	0.33	0.74
3.75	42	74	361	307	0.48*	0.32	0.73
4	47	69	368	300	0.56*	0.37	0.83
4.25	49	67	366	302	0.60*	0.41	0.90
4.5	48	68	362	306	0.60*	0.40	0.89
4.75	53	63	369	299	0.68	0.46	1.01
5	55	61	364	304	0.75	0.51	1.12
5.25	54	62	333	335	0.88	0.59	1.30
5.5	48	68	317	351	0.78	0.52	1.17
5.75	39	77	289	379	0.66	0.44	1.01
6	29	87	276	392	0.47*	0.30	0.74

*Statistically-significant OR

4.5 RESEARCH OBJECTIVE 4: VISUAL DISTRACTION

Because the onboard monitoring system records video at 4–5 Hz (a description of the limitations in this recording rate is provided earlier in this report), data analysts were only able to code driver eye glance location (eyes off forward roadway or eyes toward forward roadway) at 0.25-second intervals. Driver eye glance behavior between the 0.25-second intervals cannot be extrapolated from the data; therefore, the data was only analyzed at 0.25-second intervals and was not treated as continuous data.

4.5.1 Visual Distraction in VR and Non-VR Events in 0.25-second Intervals

Data analysts recorded the eye glance direction at 0.25-second intervals in 410 SCEs, 1,106 spurious baselines, and 1,962 random baselines. The events included events with and without driver and/or passenger voice while driving. Table 36 shows the counts per VR status for each event type.

Table 36. Counts of event types with and without observed voice distraction.

VR Status	SCEs	Spurious Baselines	Random Baselines
VR	218	569	1,007
Non-VR	192	537	955
Total	**410**	**1,106**	**1,962**

4.5.2 Visual Distraction in VR Events at 0.25-second Intervals

In the following section, the risk of EOFR glances was analyzed by comparing VR SCEs to VR spurious and random baselines. Table 37 shows the ORs for EOFR glances in 0.25-second intervals (across the entire 6-second epoch) using VR spurious baselines. In five of the 0.25-second intervals, EOFR glances significantly elevated the risk of a VR SCE. Truck and bus drivers with an EOFR glance at the intervals of 5.0, 5.25, 5.5, 5.75, and 6.0 seconds were more likely to be involved in a VR SCE (compared to a spurious baseline) than truck and bus drivers with no EOFR glances. A general trend of increasing ORs is seen in Table 37 as the time intervals approach the event marker at 5 seconds.

Table 37. ORs for EOFR glance times in 0.25-second intervals using spurious baselines.

Time Interval	VR SCE with EOFR Glance	VR SCE with Eyes Toward Forward Roadway	VR Spurious Baseline with EOFR Glance	VR Spurious Baseline with Eyes Toward Forward Roadway	OR	LCL	UCL
0	63	142	131	402	1.36	0.95	1.94
0.25	62	143	138	393	1.23	0.87	1.76
0.5	59	146	139	393	1.14	0.80	1.64
0.75	60	146	134	399	1.22	0.85	1.75
1	62	144	138	396	1.23	0.87	1.76
1.25	62	144	143	393	1.18	0.83	1.69
1.5	58	148	129	407	1.23	0.86	1.78
1.75	54	152	132	405	1.09	0.75	1.57
2	50	156	128	409	1.02	0.70	1.49
2.25	53	154	127	409	1.11	0.77	1.60
2.5	61	146	123	413	1.40	0.98	2.01
2.75	57	150	127	407	1.22	0.85	1.75
3	54	152	125	410	1.17	0.81	1.69
3.25	56	148	120	416	1.31	0.91	1.90
3.5	55	149	126	411	1.20	0.83	1.74
3.75	58	147	120	417	1.37	0.95	1.98
4	63	143	17	409	1.42	0.99	2.03
4.25	62	144	125	411	1.42	0.99	2.03
4.5	59	147	129	407	1.27	0.88	1.82
4.75	59	146	124	411	1.34	0.93	1.93
5	66	136	128	407	1.54*	1.08	2.20
5.25	71	130	125	409	1.79*	1.26	2.54
5.5	76	124	130	404	1.90*	1.35	2.70
5.75	80	122	134	399	1.95*	1.39	2.75
6	83	119	132	400	2.11*	1.50	2.98

*Statistically-significant OR

Table 38 shows the ORs for EOFR glance times in 0.25-second intervals (across the entire 6-second epoch) using VR random baselines. At eight of the 0.25-second intervals, EOFR glances significantly elevated the risk of a VR SCE. Truck and bus drivers with an EOFR glance at the intervals of 0, 0.25, 4.0, 5.0, 5.25, 5.5, 5.75, and 6.0 seconds were more likely to be involved in a VR SCE (compared to a VR spurious baseline) than truck and bus drivers with no EOFR glances.

Table 38. ORs for EOFR glance times in 0.25-second intervals using VR random baselines.

Time Interval	VR SCE with EOFR Glance	VR SCE with Eyes Toward Forward Roadway	VR Random Baseline with EOFR Glance	VR Random Baseline with Eyes Toward Forward Roadway	OR	LCL	UCL
0	63	142	228	724	1.41*	1.01	1.96
0.25	62	143	222	729	1.42*	1.02	1.99
0.5	59	146	229	722	1.27	0.91	1.78
0.75	60	146	242	709	1.20	0.86	1.68
1	62	144	238	713	1.29	0.93	1.80
1.25	62	144	244	707	1.25	0.90	1.74
1.5	58	148	249	702	1.10	0.79	1.55
1.75	54	152	240	712	1.05	0.75	1.49
2	50	156	235	717	0.98	0.69	1.39
2.25	53	154	240	712	1.02	0.72	1.44
2.5	61	146	251	700	1.17	0.84	1.62
2.75	57	150	242	708	1.11	0.79	1.56
3	54	152	234	714	1.08	0.77	1.53
3.25	56	148	235	713	1.15	0.82	1.61
3.5	55	149	240	709	1.09	0.77	1.54
3.75	58	147	228	721	1.25	0.89	1.75
4	63	143	224	726	1.43*	1.02	1.99
4.25	62	144	224	725	1.39	1.00	1.94
4.5	59	147	231	717	1.25	0.89	1.74
4.75	59	146	235	713	1.23	0.88	1.72
5	66	136	243	704	1.41*	1.01	1.95
5.25	71	130	239	706	1.61*	1.17	2.23
5.5	76	124	249	696	1.71*	1.24	2.36
5.75	80	122	250	696	1.83*	1.33	2.51
6	83	119	233	714	2.14*	1.56	2.93

*Statistically-significant OR

Figure 7 shows the distribution of VR SCEs, VR spurious baselines, and VR random baselines with EOFR glances during the 6-second epoch. The distribution is displayed by percent of event type recordings with EOFR glances. At each interval, VR SCEs have a higher percentage of EOFR glances compared to VR spurious and VR random baselines. The percentage of VR SCEs with EOFR glances noticeably rises at the 4.5-second interval through the 6-second interval. The VR spurious and VR random baselines show a fairly consistent distribution across the 6-second epoch.

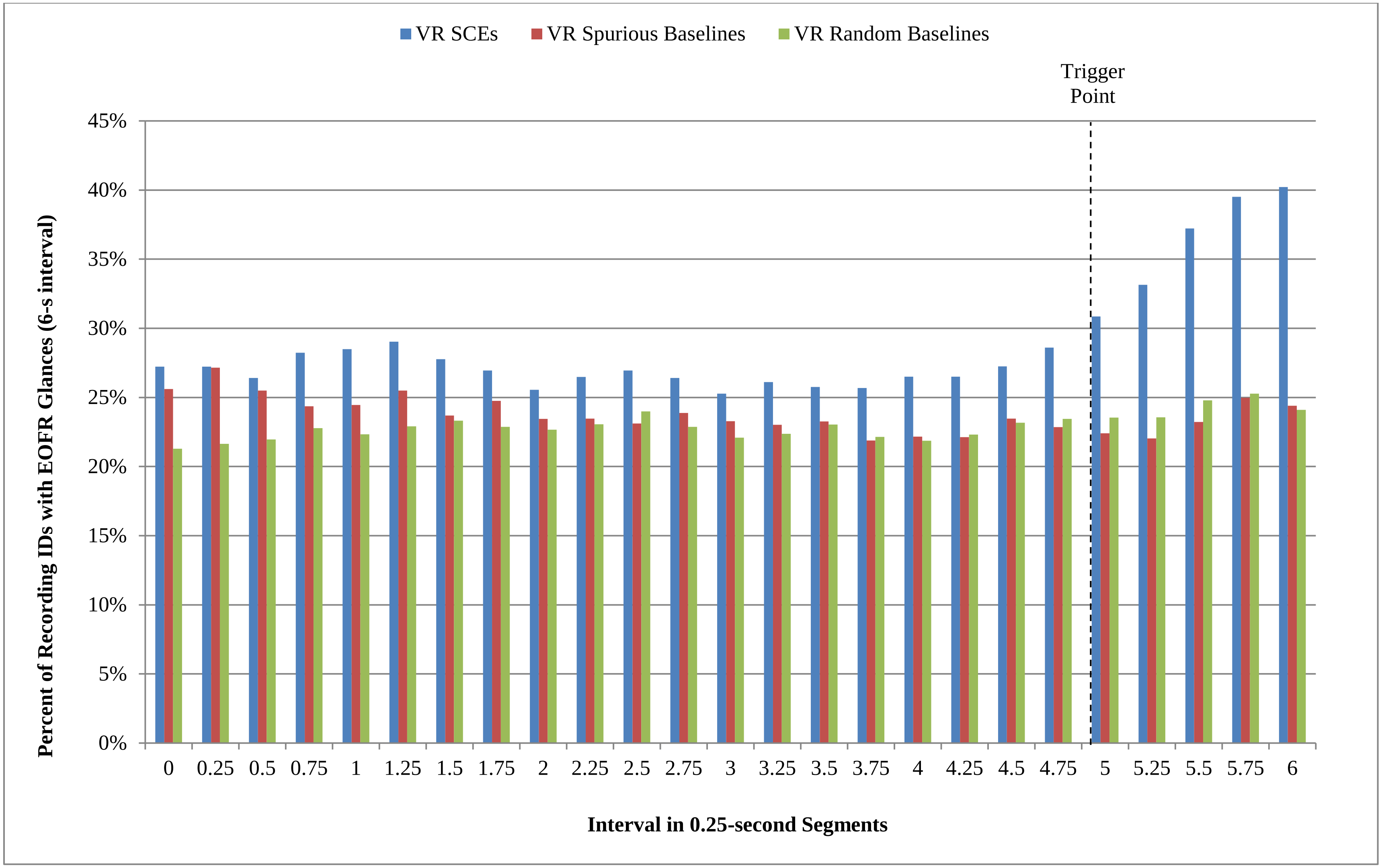

Figure 7. Chart. Distribution of percent of VR SCEs, VR spurious baselines and VR random baselines with EOFR glances (6-second interval).

4.5.3 Driver Talking and Visual Distraction in 0.25-second Intervals

The driver talking data and eye glance data were matched for each observation (VR SCEs, VR spurious baselines, and VR random baselines) to explore the relationship between talking and EOFR glance time. The nature of the voice data allowed data analysts to provide exact start and end times of speaking segments in each observation. The camera facing the driver recorded video at 4–5 Hz; thus, eye glance location data was analyzed at 0.25-second intervals. To match the driver talking data to the eye glance data, the driver talking data was broken down into 0.25-second intervals. A 0.25-second interval was marked with "Driver Talking" if the driver was talking at the start of the 0.25-second interval. This transformation was completed for the entire 6-second interval for each observation.

Figure 8 shows the distribution of the percentage of EOFR glances at each 0.25-second interval for observations of drivers talking and observations of drivers not talking, using all event types. As seen in the chart, the percentage of EOFR glances is higher when the driver is not talking than when the driver is talking.

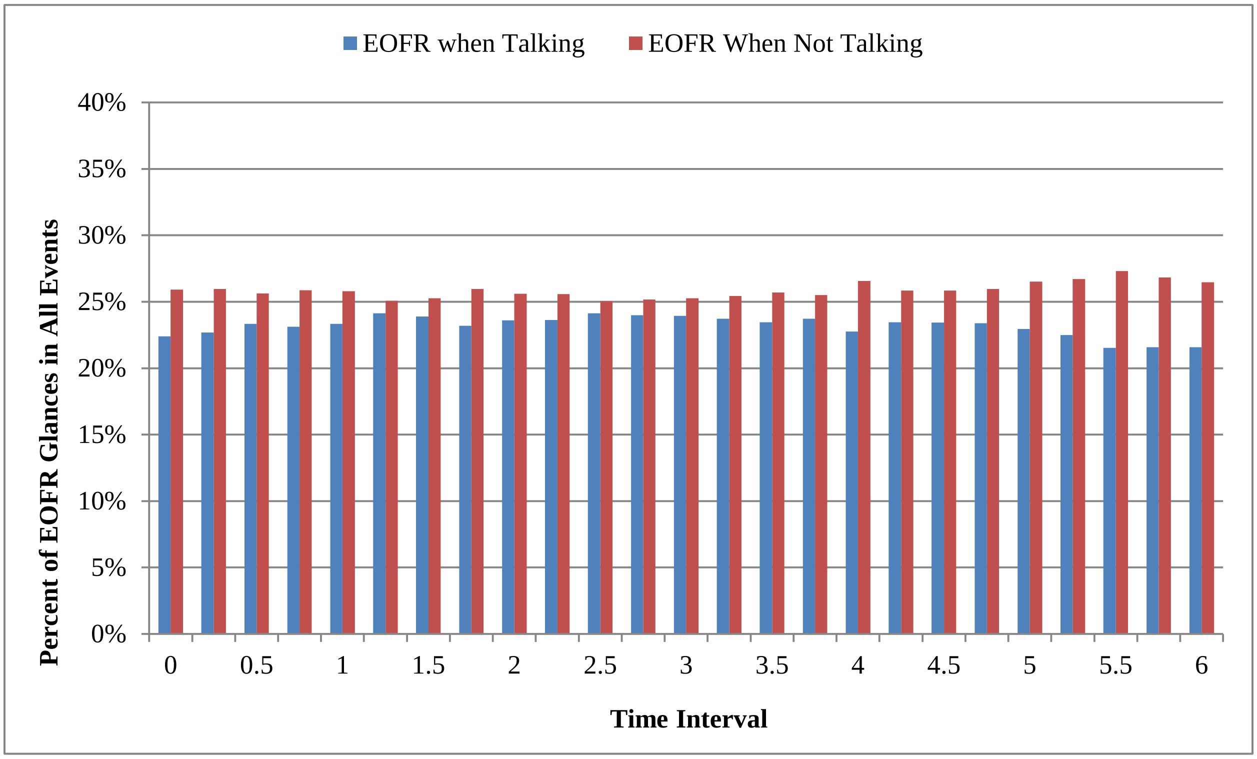

Figure 8. Chart. Percentage of EOFR glances during "Driver Talking" and "Driver Not Talking" at 0.25-second intervals for all event types.

To determine if the results in Figure 8 were statistically significant, a chi-square test was performed at each interval. The count data per 0.25-second time interval is shown in Table 39. Driver talking was found to be associated with fewer EOFR counts in all but two time intervals (1.25 seconds and 2.5 seconds).

Table 39. Chi-square test results for talking status and eye glance location at 0.25-second intervals for all event types.

Time Interval	Events with Driver Talking and EOFR Glances	Events with Driver Not Talking and EOFR Glances	Events with Driver Talking, Eyes Toward Forward Roadway	Events with Driver Not Talking, Eyes Toward Forward Roadway	X^2	*p*-value
0	2,057	4,058	7,126	11,600	38.57*	<.0001
0.25	2,318	3,797	7,900	10,826	34.88*	<.0001
0.5	2,565	3,550	8,428	10,298	17.51*	<.0001
0.75	2,622	3,493	8,720	10,006	25.27*	<.0001
1	2,777	3,338	9,128	9,598	20.51*	<.0001
1.25	2,874	3,241	9,039	9,687	2.98	0.0842
1.5	2813	3,302	8,959	9,767	6.27*	0.0123
1.75	2,805	3,310	9,290	9,436	25.80*	<.0001
2	2,901	3,214	9,389	9,337	13.42*	0.0002
2.25	2,855	3,260	9,235	9,491	12.74*	0.0004
2.5	2,864	3,251	9,001	9,725	2.80	0.0942
2.75	2,811	3,304	8,907	9,819	4.71*	0.0300
3	2,906	3,209	9,237	9,489	6.00*	0.0142
3.25	2,813	3,302	9,044	9,682	9.73*	0.0018
3.5	2,827	3,288	9,222	9,504	16.79*	<.0001
3.75	2,899	3,216	9,327	9,399	10.62*	0.0011
4	2,885	3,230	9,791	8,935	48.10*	<.0001
4.25	2,995	3,120	9,772	8,954	18.97*	<.0001
4.5	2,959	3,156	9,674	9,052	19.74*	<.0001
4.75	3,030	3,085	9,928	8,798	22.20*	<.0001
5	3,037	3,078	10,195	8,531	42.28*	<.0001
5.25	2,786	3,329	9,593	9,133	59.24*	<.0001
5.5	2,484	3,631	9,056	9,670	111.00*	<.0001
5.75	2,252	3,863	8,188	10,536	90.02*	<.0001
6	2,028	4,087	7,373	11,353	75.54*	<.0001

*Statistically-significant finding

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5. DISCUSSION

The objective of this study was to better understand the risk associated with secondary task activity (with a specific focus on VR secondary tasks) while driving a truck or bus under real-world driving conditions and pressures (naturalistic driving). The data were collected during a 4-month period from an existing naturalistic database from a vendor of onboard monitoring systems. In addition to assessing secondary task engagement while driving, the study also assessed:

- The risk of an SCE while performing a secondary task.
- Whether conversation workload affected the risk of an SCE while engaged in a secondary task.
- Whether talking time affected the risk of a VR SCE while engaged in a VR secondary task.
- Whether visual distraction affected the risk of a VR SCE while engaged in a VR secondary task.
- The differences between spurious baselines and random baselines.

5.1 SCE RISK ASSOCIATED WITH SECONDARY TASK

Unfortunately, the small sample size of specific secondary tasks prohibited an analysis at this level of the data. To increase power, the current analysis focused on secondary task categories, such as visual, VM, talk/listen on an electronic device, and talk to passengers. The results were consistent with other naturalistic truck driving research regardless of the approach used. For example, the secondary task category, talk/listen on an electronic device, was consistently found to have no significant impact on the risk of involvement in an SCE compared to spurious baselines (non-significant ORs = 1.16 and 1.26) and random baselines (non-significant ORs = 0.67 and 0.72). This result is consistent with other naturalistic truck driving research that found that talking/listening on a handheld mobile phone did not increase the risk of involvement in an SCE and that talking on a hands-free mobile phone or CB decreased the risk of involvement in a SCE.[81,82] Although the current study was not able to provide risk estimates for specific secondary tasks, the results in the current study largely support previous naturalistic truck and bus and passenger car driving studies regarding the risk of talking/listening on an electronic device.[83,84,85,86]

There were two interesting findings with regard to visual and VM secondary task categories and "Talk to Passengers." Visual and VM secondary task categories were consistently found to have no impact on the risk of involvement in an SCE compared to spurious baselines and random baselines. More specifically, the visual secondary task category was not associated with a significant increased risk of involvement in an SCE compared to spurious baselines (ORs = 2.15 and 2.32) and random baselines (ORs = 1.10 and 1.17). The VM secondary task category was not associated with a significant increased risk of involvement in an SCE compared to spurious baselines (ORs = 1.40 and 1.52) and random baselines (ORs = 1.44 and 1.52).

Although previous naturalistic driving truck studies have not aggregated secondary tasks into secondary task categories as in the current study, most of the specific secondary tasks in these prior studies have shown a significant increase in the likelihood of involvement in an SCE while performing these tasks while driving. For example, the following VM secondary tasks were found to significantly increase risk in Olson et al.[87] and Hickman et al.[88] (note that visual secondary tasks were not coded in these studies):

- Texting.
- Dialing a mobile phone.
- Reaching for a mobile phone.
- Interacting with a dispatching device.

It is premature to indicate that visual or VM secondary task categories are safe to perform while driving a truck or bus. The analysis suffers from a small sample size. Only 6 and 8 of the SCEs were coded with a visual or VM secondary task, respectively (29 and 59 of the spurious baselines and 82 and 84 of the random baselines). In fact, a small sample size (limited power) was also the reason that Fitch et al.[89] were unable to find a significant OR for text messaging/browsing in their naturalistic study with passenger car drivers. Thus, to draw any meaningful conclusions from the analysis of visual and VM secondary task categories in this study is premature.

The only significant secondary task category was “Talk to Passengers.” When a driver talked to passengers while driving, it significantly increased the likelihood of his or her involvement in an SCE as compared to spurious baselines (ORs = 3.23 and 3.26) and random baselines (ORs = 2.85 and 2.79). Talking to a passenger was not coded in Olson et al.[90] Although “passenger distraction” was coded in Hickman et al.,[91] this secondary task could also mean interacting with a passenger in ways beyond talking. Additionally, no OR was calculated in Hickman et al.[92] — this secondary task was only observed in SCEs. The research on the risk of talking to a passenger while driving is mixed. Some studies have found a decrease in risk[93] or no increase in risk.[94] Studies that have found a decrease in risk suggest that an extra pair of eyes on the road to warn the driver and/or the passenger’s ability to modulate the conversation can benefit the driver (e.g., to warn the driver of upcoming threats). Other studies have found that this secondary task increases risk,[95,96] suggesting the conversation itself and/or the propensity for drivers to look at the passenger with whom they are speaking creates a safety deficit.

5.2 CONVERSATION WORKLOAD

Research on emotion and emotional conversations while driving has been mixed. Meskan et al.[97] were able to show that specific emotions (i.e., anger, anxiety, happiness) had different correlations with road events and speeding, showing higher correlations between negative emotions and road events and speeding. Using video clips of traffic situations, Hu, Xie, and Li[98] were also able to show that negative mood states were more likely to be related to risky driving behaviors. Dula et al.[99] found that drivers in a driving simulator engaged in more dangerous driving behaviors while engaged in an emotional call (e.g., arguing the opposite position of a deeply held belief of the participant) than during an innocuous conversation. However, Shinar et al.[100] found that performing a math operation task degraded driving performance to a greater extent than engaging in an emotionally-involving conversation, and Rakauskas, Guterty, and Ward[101] were unable to find a significant difference between an easy conversation and a conversation that elicited an emotional response during a simulated driving task.

In the current study, conversation workload was measured via the expression and intensity of emotion during a conversation (on a mobile phone or with a passenger). What data analysts did find was that drivers rarely have emotional conversations while driving, and coding emotion using a brief clip of audio and video was very difficult (as indicated by the high number of "unsure" ratings). Of course, data analysts only had brief video clips and audio recordings to review; thus, it is possible that a driver may have experienced an emotion, but did not overtly display this emotion. A naturalistic study by Fitch et al.[102] supports these findings. Using video and mobile phone records, Fitch et al.[103] found that only 3.8 percent of the video clips showed some type of emotion (it should be noted that no audio was available for analysis in the Fitch et al. study). Taken together, these two naturalistic studies suggest that emotional conversations while driving are rare.

5.3 TALKING TIME AND VISUAL DISTRACTION

Unfortunately, there were very few samples of visual and VM secondary task categories, making it difficult to draw many conclusions with respect to talking time and visual distraction. On average, driver conversations were shorter on electronic devices during VR SCEs as compared to VR spurious baselines and VR random baselines. However, much like other naturalistic truck studies,[104,105] the current study found that talking/listening on an electronic device while driving did not significantly increase the likelihood of an SCE. Although other naturalistic studies that collected continuous data have cataloged the durations of mobile phone conversations,[106,107] the current study was able to asses risk as a function of 0.25-second intervals. None of the talking intervals in any of the analyses resulted in a significant increase in the likelihood of a VR SCE. In fact, the majority of intervals were significantly less likely to result in a VR SCE, especially those intervals from 0–4.0 seconds. This suggests that the amount of talking time for the interval when a driver was talking on an electronic device did not increase the likelihood of a VR SCE.

The average duration of driver conversations with a passenger was shorter during VR SCEs as compared to VR spurious baselines and VR random baselines. However, the current study found that talking to a passenger while driving significantly increased the likelihood of an SCE. Olson et al.[108] and Klauer et al.[109] both found that talking to a passenger while driving did not significantly increase risk for truck drivers or passenger car drivers. The research on the risk of a driver talking to a passenger is mixed. Some studies have suggested that drivers (and passengers) modulate their conversation based on driving demands, and that a passenger is an extra set of eyes that can warn drivers of an upcoming hazard.[110] However, Horrey and Wickens[111] found that passenger conversations were just as dangerous as mobile phone conversations, and a simulator study by Laberge[112] found little support that passengers adjusted their conversations to changes in the traffic environment. The current study supports the latter contention that drivers do not adjust their behavior based on driving demands, but it does not address why talking to a passenger while driving is more likely to result in an SCE as compared to talking/listening on an electronic device while driving.

When discussing the results of visual distraction, the reader should be aware of the limitations in the recording rate noted above. Analyses on visual distraction show an increasing trend in ORs as the time interval gets closer to the trigger point. Most of the significant ORs (which all show an increase in the likelihood of a VR SCE) were close to and after the trigger point. This suggests that the timing of the glance away from the forward roadway is very important. However, this does not invalidate the importance of mean EOFR glance times or total EOFR glance times as it is extremely difficult to predict when something unexpected will occur. If anything, greater mean EOFR and total EOFR glance times should be predictive of increased risk, as the longer a driver looks away from the forward roadway, the greater the probability that same driver will be looking away from the forward roadway when something unexpected occurs.

What is clear is that driver talking was associated with lower EOFR glance counts. Several studies have found that drivers look at the forward roadway more often when engaged in cognitive and auditory tasks.(113,114,115) This has been termed "gaze concentration." At first this was thought to be a disbenefit, as drivers were more likely to perform poorly in peripheral object detention tasks. However, this could actually benefit the driver as most unexpected traffic events are likely to occur in front of the vehicle rather than at the periphery. This would suggest that drivers are less likely to be involved in longitudinal traffic safety events (e.g., rear-end striking) while talking on a mobile phone and more likely to be involved in lateral traffic events (such as a sideswipe, as drivers are more likely to be looking at the forward roadway). To date, naturalistic driving studies have consistently found that talking/listening on a mobile phone while driving does not increase risk.(116,117,118) It is unclear if this result is solely from a reduction in longitudinal traffic safety events (and an increase in less prevalent peripheral events), as this scenario has not been assessed using naturalistic driving data.

5.4 SPURIOUS AND RANDOM BASELINES

Hickman et al. used spurious baselines (e.g., triggered non-safety events, such as traveling across train tracks or a pothole that exceeded the kinematic threshold, braking in response to no apparent traffic safety situation, etc.) in their analysis of truck and bus driver distraction.(119) Although the spurious baselines in Hickman et al.(120) were not randomly selected, they were used to evaluate the risk in performing various secondary tasks while driving. However, these baselines were not truly random, thus increasing the likelihood of possible bias to certain situations that triggered these spurious baselines (e.g., potholes, train tracks, hard braking not in response to a safety event, etc.). The current study was able to compare spurious and random baselines. When comparing the ORs for secondary task categories using spurious baselines and random baselines, the research team found that spurious baselines slightly overestimated the OR in seven of the eight comparisons, using any other secondary task category and no other secondary task category as controls. Only one comparison had the same OR: the VM secondary task category had an OR of 1.52 for spurious baselines with no other secondary task and for random baselines with no other task category. Also, the distributions of talking time and EOFR segments for VR spurious baselines and VR random baselines were very similar. These data suggest that spurious baselines can be used in place of random baselines if random baselines are unavailable. However, ORs using spurious baselines that are borderline significant should be viewed with caution, as the current study found that spurious baselines slightly overestimate risk.

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6. POSSIBLE LIMITATIONS

The authors acknowledge six caveats when interpreting the results. First, the data set involves an active safety intervention via behavioral coaching through review of video clips by safety managers. More specifically, the frequency and distribution of secondary tasks in the data set was likely skewed from normative driving data as the safety managers attempted to directly alter these behaviors. Moreover, some commercial truck and bus fleets were likely to be more stringent in their modification of certain driver behaviors (e.g., mobile phone use while driving) than other commercial truck and bus fleets in the two data sets. Hickman and Hanowski[(121)] found that the video event data recorder system reviewed in that study could reduce the mean rate of SCEs per 10,000 miles in large trucks by up to 70 percent, and McGehee et al.[(122)] found similar results in novice teen drivers. Thus, the data found in the current study likely reflects a “best case” scenario, and the prevalence of secondary tasks in the general population of commercial trucks and bus is likely to be higher.

Second, the fact that the truck and bus fleets in the study purchased an OSM system reflects a group of safety conscious truck and bus fleets. As with the first caveat noted above, the data were likely skewed from normal fleets, as the fleets included in the study likely were more proactive in regard to safety. As such, and consistent with the previous caveat, the prevalence of driver distractions in the study may be an underestimate of the normal commercial truck and bus driving population.

Third, driver exposure was not controlled in the study; thus, extremely unsafe drivers may have contributed far more SCEs than baseline events (or conversely, extremely safe drivers). However, as the study included more than 6,000 drivers (from more than 6,000 trucks), the effect of any outliers was minimized. More specifically, the effect of any one driver was minimized given the large number of drivers in the study.

Fourth, as indicated above, the eye glance analyses need to be viewed with caution given that the video data were collected at 4–5 Hz. Given the recording rate, the eye glance analysis data did not always line up with the talking time data, and it is also likely that glances were missed. Because of these limitations, the types of possible eye glance analyses were limited, especially those calculating specific EOFR glance durations.

Fifth, secondary task categories were used in place of specific secondary tasks due to small sample sizes. Although these general secondary task categories were grouped according to distraction type (except “Talking to a Passenger”), they do not provide a level of detail to discern which specific secondary tasks within each secondary task category were risky or safe.

Finally, the cell counts for Research Objectives 2–4 do not match the cell counts in Research Objective 1 due to:

- The assembly line data reduction process. Some audio and video was lost during the reduction process due to a server malfunction at the technology vendor.
- The malfunction of the forward- and/or driver-facing camera during data collection.
- The malfunction of the microphone during data collection.

It is unknown what effect these issues had on the data.

APPENDIX A: EXISTING AND NEW TECHNOLOGY-RELATED VARIABLES AND THEIR OPERATIONAL DEFINITIONS

Original Technology Vendor Variable	New Variable	New Operational Definition
N/A	Mobile Phone—Reach for and pick up phone	Includes reaching for mobile phone, picking up mobile phone, and reaching into pocket to get mobile phone to make or receive a call. Driver may or may not remove eyes from the forward roadway to reach for the mobile phone inside the vehicle. This option can be marked even when the device cannot be seen in the video IF it can be inferred from the video that the driver reached for the phone and made or answered a phone call.
N/A	Mobile Phone—Reach for and pick up headset/earpiece	Includes reaching for, picking up, and reaching into pocket for a headset/earpiece that the driver uses with a mobile phone. The headset/earpiece does not need to be seen if it can be inferred from the video that the driver reached for the earpiece and placed it in his/her ear before making/receiving a call.
N/A	Mobile Phone—Input Voice Command	Occurs when the driver presses the voice command button on the steering wheel, aftermarket device, or mobile phone (e.g., SIRI on iPhone) and inputs a voice command (e.g., dial a contact or get directions to a destination).
Mobile Phone—Texting/Dialing	Mobile Phone—Text	Driver appears to be entering text into the mobile phone. Driver is focusing on the mobile phone for an extended amount of time and continuously pressing keys.
N/A	Mobile Phone—Look at Phone	Driver is focusing on the mobile phone for an extended amount of time but is not pressing any keys.
N/A	Mobile Phone—Dial/Answer	Driver enters a small number of keyboard inputs on a mobile phone either to dial a phone number or to accept an incoming call.
Mobile Phone—Talking (Handheld)	Mobile Phone—Talk/Listen (Handheld)	Driver holds a handheld phone to his/her ear and is talking and/or listening. If driver dials mobile phone then talks on mobile phone, both options are marked.
Mobile Phone—Talking (Hands-free)	Mobile Phone—Talk/Listen (Hands-free)	Driver talks or listens to a hands-free phone. This is apparent by an earpiece in the driver's ear or by the content of the conversation.
N/A	Mobile Phone—Put mobile phone/headset/earpiece away	After the mobile phone conversation is over, the driver ends the call by pressing a button to hang up or by closing the lid of the phone. This includes reaching to put the phone away.
N/A	CB—Reach for CB	Driver reaches for his/her CB.
N/A	CB—Talk or listen to CB	Driver talks or listens to a CB microphone.
N/A	CB—Put CB away	Driver reaches to put his/her CB away.
N/A	Push-to-talk Mobile Phone—Reach for Phone	Driver reaches for his/her push-to-talk mobile phone (e.g., Nextel device).

Original Technology Vendor Variable	New Variable	New Operational Definition
N/A	Push-to-talk Mobile Phone—Talk or listen on phone	Driver talks or listens on a push-to-talk phone.
N/A	Push-to-talk Mobile Phone—Put phone away	Driver reaches to put his/her push-to-talk phone away.
Operating Other Mobile Device	Interact with dispatching device	Driver interacts with or looks at a dispatching device. The driver usually keeps the device on the passenger seat or on the floor between the two seats and holds the device on his/her lap or steering wheel while in use. Assumes driver is looking at and may reach for object.
N/A	Interact with GPS	Driver interacts with an aftermarket GPS device that is mounted on the instrument panel or dash (does NOT include an in-dash satellite radio). This may involve the driver hooking up the system or pressing buttons. Assumes driver is looking at and may reach for object.
N/A	Interact with satellite radio	Driver interacts with an aftermarket satellite radio device that is mounted on the instrument panel or dash (does NOT include an in-dash satellite radio). This may involve the driver hooking up the system or pressing buttons. Assumes driver is looking at and may reach for object.
N/A	Talk/Listen—Other	Any talking observed that does not fall into the talking/listening classifications shown above.
Reading Paperwork	Keep existing variable	Keep existing operational definition
Grooming/Personal Hygiene	Keep existing variable	Keep existing operational definition
Food	Keep existing variable	Keep existing operational definition
Beverage	Keep existing variable	Keep existing operational definition
Smoking	Keep existing variable	Keep existing operational definition
Passengers	Talk to Passengers	Driver is talking to a passenger sitting in the passenger's seat, in the sleeper berth, or in a seat behind the driver.
N/A	Look at Passengers	Driver is looking at a passenger sitting in the passenger's seat, in the sleeper berth, or in a seat behind the driver.
Other Task	N/A	N/A

APPENDIX B: STEPS IN THE VISUAL DISTRACTION PROTOCOL FOR VR ACTIVITIES

1. Load the video.
2. Enter the name of the video in the Excel log under the "Event" column.
3. Is an eye-glance review possible?
    - Yes.
    - No.
        i. The driver is wearing dark sunglasses.
        ii. The driver has thick eye glasses.
        iii. The video is missing/dark/misaligned/out of focus or other such reasons.

    If "**No,**" mark the reason down in the Excel log, and go to the next video.
    If "**Yes,**" continue to step 4.
4. Review the full 6 seconds of the sample in real time (5 seconds before the trigger to 1 second after the trigger).
5. Review the face view and the road view.
6. When you are ready to begin entering eye-glance data, make sure you are at the start of the first sync representing -5 seconds from the trigger point.
    - Identify the time frame at which the trigger occurs.
    - Subtract 5 seconds from this time point.
    - Now advance the video to the -5 second time point. This is the first frame of the eye-glance reduction.
    - Enter the time in the "Time" column on the Excel log. Make sure the column is formatted as a custom type (mn:ss.0).
7. For this frame, record in the Excel log where the driver is looking by classifying the driver's glance into one of the four categories listed in Table 40 (use the drop-down list in the Excel log).

Table 40. Glance locations and their operational definitions.

Eye-glance Location	Operational Definition
Toward the Forward Roadway	• Occurs when the driver is looking at the road ahead of the vehicle. This includes the road ahead in the left and right adjacent lanes. • If the driver is looking at the left or right side (West Coast) mirrors or windows, do not mark the glance as being towards the forward roadway. Mark it as being, "Off the forward roadway." • Because it will be difficult to tell if the driver is looking at the left or right fender mirror, mark such glances as glances towards the forward roadway.
Off the Forward Roadway	Occurs when the driver is looking anywhere that is not towards the forward roadway. This includes his/her mirrors, windows, and inside the truck cab (e.g., at the instrument panel). This also includes when the driver looks at a mobile device or passenger. His/her eyes are closed for three consecutive frames.
Unknown	Mark glance as unknown if the camera/eyes are temporarily covered by an object or other such occurrence that prevents the location of either on or off the forward roadway from being confidently reduced.
Video Frame Repeated	Mark this if the current frame is a repeat of the previous frame (due to technical bug).
No Video	Mark glance as "No Video" if video temporarily goes out.

8. After recording the driver's eye-glance location for the first frame, advance to the next frame and repeat step 6. Continue in this fashion until the last frame of the 6-second interval has been recorded.
    - Make sure the time of the trigger lines up with the "5 second" frame in the "Frame" column of the Excel log.

9. An eye glance begins with a fixation on one of the eye-glance locations defined in the table above and ends when the next eye glance starts (with the next fixation). Any transition time from one fixation to another is kept with the first glance. For example, if the driver is looking forward and shifts his/her gaze to the instrument panel, you would mark **Toward the Forward Roadway** until his/her eyes are fixated on the instrument panel (at which point you would start marking **Off the Forward Roadway**).

10. Blinking is not recorded (record the glance location of the prior frame during a blink).

11. An example of the video reduction is presented in Figure 9.

Mobile PhoneHF3	Yes		0	42:06.0	1 - Toward the Forward Roadway	
			0.25	42:06.2	1 - Toward the Forward Roadway	
			0.5	42:06.5	1 - Toward the Forward Roadway	
			0.75	42:06.7	1 - Toward the Forward Roadway	
			1	42:07.0	1 - Toward the Forward Roadway	
			1.25	42:07.2	2 - Off the Forward Roadway	Driver checking blind spot prior to making a left hand turn at an intersection. Vehicle stopped
			1.5	42:07.5	2 - Off the Forward Roadway	
			1.75	42:07.7	2 - Off the Forward Roadway	
			2	42:08.0	2 - Off the Forward Roadway	
			2.25	42:08.3	2 - Off the Forward Roadway	
			2.5	42:08.5	2 - Off the Forward Roadway	
			2.75	42:08.8	2 - Off the Forward Roadway	
			3	42:09.0	2 - Off the Forward Roadway	
			3.25	42:09.3	2 - Off the Forward Roadway	
			3.5	42:09.5	2 - Off the Forward Roadway	
			3.75	42:09.8	2 - Off the Forward Roadway	
			4	42:10.0	2 - Off the Forward Roadway	
			4.25	42:10.3	1 - Toward the Forward Roadway	
			4.5	42:10.5	1 - Toward the Forward Roadway	
			4.75	42:10.7	1 - Toward the Forward Roadway	
			5	42:11.0	1 - Toward the Forward Roadway	
			5.25	42:11.3	1 - Toward the Forward Roadway	
			5.5	42:11.5	1 - Toward the Forward Roadway	
			5.75	42:11.8	1 - Toward the Forward Roadway	
			6	42:12.0	1 - Toward the Forward Roadway	

Figure 9. Chart. Screenshot of an example visual data reduction in Excel.

12. In the Excel log, describe any special conditions that characterized the event (e.g., eyes obstructed by visor or glare for part of event).

13. Document in the comment sections of the log any situations that are unique and might affect interpretation of the glances. For example, note anything unusual in any camera view or reasons for any unusually long glances to locations off of the roadway (e.g., the participant looks at the radio continuously for 5 seconds because he/she is stopped at a red light).

14. Move on to the next event indicated in the Excel log.

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APPENDIX C: TALKING TIME AND CONVERSATION WORKLOAD PROTOCOL FOR VOICE-RELATED ACTIVITIES

1. Watch and listen to the entire 30 seconds of the event file in the system viewer.
   - Develop an understanding of when the driver talks and what his/her voice sounds like.
   - Take note of whether the driver verbally reacts to the conflict that triggered the event. There will be a question related to this driver response that you will be required to answer.

2. Create Wav File.
   - Export the audio (as a .wav file) from the videos using “Any audio converter” software: any-audio-converter.exe
     - Open “Any Audio Converter” and add the .wav files to the workspace by pressing the “Add Media Files” button (see Figure 10).

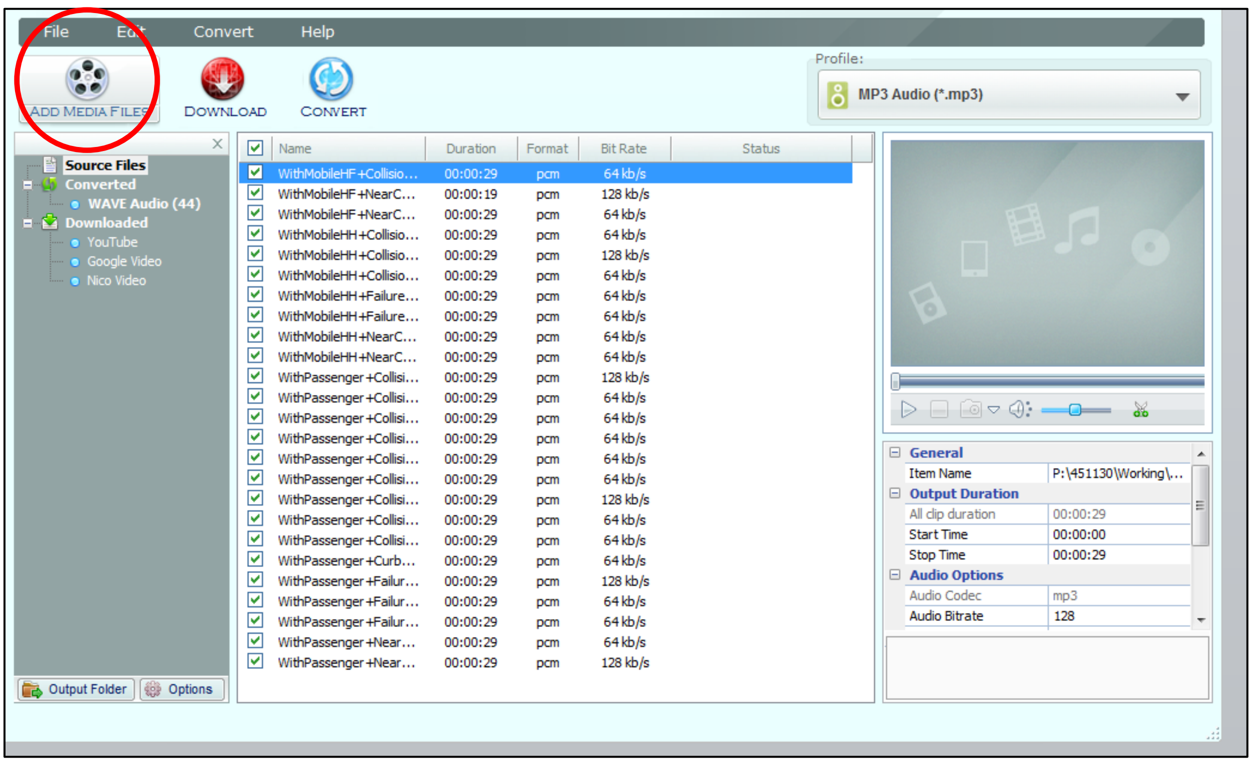

Figure 10. Screenshot. Screenshot of the audio converter.

- Please remember to select the .wav form profile in the top right corner (see Figure 11).

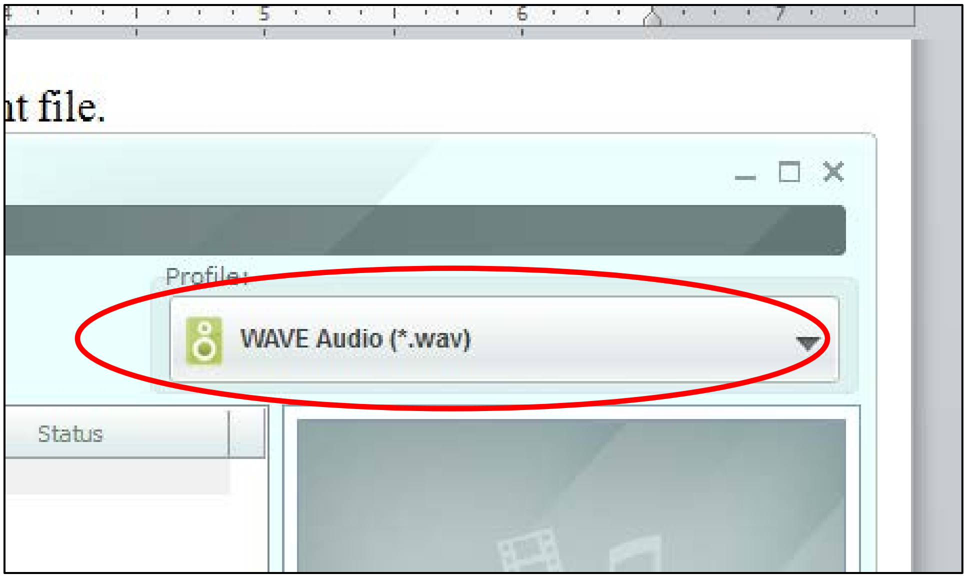

Figure 11. Screenshot. Screenshot of the .wav button.

- Specify the output folder in the options window (see Figure 12).

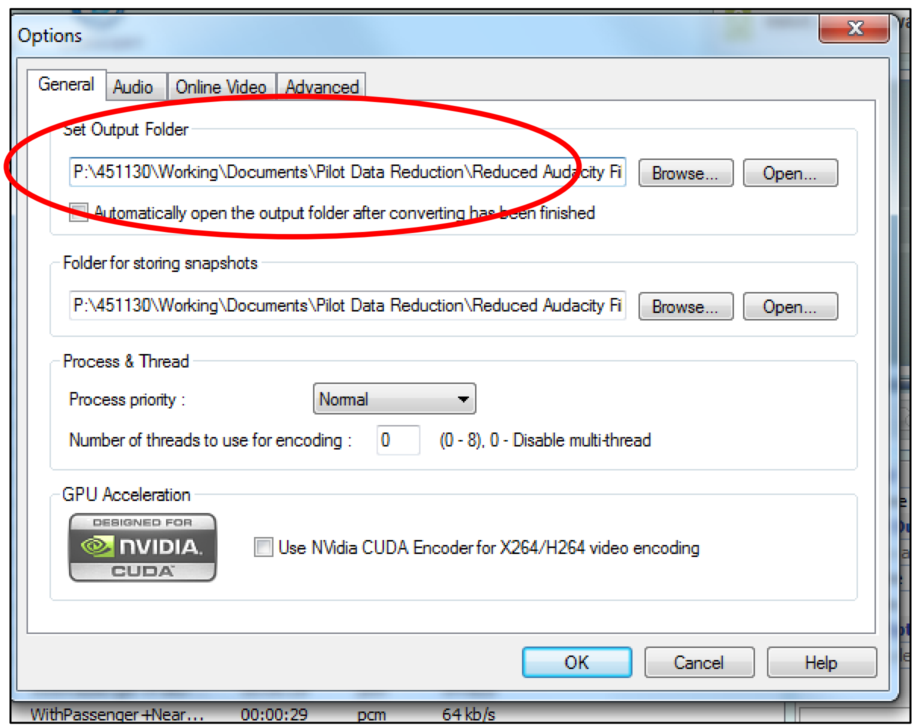

Figure 12. Screenshot. Screenshot of the output folder.

- Press Convert.

3. Open the .wav file in Audacity (note the technology vendor used a proprietary audio tool that was similar to Audacity. The freeware program, Audacity

[http://audacity.sourceforge.net/], is shown here to illustrate the steps used by the technology vendor).

- Download and install Audacity, an audio editing software: audacity-win-unicode-1.3.14.exe
- Open the .wav file in Audacity

4. You will only analyze 6 seconds of data (5 seconds before the trigger → 1 second after the trigger).
    - Step 1: Select the 6-second region in the file (i.e., the part of the file that spans the 10-second frame through to the 16-second frame; see Figure 13).
        - Use the mouse to click on the .wav file somewhere close to the 10-second mark.
        - Use the arrow keys to move the cursor to the exact 10-second mark.
            - Use the "Selection Start" field in the bottom left to make sure you're exactly at the 10-second frame.
            - If you can't get it exactly on 10 seconds, use the first frame after the 10-second mark.
    - Step 2: Press the "Shift" key then click somewhere near the 16-second mark. While holding shift, use the arrow keys to extend the selection exactly to the 16-second mark. (Alt+Shift is another way to move the cursor.) Use the "End" field to guide the selection.

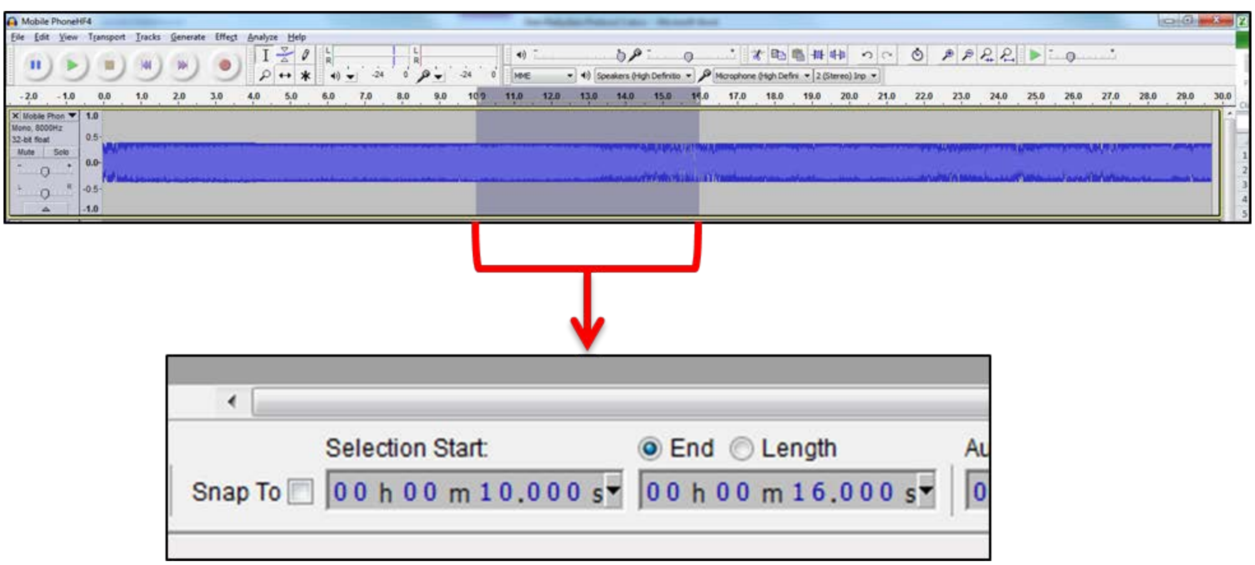

Figure 13. Screenshot. Screenshot of the editing software.

- Press CTRL + B to insert a label. Edit the label to say "6 seconds" (see Figure 14).

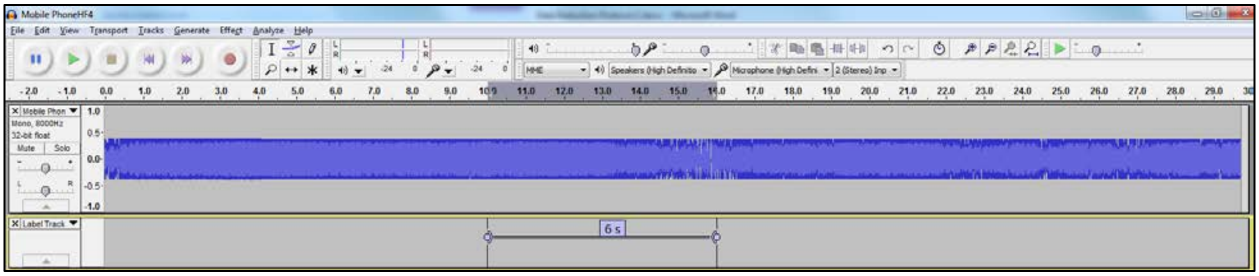

Figure 14. Screenshot. Screenshot of the edit label function in the editing software.

5. Clean up file using “Noise Removal” tool.
   - This step removes all the background noise from the file.
   - Listen to the 30 seconds of the .wav file.
   - Select a region that has no talking, just background noise. This includes a part of the file where the radio is playing. One second of background noise is sufficient, but the longer the better. The idea is to capture every noise inside the vehicle besides the conversation (see Figure 15).

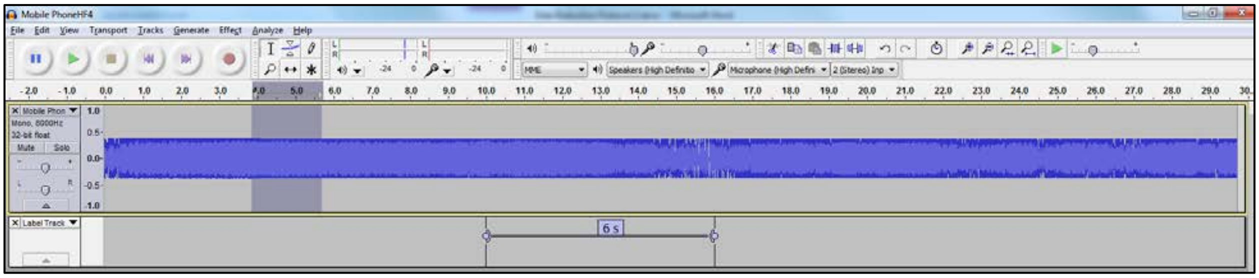

Figure 15. Screenshot. Screenshot of the noise removal tool in the editing software.

   - Select Effect→Noise Removal (see Figure 16).

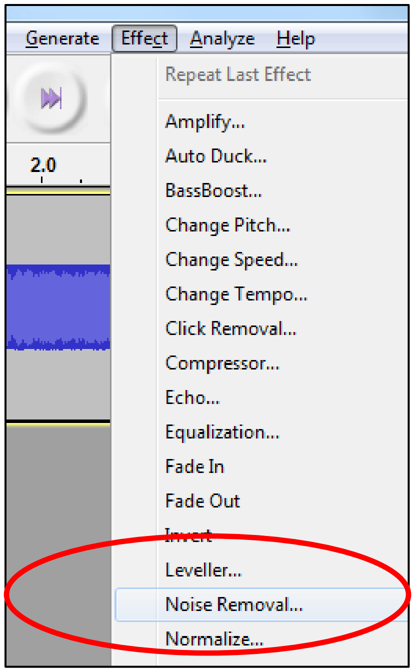

Figure 16. Screenshot. Screenshot of the "Effect" dropdown menu in the editing software.

- Click on "Get Noise Profile" (see Figure 17).
    - This identifies what sound needs to be removed from the file.

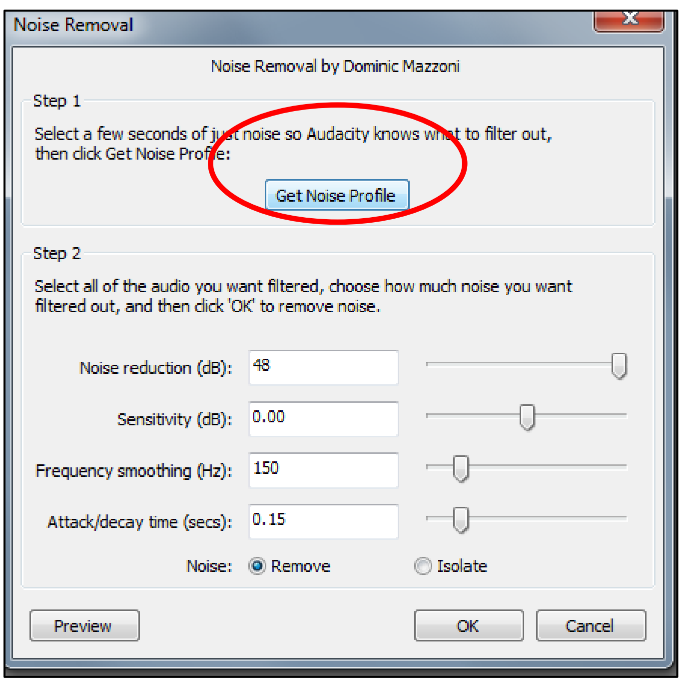

Figure 17. Screenshot. Screenshot of the "Get Noise Profile" button in the editing software.

- Select the entire clip by pressing CTRL + A.

- Select Effect→Noise Removal (or press CTRL + R) to open the noise removal dialogue box again.
    - Press “OK” to remove the noise using the noise profile you just selected.
    - Amplitude spikes now appear where talking takes place (see Figure 18).
- Repeat to further isolate the driver’s voice.

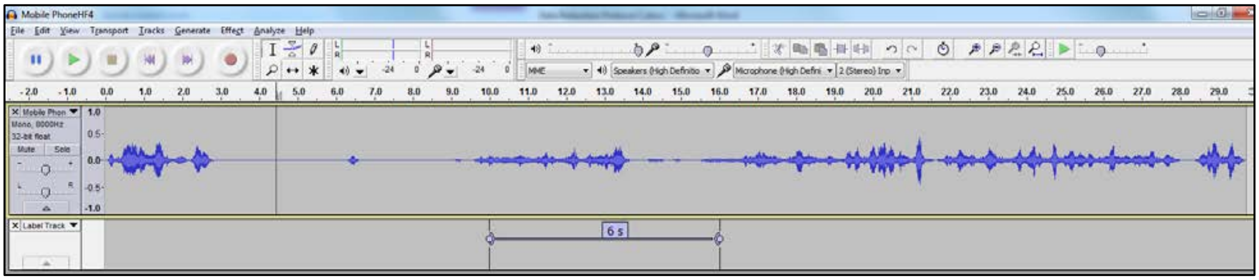

Figure 18. Screenshot. Screenshot of the audio clip with the noise filter.

6. Listen to audio file.
    - Play the 6-second interval of the audio file and listen for the driver’s voice.

7. Identify segments where driver is talking.
    - Select segments where driver is talking.
        - Press CTRL + B to insert label.
        - Mark down “Driver” if driver is talking.
        - If another person in the vehicle is talking (and can be heard), mark down “Other.”
        - Do this for all segments of conversation **<u>in</u>** the 6-second window (see Figure 19).

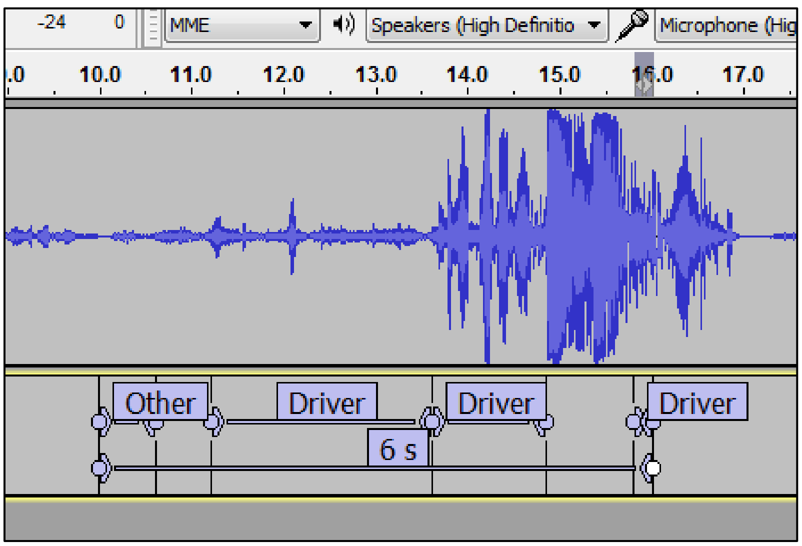

Figure 19. Screenshot. Screenshot showing talking segments in the .wav file.

- Note: If a segment in the 6-second window starts before the 6-second window or ends after the 6-second window, the label for that segment should only start at the 10-second mark or end at the 16-second mark.
- In the example above, even though the driver starts talking before the 10-s mark, the "Driver" segment starts at the 10-second mark.

8. Export Data to Excel.
   - Save your project as the name of the file. Before clicking "Save," copy the name of the file by pressing CTRL + C.
   - Click on File→Export Labels (see Figure 20).

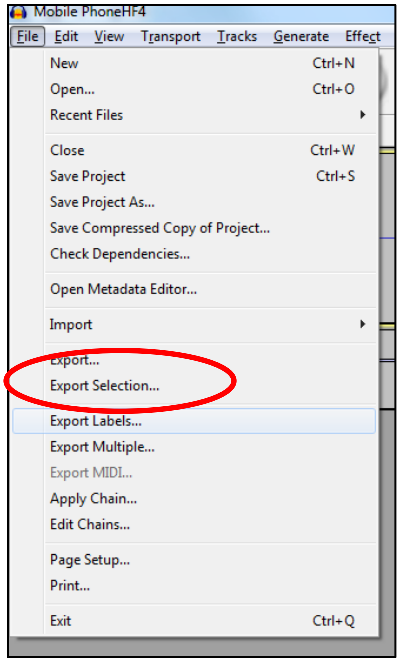

Figure 20. Screenshot. Screenshot of the "File" dropdown menu in the editing software.

- Save the Txt file by pasting the name of the file and inserting ".txt" afterwards.
- Open the .txt file.
  - If the "6 second" segment is not listed first in the list, copy and paste it to the top of the file (see Figure 21).

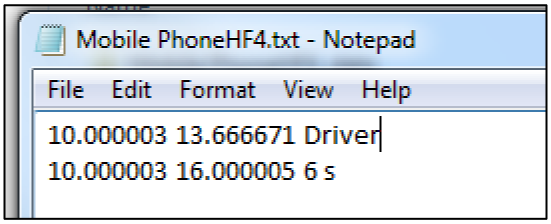

Figure 21. Screenshot. Screenshot of the .txt file in Notepad.

- Copy the contents into the Excel reduction file (columns D – F; see Figure 22).
    - Index the file with a number ("1" is used below in column A).
    - Write down the name of the file in column B.
    - Specify the device that was used in column C using the dropdown list.

	A	B	C	D	E	F
1	Number	File	Device	Begin	End	Label ID
2	1	MobileHF4	HF Cell	10	16.00001	6 s
3				10	13.66667	Driver

Figure 22. Screenshot. Screenshot of the Excel reduction file.

- If the event is an SCE, use the "reaction" column (column G) to indicate whether each talking segment is the driver reacting to the conflict (see Figure 23).
    - This is important as it will allow us to remove any talking done in response to the conflict.
    - If the driver says something like, "Whoa," "Oh, God," or screams as the conflict unfolds, mark a "1" in the "reaction" column for the segments that span these reactions. Do the same if the driver uses profanity in response to the conflict or after it occurs.
    - Since all baselines have no SCEs, mark "0" for each segment in the reaction column (as shown below).

	A	B	C	D	E	F	G
1	Number	File	Device	Begin	End	Label ID	Reaction t
2	1	MobileHF4	HF Cell	10	16.00001	6 s	
3				10	13.66667	Driver	0
4	2	WithMobileHI	HF Cell	10.00119	16.01738	6 s	
5				10.00119	13.05764	Driver	0
6				15.61114	16.01738	Driver	1
7	3	WithPassenge	Passenger	10.00119	16.01738	6 s	
8				10.00119	10.62022	Other	0
9				11.2199	13.61864	Driver	0
10				13.61864	14.8567	Driver	1
11				15.80459	16.01738	Driver	1

Figure 23. Screenshot. Screenshot of the "Reaction" column in the Excel file.

9. Return to Audacity to Reduce the Type of Conversation.
    - Listen to the conversation during just the 6-second window to become familiar with the conversation during this interval of time.
        - You can listen to the conversation during the first <u>16 seconds</u> to help you develop an understanding of the conversation.

- For the conversation heard in the 6-second window, answer the following questions with the rating scales provided.

  A. Can the driver's voice be understood?
     - Yes.
     - No (skip steps 9B and 9C).
     - Not Speaking English (skip steps 9B and 9C).

  B. What emotion does the driver show (see Table 41)?
     - Use the video file to help you judge the emotion the driver shows in the conversation taking place in the 6-second window.
       - Please note, if the event is an SCE, your judgment should not be influenced by any reaction the driver may make in response to the SCE (i.e., conflict on the road that triggered the event).
     - If the driver is neutral during the first 5 seconds of the window then yells at a car cutting in front at the 5-second mark, do not rate the driver to be angry since the yelling took place in response to the event.
     - Because the driver was not angry before the event unfolded, rate the driver's emotion as neutral.
     - It is useful to use the "reaction" column in the Excel file to help you reduce segments that are not reactions to the conflict.

Table 41. Emotions exhibited by drivers and their operational definitions.

Emotion	Operational Definition
0—Conversation takes place after trigger	• Both talking and listening take place after the trigger time point (15 seconds into the file).
1—Unsure	• Cannot tell what emotion the driver is showing.
2—Neutral/No Emotion Shown	• The driver has a straight face, does not smile or laugh, does not gesture. • The driver talks in a monotone voice.
3—Happy	• The driver smiles or laughs. • The driver gestures in excitement. • The driver raises his/her voice. • The driver intonates his/her voice.
4—Angry/Frustrated	• The driver lowers/squeezes eyebrows, wrinkling forehead. • The driver clenches his/her teeth. • The driver raises his/her voice. • The driver gestures in anger/frustration. • The driver raises his/her upper lip or tightens lips.
5—Sad	• The driver has droopy eyebrows (raises inner eyebrows, lowers outer eyebrows). • The driver frowns by lowering the outer corners of his/her lips. • The driver sighs. • The driver talks slowly by drawing out his/her words. • The driver talks quietly under his/her breath.
6—Opinionated	• The driver raises his/her voice. • The driver expresses disagreement but is not angry/frustrated. • The driver gestures.
7—Surprise	• The driver's eyebrows raise. • The driver's mouth opens. • The driver expresses shock by saying in a raised voice: "What!," "Really!," "My God!," "No Way!," "I Can't Believe It!"
8—Concerned	• The driver's eyebrows raise. • The driver's mouth opens. • The driver expresses concern by saying in a raised voice: "Are you OK?"
9—Apologetic/Guilt	• The driver's eyebrows slant (raises inner eyebrows, lowers outer eyebrows). • The driver's mouth opens. • The driver expresses an apology by saying: "I'm sorry."

C. What is the intensity of the emotion (see Table 42)?
- Rate the intensity of the emotion using the ratings listed below.
- Rate the highest emotional level observed in the 6 seconds of the file.

- Do not use any talking that is a reaction to the SCE to judge emotional intensity.

Table 42. Intensity of emotion exhibited by drivers and their operational definitions.

Intensity of Emotion	Operational Definition
0—Conversation takes place after trigger	• Both talking and listening take place after the trigger time point (15 seconds into the file).
1—Unsure	• Cannot tell the intensity of the emotion.
2—Neutral/No Emotion Shown	• The driver has a straight face, does not smile or laugh, does not gesture. • The driver talks in a monotone voice.
3—Slight (Emotion Somewhat Shown)	• The driver no longer has a straight face. • The driver intonates his/her voice. • The driver somewhat raises his/her voice.
4—Marked or Pronounced (Emotion Very Much Shown)	• The driver no longer has a straight face. • The driver intonates his/her voice. • The driver raises his/her voice and/or gestures.
5—Severe (Emotion Extremely Shown)	• The driver has wide eyes and a wide open mouth. • The driver is screaming. • The driver intonates his/her voice. • The driver gestures wildly.

- Answer the "emotion" questions in the Excel log (see Figure 24).
    - Only the "Driver" segment that does not have a reaction scored as "1" is used to assess "emotion" and "intensity."
    - Example emotion and intensity reductions are shown below.

B	C	D	E	F
		Yes	0 – Conversation takes place after trigger	0 – Conversation takes place after trigger
		No	1 – Unsure	1 – Unsure
		Not Speaking English	2 - Neutral / No Emotion Shown	2 - Neutral / No Emotion Shown
			3 – Happy	3 – Somewhat Shown
			4 – Angry/Frustrated	4 – Very Much Shown
			5 – Sad	5 – Extremely Shown
			6 - Opinionated	
			7 – Shock	
			8 – Concerned	
			9 – Apologetic/Guilt	

Number	File	Voice Comprehensible	Emotion	Intensity
1	CBradio1	Yes	1 - Neutral / No Emotion Shown	1 - Neutral / No Emotion Shown
2	Mobile PhoneHF1	Yes	2 – Happy	2 – Somewhat Shown
3	Mobile PhoneHF2	Yes	2 – Happy	3 – Very Much Shown
4	Mobile PhoneHF3	Yes	2 – Happy	2 – Somewhat Shown
5	Mobile PhoneHF4	Yes	1 - Neutral / No Emotion Shown	1 - Neutral / No Emotion Shown
6	Mobile PhoneHH1	Yes	5 - Opinionated	3 – Very Much Shown
7	Mobile PhoneHH2	Yes	7 – Concerned	3 – Very Much Shown
8	Mobile PhoneHH3	Yes	3 – Angry/Frustrated	3 – Very Much Shown
9	Mobile PhoneHH4	Yes	1 - Neutral / No Emotion Shown	1 - Neutral / No Emotion Shown
10	passenger conversation1	Yes	1 - Neutral / No Emotion Shown	1 - Neutral / No Emotion Shown
11	passenger conversation2	Yes	1 - Neutral / No Emotion Shown	1 - Neutral / No Emotion Shown
12	passenger conversation3	Yes	2 – Happy	2 – Somewhat Shown
13	passenger conversation4	Yes	2 – Happy	2 – Somewhat Shown
14	WalkieTalkie1	Yes	0 – Conversation takes place after trigger	0 – Conversation takes place after trigger
15	WalkieTalkie2	Yes	2 - Neutral / No Emotion Shown	2 - Neutral / No Emotion Shown

Figure 24. Chart. Screenshot of the emotion and intensity Excel file.

APPENDIX D: ENVIRONMENTAL VARIABLES

Below are the outputs for the environmental variables, including light condition, weather condition, relation to junction, traffic density, and driver task workload (a combination of environmental variables meant to reflect the workload experienced by the driver). Table 43 shows the number of SCEs, random baselines, and spurious baselines by light condition.

Table 44 shows the number of SCEs, random baselines, and spurious baselines by weather condition.

Table 45 shows the number of SCEs, random baselines, and spurious baselines by relation to junction.

Table 46 shows the number of SCEs, random baselines, and spurious baselines by traffic density. The traffic density variable “traffic deadlock” is not shown in Table 46 due to low cell counts (total of five counts).

Table 47 shows the mean vehicle speed (in miles per hour) for SCEs, random baselines, and spurious baselines as a function of VR secondary categories, including visual, visual/manual, and talk/listen on an electronic device. As indicated above, vehicle speed was automatically captured at the beginning of each SCE, random baseline, and spurious baseline.

Table 48 shows the number of SCEs, random baselines, and spurious baselines by workload condition. The univariate analyses described above make it difficult to form a complete picture of how environmental variables influence risk. A more useful analysis combines the environmental variables and how these variables influence driver workload. Workload refers to the amount of perceived effort by the driver in the face of various task demands (e.g., environmental conditions, such as driving in severe weather conditions, being one aspect of perceived effort). Using naturalistic driving data, Fitch and Hanowski[123] grouped various environmental variables into low, medium, and high workload conditions. The current study used the groupings from Fitch and Hanowski [124] to define two workload conditions: high and low. High workload was defined using the following environmental variables: inclement weather; in, or close to, an intersection; on an entrance/exit ramp; traveling in stop-and-go traffic; or traveling with multiple cars ahead (in any lane). High workload could occur during the day (includes dawn and dusk) or at night (includes lighted roads at night). Low workload was defined using the following environmental variables: day (includes dawn and dusk); clear weather; traveling in a junction not related to an intersection, entrance/exit ramp, or parking lot; and no cars in view.

Table 43. Number of SCEs, random baselines, and spurious baselines by light condition.

VR Secondary Task Category	Day* SCEs	Day Spurious Baselines	Day Random Baselines	Day Total	Night† SCEs	Night Spurious Baselines	Night Random Baselines	Night Total
No Distraction Found	548	5,933	6,358	12,839	98	1,230	3,944	5,272
Visual	6	19	53	78	0	10	29	39
VM	16	42	52	110	2	16	32	50
Talk/Listen on an Electronic Device	18	153	287	458	3	33	176	212
Talk to Passengers	75	250	312	637	3	20	138	161
Total	**663**	**6,397**	**7,062**	**14,112**	**106**	**1,309**	**4,319**	**5,734**

*Day includes dawn and dusk

†Night includes lighted roads at night

Table 44. Number of SCEs, random baselines, and spurious baselines by weather condition.

Secondary Task Category	Clear SCEs	Clear Spurious Baselines	Clear Random Baselines	Clear Total	Inclement* SCEs	Inclement Spurious Baselines	Inclement Random Baselines	Inclement Total
No Distraction Found	626	6,865	9,886	17,377	9	111	245	365
Visual	5	28	80	113	1	0	2	3
VM	8	55	82	145	0	1	2	3
Talk/Listen on an Electronic Device	20	176	438	634	1	6	12	19
Talk to Passengers	76	264	437	777	2	4	11	17
Total	**735**	**7,388**	**10,923**	**19,046**	**13**	**122**	**272**	**407**

*Inclement: Rain/Snow/Sleet/Fog/Other (smog, smoke, sand, dust, crosswind, hail)

Table 45. Number of SCEs, random baselines, and spurious baselines by relation to junction.

VR Secondary Task Category	SCEs: Entrance/ Exit Ramp	Spurious Baselines: Entrance/ Exit Ramp	Random Baselines: Entrance/ Exit Ramp	Total: Entrance/ Exit Ramp	SCEs: In, or Close to, an Intersection	Spurious Baselines: In, or Close to, an Intersection	Random Baselines: In, or Close to, an Intersection	Total: In, or Close to, an Intersection	SCEs: Not Intersection-, Entrance/Exit Ramp-, or Parking Lot-Related	Spurious Baselines: Not Intersection-, Entrance/Exit Ramp-, or Parking Lot-Related	Random Baselines: Not Intersection-, Entrance/Exit Ramp-, or Parking Lot-Related	Total: Not Intersection-, Entrance/Exit Ramp-, or Parking Lot-Related	SCEs: Parking Lot	Spurious Baselines: Parking Lot	Random Baselines: Parking Lot	Total: Parking Lot
No Distraction Found	7	119	16	142	236	1,537	1,885	3,658	309	4,211	7,621	12,141	60	783	543	1,386
Visual	1	0	0	1	1	5	21	27	3	20	53	76	1	1	7	9
VM	0	0	1	1	4	12	7	23	4	36	68	108	0	4	6	10
Talk/Listen on an Electronic Device	0	5	3	8	6	37	36	79	13	108	390	511	0	21	20	41
Talk to Passengers	2	4	1	7	29	55	139	223	42	162	273	477	3	35	29	67
Total	**10**	**128**	**21**	**159**	**276**	**1,646**	**2,088**	**4,010**	**371**	**4,537**	**8,405**	**13,313**	**64**	**844**	**605**	**1,513**

Table 46. Number of SCEs, random baselines, and spurious baselines by traffic density.

Secondary Task Category	SCEs: Multiple Cars Ahead (in any lane)	Spurious Baselines: Multiple Cars Ahead (in any lane)	Random Baselines: Multiple Cars Ahead (in any lane)	Total: Multiple Cars Ahead (in any lane)	SCEs: No Cars in View	Spurious Baselines: No Cars in View	Random Baselines: No Cars in View	Total: No Cars in View	SCEs: One Car Ahead (in any lane)	Spurious Baselines: One Car Ahead (in any lane)	Random Baselines: One Car Ahead (in any lane)	Total: One Car Ahead (in any lane)	SCEs: Stop-and-go Traffic	Spurious Baselines: Stop-and-go Traffic	Random Baselines: Stop-and-go Traffic	Total: Stop-and-go Traffic
No Distraction Found	416	3,370	6,057	9,843	76	1,880	2,634	4,590	78	888	1,182	2,148	23	15	98	136
Visual	0	13	48	61	1	7	19	27	1	6	11	18	3	0	0	3
VM	6	19	42	67	1	21	28	50	0	8	13	21	1	0	0	1
Talk/Listen on an Electronic Device	14	199	281	494	3	37	109	149	0	23	54	77	1	0	1	2
Talk to Passengers	56	130	286	472	6	76	83	165	6	30	62	98	5	1	4	10
Total	**492**	**3,731**	**6,714**	**10,937**	**87**	**2,021**	**2,873**	**4,981**	**85**	**955**	**1,322**	**2,362**	**33**	**16**	**103**	**152**

Table 47. Mean vehicle speed (miles per hour [mi/h]) for secondary task categories across SCEs, random baselines, and spurious baselines.

Secondary Task Category	*Count	*Average Speed (mi/h)	*SE Speed	†Count	†Average Speed (mi/h)	†SE Speed	‡Count	‡Average Speed (mph)	‡Standard Error Speed
No Distraction Found	555	19.33	0.74	6,403	24.37	0.24	10,398	34.99	0.18
Visual	5	17.78	10.44	21	27.00	3.88	82	21.97	2.21
VM	8	12.50	5.02	50	24.84	2.57	84	35.06	2.32
Talk/Listen on an Electronic Device	18	16.44	4.96	166	27.17	1.62	469	40.98	1.00
Talk to Passengers	70	18.23	2.10	248	22.73	1.17	452	22.55	0.69

*SCEs

†Spurious baselines

‡Random baselines

Table 48. Number of SCEs, random baselines, and spurious baselines by workload condition.

Secondary Task Category	High Workload SCEs	High Workload Spurious Baselines	High Workload Random Baselines	High Workload Total	Low Workload SCEs	Low Workload Spurious Baselines	Low Workload Random Baselines	Low Workload Total
No Distraction Found	536	4,763	8,459	13,758	24	1,041	1,019	2,084
Visual	4	19	66	89	0	3	5	8
VM	8	35	66	109	0	11	10	21
Talk/Listen on an Electronic Device	17	138	386	541	2	17	46	1
Talk to Passengers	65	161	376	602	2	46	30	78
Total	**630**	**5,116**	**9,353**	**15,099**	**28**	**1,118**	**1,110**	**2,256**

REFERENCES

[1] National Highway Traffic Safety Administration (NHTSA). (2015). Traffic Safety Facts: Research Note—Distracted Driving 2013. (Report # DOT-HS-812-132). Washington, DC: U.S. Department of Transportation. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/812132.pdf.

[2] Ranney, T. A., Mazzai, E., Garrott, R., & Goodman, M.J. (2000). NHTSA Driver distraction research: Past, Present, and Future. Washington, DC: National Highway Traffic Safety Administration, USDOT. Retrieved from http://www-nrd.nhtsa.dot.gov/departments/Human%20Factors/driver-distraction/PDF/233.PDF.

[3] Olson, R. L., Hanowski, R.J., Hickman, J.S., and Bocanegra, J. (2009). Driver Distraction in Commercial Vehicle Operations. (Report No. FMCSA-RRR-09-042). Washington, DC: Federal Motor Carrier Safety Administration, USDOT.

[4] Hickman, J. S., & Hanowski, R.J. (2011). Use of a video monitoring approach to reduce at-risk driving behaviors in commercial vehicle operations. Transportation Research Part F: Traffic Psychology and Behavior, 14, 188-198.

[5] Fitch, G. M., Soccolich, S.A., Guo. F., McClafferty, J., Fang, Y., Olson, R.L., Perez, M.A., Hanowski, R.J., Hankey, J.M., and Dingus, T.A. (2013). The Impact of Hand-Held and Hands-Free Cell Phone Use on Driving Performance and Safety-Critical Event Risk. (Report # DOT HS 811 757). Washington, DC: National Highway Traffic Safety Administration.

[6] Olson et al., 2009.

[7] Hickman et al., 2010.

[8] Olson et al., 2009.

[9] Hickman, J. S., Hanowski, R.J., & Bocanegra, J. (2010). Distraction in Commercial Trucks and Buses: Assessing Prevalence and Risk in Conjunction with Crashes and Near-Crashes. (Contract No. DTMC75-09-J-00045). Washington, DC: Federal Motor Carrier Safety Administration, USDOT.

[10] Drews, F. A., Pasupathi, M., & Strayer, D. L. (2008). Passenger and Cell Phone Conversations During Simulated Driving. Journal of Experimental Psychology: Applied, 14, 392-400.

[11] Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J.D., & Ramsey, D.J.(2006). Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data. (Report No. DOT-HS-810-594). Washington, DC: National Highway Traffic Safety Administration.

[12] McEvoy, S. P., Stevenson, M.R., & Woodward, M. (2007). The contribution of passengers versus mobile phone use to motor vehicle crashes resulting in hospital attendance by the driver. Accident Analysis and Prevention, 39, 1170-1176.

[13] Sayer, J., Devonshaire, J., Flannagan, C. (2007). Naturalistic driving performance during secondary tasks. Paper presented at the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design.

[14] Fitch et al., 2013.

[15] Fitch et al., 2013.

[16] NHTSA, 2010.

[17] Olson et al., 2009.

[18] Olson et al., 2009.

[19] Beede, I.E., & Kass, S.J. (2006). Engrossed in conversation: The impact of cell phones on simulated driving performance. Accident Analysis and Prevention, 38, 415-421.

[20] McEvoy, S. P., Stevenson, M.R., McCartt, A.T., Woodward, M., Haworth, C., Palamara, P., & Cercarelli, R. (2005). Role of mobile phones in motor vehicle crashes resulting in hospital attendance: A case-crossover study. British Medical Journal, 331, 428-430.

[21] Patten, C. J. D., Kircher, A., Östlund, J., & Nilsson, L. (2004). Using mobile telephones: Cognitive workload and attention resource allocation. Accident Analysis and Prevention, 36, 341-250.

[22] Redelmeier, D.A., & Tibshirani, R.J. (1997). Association between cellular-telephone calls and motor vehicle collisions. New England Journal of Medicine, 336(453-458).

[23] Strayer, D. L., & Johnston, W.A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular phone. Psychological Science, 12, 462-466.

[24] Strayer, D. L., Drews, F.A., & Johnston, W.A. (2003). Cell phone-induced failures of visual attention during simulated driving. Journal of Experimental Psychology, 9, 23-32.

[25] Olson et al., 2009.

[26] Hickman et al., 2010.

[27] Hickman et al., 2010.

[28] Hickman et al., 2010.

[29] National Highway Traffic Safety Administration. (2008). Driver Distraction: A Review of the Current State-of-Knowledge. (Report# DOT-HS-810-787). Washington, DC: U.S. Department of Transportation. Retrieved from http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2008/810787.pdf.

[30] National Safety Council. (2010). Understanding the Distracted Brain: Why Driving while using Hands-Free Cell Phones is Risky Behavior. Washington, DC: National Safety Council Retrieved from http://www.nsc.org/safety_road/Distracted_Driving/Documents/Dstrct_Drvng_White_Paper_1_2011.pdf.

[31] Beede & Kass, 2006.

[32] Patten et al., 2004.

[33] Strayer & Johnston, 2001.

[34] Strayer et al., 2003.

[35] National Safety Council, 2010.

[36] McCartt, A. T., Hellinga, L.A., & Braitman, K.A. (2006). Cellphones and driving: Review of research. Traffic Injury Prevention, 7, 89-106.

[37] McCartt et al., 2006.

[38] NHTSA, 2008.

[39] Fitch, G. M., & Hanowski, R.J. (2011). The risk of a safety-critical event associated with mobile device use as a function of driving task demands. Paper presented at the 2nd International conference on Driver Distraction and Inattention, Gothenburg, Sweden.

[40] Funkhouser & Sayer, 2012.

[41] Ranney et al., 2000.

[42] Briggs, G. F., Hole, G.J., & Land, M.F. (2011). Emotionally involving telephone conversations lead to driver error and visual tunneling. Transportation Research Part F: Traffic Psychology and Behaviour, 14, 313-323.

[43] Dula, C. S., Martin, B.A., Fox, R.T., & Leonard, R.L. (2011). Differing types of cellular phone conversations and dangerous driving. Accident Analysis and Prevention, 43, 187-193.

[44] Patten et al., 2004.

[45] Strayer & Johnston, 2001.

[46] Al-Tarawneh, B. S., Cohen, W.J., Trachtman, D., Krauss, D.A., & Bishu, R.R. (2004). The effect of hands-free cellular telephone conversation complexity on choice response time in a detection task. Paper presented at the Human Factors and Ergonomics Society, New Orleans, LA.

[47] NHTSA, 2008.

[48] Olson et al., 2009.

[49] Olson et al., 2009.

[50] Olson et al., 2009.

[51] Olson, P. L., & Farber, G. (2003). Forensic Aspects of Driver Perception and Response (2nd ed.). Tucson, AZ: Lawyers and Judges Publishing Company, Inc.

[52] Olson et al., 2009.

[53] Reimer, B., Mehler, B., Wang, Y., & Coughlin, J.F. (2010). The impact of systematic variation of cognitive demand on drivers' visual attention across multiple age groups. Paper presented at the Human Factors Ergonomics Society Annual Meeting.

[54] Victor, T. W., Harbluk, J.L., & Engstrom, J.A. (2005). Sensitivity of eye-movement measures to in-vehicle task difficulty. Transportation Research Part F: Traffic Psychology and Behaviour, 8, 167-190.

[55] Olson et al., 2009.

[56] Hickman et al., 2010.

[57] Olson et al., 2009.

[58] Dingus, T. A., Klauer, S.G., Neale, V.L., Petersen, A., Lee, S.E., Sudweeks, J., et al. (2006). The 100-Car Naturalistic Driving Study, Phase II – Results of the 100-Car Field Experiment. (Report # DOT HS 810 593). Washington, DC: National Highway Traffic Safety Administration, USDOT. Retrieved from www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/Driver%20Distraction/100CarMain.pdf.

[59] Hickman et al., 2010.

[60] Olson et al., 2009.

[61] Olson et al., 2009.

[62] Dingus et al., 2006.

[63] Schiffman, H. R. (2011). Sensation and Perception. An Integrated Approach. New York: John Wiley and Sons, Inc.

[64] Fischer, B., & Ramsperger, E. (1984). Human express saccades: Extremely short reaction times of goal directed eye movements. Experimental Brain Research, 57, 191-195.

[65] Olson et al., 2009.

[66] Klauer et al., 2006.

[67] Hsieh, L. (January 27, 2012). Personal communication: References relating to speech, intonation, emotion, and driving.

[68] Blanco, M., Hickman, J. S., Olson, R. L., Bocanegra, J., Hanowski, R. J., Nakata, A., Greening, M., Madison, P., Holbrook, G. T., and Bowman, D. (In press). Investigating critical incidents, driver restart period, sleep quantity, and crash countermeasures in commercial vehicle operations using naturalistic data collection. Washington, DC: Federal Motor Carrier Safety Administration, USDOT.

[69] Hickman, J. S., Knipling, R. R., Olson, R. L., Fumero, M. C., Blanco, M., & Hanowski, R. J. (In press). Heavy vehicle-light vehicle interaction data collection and countermeasure research project: Phase I: Preliminary analysis of data collected in the drowsy driver warning system field operational test. (Contract No. DTNH22-00-C-07007 [Task Order No. 21]). Washington, DC: Federal Motor Carrier Safety Administration, USDOT.

[70] Maclure, M., & Mittleman, M. A. (2000). Should we use a case-crossover design? Annual Review of Public Health, 21, 193-221.

[71] Maclure & Mittleman, 2000.

[72] Fitch et al., 2013.

[73] Olson et al., 2009.

[74] Klauer et al., 2006.

[75] Mosteller, F. (1968). Association and estimation in contingency tables. Journal of the American Statistical Association, 63, 1-28.

[76] Woolf, B. (1955). On estimating the relationship between blood group and disease. Annals of Human Genetics, 19, 251-253.

[77] Olson et al., 2009.

[78] Hickman et al., 2010.

[79] Fitch & Hanowski, 2011.

[80] Fitch & Hanowski, 2011.

[81] Olson et al., 2009.

[82] Hickman et al., 2010.

[83] Olson et al., 2009.

[84] Fitch et al., 2013.

[85] Hickman et al., 2010.

[86] Klauer et al., 2006.

[87] Olson et al., 2009.

[88] Hickman et al., 2010.

[89] Fitch et al., 2013.

[90] Olson et al., 2009.

[91] Hickman et al., 2010.

[92] Hickman et al., 2010.

[93] Drews et al., 2008.

[94] Klauer et al., 2006.

[95] McEvoy et al., 2007.

[96] Sayer et al., 2007.

[97] Meskan, J., Hagenzieker, M.P., Rothengatter, T., & de Waard, D. (2007). Frequency, duration, and consequences of different drivers' emotions: An on-the-road study using self-reports, (observed) behavior, and physiology. Transportation Research Part F: Traffic Psychology and Behaviour, 10, 458-467.

[98] Hu, T.-Y., Xie, X., Li, J. (2013). Negative or positive? The effect of emotion and mood on risky driving. Transportation Research Part F: Traffic Psychology and Behaviour, 16, 29-40.

[99] Dula et al., 2011.

[100] Shinar, D., Tractinsky, N., Compton, R. (2005). Effects of practice, age, and task demands, on interference from a cell phone task while driving. Accident Analysis and Prevention, 37, 315-326.

[101] Rakauskas, M. E., Gugerty, L.J., & Ward, N.J. (2004). Effects of naturalistic cell phone conversations on driving performance. Journal of Safety Research, 25, 453-463.

[102] Fitch et al., 2013.

[103] Fitch et al., 2013.

[104] Olson et al., 2009.

[105] Hickman et al., 2010.

[106] Fitch et al., 2013.

[107] Funkhouser & Sayer, 2012.

[108] Olson et al., 2009.

[109] Klauer et al., 2006.

[110] Drews et al., 2008.

[111] Horrey, W., & Wickens, C. (2006). Examining the impact of cell phone conversations on driving using meta-analytic techniques. Human Factors, 38, 196-205.

[112] Laberge, J., Sciafla, C., White, C., & Caird, J. (2004). Effect of passenger and cellular phone conversations on driver distraction. Transportation Research Record: Journal of the Transportation Research Board, 1899, 109-116.

[113] Victor et al., 2005.

[114] Nunes, L., & Recarte, M. A. (2002). Cognitive demands of hands-free-phone conversation while driving. Transportation Research Part F: Traffic Psychology and Behaviour, 5, 133-144.

[115] Recarte, M. A., & Nunes, L. M. (2003). Mental workload while driving: Effects on visual search, discrimination and decision making. Journal of Experimental Psychology: Applied, 9, 119-137.

[116] Olson et al., 2009.

[117] Hickman et al., 2010.

[118] Klauer et al., 2006.

[119] Hickman et al., 2010.

[120] Hickman et al., 2010.

[121] Hickman & Hanowski, 2011.

[122] McGehee, D. V., Raby, M., Carney, C., Lee, J.D., & Reyes, M.L. (2007). Extending parental mentoring using an event-triggered video intervention in rural teen drivers. Journal of Safety Research, 38, 215-227.

[123] Fitch & Hanowski, 2011.

[124] Reimer et al., 2010.