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An Analysis of Driver Inattention Using a Case-Crossover Approach On 100-Car Data: Final Report

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13. ABSTRACT (Maximum 200 words)
Using the 100-Car Study database, two analyses were conducted: re-calculation of odds ratios (ORs) using a case-crossover baseline, and characterization of secondary task engagement in real-world environments. First, ORs were recalculated for drowsiness, secondary task engagement, and total time eyes-off-road (TEOR) using conditional logistic regression. The results suggested that drowsiness (OR 38.7; CI 26.4 – 56.8), tasks with >2 eyeglances away from the forward roadway or >2 button presses (OR 2.3; CI 1.3 – 3.1), and tasks with 1-2 eyeglances and/or 1-2 button presses (OR 1.4; CI 1.1-1.7) significantly increased crash/near-crash risk. The results also indicated that total TEOR of 2 s or greater during a 6-second task period increased crash/near-crash risk (OR 1.6; CI 1.3 – 2.0) and a 3 s or greater total TEOR over a 15-second task period significantly increased crash/near-crash risk (OR 1.3; CI 1.1 - 1.6). These OR point estimates are lower than the results obtained using a case-control; however, they are still statistically significant in both analyses indicating that these behaviors increase risk.

The second analysis assessed secondary task duration, frequency, and the relationship of task duration to total TEOR. Results indicated that drivers in the 100-Car Study engaged in secondary tasks 23.5 percent of the time that they were driving, approximately 40 percent higher than indicated in previous research. Secondary tasks that were found to be both of long duration and with a high percent of total TEOR (such as applying makeup) had crash/near-crash risk ratios that were not significantly greater than 1.0. In contrast, analysis of all secondary tasks of long duration, including those with lower total TEOR (such as talking with passengers), had OR values significantly less than 1.0.

The results from both of these analyses suggest that in-vehicle display designers need to assess and be cognizant of the total TEOR for in-vehicle displays for two reasons: 1) a brief total TEOR will increase risk for drivers, and 2) total TEOR is associated with involvement in crashes/near-crashes. Assessment tools like the “15-second rule” developed by the Society of Automotive Engineers (SAE) or the ‘2-second rule’, developed by the Alliance of Automobile Manufacturers (AAM) have not been shown to be associated with or predictive of crash/near-crash risk for any type of task. Thus, the authors argue that total TEOR should be included in the list of assessment tools for in-vehicle display designers.

14. SUBJECT TERMS
Case-control, case-crossover, driver drowsiness, driver inattention, relative risk calculations

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EXECUTIVE SUMMARY

The following analyses used the 100-Car Naturalistic Driving database which represents the largest, most comprehensive pre-crash and pre-near-crash driving behavior data collected to date. The power of these data provides a unique opportunity to calculate relative crash/near-crash risks that are associated with various types of secondary tasks. Naturalistic driving data allow a precise record of multiple driving behaviors within the seconds leading up to a crash or near-crash. Use of these new and unique data sources is a critical step to furthering our knowledge of not only the types of behaviors that actually increase drivers' crash/near-crash risk but also in directing research towards the mitigation of these behaviors to most effectively save lives. The limitations of the data include the fact that they were collected in a single geographic area of the United States, and that the participant sample was slightly weighted towards participants who were more likely to be involved in crashes (by age or gender).

The volume of 100-Car data also provides a unique opportunity to develop different types of baseline samples to determine: 1) the stability of the relative risk estimate, and 2) a sense of how large and how representative the baseline sample of driving must be to effectively calculate risk. These analyses are critical to furthering knowledge for both future naturalistic driving studies and for future analyses with existing naturalistic driving data.

The development of baseline driving samples further provides opportunities to assess driving behavior under normal, everyday driving conditions. These baseline driving databases were used to assess the percentage of time that drivers engage in secondary tasks, the frequency and types of secondary tasks that drivers engage in, and the resulting total time that eyes are off the forward roadway (TEOR) for each of these secondary tasks. This exposure-level information is critical to accomplishing the National Highway Traffic Safety Administration's (NHTSA) goal of recommending design guidelines for in-vehicle device manufacturers to reduce driver distraction.

Two primary analyses were conducted for this report: 1) a re-calculation of the relative crash risks associated with types of secondary tasks using a case-crossover baseline, and 2) a characterization of the relationship between the frequency, duration, and subsequent total TEOR for these types of secondary tasks in a real-world driving environment. The case-crossover approach was used as a comparison to the original case-control study since a case-crossover approach controls for potential confounds and interactions by selecting comparison samples of the same driver on an a priori list of matching similar conditions (e.g., day of week, time of day), whereas the case-control approach draws a random sample from the total possible drivers which may or may not be similar to the original driving events. One of the benefits for using a case-crossover approach includes the fact that confounding variables are better controlled than when using the case-control; however, the process of matching is difficult, time-consuming, and costly.

The benefits of using a case-control approach include the fact that a more generic baseline can be used to calculate a wide variety of odds ratios (ORs), which is simpler and easier to develop. The difficulties of using a case-control baseline are that any confounding variables associated with these ORs must be controlled for using complex statistical models.

METHOD

Three databases, all generated from the 100-Car Study, were used in these analyses: the 100-Car event database (crashes and near-crashes), the case-control baseline database, and the case-crossover baseline database. Similar types of reduction were completed on all three of these databases.

Specifically, the following research objectives were addressed:

- Task 1:
    - Recalculate the relative risks for crashes and near-crashes using a case-crossover baseline sample and compare these to the relative risk calculations conducted previously using a case-control approach.
    - Recalculate the relative near-crash/crash risk for total TEOR and compare this to the relative risk calculations conducted previously using a case-control approach. Assess whether total TEOR significantly impacts driving performance.
- Task 2:
    - Characterize the duration of various task types. Determine the importance of total TEOR in relation to task duration. Calculate relative risk for task duration.
    - Characterize eyeglance behavior while using wireless devices.

TASK 1 RESULTS

The primary results for Task 1 are as follows:

- Table 1 shows that the point estimates for moderate and complex tasks are lower for the case-crossover than for the case-control calculations. However, the moderate and complex secondary tasks are shown to significantly increase crash/near-crash risk in both the case-control and case-crossover calculations. Simple secondary task engagement does not increase crash/near-crash risk for either calculation.

Table 1. Odds Ratios for Secondary Task Engagement versus No Secondary Task Engagement

Distraction	Case Cross-over Odds Ratio	95% Odds Ratio Confidence Limits		Case-Control Odds Ratios	95% Odds Ratio Confidence Limits	
Simple	0.8	0.62	1.05	1.2	0.88	1.57
Moderate	**1.3**	**1.00**	**1.70**	**2.1**	**1.62**	**2.72**
Complex	**2.1**	**1.19**	**3.58**	**3.1**	**1.72**	**5.47**

*Odds ratios were calculated using only the crashes and near-crashes where the driver was deemed to be at fault or partially at fault.

- The ORs for drowsiness were also calculated for the case-crossover and compared to the results obtained using a case-control baseline. The OR using the case-crossover was 38.7 (CI 26.4-56.8), whereas the OR using the case-control was 4.24 (CI 3.3 – 5.5). This result suggested that drowsiness significantly increases crash/near-crash risk and this result is consistent across both sampling techniques.
- The results for the OR calculation for total TEOR greater than 2 s within a 6-second time period was 1.6 (CI 1.3, 2.0). This is slightly lower than the OR calculated using the case-control baseline which was 2.1 (CI: 1.7, 2.8).
- For the 15-second total TEOR analysis, the results indicated that as total TEOR increased past 3 s (or 20 percent of the total time), the ORs also showed statistically significant increased crash/near-crash risk (Figure 1). While previous results showed statistically significant results in total TEOR greater than 2 s out of 6 s (or 30 percent of the time), this comparable analysis shows that as task duration increases, lower percentages of total TEOR time increase crash/near-crash risk. This is an important finding, indicating that the Alliance of Automobile Manufacturers (AAM) rules regarding a single glance duration of 2 s is not stringent enough. Risk of crash/near-crash involvement increases far more quickly than this rule suggests.

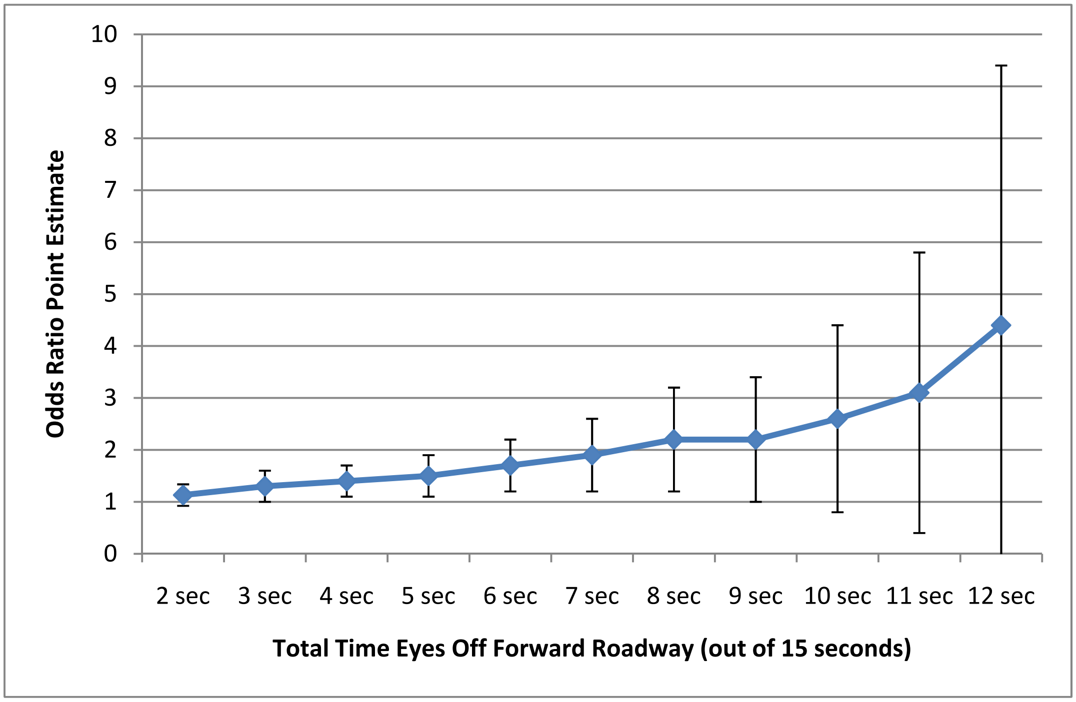

Figure 1. The Case-Crossover OR Calculations for total TEOR for Durations from 2 s to 12 s out of 15 s of Time

TASK 2 RESULTS

The case-crossover baseline was used to assess the frequency of occurrence, the task duration, and total TEOR for 56 distinct secondary tasks. To determine the visual demand for each task, the percent total TEOR was calculated for each task type. The mean percentages of total TEOR are presented in Figure 2. The order of secondary tasks (on x-axis) lists the tasks in order of low to high task duration. Note that there are six tasks that require total TEOR for greater than 50 percent of the task duration time. These are dialing a cell phone, lighting a cigarette, reading, looking at objects (either in or outside of the vehicle), and other external distractions. Note that adjusting the radio also has a high visual demand per duration but the duration of this task is quite short. Given that the order of the tasks on the x-axis is based upon task duration, the tasks on the right side of the x-axis that also have high total TEOR percentage (the longer bars) are both long in duration and also require the longest total TEOR. These tasks are pet in vehicle, applying makeup, dialing a cell phone, and reading. These tasks were also found to have a higher associated risk in Klauer et al. (2006).

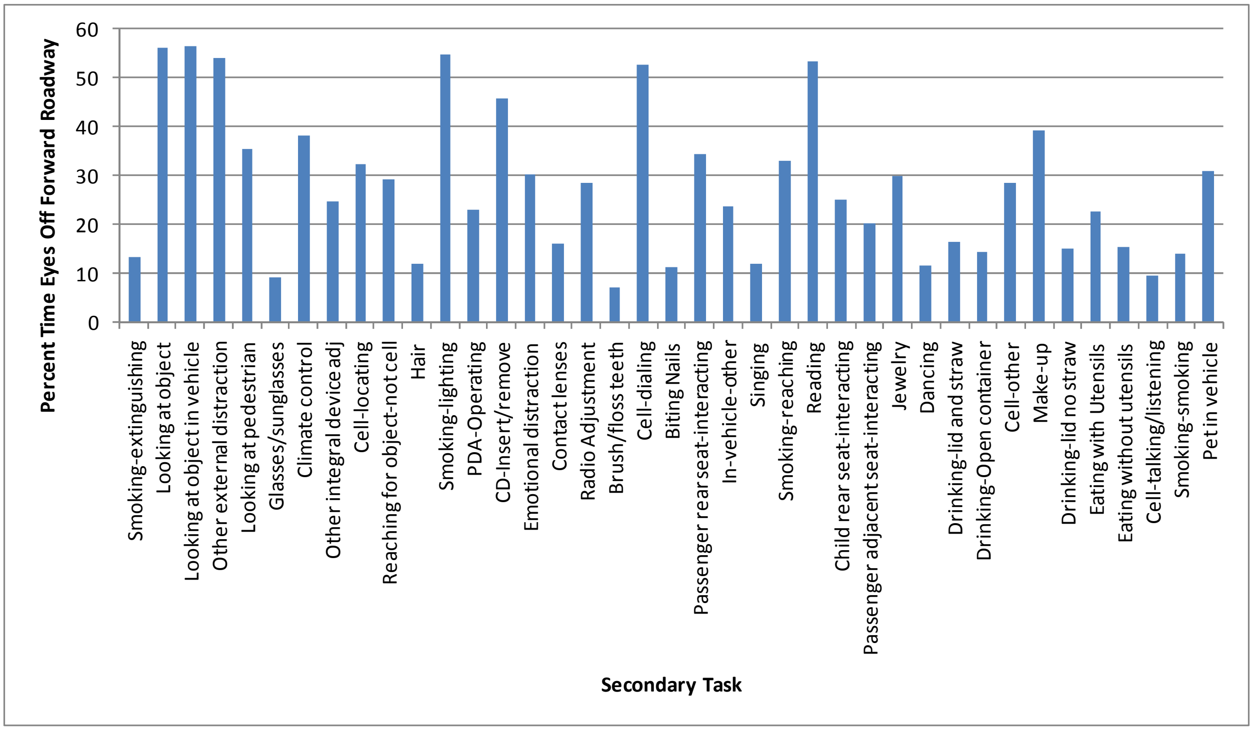

Figure 2. The Relative Visual Demand of Each Secondary Task as Calculated by the Percent Total TEOR Task Duration

This is an important finding because it indicates that assessment tools developed by the Society of Automotive Engineers (SAE) and AAM could be improved. Currently, existing guidelines look at task duration (15-second rule) or single glance duration (2-second rule), which state:

a. Any navigation function that is accessible by the driver while a vehicle is in motion shall have a static total task time of less than 15 s (SAE); and
b. Single glance durations generally should not exceed 2 s (AAM).

These rules have not been shown to be associated with crash/near-crash risk for any task type. The rule was developed and tested on tasks that were complicated, multi-step tasks. Therefore, it is important that display designers also include an evaluation of total TEOR. This research clearly shows an association to increased risk of crash/near-crash occurrence when total TEOR is 20% for a 15 second task duration or 30% total TEOR for a 6 second task duration.

Some additional key findings included:

- The total percentage of time that drivers engaged in some form of secondary task when behind the wheel was 23.5 percent. This is 40 percent higher than the percentage (16 percent) reported by Stutts et al. (2003).
- The results also support previous research that found smoking, talking to passengers, and looking at external objects were some of the longest duration tasks (Stutts et al., 2003).

CONCLUSIONS

- The OR calculations using the case-crossover approach represented lower risk levels than those calculated using the case-control approach. The relationship and statistical significance among all of the calculations remained constant.
- The slight drop in the point estimates of the case-crossover ORs was expected given that all of the baselines were matched on specific temporal, environmental, and driver factors (time of day and day of the week, relationship to junction, and the same driver). This drop could potentially be explained by the fact that driver characteristics, especially those characteristics that are known risk factors (such as age), were matched in the case-crossover study.
- The application of these results to future naturalistic driving studies, those both smaller and larger than the 100-Car Study, may suggest that using a case-crossover approach should be used when precise OR calculations are the goal. Case-control approaches may provide more generalizable data that can be used to not only accurately assess the prevalence of various driving behaviors but also to calculate a wider variety of relative risk calculations and answer a wider range of research questions. Case-control approaches may also be conducted with a more efficient use of resources, given that a naturalistic study is comprised of massive amounts of un-coded video data which require viewing and coding, typically by human researchers.
- There are a few limitations regarding the above analyses, including:
    - The ORs calculated using the case-control baseline were calculated using a 'crude odds ratio' which does not adjust for driver or other effects. Further research should be conducted to calculate these same ORs using a logistic regression model with the case-control baseline to assess whether the OR point estimates also are slightly lowered when driver age is accounted for in the model.
    - Both crashes and near-crashes were used in the calculation of relative risk to increase the statistical power of these calculations. Many of these crashes and all of the near-crashes are of less severity (i.e., no fatalities) than those crashes recorded in crash databases or used in other transportation safety studies calculating relative risk. While this may at first appear to be a severe limitation, the collection of these data provides unique opportunities given that these represent some form of vehicular loss of control and are not collected or analyzed in any other area of transportation safety.
    - The matching factors selected for the case-crossover baseline epochs may not have been comprehensive, and an important factor may have been missed or overlooked. Potential examples include traffic density or number of lanes, both of which could easily impact crash/near-crash risk when driving inattentively.
    - If the assumption that the ORs calculated with the case-crossover baseline are more precise estimates for secondary task engagement, it may make sense to

reassess the groupings or operational definitions of complex, moderate, and simple secondary task engagement.

ACRONYMS AND ABBREVIATIONS

AAM – Alliance of Automobile Manufacturers

ANOVA – Analysis of Variance

DAS – Data Acquisition System

EDR – Electronic Data Recorder

FARS – Fatality Analysis Reporting System

FOV – Field of View

FV – Following Vehicle

GES – General Estimates System

GLM – General Linear Model

GPS – Global Positioning System **–** used by data reductionists to locate participant vehicle for information on an event.

RF – Radio Frequency

HVAC – Heating, Ventilating, and Air-Conditioning System

I/O – Input and output device

IVI – Intelligent Vehicle Initiative

IR LEDs – Infrared Light-emitting Diodes

LV – Lead vehicle

MVMT – Million Vehicle Miles Traveled

NHTSA – National Highway Traffic Safety Administration

OR – Odds Ratio

PDA – Personal Digital Assistant

RT – Road Type

SAE – Society of Automotive Engineers

SUV – Sport Utility Vehicle

TTC – Time To Collision

TEOR –Time Eyes Off the Forward Roadway

U.S. DOT – United States Department of Transportation

VDOT – Virginia Department of Transportation

VMT – Vehicle Miles Traveled

VTTI – Virginia Tech Transportation Institute

GLOSSARY OF TERMS

Additional driver – Family member or friend of the primary driver who drove the participant's vehicle but was not involved with the in-processing.

Associative Factors – Any environmental or vehicular factor where direct causation to crashes, near-crashes, or incidents is not possible to attain but correlation may be determined.

At fault – If a behavior by the participant or the driver of another vehicle is observed that contributes to the occurrence of an event, that driver is deemed to be at fault. If both drivers are observed exhibiting behaviors that contribute to the occurrence of the event, then the event is deemed to have partial fault among the drivers involved.

Backing crash – A crash that occurs while the driver's vehicle is in reverse gear.

Chase vehicle – Vehicle designated for locating (through GPS or other means) and downloading data from participant vehicles.

Contributing factors – Any circumstance that leads up to or impacts the outcome of the event. This term encompasses driver proficiency, willful behavior, roadway infrastructure, distraction, vehicle contributing factors, and visual obstructions.

Crash – Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated. Includes other vehicles, roadside barriers, miscellaneous objects on or off of the roadway, pedestrians, pedalcyclists or animals.

Crash-Relevant Event – Any circumstance that requires a crash avoidance response on the part of the participant vehicle, any other vehicle, pedestrian, pedalcyclist, or animal that is less severe than a rapid evasive maneuver, but greater in severity than a "normal maneuver" to avoid a crash. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. A "normal maneuver" for the participant vehicle is defined as a control input that falls outside of the 95 percent confidence limit for control input as measured for the same participant. *Note that crash-relevant conflicts and proximity conflicts were combined to form 'incidents' as used in this report.*

Conflict Type – All crashes, near-crashes, crash-relevant conflicts and proximity conflicts were categorized based on the initial conflict that led to the crash that occurred or would have occurred in the case of near-crashes and incidents (crash-relevant conflicts and proximity conflicts were combined to form *incidents*, as used in this report). There were 20 types of conflicts used which are as follows: conflict with lead-vehicle, following vehicle, oncoming traffic, vehicle in adjacent lane, merging vehicle, vehicle turning across subject vehicle path (same direction), vehicle turning across subject vehicle path (opposite direction), vehicle turning into subject vehicle path (same direction), vehicle turning into subject vehicle path (opposite direction), vehicle moving across subject vehicle path (through intersection), parked vehicle, pedestrian, pedalcyclist, animal, obstacle/object in roadway, single vehicle conflict, other, no known conflict, unknown conflict. This list is primarily derived from National Automotive Sampling System: General Estimates System (NASS GES) Accident Types.

Data Reduction – Process used by which trained Virginia Tech Transportation Institute (VTTI) employees reviewed segments of driving video and recorded a taxonomy of variables that provided information regarding the sequence of events leading up to the crash, near-crash, incident, environmental variables, roadway variables, and driver behavior variables.

Driver Impairment – The driver's behavior, judgment or driving ability is altered or hindered. Includes fatigue, use of drugs or alcohol, illness, lack of or incorrect use of medication, or disability.

Driver-Related Inattention to the Forward Roadway – Inattention due to a necessary and acceptable driving task where the participant is required to shift attention away from the forward roadway (e.g., checking blind spots, center mirror, or instrument panel).

Driver Reaction – The evasive maneuver performed in response to the precipitating event.

Driver Seat Belt Use – Variable indicating if the participant is wearing a seat belt during an event.

Epoch – Typically, a 90-second period of time around one or more triggers in the data; can include one or more events.

Event – a term referring to all crashes, near-crashes, and incidents. The 'event' begins at the onset of the precipitating factor and ends after the evasive maneuver.

Event Nature – Classification of the type of conflict occurring in the event (e.g., conflict with lead vehicle, conflict with vehicle in adjacent lane).

Event Severity – Classification of the level of harm or damage resulting from an event. The five levels were crash, near-crash, crash-relevant, proximity, non-conflict.

Inattention Event – Any event where fatigue, driver-related inattention to the forward roadway, driver secondary tasks, or non-specific eyeglances away from the forward roadway were identified as contributing factors to the event.

Incident – Encompasses the event severities of crash-relevant conflicts and proximity-conflicts.

Invalid Trigger – Any instance where a pre-specified signature in the driving performance data stream is observed but no safety-relevant event is present.

Naturalistic – Unobtrusive observation; observation of behavior taking place in its natural setting.

Near-crash – Any circumstance that requires a rapid, evasive maneuver by the participant vehicle, or any other vehicle, pedestrian, pedalcyclist, or animal in order to avoid a crash. A rapid, evasive maneuver is defined as steering, braking, or accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities.

Non-Conflict – Any incident that increases the level of risk associated with driving, but does not result in a crash, near-crash, or incident as defined above. Examples include driver control error without proximal hazards being present, driver judgment error such as unsafe tailgating or excessive speed, or cases in which drivers are visually distracted to an unsafe level.

Non-Subject Conflict – Any incident that gets captured on video (crash-relevant, near-crash, or crash) that does not involve the participant driver. Data reduction was not completed on these events.

Onset of Conflict – Sync number designated to identify the beginning of a conflict; also known as the beginning of the precipitating factor.

Precipitating Factor – The action by a driver that begins the chain of events leading up to a crash, near-crash, or incident. For example, for a rear-end striking collision, the precipitating factor most likely would be "lead vehicle begins braking" or "lead vehicle brake lights illuminate".

Primary Driver – The recruited participant designated as the main the driver of his/her own vehicle or the leased vehicle

Proximity Event – Any circumstance resulting in extraordinarily close proximity of the participant vehicle to any other vehicle, pedestrian, pedalcyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, pedalcyclists or animals, there is no avoidance maneuver or response. Extraordinarily close proximity is defined as a case where the absence of an avoidance maneuver or response is inappropriate for the driving circumstances (including speed, sight distance, etc.). *Note that crash-relevant conflicts and proximity conflicts were combined to form 'incidents' as used in this report.*

Pre-Incident Maneuver – The maneuver that the driver was performing immediately prior to an event.

Secondary Task – Task, unrelated to driving, which requires drivers to divert attention from the driving task (e.g., talking on a cell phone, talking to passenger[s], eating, etc.).

Time Eyes Off the Forward Roadway (TEOR) – Refers to the time a driver's eyes are not gazing in the direction of the forward roadway.

Total TEOR – This metric would encompass not only the duration of each driver's glance away from the forward roadway but the combined duration of multiple glances away from the forward roadway for a given duration of time.

Trigger/Trigger Criteria – A signature in the data stream that, when exceeded, results in 90 s of video and corresponding driving performance data being copied and saved to a database (60 s prior and 30 s after the data exceedence). Trained data reductionists assess these segments of video and driving performance data to determine whether or not this segment of data contains a safety-relevant conflict (i.e., crash, near-crash, or incident). Examples of triggers include a driver braking at 0.76 *g* longitudinal deceleration or swerving around an obstacle with 0.8 *g* lateral acceleration.

Valid Event or Valid Trigger – Those events where a specific signature in the data stream was identified, viewed by a data reductionist, and deemed to contain a safety-relevant conflict. Data reductionists record all relevant variables and store this data in the 100-Car Database.

Vehicle Run-Off-Road – Describes a situation where the participant vehicle departs the roadway.

Virginia Tech Fleet Services – An extension of the Virginia Tech Office of Transportation.

Visual Obstruction – This variable refers to glare, weather, or an object obstructing the view of the driver that influences the event in any way.

Willful Behavior – The driver knowingly and purposefully drives in an unsafe or inappropriate manner. Willful behavior includes the following: aggressive driving, purposeful violation of traffic laws, and use of vehicle for improper purposes (e.g., intimidation).

Yaw rate – The data collected by the data acquisition system gyro indicating rate of rotation around the vertical axis.

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CHAPTER 1. INTRODUCTION

Driver inattention has long been regarded as a frequent contributing factor to crashes. Different studies have suggested that driver inattention, including secondary task engagement and drowsiness, contributes to 25 percent (Wang, Knipling, and Goodman, 1996) to 78 percent (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006) of all crashes. These large percentages become even more worrisome given the proliferation of portable wireless devices that are being brought into vehicles with increasing frequency. Examples include cell phones, iPods, BlackBerries, navigation devices, and portable DVD players. Two analyses that would greatly improve our understanding of the driver distraction problem are: 1) a calculation of the relative crash risks associated with types of driver distraction, and 2) a characterization of the relationship between the frequency, duration, and the subsequent total time eyes-off-road (TEOR) of these types of distractions, in a real-world driving environment.

RELATIVE CRASH RISK

Relative crash risk is a calculation used primarily in injury epidemiology to provide a measure of an individual's risk when engaging in specific behaviors while driving. Until recently, crash databases have been used to calculate relative risk in transportation safety; however, these data sources are far from precise. Naturalistic driving data provide a unique opportunity to precisely record many driving behaviors within the seconds leading up to a crash or near-crash. Given the importance of risk calculations in driving safety, use of these new and unique data sources is a critical step to furthering our knowledge of the types of behaviors that increase crash/near-crash risk. Two methods for calculating relative crash risk are the case-control design and the case-crossover design.

Case-control designs are one approach to calculating relative risk (relative risk is approximately equal to odds ratio [OR] for rare events). Greenberg, Daniels, Flanders, Eley, & Boring (2001) argue that case-control designs allow for an efficient means to study rare events, such as automobile crashes, by using relatively smaller sample sizes than are used in a typical crash database analysis. In a case-control design, the controls are selected randomly to account for any potentially confounding factors. However, random selection does not necessarily control for a variety of confounding factors, including individual differences within drivers, traffic densities common at the time of crashes and near-crashes, and geometry of roadways at crashes and near-crashes. Also, a relatively large number of controls are needed when using the case-control approach as statistical models are needed to better account for these confounding variables.

In a case-crossover design, the cases remain the same; however, the controls are selected to match the cases on as many situational and environmental variables as possible. These factors may include items such as driver age, driver sex, time of day, day of week, and geographic location. A case-crossover design also provides an efficient means to assess relatively rare events where the exposure to the case is transient. A case-crossover approach to the relative risk calculation has several strengths. First, there are a number of potentially confounding variables that are present during crashes and near-crashes that can be matched in the selection process of the baseline epochs so that these potentially confounding variables are present in both the cases and controls (e.g., time of day, day of week, location). Second, fewer controls per case may be required in a case-crossover design. Maclure & Mittleman (2000) suggest that four controls per case is the rule-of-thumb for case-crossover designs. Finally, the case-crossover approach has been used to calculate relative risk in a variety of other transportation safety studies investigating different types of driver distraction, such as cell phone use (Redelmeier & Tibshirani, 1997; McEvoy et al., 2005). However, the case-crossover approach is very difficult to implement, as the selection of matching factors and the process of matching each control to the specified factors of each case is quite difficult, time-consuming and costly.

CHARACTERIZING SECONDARY TASK DURATION, FREQUENCY, AND EYEGLANCE BEHAVIOR

While simulator, test-track, and instrumented-vehicle research provide insight into the required total task time or visual demand of various tasks, it is still unknown what realistic task time or visual demand is required for drivers who are under normal daily pressures driving on their normal routes. Stutts et al. (2003) assessed drivers' secondary task engagement using a naturalistic data collection system that drivers placed in their own vehicles for 1 month. This research indicated that drivers were engaging in some type of secondary task for 16 percent of the time that the vehicle was moving. The secondary tasks with the longest duration or greatest percentages of total driving time were eating or drinking, internal distractions, external distractions (not driving-related), and smoking. The tasks with the longest percentage of time with eyes directed away from the forward roadway included dialing a hand-held cell phone, eating or drinking, adjusting audio devices, lighting or extinguishing a cigarette, and reading or writing. While these data give a first insight into what drivers actually do while driving their own vehicles on their daily routes, these data were collected in 2001 and 2002 when cell phone and other wireless device use was not as prevalent as it currently is. In addition, no crashes or near-crashes were observed and, thus, crash risk could not be calculated using the data from that study.

Of particular interest to many researchers is the percentage of time that drivers are engaged in cell phone conversations and the rate of increased usage over the past 4 to 5 years. The National Occupant Protection Use Survey (Traffic Safety Facts, 2008) was conducted by trained observers to observe drivers' behavior at selected intersections and record specific behaviors such as cell phone use. The results indicated that cell phone use was approximately 6 percent in 2007. Thus, 6 percent of all drivers are talking on their cell phones at any one moment in time. These results are increased from previous years: in 2002, it was estimated that 4 percent of all drivers were on cell phones, 5 percent in 2004, and 6 percent in 2005. The numbers decreased to 5 percent in 2006 and then increased again to 6 percent in 2007.

While talking on a cell phone, many researchers have found that driver's eye-scanning patterns are significantly reduced in that the driver spends a greater percentage of time looking straight ahead rather than scanning the driving environment (Harbluk, Noy, Trbovich, & Eizenmann, 2007; Victor, 2005). These studies were conducted using simulated cell phone use in either instrumented vehicles or a simulator. Cell phone conversations used in these experiments included mathematical calculations (simple and difficult) as well as answering questions. While these experimental scenarios are appropriate approximations to assess driver performance while using cell phones, these types of cell phone conversations are not motivated by the driver's personal goals and thus these conversations may be different than those occurring in the real world.

In an effort to better improve our understanding of the driver distraction problem, the National Highway Traffic Safety Administration (NHTSA) sponsored a public forum on driver distraction in 2000. As part of this effort, NHTSA requested that automobile manufacturers and other standards organizations (e.g., the Society of Automotive Engineers [SAE]) develop design guidelines and specifications that designers of in-vehicle telematics devices must adhere to in an effort to minimize the effects of driver distraction. The Alliance of Automobile Manufacturers (AAM) responded to NHTSA by releasing *Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communications Systems (*AAM, 2003). Within this document, design guidelines, rationale for the guidelines, criteria for design, and justification for these criteria are listed. While many guidelines are listed for items such as display location, legibility, glare, and use of auditory displays, two guidelines specifically referred to task completion time and eyeglance durations. These two guidelines were written as follows:

- Single glance durations generally should not exceed 2 s; and
- Task completion should require no more than 20 s of total glance time to task display(s) and controls.

These two guidelines are similar to guidelines from SAE, although SAE has a 15-second rule rather than a 2-second rule. Likewise, SAE has discussed glance duration and generally accepts that glances should not exceed 2 s, even though the organization has not stated an official position to this effect.

The research behind these guidelines has been somewhat mixed and controversial. The 2-second rule was based on research conducted by Rockwell (1988). He did an analysis of length of eyeglances away from the forward roadway in instrumented-vehicle studies over a multi-year period. Using these data, he constructed a distribution of eyeglance lengths. The 85^{th} percentile eyeglance length was approximately 1.9 s. This was rounded up to 2.0 s to provide a design criterion in whole numbers.

Other simulator and instrumented-vehicle research conducted by Green (1999), Wierwille (1993), and Dingus, Antin, Hulse, & Wierwille (1989) all suggest that drivers have self-limiting behavior in that drivers tend to not look away from the forward roadway for greater than 1.5 s. Rather, if engaged in a task, they will look back and forth between the task and the roadway, not looking away from the forward roadway for more than 1.5 s at any one time, until the task is complete. Therefore, a 2-second design guideline may not be a practical guideline for designers, since very few displays would produce a single eyeglance length of 2.0 s or more. Total TEOR during the completion of the task may be a better limiter and could potentially be used as a design guideline. If total task time cannot exceed 20 s, this could mean that drivers' eyes are off the forward roadway 15 s out of 20 s (e.g., drivers' eyes on device for 1.5 s followed by a 0.5 s glance to roadway and so on for 20 s).

APPROACH

The 100-Car Naturalistic Driving Study provides a unique opportunity to assess the relative risk of secondary task engagement as well as secondary task frequency, duration, and eyeglance patterns for drivers who are under normal daily pressures in everyday urban driving environments. The calculation of relative risks will be discussed in the Task 1 chapter and the characterization of secondary task engagement will be discussed in the Task 2 chapter.

Given the novelty of naturalistic driving data and the importance of risk calculations in driving safety, this report will first present relative risk calculations for secondary task engagement, drowsiness, and total TEOR using the case-crossover approach. These results will be compared to the results of a previous analysis of the same data set using the case-control approach (Klauer et al., 2006). The strengths and weaknesses of each approach will be assessed and discussed in the Task 1 chapter.

Secondly, the frequency of secondary task occurrence, task duration, and total TEOR during normal, baseline driving will be presented for a variety of secondary tasks. Eyeglance behavior while conversing on a cell phone was also evaluated and the results of this analysis will be presented. The data used for these analyses included only those data collected during normal, baseline driving conditions. ORs for total TEOR were also calculated and will be presented in the Task 2 chapter (which includes both event and baseline data).

This comparative approach will provide insight into the relative risk of driving while inattentive, and into how the results from naturalistic driving studies compare to other epidemiological and empirical research studies in transportation research. These unique data will also provide a greater understanding of the frequency, duration, and impact on eyeglance behavior in real-world environments than previous research has been able to provide.

The research objectives for Tasks 1and 2 of this current work are as follows:

- Task 1: Recalculate relative risks for crashes and near-crashes using a case-crossover baseline sample and compare to the relative risk calculations conducted previously using a case-control approach.
- Task 1: Recalculate the relative near-crash/crash risk for total time eyes off forward roadway (TEOR) and compare to the relative risk calculations conducted previously using a case-control approach.
- Task 1: Assess whether total TEOR significantly impacts driving performance.
- Task 2: Characterize the duration of various task types. Determine the importance of total TEOR in relation to task duration. Calculate relative risk for task duration.
- Task 2: Characterize eyeglance behavior while using wireless devices such as cell phones and PDAs.

CHAPTER 2. METHOD

This section will provide an abbreviated description of the data collection and data reduction process used for the original 100-Car Naturalistic Driving Study. Interested readers should refer to Dingus et al. (2006). More detail will be provided on the data reduction process used to identify and reduce the case-crossover baseline database and the additional data reduction (distraction reduction) that was completed on the crashes and near-crashes for the analyses in this report.

Instrumentation

The 100-Car Study instrumentation package was engineered by the Virginia Tech Transportation Institute (VTTI) to be rugged, durable, expandable, and unobtrusive. The system consisted of a Windows-based computer that received and stored data from a network of sensors distributed around the vehicle. Data storage was achieved via the system's hard drive, which was large enough to store data for several weeks of driving between data downloads.

Each of the sensing subsystems in the car was independent, so any failures that occurred were constrained to a single sensor type. Sensors included a vehicle network box that interacted with the vehicle network, an accelerometer box that obtained longitudinal and lateral kinematic information, a headway detection system to provide information on leading or following vehicles, side obstacle detection to detect lateral conflicts, an incident box to allow drivers to flag incidents for the research team, a communication system that was comprised of Global Positioning System (GPS) sensor and cell phone communications, a video-based lane-tracking system to measure lane-keeping behavior, and video to validate any sensor-based findings. The video subsystem was particularly important as it provided a continuous window into the happenings in and around the vehicle. This subsystem included five camera views monitoring the driver's face and driver side of the vehicle, the forward view, the rear view, the passenger side of the vehicle, and an over-the-shoulder view for the driver's hands and surrounding areas. An important feature of the video system is that it was digital, with software-controllable video compression capability. This allowed synchronization, simultaneous display, and efficient archiving and retrieval of 100-Car Study data. A frame of compressed 100-Car Study video data is shown in Figure 3.

Figure 3. A Compressed Video Image from the 100-Car Study Data

The driver's face (upper left quadrant) is distorted to protect the driver's identity. The lower right quadrant is split with the left-side (top) and the rear (bottom) views.

The data collection system included several major components and subsystems that were installed on each vehicle. These included the main data acquisition system (DAS) unit that was mounted under the package shelf for the sedans (Figure 4) and behind the rear seat in the sport utility vehicles (SUVs). Doppler radar antennas were mounted behind special plastic license plates on the front and rear of the vehicle (Figure 5). The location behind the plates allowed the vehicle instrumentation to remain inconspicuous to other drivers.

Figure 4. The Main DAS Unit Mounted under the "Package Shelf" of the Trunk

Figure 5. Doppler Radar Antenna Mounted on the Front of a Vehicle, Covered by one of the Plastic License Plates used for this Study

The final major components in the 100-Car Study hardware installation were mounted above and in front of the center rearview mirror. These components included an "incident" box which housed a pushbutton that the participant could press whenever an unusual event happened in the driving environment (Figure 6). The housing also contained an unobtrusive miniature camera that provided the driver face view. The camera was invisible to the driver since it was mounted behind a "smoked" Plexiglas cover. The forward-view camera and the glare sensor were mounted behind the center mirror. This location was selected to be as unobtrusive as possible and did not occlude any of the driver's normal field of view.

Figure 6. The Incident Pushbutton Box Mounted above the Rearview Mirror (The portion on the right contains the camera aimed at the driver's face hidden by a smoked Plexiglas cover.)

Participants

One-hundred drivers who commuted into or out of the Northern Virginia and Washington, DC metropolitan areas were initially recruited as primary drivers to have their vehicles instrumented or to receive a leased vehicle for this study. Drivers were recruited by placing flyers on vehicles, and by placing newspaper announcements in the Classified section. Drivers who had their private vehicles instrumented (N = 78) received $125.00 per month and a bonus at the end of the study for completing the necessary paperwork. Drivers who received a leased vehicle (N = 22) received free use of the vehicle, including standard maintenance, and the same bonus at the end of the study for completing the necessary paperwork. Drivers of leased vehicles were insured under the Commonwealth of Virginia policy.

As some drivers had to be replaced for various reasons (for example, a move from the study area or repeated crashes in leased vehicles), 109 primary drivers were included in the study. Since other family members and friends occasionally drove the instrumented vehicles, data were collected on 132 additional drivers.

A goal of this study was to maximize the potential to record crash and near-crash events through the selection of participants with higher than average crash or near-crash risk exposure. Exposure was manipulated through the selection of a larger sample of drivers below the age of 25, and by the selection of a sample that reported driving more than the average number of miles. The data are slightly biased compared to the national averages in each case, based on TransStats, 2001. Nevertheless, the distribution was generally representative of national averages when viewed across the distribution of mileages within the TransStats data.

One demographic issue with the 100-Car Study data sample is that the data were collected in only one area (i.e., the Northern Virginia and Washington, DC metropolitan area). This area represents primarily urban and suburban driving conditions, often in moderate to heavy traffic. Thus, rural driving, as well as differing demographics within the United States, is not well represented.

A goal of the recruitment process was to attempt to avoid extreme drivers in either direction (i.e., very safe or very unsafe). Self-reported historical data indicate that a reasonably diverse distribution of drivers was obtained.

Vehicles

Since over 100 vehicles had to be instrumented with a number of sensors and data collection hardware, and since the complexity of the hardware required a number of custom mounting brackets to be manufactured, the number of vehicle types had to be limited for this study. Six vehicle models were selected based upon their prevalence in the Northern Virginia area. These included five sedan models (Chevrolet Malibu and Cavalier, Toyota Camry and Corolla, and Ford Taurus) and one SUV model (Ford Explorer). The model years were limited to those with common body types and accessible vehicle networks (generally 1995 to 2003). The distribution of these vehicle types was:

Toyota Camry – 17 percent

Toyota Corolla – 18 percent

Chevy Cavalier – 17 percent

Chevy Malibu – 21 percent

Ford Taurus – 12 percent

Ford Explorer – 15 percent

DATA REDUCTION

Sensitivity Analysis

As stated in Dingus et al. (2006), data were collected continuously onboard the instrumented vehicles. As project resources did not allow for the review of all the data, a sensitivity analysis was conducted to establish post-hoc "triggers." A post-hoc trigger uses either a single signature (e.g., any lateral acceleration value greater than ±0.6*g*) or multiple signatures (e.g., forward time-to-collision (TTC) value > 3 s plus a longitudinal deceleration value > -0.5 *g*) in the driving performance data stream to identify those points in time when it was likely that a driver was involved in any safety-related event.

Data reductionists then viewed all of the events produced from the liberal trigger criteria and classified each event as valid or invalid. The numbers of valid events and invalid events that resulted from this baseline setting were recorded. The trigger criteria for each dependent variable were then modified, and the resulting number of valid and invalid events were counted and compared to the first frequency count. The trigger criteria were made more and more conservative and the number of valid and invalid triggers were counted and compared until an optimum trigger value was determined (a level which resulted in a minimal amount of valid events lost and a reasonable amount of invalid events identified). The goal in this sensitivity analysis was to obtain a miss rate of less than 10 percent and a false alarm rate of less than 30 percent. The list of dependent variables ultimately used as triggers is presented in Table 2.

Table 2. Dependent Variables Used as Event Triggers

Trigger Type	Description
1. Lateral Acceleration	Lateral motion equal to or greater than 0.7 *g*.
2. Longitudinal Acceleration	Acceleration or deceleration ≥ 0.6 *g*. Acceleration or deceleration ≥ 0.5 *g* coupled with a forward Time-to-Collision (TTC) of 4 s or less. All longitudinal decelerations between 0.4 *g* and 0.5 *g* coupled with a forward TTC value of ≤ 4 s and that the corresponding forward range value at the minimum TTC is not greater than 100 ft.
3. Event Button	Activated by the driver by pressing a button located on the dashboard when an event occurred that he or she deemed critical.

4. Forward TTC	Acceleration or deceleration ≥ 0.5 *g* coupled with a forward TTC of 4 s or less. All longitudinal decelerations between 0.4 *g* and 0.5 *g* coupled with a forward TTC value of ≤ 4 s with the corresponding forward range value at the minimum TTC < 100 ft.
5. Rear TTC	Any rear TTC trigger value of 2 s or less that also has a corresponding rear range distance of ≤ 50 ft AND any rear TTC trigger value in which the absolute acceleration of the following vehicle is > 0.3 *g*.
6. Yaw rate	Any value ≥ both a plus AND minus 4 degree change in heading (i.e., vehicle must return to the same general direction of travel) within a 3-second window of time.

It was soon discovered, after the sensitivity analysis process began, that the variability in light-vehicle drivers' braking, acceleration, and steering behavior is larger than previously thought. These differences in variability are primarily due to the differences in vehicle dynamics and the more uniform driving skills of other well-researched vehicle operators, such as commercial truck drivers. While greater variability was expected, the extent to which this is true was an interesting result.

The sensitivity analysis proved to be challenging, given the variability in light-vehicle driving performance. VTTI researchers determined that the best option was to accept a very low miss rate while accepting a fairly high false alarm rate to ensure that few valid events were missed. This resulted in viewing over 110,000 triggers in order to validate 10,548 safety-related events. The distribution of the total number of reduced safety-related events and operational definitions by severity is shown in Table 3.

Table 3. The Total Number of Events Reduced for each Severity Level

Event Severity	Operational Definition	Total Number
Crash	Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated. Includes other vehicles, roadside barriers, objects on or off of the roadway, pedestrians, pedalcyclists, or animals.	69
Near-Crash	Any circumstance that requires a rapid, evasive maneuver by the participant vehicle, or any other vehicle, pedestrian, pedalcyclist, or animal to avoid a crash. A rapid, evasive maneuver is defined as a steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities.	761
Incidents (Crash-relevant Conflicts and Proximity Conflicts)	Any circumstance that requires a crash-avoidance response on the part of the participant vehicle, any other vehicle, pedestrian, pedalcyclist, or animal that is less severe than a rapid evasive maneuver (as defined above), but greater in severity than a "normal maneuver" to avoid a crash. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. A "normal maneuver" for the participant vehicle is defined as a control input that falls inside the 95 percent confidence limit for control input as measured for the same participant.	8,295

Once the trigger criteria were set, data reductionists watched 90-second epochs for each event (60 s prior to and 30 s after), then reduced and recorded information such as the nature of the event, driving behavior prior to the event, the state of the driver, and the surrounding environment. The specific variables recorded in the data reduction process are described in detail in the data reduction section of this chapter.

Note that the analyses presented in this report primarily used crashes and near-crashes; therefore, incidents will not be discussed in greater detail. (Incidents will be briefly referred to again in the discussion of the case-control baseline database.) Incidents were not used in the calculation of risk because they were found to be highly variable. More research is required, but one theory is that incidents represent the frequency with which drivers experience traffic conflicts with appropriate responses, and thus do not increase danger to the driver and property damage to the vehicle. Further information on the sensitivity analysis can be found in Dingus et al. (2006).

Database Reduction

For the analyses reported in this technical report, three reduced databases were used: the event database, the case-control database, and the case-crossover database. The event database and the case-crossover database consist of three separate parts: scenario reduction, eyeglance reduction, and secondary task reduction. Each of these data reduction efforts will be described in detail in the event database description below. Those aspects that are noteworthy will be described in detail in the description of the baseline databases; however, the reader should assume that the reduction processes for the scenario reduction, eyeglance reduction, and secondary task reduction are similar for each database. Table 4 presents the reduction task conducted for each database and whether this task was completed for a previous analysis or for the current analysis.

Table 4. Description of the Reduction Tasks Completed for each 100-Car Database and the Calendar Year in which the Reduction Task Was Completed

	Reduction Task	Completion Date
Event Database	1. Scenario Reduction	2004
	2. Eyeglance Reduction	2004
	3. Secondary Task Reduction	2008
Case-Control Database	1. Scenario Reduction	2004
	2. Eyeglance Reduction	2004
Case-Crossover Database	1. Scenario Reduction	2008
	2. Eyeglance Reduction	2008
	3. Secondary Task Reduction	2008

Event Database

As stated previously, there are three parts to the event database: the scenario reduction, the secondary task reduction, and the eyeglance reduction. These are discussed in detail below.

Scenario reduction. The scenario reduction was created to identify and record various driving behaviors and environmental characteristics for crashes and near-crashes only. The operational definitions for these severity levels were presented in Table 3. The variables recorded were selected based upon past instrumented-vehicle studies (Hanowski et al., 2000; Dingus et al., 2001), national crash databases (the General Estimates System [GES] and the Fatality Analysis Reporting System [FARS]), and questions on Virginia State Police Accident Reports. Using this technique, the reduced database can be used to directly compare crash data from GES and FARS to the crashes and near-crashes identified in this data set.

The general method for data reduction of crashes and near-crashes was to have the data reduction manager and project manager perform the data reduction. All events were then reviewed a second time by three experienced data reductionists. Any discrepancies were decided by a senior researcher.

A total of four data categories were recorded for each event type. These included: vehicle variables, event variables, environmental variables, and driver state variables. Table 5 defines each category of data reduction, provides examples, and describes additional features of the data reduction. The complete list of all variables reduced is shown in Appendix A. It is important to note that driver behaviors such as driver inattention or drowsiness must have been observed within 5 s prior to the onset of the conflict or during the crash/near-crash in order to have been recorded as a contributing factor. This criterion was used to ensure that any behavior recorded in this reduction most likely contributed to the occurrence of the crash or near-crash. Further information on the scenario reduction can be found in Dingus et al. (2006).

Table 5. Categories of Data Reduction, Definitions, and Examples of the Scenario Reduction Used in the 100-Car Event Database

Category	Definition	Examples
Vehicle Variables	All of the descriptive variables, including the vehicle identification number, vehicle type, ownership, and those variables collected specifically for that vehicle, such as vehicle miles traveled (VMT).	Vehicle ID, Vehicle type, Driver type (leased or private), and VMT.
Event Variables	Description of the sequence of actions involved in each event, list of contributing factors, and safety or legality of these actions.	Nature of Event, Crash type, Pre-event maneuver, Precipitating Factors, Corrective action or Evasive maneuver, Contributing Factors, Types of Inattention, Driver impairment, etc.
Environmental Variables	General description of the immediate environment, roadway, and any other vehicle at the moment of the incident, near-crash, or crash. Any of these variables may or may not have contributed to the event, near-crash or crash.	Weather, ambient lighting, road type, traffic density, relation to junction, surface condition, traffic flow, etc.
Driver's State	Description of the instrumented-vehicle driver's physical state.	Hands on wheel, seat belt usage, fault assignment, eyeglance, PERCLOS, etc.
Driver/Vehicle 2	Description of the vehicle(s) in the general vicinity of the instrumented vehicle and the vehicle's action.	Vehicle 2 body style, maneuver, corrective action attempted, etc.
Narrative	Written description of the entire event.	
Dynamic reconstruction	Creation of an animated depiction of the event.	

Secondary Task Reduction. The secondary task reduction was performed for all of the crashes and near-crashes and case-crossover baselines for 30 s. For this task, trained data reductionists recorded, frame-by-frame, whether or not the driver was engaged in any secondary task. In this manner, the frequency of secondary task engagement as well as the duration of the task engagement was recorded. The complete list of secondary tasks and the operational definitions for each are listed in Appendix B. The secondary tasks recorded are listed below.

- Cell: dialing
- Cell: dialing hand-held
- Cell: dialing (quick-keys)
- Cell: locating
- Cell: other
- Cell: talking/listening
- Center console: Cassette-insert
- Center console: Climate control
- Center console: CD-Insert/remove
- Center console: Other integral devices
- Center console: Radio Adjustment
- Cognitive distraction: Writing
- Cognitive distraction: Dancing
- Cognitive distraction: Emotional distraction
- Cognitive distraction: Reading
- Cognitive distraction: Singing
- Drinking: lid and straw
- Drinking: lid no straw
- Drinking: Open container
- Drinking: straw no lid
- Eating: with utensils
- Eating: without utensils
- External distraction: Other
- External distraction: Looking at object
- External distraction: Looking at pedestrian
- External distraction: Looking at previous incident
- Hygiene: Biting Nails
- Hygiene: Brush/floss teeth
- Hygiene: Contact lenses
- Hygiene: Glasses/sunglasses
- Hygiene: Hair
- Hygiene: Jewelry
- Hygiene: Makeup
- Object in vehicle: Looking at object
- Object in vehicle: Moving object in vehicle
- Object in vehicle: other
- Object in vehicle: Reaching for object
- Object in Vehicle: Insect in vehicle
- Object in vehicle: Pet in vehicle
- Passenger: Child rear seat
- Passenger: in adjacent seat
- Passenger: rear-seat
- Passenger: Child in adjacent seat
- PDA: Locating/reaching
- PDA: Operating
- PDA: Other
- PDA: Viewing
- Smoking: reaching
- Smoking: extinguishing
- Smoking: lighting
- Smoking: smoking

Trained reductionists were able to complete events at the rate of approximately 6-8 per hour, and all reductionists spent time each week conducting and recording spot checks on completed events. All disagreements were reviewed by a senior reductionist or the data reduction manager. At completion, 32 percent of all events had been spot-checked. Before the data were considered complete, they underwent an additional data verification step that checked data for internal consistency.

Eyeglance Analysis. An eyeglance analysis was performed for all crashes and near-crashes, 5,000 case-control baseline epochs, and all of the case-crossover baseline epochs (where possible). If the reductionists were not confident in their ability to accurately complete the eyeglance analysis (e.g., due to dark sunglasses, poor camera alignment, or poor driver posture), then the eyeglance analysis was not performed for a particular event. Eyeglance analysis followed the standard protocol developed by VTTI for other projects. In this protocol, eyeglance analysis is performed with the video progressing at half speed or less and transitions are coded to the first glance location until the eyes are fixated on the new location.

Before reductionists began to work on this project, they were trained by observing an experienced eyeglance reductionist, going through a training program with the data reduction manager, and then spending a minimum of one full 4-hour shift practicing on actual baseline data. Finally, they completed an inter-rater test where their scores were compared against the data reduction manager as the gold standard. All eyeglance reductionists reached reliability scores of 92-95 percent before beginning to record any official eyeglance data. Trained reductionists were able to complete events at the rate of approximately 8-10 per hour. The glance locations used are defined in Table 6. Further information on the eyeglance reduction can be found in Klauer et al. (2006).

Table 6. Eyeglance Location Definitions

Glance Location	Description
Forward	Any glance in the direction of the vehicle's travel. Note that when the vehicle is turning, these glances may not be directed directly forward but towards the vehicle's predicted or intended heading.
Left Windshield	Any glance out the left portion of the windshield, to the left of forward (e.g., NOT looking in the direction of travel). Glances should be coded only if clear, and finite. Left Windshield glances may be directed to vehicles ahead in the adjacent lane or other external distractions slightly ahead of the participant. These glances may also be taken while in the process of turning into or crossing a road (e.g., the vehicle is crossing through an intersection and the driver looks left and right to check traffic

Glance Location	Description
	conditions).
Right Windshield	Any glance out the right portion of the windshield, to the right of forward (e.g., NOT looking in the direction of travel). Glances should be coded only if clear, and finite. Right Windshield glances may be directed to vehicles ahead in the adjacent lane or other external distractions slightly ahead of the participant. These glances may also be taken while in the process of turning into or crossing a road (e.g., the vehicle is crossing through an intersection and the driver looks left and right to check traffic conditions).
Instrument Cluster	Any glance to the instrument cluster underneath the dashboard. This includes glances to the speedometer, control stalks, and steering wheel. Note that clusters may be in different places (e.g., driver-centerline versus vehicle-centerline), but they will be included in this category regardless of location. In the case of trucks this might include an area that 'wraps' around the driver.
Rearview Mirror	Any glance to the rearview mirror or equipment located around it. This category does not include any glances to the Center Stack.
Left Mirror	Any glance to the left side mirror.
Right Mirror	Any glance to the right side mirror.
Left Window	Any glance out the left side window.
Right Window	Any glance out the right side window.
Over-The-Shoulder (left or right)	Any glance over either of the participant's shoulders. In general, this will require the eyes to pass the B-pillar, but the eyes may not be visible.
Center Stack	Any glance to the vehicle's center stack (the vertical portion), usually housing the radio, climate control, etc. Not to be confused with center console (cup holder area between driver and passenger).
Cell Phone (electronic communications device)	Any glance at a cell phone or other electronic communications device (e.g., BlackBerry) or associated items (e.g., power cord, charger, etc.), no matter where they are located.
iPod (or similar)	Any glance at an iPod or other personal digital music device, no matter where it is located
Interior Object	Any glance to an identifiable object in the vehicle other than an electronic communications device or iPod. These objects include personal items brought in by the participant (e.g., purse, food,

Glance Location	Description
	papers), any part of their body that they may look at (e.g., hand, ends of hair), other electronic devices (e.g., laptop), and also original equipment manufacturer (OEM)-installed devices that don't fall into other categories (e.g., door lock, seat belt, window and seat controls). Glances to the center console (cup holder area between passenger seat and driver seat) are also included in this category. The object does not need to be in the camera view for a specific frame to be coded with this category. If it is clear from surrounding video that the participant is looking at the object, this category may be used. This category can be used regardless of whether the participant's hands are visible.
Passenger	Any glance to a passenger, whether in front seat or rear seat of vehicle. Context is used (e.g., they are conversing) in order to determine this in some situations.
No Video	Unable to complete eyeglance analysis because the face video view is unavailable. Used only when this condition is intermittent and surrounding syncs can be completed.
No Eyes Visible - Glance Location Unknown	Unable to complete glance analysis due to an inability to see the driver's eyes and face. Video data are present, but the driver's eyes and face are not visible due to an obstruction (e.g., visor, hand), or due to glare. This category was used when there was no way to tell whether the participant's eyes are on or off the road.
No Eyes Visible - Eyes Are Off-Road	Unable to determine specific glance location due to an inability to see the driver's eyes and face. However, it is clear that the participant is not looking at the roadway. Video is present, but the driver's eyes and face are not visible due to an obstruction (e.g., visor, hand), head position, or due to glare. Use this category when the eyes are not visible, you are not sure what the participant is looking at, but it is obvious that the eyes are not on the roadway.
Eyes Closed	Any time that the participant's eyes are closed outside of normal blinking (e.g., the participant is falling asleep). As a rule of thumb, if the eyes are closed for five or more syncs (0.5s) during a slow blink, it is coded as Eyes Closed.
Other	Any glance that cannot be categorized using the above codes (e.g., specific built-in vehicle features).

Case-Control Baseline Database

The case-control baseline database was comprised of approximately 20,000 6-second segments where the vehicle maintained a velocity of greater than 5 mph (referred to as an *epoch*). Kinematic triggers on driving performance data were not used to select these baseline epochs. Instead, these epochs were selected at random throughout the 12- to 13-month data collection period per vehicle. A 6-second segment of time was used since this was the time frame used by data reductionists to determine whether a particular secondary task was a contributing factor for each crash, near-crash, and incident. For example, a driver had to take a bite of a sandwich within 5 s prior to or 1 s after the onset of the conflict for the activity to be considered a contributing factor to the crash, near-crash, or incident.

Each case-control baseline epoch was randomly selected from the 12 months of data collected on each vehicle. However, the number of case-control baseline epochs selected per vehicle was stratified as a proportional sample based upon vehicle involvement in crashes, near-crashes, and incidents. This stratification, based on frequency of crash, near-crash, and incident involvement, was conducted to create a case-control data set in which there are multiple baseline epochs per vehicle for comparison to each crash and near-crash.

The number of case-control baseline epochs was dependent upon the number of crashes, near-crashes, and incidents collected for each vehicle; therefore, four vehicles that did not have any crashes, near-crashes, or incidents were eliminated from the case-control baseline database. The lack of crashes, near-crashes, and incidents for these vehicles may have been due to either very low mileage (primarily due to driver attrition or frequent mechanical malfunctions) or because the drivers exhibited safe driving behavior.

Figure 7 shows the number of events for each vehicle (y-axis) and the corresponding number of baseline epochs for that vehicle (x-axis). Note that vehicles that were involved in multiple crashes, near-crashes, and incidents also had a larger number of case-control baseline epochs.

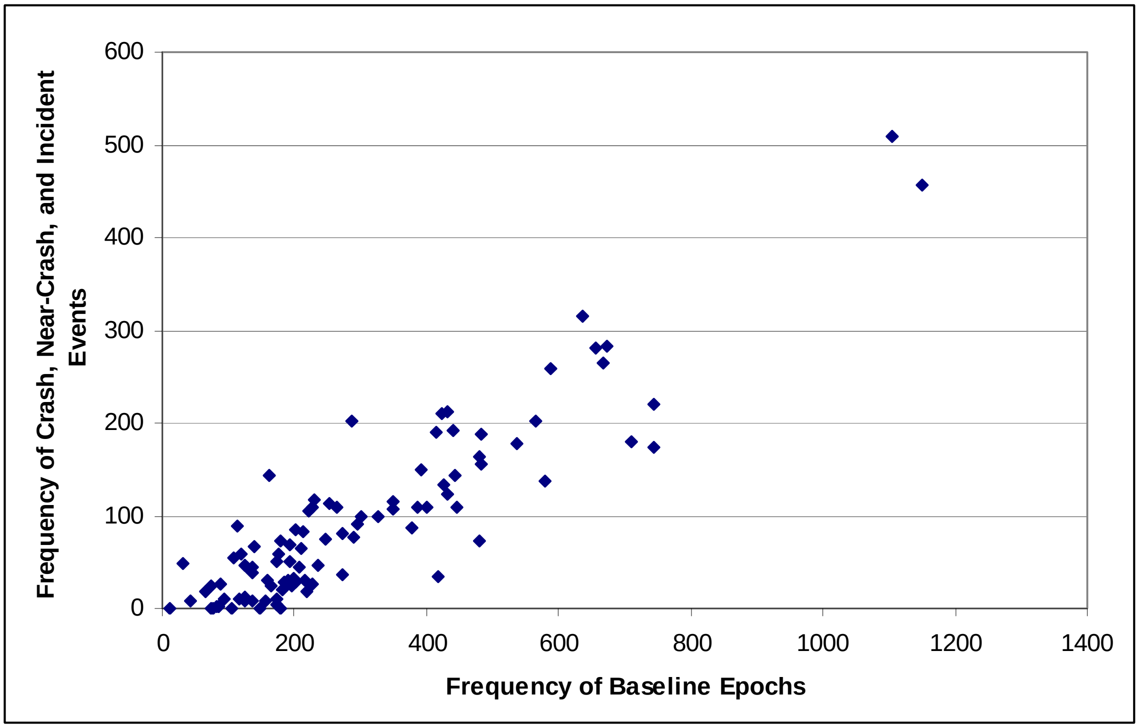

Figure 7. The Frequency of Each Vehicle's Involvement in Crash, Near-crash, and Incident Events versus the Number of Case-Control Baseline Epochs Selected for Each Vehicle

While the reader should keep in mind that the case-control baseline epochs were stratified, this does not reduce the generalizability of the data analysis for the following reasons:

- 99 of 103 vehicles are represented in the 20,000 baseline epochs
- 101 out of 109 primary drivers are represented in the baseline epochs
- Multiple drivers drove each vehicle
- No environmental or driver behavior data were used in the stratification

Scenario Reduction and Eyeglance Reduction. The variables recorded for the 20,000 case-control baseline epochs included the vehicle, environmental, and most driver state variables. In addition, eyeglance analyses were performed for 5,000 randomly selected baseline epochs from the 20,000 baseline epochs. These 5,000 baseline epochs also represent data from all 99 vehicles and 101 of the primary drivers.

The event variables (the second row in Table 5) were not recorded for the case-control baseline epochs or the case-crossover baseline epochs because these variables (e.g., precipitating factor, evasive maneuver) were not present when an incident, near-crash, or crash did not occur. The secondary task reduction was also not completed for the case-control database. To assess the similarities and differences of the types of data that were recorded for the case-control baseline database and the event database, the reader should refer to Table 5. Further information on the case-control scenario and eyeglance reduction can be found in Klauer et al. (2006).

Case-Crossover Baseline Database

A case-crossover database was created by selecting baseline epochs for the 830 crashes and near-crashes identified as part of the original 100-Car Study data reduction process. Previous research has found that four baseline epochs provide adequate comparison to each event (Maclure & Mittleman, 2000). Given the exploratory nature of this analysis, reductionists attempted to identify a maximum of 15 baseline epochs per crash or near-crash with a minimum of 6 baselines per crash/near-crash. This would have resulted in a baseline database consisting of a maximum of 12,450 case-crossover baseline epochs and a minimum of 4,980.

In order to find the potential 12,450 baseline epochs, software engineers oversampled the continuous 100-Car Study database for potential baseline epochs. These potential baseline epochs were sampled from the time period before the occurrence of the crash or near-crash to ensure that the crash/near-crash involvement did not alter or affect subsequent driving performance (Figure 8).

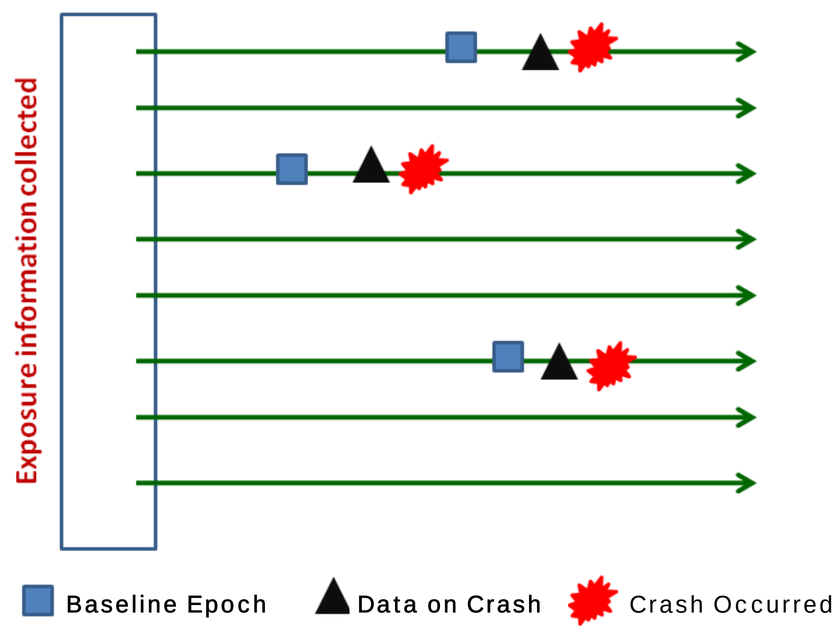

Figure 8. Depiction of the Timeline of Continuous Data Collected for each Vehicle and how each Baseline Epoch was Selected Prior to the Occurrence of a Crash/Near-crash and Matched based upon the Data Recorded for each Crash/near-crash

Baseline Identification. An attempt was made to identify up to 15 corresponding baselines for each event (crash or near-crash). The goal was to locate baselines that matched (as closely as possible) the conditions present during the event. To qualify, these 30-second baseline episodes were required to meet the following criteria:

1. The same participant must be driving that was driving in the event,
2. The baseline must occur during the same general day of the week (weekend versus weekday),
3. The baseline must occur during the same time of day (event time +/- 2 hours),
4. The baseline must occur at or near the same location (match GPS ± 100 m OR match relation to junction),
5. The baseline must occur at a date/time prior to the date/time of the event,
6. The necessary video must be present in order to perform the analysis (forward view and face views were required to be present),
7. All baselines for a given event needed to occur in different trip files (e.g., if 15 baselines were found, they had to occur in 15 different time- and participant-matched trip files), and
8. If two baselines for two different events occurred in the same file, they could not overlap by more than 10 s.

Some challenges and assumptions involved in meeting the above criteria include:

a. It was assumed that the time stamps on each file were correct unless there was an obvious problem (e.g., the video was clearly at night but the time stamp denoted mid-day). Files with an obvious problem (which could be noticed only after loading and viewing the file) were discarded from the search.
b. Many of the events occurred very shortly after a particular participant started the study (e.g., many times, within days of starting the study). In these cases, there were very few, if any, files that met the timing criteria (items 2, 3, and 4 above) and thus it was not possible to obtain the target of 15 baselines.
c. Many of the events occurred while an infrequent secondary driver was driving. In these cases, even though there may have been several hundred files that met the timing criteria, very few met the participant criteria (item 1 above).
d. The operation and alignment of the video cameras and lighting conditions often impacted the ability to identify the driver or to observe distractions and eyeglances. If the driver could not be identified or if none of the analyses could be performed (distraction analysis or eyeglance), then that file was excluded from the search. Unfortunately, camera issues tended to occur consistently within certain vehicles and for certain drivers. Usable baselines were very difficult to find for events involving these drivers.

During baseline identification, every potential file (based on time) needed to be loaded and viewed in order to confirm all of the above conditions. As reductionists began the baseline identification process, it soon became apparent that GPS data were not available for a majority of the files. Thus, a two-stage process was implemented whereby as many GPS matches were found and, where GPS data were not available, reductionists would match on the variable ‘relation to junction’ in order to reach the 15-per-event goal whenever possible. Relation to junction is a GES-based variable that indicates whether the vehicle was at/near an intersection, merge ramp, driveway, etc., or on a straight roadway. Both GPS and Junction Match processes, along with the challenges, assumptions, and baseline counts associated with each, are described in detail below. Once all events were complete, reductionists had sorted through approximately 170,700 files/epochs, and located a final count of 10,008 baselines across 796 events for an average of 12.6 baselines per event. (See the situational criteria breakdowns in the next section.)

GPS Match Criterion. For all events where reliable GPS data were available, a search was first conducted for baselines that met all of the above criteria plus a GPS match criteria. For these baselines, the participant must have passed through the same GPS location, ± 100 meters, from where the corresponding event occurred.

To begin this search, an automated trigger was run that flagged points in trip files where all of the time and GPS criteria were met. From that list, reductionists reviewed every file to confirm participant matches, confirm video operations, confirm GPS operations, and specify the 30-second baseline interval. During this GPS Match process, 9,815 potential baselines were examined. From this pool, 2,760 baselines across 427 events were identified and included in the analysis. In the planning phase of this analysis, it was hoped that enough baseline epochs could be found to calculate ORs using the GPS Match versus using the entire data set. Unfortunately, not enough case-crossover baseline epochs were identified using GPS Match to calculate ORs, so this analysis will not be presented in this report.

The biggest challenge for this criterion (in addition to those listed above) was the assumption of accurate GPS data. This was verified for each event and baseline through a GPS linked program, Microsoft MapPoint, which allowed reductionists to see the path that the vehicle took during that trip and make a judgment as to GPS accuracy. If the GPS was deemed inaccurate during the event or during the identified potential baseline, that event or baseline was excluded from the GPS Match search.

Limitations in the analysis of the GPS Match baselines include the variable traffic conditions that exist at the location of many events (especially, but not exclusively, near intersections) and the lack of sensitivity of the GPS Match baseline to direction of travel. The research team attempted to find baselines where the vehicle was moving for the majority of the time, but in stop-and-go traffic and/or when the traffic light of interest was red with long queue lines, this was not always possible. This resulted in the first two limitations listed below, with a third limitation present by direction of travel:

1. In order to maximize vehicle-moving time during the 30-second baseline (for the eyeglance and secondary task analysis), the 30-second window was marked so that the GPS location of interest was included in the 30 s, but the end point of the baseline epoch (where most of the environmental questions were answered) occurred at various points

after the precise event location. Thirty seconds was used because it was determined that enough context of the driving environment could be effectively evaluated using a 30-second window.

2. When it was not possible to place the baseline to maximize vehicle-movement time, baselines were included where the vehicle was in stop-and-go traffic. In these cases, the vehicle may be stationary for a significant portion of the 30 s.
3. An additional limitation is that the GPS criterion was blind to the direction of travel. This means that the GPS Match baselines may capture the participant driving in the opposite direction of the same roadway or on a cross-road (in the case of intersections), rather than in the direction the participant was driving at the time of the event. Note that traffic conditions and driving task complexity can vary depending on these factors. Also, for intersections, the driver's turn intent (straight, left, or right) may be different for the baselines than it was for the event, which can also impact the complexity of the driving task.

Junction Match. Once all possible GPS matches were found, the events that still did not have 15 baselines identified were included in the Junction Match search. The Junction Match criteria required that the end of the baseline epoch be at the same type of junction as the corresponding event and that the vehicle be moving for the majority of the 30-second interval, if possible. The Junction descriptors used in this reduction process are as follows:

- Non-junction: Does not meet any of the criteria, as specified below.
- Intersection: The vehicle is in or is within 1 car length of an intersection.
- Intersection-related: The vehicle is within 2-3 car lengths of an intersection, regardless of turn lanes, queues, etc., that may extend farther than this.
- Exit/entrance Ramp: The vehicle is on an entrance or exit ramp that is physically separated from a main road by a barrier or grass strip.
- Interchange Area: The vehicle is on an Interstate or other road where entrance or exit ramps are present. Includes when the vehicle is in an exit or entrance lane that is not yet (or is no longer) separated from the main road by a physical barrier.
- Parking Lot: The vehicle is in or is turning into a parking lot, or the event occurs as a direct result of an interaction with another vehicle turning out of or into a parking lot.
- Driveway, Alley access The vehicle is in, or is turning into, a driveway or alley access, or the event occurs as a direct result of an interaction with another vehicle turning out of or into a driveway or alley access.
- Railroad crossing: The vehicle is on or within 1 car length of a railroad crossing.
- Other: The vehicle is at some other junction type (includes toll booths).

For these baselines, automatic triggering within trip files was not possible. Instead, a list of all possible trip files that met (for at least part of the trip) all of the timing criteria (time of day and day of week) was generated for each event. From that list, every file was reviewed to confirm participant matches and to confirm the quality of the video. Then, the trip file was reviewed (using fast-forwarding video controls) to locate an appropriate junction match if present, and specify the 30-second baseline interval as starting 30 s before the junction match and ending at the junction match. During this Junction Match process, 160,911 time-matched trip files were examined. From this pool, 7,248 baselines across 728 events were identified and included in the analysis.

The biggest challenge for this criterion (in addition to those listed above) was the time required to review the video to locate the appropriate relation to junction match. Initially, the protocol required looking for similar road type (RT) and junction matches (RT & Junction Match), which required baselines to not only end at the same junction type, but to also be on the same road type (number of travel lanes and divided versus undivided) for the majority of the 30-second time period. This manual process required more resources than the project would allow. Therefore, it was decided by project sponsors that matching for junction was the most important part of this process. Baseline identification then sped up by a factor of 5-10, but was still very time-consuming. Within the 7,248 Junction Match baselines located, only 525 baselines across 70 events are actually RT & Junction Match baselines.

Limitations in the analysis of the Junction Match baselines are presented by the subjective nature of Junction definitions and the difficulty of interpreting video consistently. For instance, "intersection-related" is based on an estimate of the number of car lengths. That estimate can vary between and even within individual reductionists, and also with the quality of the video and the angle of the camera. Therefore, there can be some disagreement on whether a particular video frame is Non-junction versus Intersection-related or Intersection-related versus Intersection. In addition, video quality often makes it difficult to distinguish between driveways/alleys/parking lots (coded as non-junction if the participant drives straight past) and side roads (intersections). Also, Interchange Area can be easily confused with Non-junction on large, multi-lane Interstates with heavy traffic. Finally, due to the highly variable traffic situations present in the area where the 100-Car study took place (Northern Virginia & Washington, DC), it is sometimes difficult to place a particular location into one of the Junction categories. For example, intersections often have characteristics of interchange areas and exit/entrance ramps, and undivided roads (e.g., in residential areas of apartment complexes, etc.) often have characteristics of parking lots. All of these challenges need to be taken into consideration when interpreting the Junction Match and RT & Junction Match reduced data.

Case-Crossover Baseline Reduction

Once baseline events were identified, the data reduction step began. Data reduction consisted of three steps: scenario reduction, secondary task reduction, and eyeglance analysis. These steps are described below.

Scenario Reduction and Secondary Task Reduction. A scenario reduction and secondary task reduction was performed for all identified baselines. In addition, since the original 100-Car Study only included the presence of distraction for approximately a 6-second time period (5 s before event start through 1 s after event end), reductionists also recorded the presence of the secondary tasks on the events during this reduction in order to have a comparable 30-second time period for the analysis.

In the scenario reduction, the same environmental, roadway, and secondary task engagement questions were recorded for the case-crossover baseline as were recorded for both the event and case-control baseline databases. Trained reductionists were able to complete events at the rate of approximately 6-8 per hour, and all reductionists spent time each week conducting and recording spot checks on completed events. All disagreements were reviewed by a senior reductionist or the data reduction manager. At completion, 32 percent of all events had been spot-checked. Before the data were considered complete, they went through an additional data verification step that checked data for internal consistency.

Eyeglance analysis. Where possible, an eyeglance analysis was performed for all case-crossover baseline epochs. If the eyeglance reductionists were not confident in their ability to accurately complete eyeglance reduction (e.g., due to dark sunglasses, poor camera alignment, or poor driver posture), eyeglance analysis was not performed for a particular event. Eyeglance analyses followed the standard protocol developed by VTTI for other projects. In this protocol, eyeglance analysis is performed at half speed or below and transitions are coded to the first glance location until the eyes are fixated on the new location.

The glance locations, operational definitions, and training procedures were the same as were used for the event reduction. Please refer to the event reduction section for complete details. For a comparison of the types of data that were reduced for the three databases, please refer to Table 7.

Table 7. Description of the Data Reduced for the Event, Case-control, and Case-crossover Databases

100-Car Event Database	Case-Control Database (baseline epochs)	Case-Crossover (baseline epochs)
Vehicle variables	Vehicle variables	Vehicle variables
Event variables	N/A	N/A
Environmental Variables	Environmental Variables	Environmental Variables
Driver-state Variables	Driver-state Variables	Driver-state Variables
Eyeglance data (crashes, near-crashes, and incidents)	Eyeglance data on 5,000 randomly selected baseline epochs.	Eyeglance data on all 10,007 baseline epochs.
Observer Rating of Drowsiness (ORD) for Crashes and Near-crashes	Drowsiness was marked yes/no with 'yes' = ORD of 60 or above.	Drowsiness was marked yes/no with 'yes' = ORD of 60 or above.
Driver/Vehicle 2	N/A	N/A
Narrative	N/A	N/A
Secondary Task Reduction (frame by frame over 30-second period)	N/A	Secondary Task Reduction (frame by frame over 30-second period)

Data Reduction Training and Inter- and Intra-Rater Reliability

Training procedures were implemented to improve both inter- and intra-rater reliability, given that data reductionists were asked to perform subjective judgments on the video and driving data. Reliability testing was then conducted to measure the resulting inter- and intra-rater reliability.

Most reductionists assigned to this project were taken from a large pool of staff reductionists. Training included discussions on the proper treatment of human participant video data (and signed confidentiality/non-disclosure agreements), a demonstration of how to access the data from the server, and hands-on training in how to operate the data reduction software. Next, reductionists were provided with a data reduction manual which provided steps in operating the software, background about the study, and a detailed description of the steps to take in analyzing each event. Examples were demonstrated by the data reduction manager or project manager, and then reductionists spent at least one full 4-hour work shift working with another more experienced reductionist. The orientation and training sessions combined took approximately 8 hours.

After formal training, reductionists practiced on their own under the observation of the data reduction manager and the senior reductionist. Questions were encouraged throughout the study, not just during training. All events reduced by new reductionists were subject to a 100-percent review by the senior reductionist. Any errors were documented, and the reductionist was required to go back to review those events and make the corrections. These 100-percent reviews were repeated until a reductionist's error rate dropped below 10 percent. This often took a week or more of 4-hour shifts to reach this level of reliability for the secondary task analysis. At this point, reductionists began working independently with regular "spot-check" monitoring and supervision from the reduction manager and senior reductionist.

Spot-check monitoring started as soon as reductionists began working independently, and started with an approximately 25-percent review (1 hour per day per reductionist) and was reduced to approximately 10 percent (1 hour twice per week per reductionist) as competence was gained. Each reductionist participated in the spot-check process by reviewing files completed by other reductionists and recording their agreement or disagreement with each question. Any disagreements were then reviewed by the data reduction manager or the senior reductionist as a third reviewer, and necessary corrections were made. The entire process for ensuring quality and reliability in the data reduction process is shown in Figure 9.

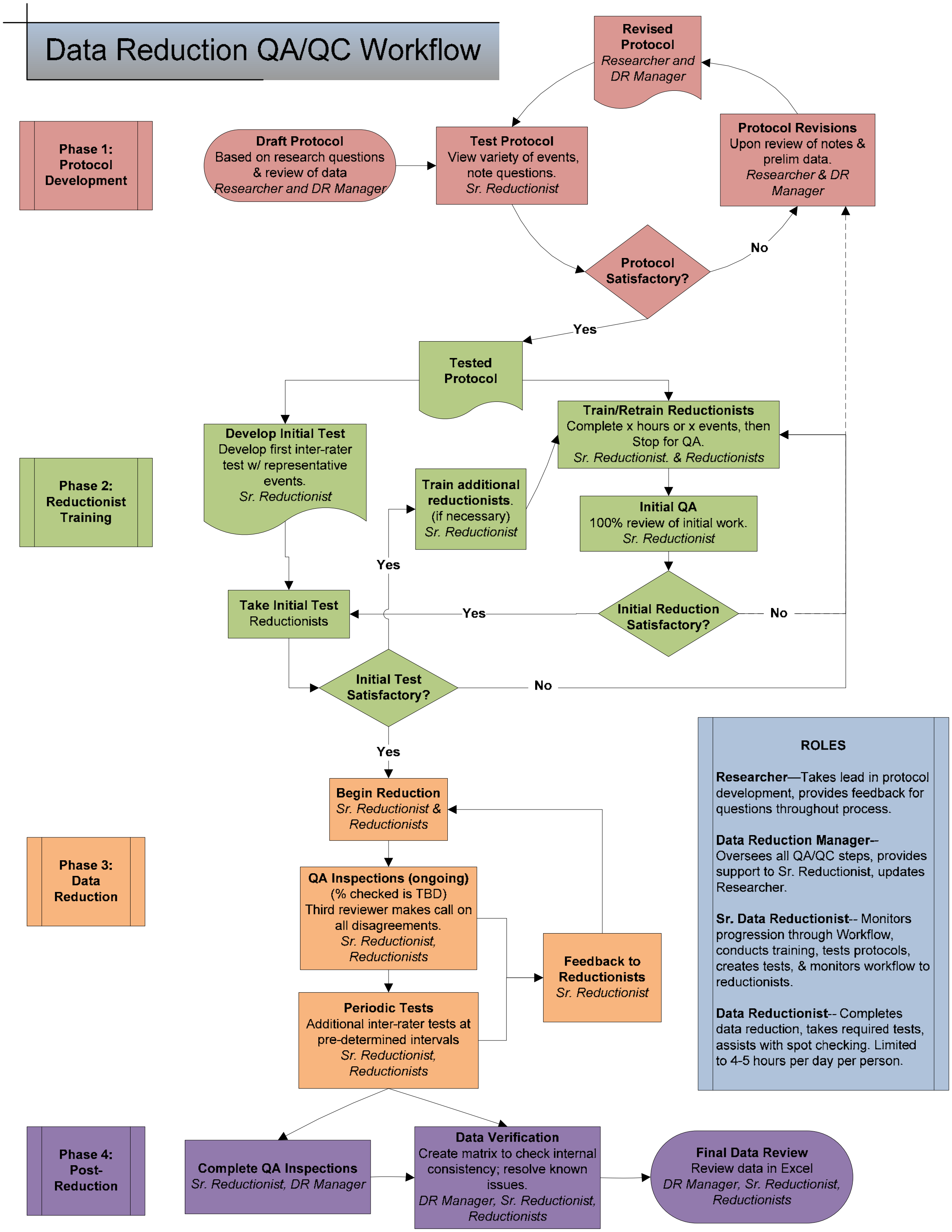

Figure 9. The Quality Assurance and Quality Control Flow Chart for Data Reduction at VTTI

Comparison of Case-Control and Case-Crossover Databases

Given that the ORs using these two separate databases will be compared in the following sections, it is important to present descriptive statistics regarding the two databases, as shown in Table 8. Note that the case-control database is larger; however, the size of the database is irrelevant. The calculations conducted are essentially ratios and, therefore, are not dependent upon the number of observations in each database.

Table 8. Descriptive Statistics for the Two Baseline Databases

	Case-Control Database	Case-Crossover Database
Number of Baseline Epochs	19,645	10,008
Number of Participants	293	142
Number of Primary Drivers	101	96
Hours of Video Reduced	32.7 hours	83.4 hours

Recall that the case-crossover database was matched to the crashes and near-crashes based upon GPS location and/or relation to junction. The matching task likely altered or biased the case-crossover data set toward various road types and to junctions. To assess the environmental differences between these two databases, a comparison of the percentage of epochs from each baseline database for each of the environmental variables was conducted. The environmental variables assessed were:

- Weather
- Traffic density
- Relation to Junction
- Number of Travel Lanes
- Lighting
- Alignment
- Traffic Flow

The analyses that demonstrated a greater than 10 percent difference in the data are presented in graphic form below. Figure 10 shows the differences in the percentage of epochs at various levels of traffic density. The case-crossover database has a higher percentage of baseline epochs at the traffic density level of 'flow with restrictions' whereas the case-control database has a higher percentage of baseline epochs at the traffic density level of 'free flow.' The relative percentages for the rest of the traffic densities are nearly identical between the two baseline databases. This difference suggests that more traffic is present in the case-crossover database than in the case-control database. This could also further support the idea that more crashes and near-crashes occur in higher traffic densities than at lower traffic densities.

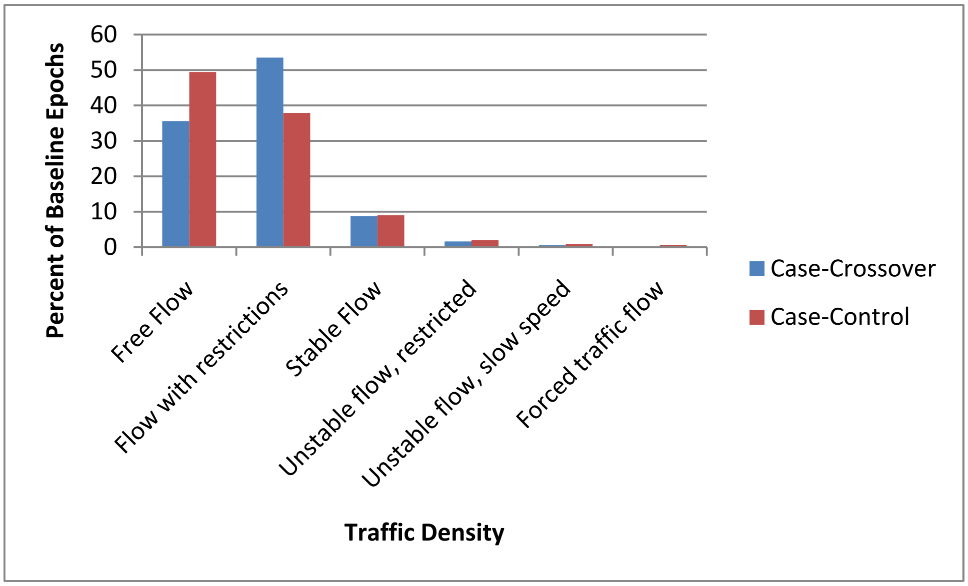

Figure 10. The Percentage of Baseline Epochs at Each Level of Traffic Density

Differences were also identified in the number of travel lanes present in the case-crossover baseline versus the case-control baseline (Figure 11). The case-crossover baseline has more epochs with four travel lanes compared to the case control, whereas the case-control baseline has more epochs with two travel lanes. This result is most likely highly correlated with the differences in traffic density and relation to junction discussed below.

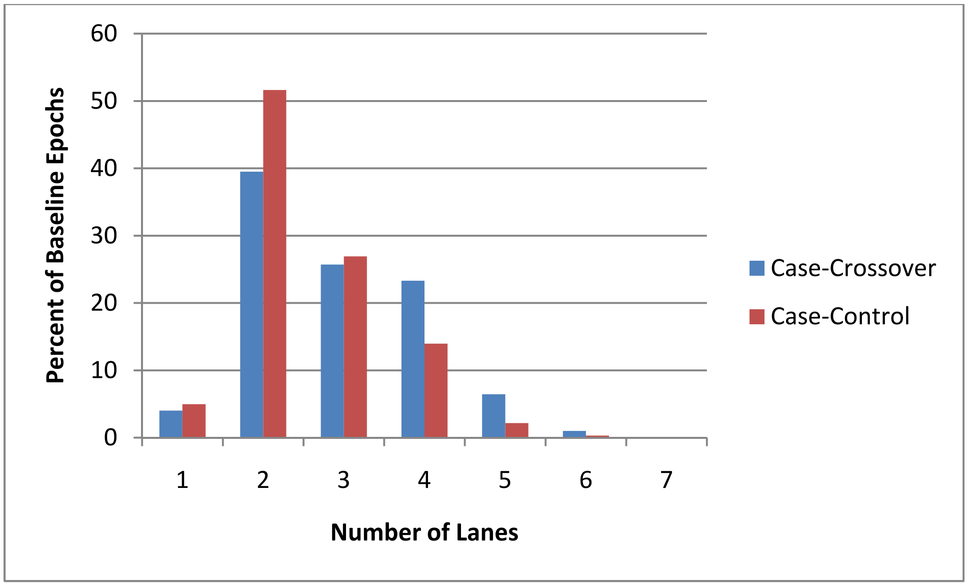

Figure 11. The Percentage of Baseline Epochs Given the Number of Travel Lanes

The third and final environmental variable was the relation to junction variable. Given that this variable was specifically used to match the case-crossover baseline epochs, these differences are not surprising. Regardless, Figure 12 shows that there are more non-junction baseline epochs in the case-control database and more intersection, intersection-related, and interchange epochs in the case-crossover database. More crashes occur in intersections than in other roadway locations and therefore more of the case-crossover baseline epochs were also selected from these areas during the matching process. This indicates that the case-crossover approach more closely matched the situations of the initial triggering event or incident (same time of day, location, etc.), while the case-control approach selected random situations that may or may not have been similar to the driving environment.

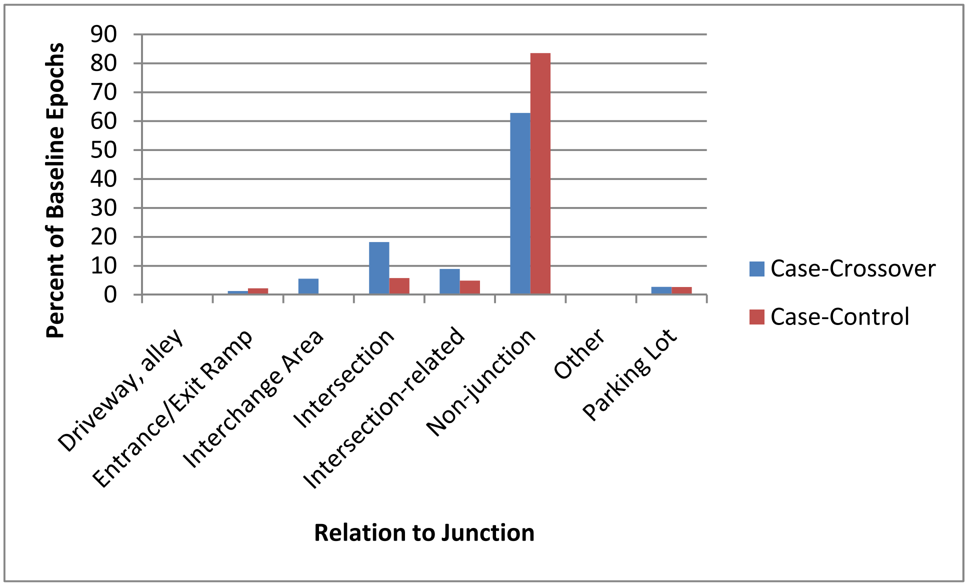

Figure 12. The Percentage of Baseline Epochs Given the Interchange Type

To summarize, the case-crossover and the case-control databases differ in that a greater frequency of intersections and interchanges, number of travel lanes, and higher traffic densities occur with the case-crossover database than with the case-control database. These two baselines do not differ on weather, lighting, roadway alignment, or traffic flow variables. The number of participants represented in the case-control database is nearly twice as many as are represented in the case-crossover database; however, the number of primary drivers are similar for each database. Also, nearly twice as many hours of video were reduced for the case-crossover baseline as were reduced for the case-control. The actual size (number of epochs) of the sample for each database should not affect the risk calculations since the calculations are ratios and thus the frequency counts affect the numerator and denominator equally.

CHAPTER 3. RESULTS FOR TASK 1

There were two primary research objectives for the Task 1 analyses:

- Recalculate relative risks for driver inattention and drowsiness for crashes and near-crashes using the new case-crossover baseline sample.
- Recalculate the relative near-crash/crash risk for total TEOR. Assess the impact of total TEOR on driving performance.

As part of the re-calculation of ORs for driver inattention, drowsiness, and total TEOR, the method and the calculations using the case-crossover baseline were compared to the previous method and calculations using a case-control baseline. These two calculations were conducted using completely different baseline samples and different methods of calculating ORs. The first method used a case-control baseline and the ORs were calculated using crude ORs. The method presented in this report used a case-crossover baseline and the ORs were calculated using conditional logistic regression and adjusted for the matching factors, as described in the Method section. It is important to note that any difference between these two calculations should not be considered qualitatively better or worse. The comparisons that will be discussed will be limited to the relative comparisons among all of the ORs calculated and the benefits and limitations of the method used to obtain these results.

Assessment of Risk

In this section, the associations between crashes and near-crashes and the presence of secondary task engagement, drowsiness, or total TEOR were quantitatively evaluated as observed via video. For this analysis, 790 (of the 830 total) crashes and near-crashes, as well as 9,984 baseline epochs, were used in the assessment of risk. Note that near-crashes were included in the assessment of risk based on an analysis conducted by Dingus et al. (2006) that demonstrated that crashes and near-crashes had similar kinematic properties.

Definition of an Odds Ratio Calculation. A commonly used measure of the likelihood of event occurrence is termed as the *odds*. The odds measure the frequency of event occurrence (i.e., presence of inattention type) to the frequency of event non-occurrence (i.e., absence of inattention type). That is, the *odds of event occurrence* is defined as the probability of event occurrence divided by the probability of non-occurrence. The 2x2 contingency table in Table 9 will be used to illustrate this and related measures.

Table 9. An Example of a 2x2 Contingency Table that Would Be Used to Calculate the Inattention-Type Odds Ratio

	Inattention Present	Inattention Not Present (Driver Alert)	
Reduced Event	n_{11}	n_{12}	$n_{1.}$
Baseline Epoch	n_{21}	n_{22}	$n_{2.}$
	$n_{.1}$	$n_{.2}$	$n_{..}$

Where:

n_{11} = the number of crash/near-crash events where <inattention> was present

n_{12} = the number of crash/near-crash events where <alert driver> was present

n_{21} = the number of baseline epochs where <inattention> was present

n_{22} = the number of baseline epochs where <alert driver> was present

If the probability of success (inattention present) for the first row of the table is denoted by $\pi_1 = n_{11}/n_{1.}$ and the probability of failure (inattention not present) is defined as $(1 - \pi_1) = n_{12}/n_{1.}$, then the odds of success is defined as $\pi_1/(1-\pi_1) = n_{11}/n_{12}$. The odds of success for the second row are defined similarly with the corresponding success probability, π_2.

The ratio of the odds is a commonly employed measure of association between the presence of cases (crash and near-crash events) and the controls (baseline driving epochs). ORs are used as an approximation of relative near-crash/crash risk in both matched and unmatched control designs. This approximation is necessary due to the separate sampling employed for the events and baselines and is valid for evaluations of rare events (Greenberg, Daniels, Flanders, Eley, & Boring, 2001). Referring to Table 9, the OR would be defined as:

$$\theta = \frac{\pi_1 / (1-\pi_1)}{\pi_2 / (1-\pi_2)} = \frac{\frac{n_{11}}{n_{12}}}{\frac{n_{21}}{n_{22}}} = \frac{n_{11} n_{22}}{n_{12} n_{21}} \qquad \textit{Equation 1}$$

and is a comparison of the odds of success in row 1 versus the odds of success in row 2 of the table. The odds ratio calculation from the above formula is the crude odds ratio and assumes the observations are independent, which is not true for case-crossover design. Furthermore, crude OR is not adjusted for other factors. A more rigorous analysis based on conditional logistic regression was used instead.

In interpreting ORs, a value of 1.0 indicates no significant danger above normal, baseline driving. An OR of less than 1.0 indicates that this activity is safer than normal, baseline driving or that it creates a protective effect. An OR of greater than 1.0 indicates that this activity increases one's relative risk of a crash or near-crash by the value of the OR. For example, if *inattention* obtained an OR of 4.0, then this indicates that a driver is four times more likely to be involved in a crash or near-crash when traveling while inattentive than if he or she was driving while alert.

MODEL DESCRIPTION

A conditional logistic regression model was used to calculate the ORs for drowsiness and for simple, moderate, and complex secondary task engagement. As discussed in the Method section, the design of the case-crossover approach ensures that there will be one case and several baselines within each matched case-baseline set. Furthermore, there are similarities between the cases and baselines because they share the same values for matching factors (such as driver, time of day, and type of weekday). The conditional logistic regression can incorporate these correlations by modeling the probability of crash/near-crash occurrence in that there will be only one crash/near-crash per matched set. The model has the following format.

Let p_{ij} be the probability of crash/near-crash for *jth* observation in *ith* matched set.

Define $Y_{ij} = \begin{cases} 1 if the jth observation in ith matched set is a accident. \\ 0 if the jth observation in ith matched set is a baseline. \end{cases}$

The matched sampling mechanism leads to:

$$\sum_j Y_{ij} = 1$$

Let p_{ij} be the probability of crash/near-crash for *jth* observation in *ith* matched set. The conditional logistic regression model assumes

$$\text{logit}(p_{ij}) = \alpha_i + \beta * \text{X}_{ij}$$

where X_{ij} is the status of the risk factor for the *jth* observation in the *ith* matched set. For example, for drowsiness the X is defined as,

$$X_{ij} = \begin{cases} 1 \text{ if drowsiness was presented in the jth observation in ith matched set} \\ 0 \text{ Otherwise} \end{cases}$$

In this model exp (β) is the estimated OR for drowsiness. The α_i is a term associated with match set i and its value influences the risk of set i. The value of α_i is not of interest for this study. A conditional maximum likelihood estimation method was used to estimate the β without estimating the α_i.

Question 1. Recalculate relative risks for driver inattention and drowsiness for crashes and near-crashes using the new case-crossover baseline sample.

The OR for driver drowsiness using this model was 38.7 (CI 26.4, 56.8). This result is much higher than the original calculation, which was 4.24 (CI 3.3, 5.5). There are several reasons for this larger OR. First, as presented in the Method section, the case-crossover baseline epochs were selected in higher traffic densities, a higher number of lanes, and closer to intersections than the case-control baseline epochs. These are all locations and scenarios where Klauer et al. (2006) found that drowsiness occurs less frequently. Thus, the frequency of identifying extreme drowsiness behaviors in the case-crossover baseline epochs was eight times lower than for the case-control epochs. Specifically, 0.5 percent of all case-crossover baseline epochs contained drowsiness whereas 4 percent of case-control baseline epochs contained drowsiness. Similarly, the differences between the two ORs also reflect a difference by nearly a factor of 8, which mirrors the differences in the baselines.

For secondary task engagement analysis, secondary tasks were separated by complexity using Dingus, Antin, Hulse, & Wierwille (1992) classifications, as shown in Table 10. Based upon this study, simple secondary tasks are those tasks that require, at most, one button press or eyeglance away from the forward roadway. A moderate secondary task required one to two button presses and/or eyeglances away from the forward roadway. Complex secondary tasks required more than two button presses and/or eyeglances away from the forward roadway.

Table 10. Assignment of Secondary Tasks into Three Levels of Manual/Visual Complexity

Simple Secondary Tasks	Moderate Secondary Tasks	Complex Secondary Tasks
1. Adjusting radio	1. Talking/Listening to Hand-Held Device	1. Dialing a hand-held device
2. Adjusting other devices integral to the vehicle	2. Hand-Held Device-Other	2. Locating/Reaching/ Answering Hand-Held Device
3. Talking to passenger in adjacent seat	3. Inserting/Retrieving CD	3. Operating a PDA
4. Talking/Singing: No passenger present	4. Inserting/Retrieving cassette	4. Viewing a PDA
5. Drinking	5. Reaching for object (not hand-held device)	5. Reading
6. Smoking	6. Combing or fixing hair	6. Animal/Object in Vehicle
7. Lost in Thought	7. Other personal hygiene	7. Reaching for a moving object

8. Other	8. Eating	8. Insect in Vehicle
	9. Looking at external object	9. Applying Makeup

Odds ratio calculation comparing one level of secondary task engagement to no secondary task engagement. These ORs were also calculated using a conditional logistic regression similar to the model described for the drowsiness ORs.

$$\text{logit}\left(p_{ij} \middle| \sum_j Y_{ij} = 1\right) = \beta_1 * inattentaion_{ij} + \beta_2 * drowsy_{ij},$$

where $inattention_{ij}$ and $drowsy_{ij}$ are the inattention and drowsiness status for *jth* observation in *ith* matched set. In this model exp (β_1) is the estimated OR for inattention and exp (β_2) is the estimated OR for drowsiness. By putting both variables in the same model, the OR for inattention is adjusted for the effects of drowsiness.

Using these classifications, two separate calculations were conducted. These two calculations were conducted to both demonstrate what differences, if any, exist when the calculations are conducted using slightly different denominators for the odds ratio. When calculating ORs, defining the denominator is complex and it is the authors hope that this report should serve as a guide for future researchers for calculating ORs.

The first calculation compared simple secondary task engagement to no secondary task engagement, moderate secondary task engagement to no secondary task engagement, and complex secondary task engagement to no secondary task engagement. Thus, those events where the driver is engaging in any other secondary task, other than those included in the analysis, were removed from the analysis.

In the second calculation, the comparison was modified to maintain all of the crashes and near-crashes in the OR calculation. As shown in Table 11, complex secondary tasks (blue box) were compared to engagement in all other secondary task types plus no secondary task (green boxes).

Table 11. Odds Ratios where Complex Tasks are Compared to all other Tasks Plus No Distraction

Complex (or in combination with other) Secondary Task
Moderate Secondary Task
Simple Secondary Task
No distraction

The moderate or complex secondary task OR was calculated comparing those tasks where the driver was engaging in a moderate or complex secondary task (either alone or in combination) versus all other secondary tasks plus no secondary task (as shown in Table 12).

Table 12. Odds Ratios where Complex and Moderate Tasks are Compared to Simple Tasks Plus No Distraction

Complex Secondary Task
Moderate Secondary Task (or in combination with other)
Simple Secondary Task
No distraction

Finally, all secondary task ORs were calculated comparing those tasks where the driver engaging in any secondary task (either alone or in combination) with no secondary tasks (as shown in Table 13).

Table 13. Odds Ratios where Complex, Moderate and Simple Tasks are Compared to all other Tasks Plus No Distraction

Complex Secondary Task
Moderate Secondary Task
Simple Secondary Task (or in combination with other)
No distraction

The odds ratio can be interpreted as the relative risk of engaging in more severe distraction versus less severe distraction. The benefit to calculating the OR in this manner is that the number of observations remains equivalent across all four OR calculations and will increase statistical power due to the increased numbers in the analysis. Please note that frequency counts for secondary task engagement were only calculated on the last 6 s of each baseline epoch and compared to the original event database (5 s prior to the onset of the conflict and 1 s past the onset of the conflict for all crashes and near-crashes).

Odds ratio calculation comparing one level of secondary task engagement to no secondary task engagement. These ORs were also calculated using a conditional logistic regression similar to the model described for the drowsiness ORs. The results of this case-crossover analysis and the case–control analysis are shown in Table 14. The OR point estimates for simple, moderate, and complex secondary tasks are generally lower for the case-crossover than for the case-control calculations. However, the relationship among the three levels of secondary task engagement remain similar in that complex and moderate tasks increase crash/near-crash risk whereas simple secondary tasks do not significantly increase crash/near-crash risk.

Table 14. Odds Ratios for Secondary Task Engagement versus No Secondary Task Engagement

Distraction	Case Cross-over Odds Ratio	95% Odds Ratio Confidence Limits		Case-Control Odds Ratios	95% Odds Ratio Confidence Limits	
Simple	0.8	0.62	1.05	1.2	0.88	1.57
Moderate	**1.3**	**1.00**	**1.70**	**2.1**	**1.62**	**2.72**
Complex	**2.1**	**1.19**	**3.58**	**3.1**	**1.72**	**5.47**

*Odds ratios were calculated using only the crashes and near-crashes where the driver was deemed to be at fault or partially at fault.

Odds ratio calculation comparing more severe secondary task engagement to less severe tasks plus no secondary task engagement. A conditional logistic regression was also used to calculate these ORs. The results are presented in Table 15. Note that this calculation is similar, with the notable exception that each of the point estimates for the ORs are slightly higher in this calculation than in the first calculation using the case-crossover database. As with the first calculations, these ratios are also lower than the calculation using the case-control database. However, the moderate and complex secondary tasks are shown to significantly increase crash/near-crash risk in both the case-control and case-crossover calculations. Simple secondary task engagement does not significantly increase crash/near-crash risk. The frequency counts for these analyses are listed in Appendix C.

Table 15. Odds Ratios for Secondary Task Engagement by Comparing Secondary Task Engagement to Less-Severe Secondary Task Engagement Plus No Secondary Task Engagement

Exposure	Non-Exposure	Case Cross-over Odds Ratio	95% Odds Ratio Confidence Limits	
Simple/Moderate/Complex	**No distraction present**	1.1	0.86	1.30
Moderate/complex	**Simple + No distraction present**	**1.4**	**1.1**	**1.7**
Complex	**Moderate/Simple + No distraction present**	**2.3**	**1.3**	**3.1**

*Odds ratios were calculated using only the crashes and near-crashes where the driver was deemed to be at fault or partially at fault.

Question 2. Recalculate the relative near-crash/crash risk for total time eyes off forward roadway (TEOR) and compare to the relative risk calculations conducted previously using a case-control approach. Does total TEOR significantly impact driving performance?

The effects of total TEOR were evaluated by comparing observations with longer total TEOR with the observations with shorter total TEOR. For a given critical value $t*$, the observations can be divided into the following contingency table and the calculation of OR will be similar to that of the secondary task. By varying the critical value $t*$, the corresponding contingency table can be generated for risk assessment (Table 16).

Table 16. An Example of a 2x2 Contingency Table for Threshold Value $t*$

	EOR>t*	EOR<t*	
Reduced Event	n_{11}	n_{12}	$n_{1.}$
Baseline Epoch	n_{21}	n_{22}	$n_{2.}$
	$n_{.1}$	$n_{.2}$	$n_{..}$

A conditional logistic regression was also used to calculate the ORs for total TEOR. The previous analysis only had eyeglance data for 6 s for each case-control baseline; therefore, the ORs were calculated using a 6-second time period for comparison purposes. An additional analysis was calculated for 15 s, given that more eyeglance data were now available with the case-crossover database. For the case-crossover analysis (and similarly the case-control analysis), total TEOR is operationally defined as any time that the eyes were not looking at the forward roadway. Thus, total TEOR could include one single glance or the sum of multiple glances away from the forward roadway. As was described previously, these analyses used only those crashes and near-crashes where the driver was deemed to be at fault or partially at fault for the occurrence of the crash/near-crash.

6-second analysis. Using the case-crossover approach, the OR for total TEOR greater than 2 s was 1.6 (CI 1.3, 2.0). This is slightly lower than the OR calculated using the case-control baseline which was 2.1 (CI: 1.7, 2.8). The slightly lower OR result appears to be fairly similar to the driver inattention ORs.

15-second analysis. For the 15-second data analysis, total TEOR time was calculated in increments of 1 s, starting with 2 s and increasing to 12 s. Each OR was calculated with the following comparison groups:

- Greater than 2 s compared to ≤ 2 s
- Greater than 3 s compared to ≤ 3 s
- Greater than 4 s compared to ≤ 4 s
- Greater than 5 s compared to ≤ 5 s

- Greater than 6 s compared to ≤ 6 s
- Greater than 7 s compared to ≤ 7 s
- Greater than 8 s compared to ≤ 8 s
- Greater than 9 s compared to ≤ 9 s
- Greater than 10 s compared to ≤ 10 s
- Greater than 11 s compared to ≤ 11 s
- Greater than 12 s compared to ≤ 12 s

In this analysis, the 15-second interval may include one or more relatively long tasks or one or more short tasks; multiple tasks in this interval may differ from each other in type. Also, the 15-second duration is used primarily because this is a useful human factors metric—given the SAE 15-second rule for task duration—and will provide a useful comparison of how risk increases over this time period as total TEOR increases.

The results in Figure 13 indicate that as total TEOR increased past 3 s or 20 percent of the total time, the ORs also showed statistically significantly increased risk. Note that the error bars in Figure 13 represent the confidence intervals. While previous results showed statistically significant results in total TEOR greater than 2 s out of 6 s, or 30 percent of the time (Klauer, et al., 2006), this comparable analysis shows that as duration of measurement increases, lower percentages of total TEOR indicate a statistically significant increase in crash/near-crash risk.

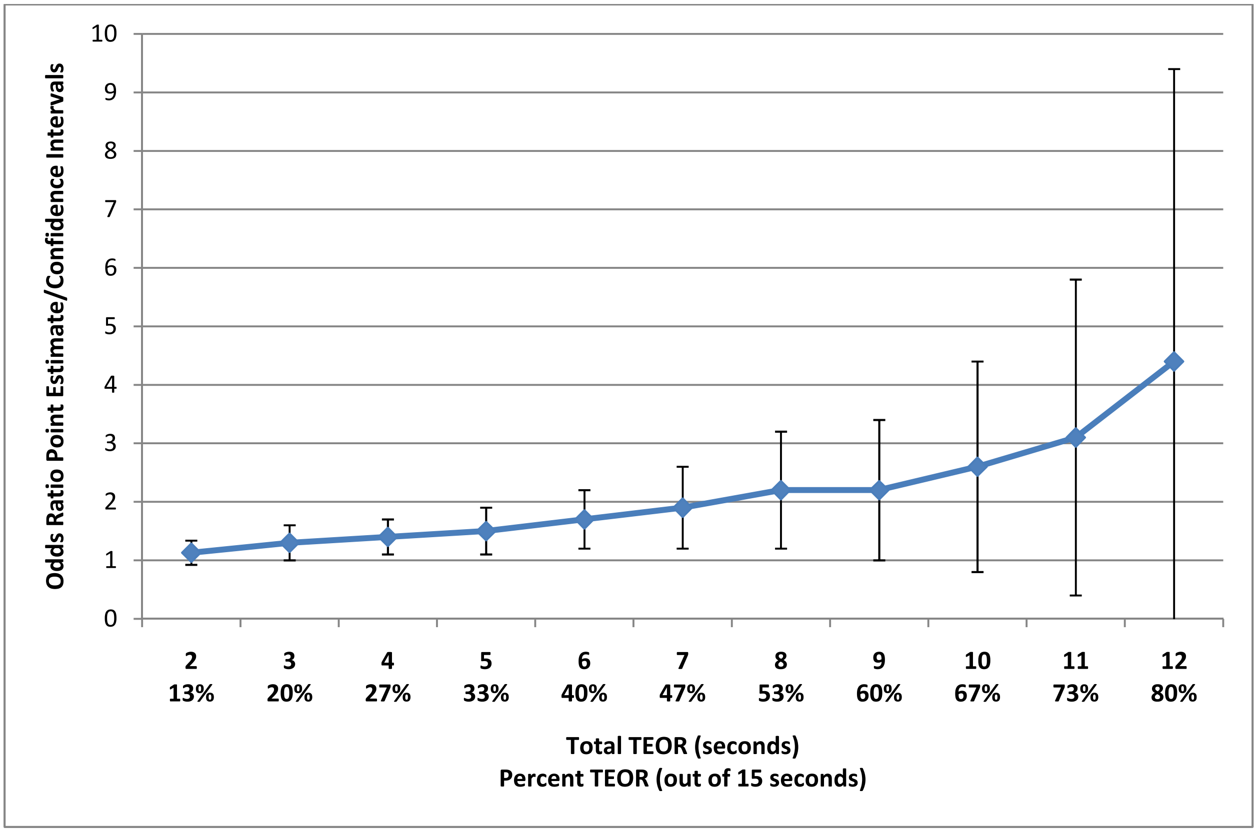

Figure 13. The Odds Ratios for the Total Time Eyes off the Forward Roadway using the At-Fault and Partial-Fault Crashes and Near-Crashes

CHAPTER 4. RESULTS FOR TASK 2

Statistical analyses were conducted using the SAS Statistical Software Package (v 9.2 for Windows). A *p* value of 0.05 was considered to indicate significance. For the following analyses, the case-crossover baseline database was used to characterize the driver's secondary task engagement (duration, frequency, and total TEOR) and cell phone use. Total TEOR is operationally defined as any glance in which the driver's eyes are not looking forward. Any glances at mirrors, the instrument panel, passengers, or other objects are all considered 'off the forward roadway.'

A conditional logistic regression model was used to calculate the ORs for task duration. Note that only those crashes and near-crashes in which the driver was deemed to be at fault or partially at fault were included in the OR analyses.

Research Question 1. Assessing the impact of Total TEOR on driving performance

An analysis using basic summary measures for driving performance was compared to Percent total TEOR for each baseline epoch to assess whether total TEOR impacts driving performance. The summary measures calculated were mean speed, standard deviation of speed, peak lateral acceleration, peak longitudinal acceleration, and peak yaw rate. The mean, standard deviation, and peak acceleration values were calculated over the entire 30-second epoch, so the average speed or standard deviation of speed over 30 s was calculated as was the peak for that same 30-second time period. The total TEOR was used as an independent variable where the baseline epochs were grouped by total TEOR greater than or equal to 10 s (33 percent of the time) versus less than 10 s (or less than 33 percent of the time). This distinction was made due to the results from Klauer et al. (2006) where it was suggested that total TEOR of 2 s out of 6s (33 percent) increased crash/near-crash risk by 2 times that of drivers with their eyes on the forward roadway. Of the 9,458 baseline epochs with driving performance data, there were 837 epochs (8.8 percent of the total epochs) with total TEOR greater than 33 percent.

T-tests were conducted comparing the epochs with total TEOR greater than 33 percent (TEORGT_33) of the time versus total TEOR less than 33 percent (TEORLT_33) of the time. The Proc GLM (General Linear Model) routine in SAS v 9.1 was used due to its ability to account for unequal cell sizes. Significant differences were found for mean speed, with mean travel speed being significantly lower for the TEORGT_33 (M = 30.03 MPH) group versus the TEORLT_33 (M = 38.01 MPH) group ($T(9432) = 162.68$, $p < 0.0001$). While this result may suggest that drivers opt to engage in secondary tasks only when they are traveling at slower speeds, results from controlled experiments in simulators and on test tracks suggest otherwise. Controlled studies have repeatedly found that drivers reduce their speeds when they choose to engage in secondary tasks, perhaps to compensate for reduced attention to the forward roadway (Caird, Willness, Steel, & Scialfa, 2008; Hancock, Lesch, & Simmons, 2003; and Lee, Caven, Haake, & Brown, 2001). This result appears to support the controlled studies in that the drivers in this study may also have compensated for reduced attention by slowing their vehicle speed in real-world situations. However, without knowing the speed limits or the exact traffic conditions, nor the driver's state of mind, researchers cannot ever be entirely sure of motivations.

T-tests indicated that the standard deviations of speed were also significantly different between the two groups (t (9432) = 24.98, p <0.0001). The speed deviations were significantly greater for those epochs with TEORGT_33 (M = 6.07) versus those with TEORLT_33 (M = 5.30). Therefore, when drivers were looking away from the forward roadway more than 33 percent of the time, their speeds decreased and speed deviations increased compared to those drivers who were not looking away from the forward roadway more than 33 percent of the time.

Peak longitudinal decelerations were also higher for the baseline epochs where TEORGT_33 (t (9432) = 51.22, p <0.0001). Drivers who looked away more than 33 percent of the time had significantly higher average peak decelerations (M = 0.21 *g*) compared to those drivers who looked away from the forward roadway less than 33 percent of the time (M = 0.19 g). While the *g*-force levels are not dramatically different, these represent the mean peak decelerations of baseline driving epochs where no safety-related event (i.e., crash/near-crash) occurred. Thus, these are representative of normal, baseline driving and yet were statistically significantly different. In comparison, the peak lateral accelerations between the TEORGT_33 compared to the TEORLT_33 were not significantly different. Thus, it could be argued that total TEOR time may increase risk due to the fact that it has greater impact on drivers' ability to stop or brake appropriately than it does on maintaining lateral control of the vehicle. This result provides further support for the earlier finding by Dingus et al. (2006) where 93 percent of all rear-end collisions involved the driver looking away from the forward roadway at least once in the 6 s prior to the collision.

The t-test using peak yaw rate (i.e., swerve) also yielded significant differences between the drivers who looked away from the forward roadway greater than or equal to 33 percent of the time versus less than 33 percent of the time (t (9432) = 21.41, p <0.0001). The TEORGT_33 (M = 9.06 degrees/s) group had significantly larger mean yaw rates than the TEORLT_33 (M = 7.62 degrees/se) group. This suggests that those drivers who are looking away also have a higher propensity to swerve sharper and faster than the drivers who look away from the forward roadway less than 33 percent of the time. While swerving may be related to lateral control of the vehicle, it may also be more directly related to avoiding obstacles that the driver missed because of the lower percentage of time that eyes were looking forward. While this may be correlated to lateral control, the lack of significant results in the lateral acceleration data suggests otherwise.

Research Question 2. Characterize the frequency and duration of various task types. Determine the importance of total TEOR in relation to task duration. Calculate relative risk for task duration.

The duration and frequency of each recorded secondary task in the case-crossover baseline database are presented in Figures 14 and 15 in ascending order of task duration. The operational definitions for most of these tasks are defined as less than 30 s (e.g., eating a sandwich required either taking a bite or chewing, not just holding the sandwich; passenger in vehicle required that the driver was visibly interacting with passenger and does not include simply listening to the passenger).

The top three longest task durations were interacting with a pet, smoking, and cell phone: talking/listening. Twenty-five of the 41 tasks had a mean duration of less than 10 s, 9 tasks had a mean duration between 10 s and 20 s, and only 7 tasks had a mean duration of greater than 20 s. Note also that not all tasks that were recorded are present in Figures 14 and 15. Those tasks that were observed less than 10 times in the entire baseline sample were excluded from the analyses due to the low frequency counts.

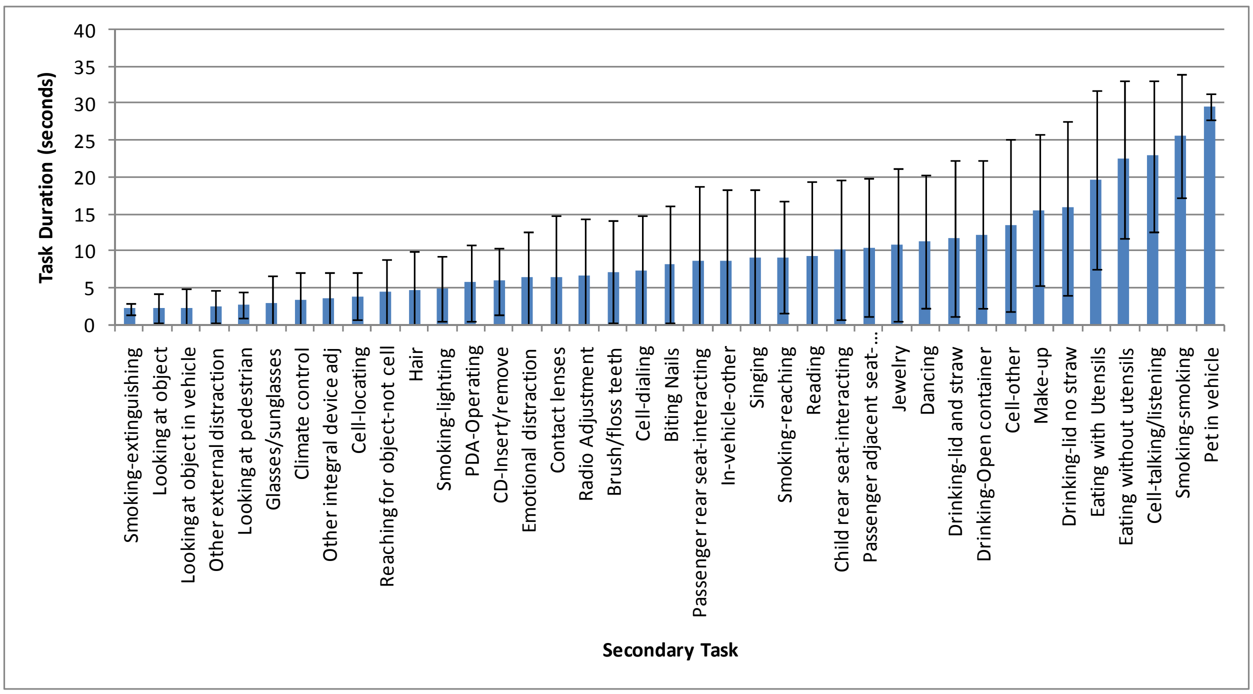

Figure 14. Secondary Task Duration (and Standard Deviation) for Each Secondary Task that was Observed at Least 10 Times in the Case-Crossover Baseline Sample

Figure 15 shows the secondary tasks (x-axis) in an identical order to Figure 14 but presents the frequency of occurrence for each of these tasks. Many of the baseline epochs had multiple secondary tasks present; therefore, the frequencies presented in this figure cannot be summed to equal the number of baseline epochs. Note that low and high frequency of occurrence spans across the short, medium, and long duration tasks. Theoretically speaking, of primary concern would be those tasks that are both frequent and of long duration, which includes talking to passengers and talking on a cell phone. Previous research has shown that the ORs for talking to passengers showed a protective effect whereas the OR for talking on a cell phone showed a slight increase that was not significantly different from 1.0 (Klauer et al., 2006).

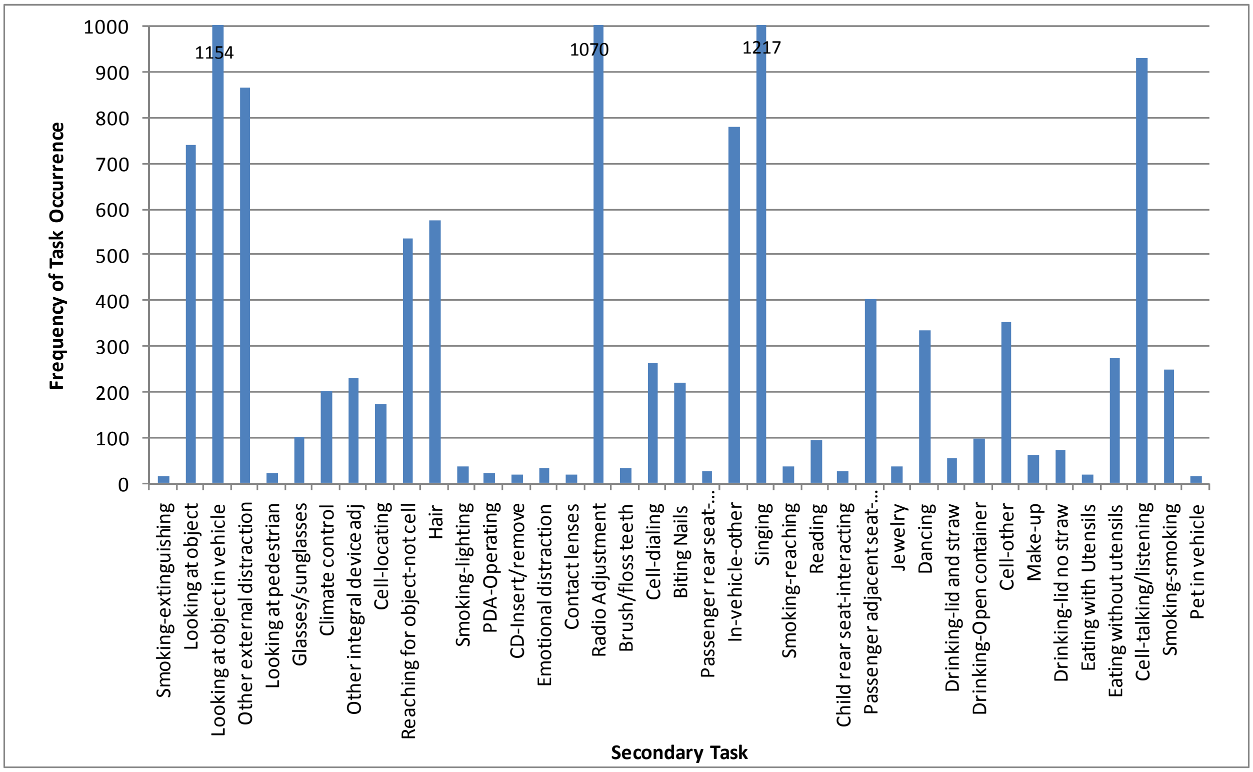

Figure 15. Frequency of Each Secondary Task Being Observed in the Case-Crossover Baseline Sample (Only those Secondary Tasks that were Observed at Least 10 Times)

To determine the visual demand for each task, the percent total TEOR was calculated for each task type and presented in Figure 16. The order of secondary tasks has been maintained for easy comparison to the figures presenting task duration and frequency. Note that there are six tasks that require total TEOR for greater than 50 percent of the task duration time. These are dialing a cell phone, lighting a cigarette, reading, or looking at objects (either in or outside of the vehicle) and other external distractions. Note that adjusting the radio also has a high visual demand per duration but the duration of this task is quite short. Given that the order of the tasks on the x-axis is based upon task duration, the tasks to the right side of the x-axis that also have high total TEOR percentage (the longer bars) are both long in duration and also require the longest total

TEOR. These tasks are pet in vehicle, applying makeup, dialing a cell phone, and reading. These tasks were also found to have a higher associated risk in Klauer et al. (2006).

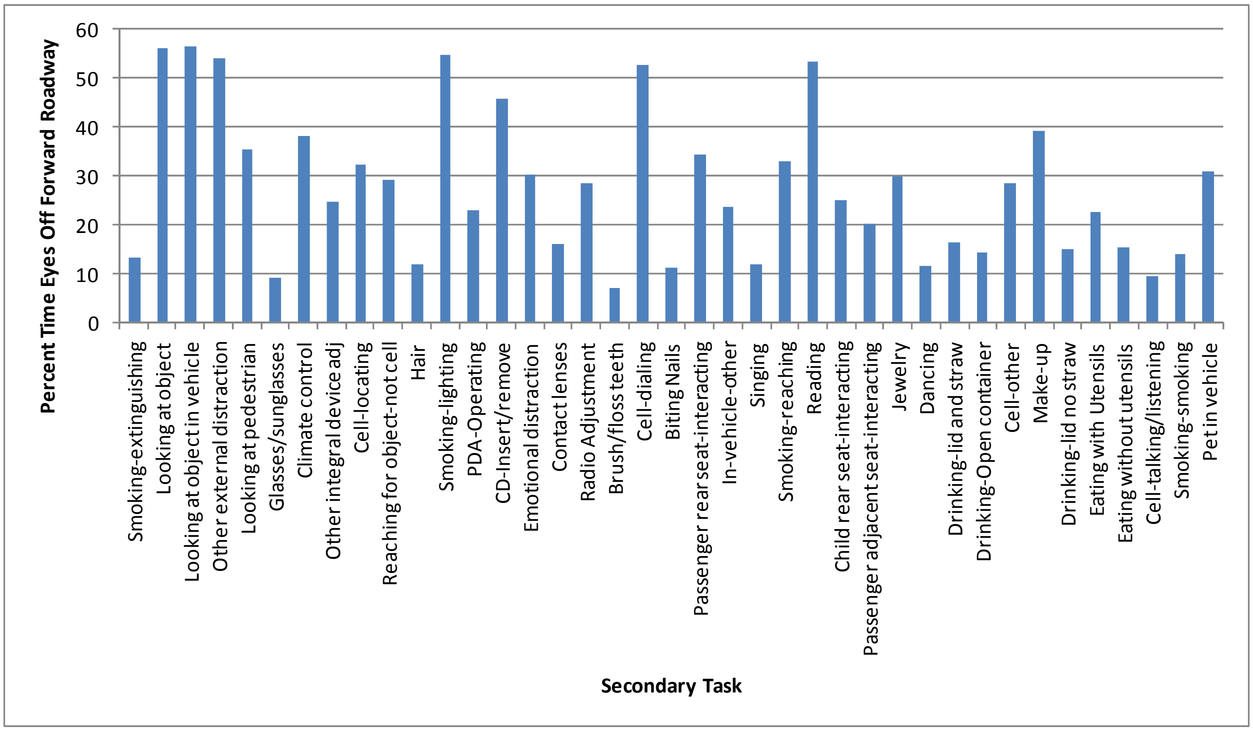

Figure 16. The Relative Visual Demand of Each Secondary Task as Calculated by the Percent Total TEOR

To further understand the relationship between the task duration and total TEOR, total TEOR was calculated for the duration of each task. Total TEOR is also operationally defined as any glance in which the driver's eyes are not looking forward (e.g., mirror glances were considered 'off-road'). The mean task durations and corresponding total TEOR are presented in a scatter plot in Figure 17. Note that while there is some scatter to the data, there is an upward trend indicating that as task duration increases, so does total TEOR. A Pearson Correlation was conducted on these data which indicated a positive R value of 0.49 ($p < 0.0001$). This is a modest effect size in the behavioral sciences and is an important finding given the high degree of variability in the data set (as demonstrated by the large standard deviation bars in Figure 14).

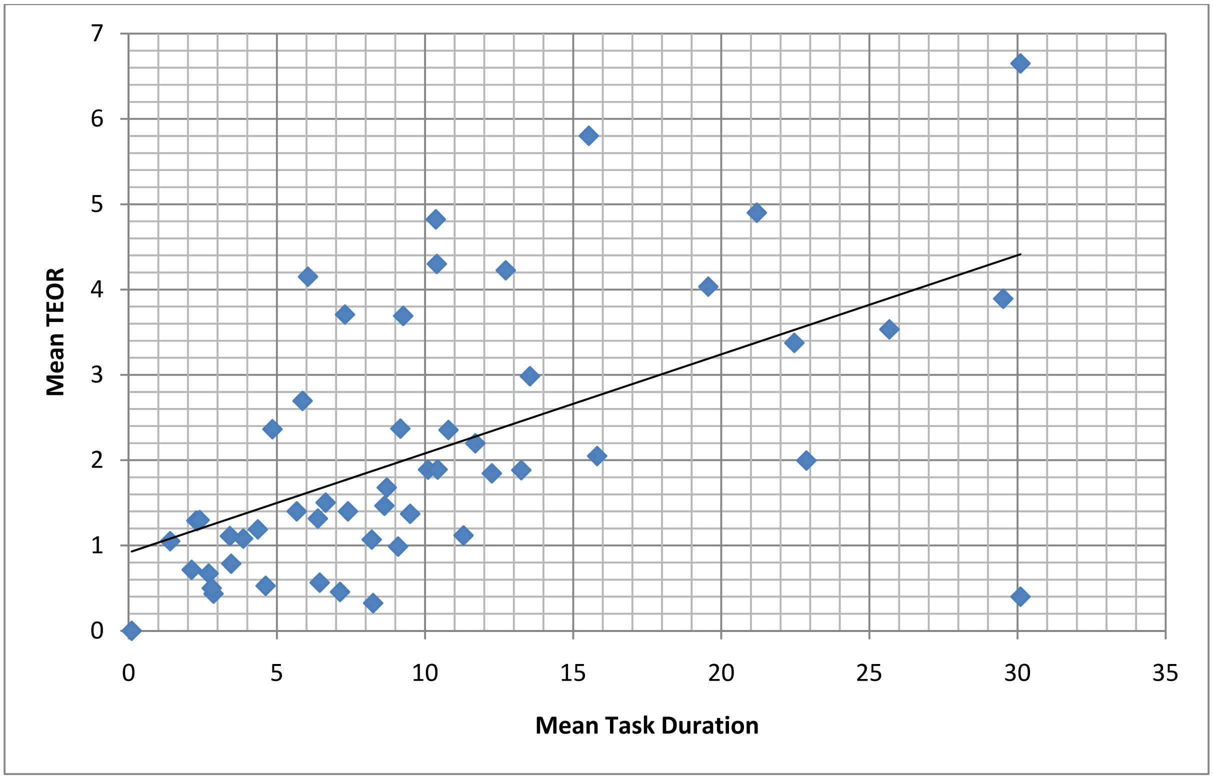

Figure 17. Relationship Between Task Duration (seconds) and Total TEOR (seconds)

The total percentage of driving time that drivers engaged in some form of secondary task was also calculated. The average percentage of time that drivers were engaged in some secondary task for all 10,006 baseline epochs was 23.5 percent. This is slightly higher than the percentage reported by Stutts et al. in their 2003 report. Note that the data for that study were collected in 2001 and 2002 and the data for this study were collected in 2003 and 2004. Also, the operational definitions used for task duration in this report were not taken directly from Stutts et al. (2003) and thus some differences most likely exist between the two analyses. Therefore, the increase in secondary task engagement could be due to an increase in cell phone use as cell phones became more widely used in the later years, as found by the National Occupational Protection Use Survey (NHTSA, 2008), but also due to slightly different task duration operational definitions.

Odds Ratio Calculation for Task Duration

To calculate the ORs for task duration, a conditional logistic regression model was used to calculate the OR for all tasks, then separately for those tasks that were considered to be complex. A complex task is operationally defined as any task that required multiple button presses or multiple glances away from the forward roadway. The list of complex tasks is listed in Table 10 above.

As discussed in the Method section, the design of the case-crossover approach ensures that there will be one case and a minimum of six baseline epochs within each matched case-baseline set. Furthermore, there are similarities between the cases and baseline epochs because they share the same values for matching factors (such as driver, time of day, and day of week). The conditional logistic regression can incorporate these correlations by modeling the probability of the at-fault or partially at-fault crash/near-crash occurrence. The model has the following format:

Define $Y_{ij} = \begin{cases} 1 \text{ifthejthobservationinithmatchedsetisaaccident.} \\ 0 \text{ifthejthobservationinithmatchedsetisabaseline.} \end{cases}$

The matched sampling mechanism leads to:

$$\sum_j Y_{ij} = 1$$

Let p_{ij} be the probability of crash/near-crash for *jth* observation in *ith* matched set. The conditional logistic regression model assumes

$$\text{logit}(p_{ij}) = \alpha_i + \beta * \text{X}_{ij}$$

where X_{ij} is the status of the risk factor for the *jth* observation in the *ith* matched set. In this model exp (β) is the estimated OR for factor X. The α_i is a term associated with match set i and its value influences the risk of set i. The value of α_i is not of interest for this study. A conditional maximum likelihood estimation method was used to estimate the β without estimating the α_i.

Task duration was broken into five segments of time out of a 15-second window. The ORs were calculated for the following comparison groups:

- Task duration of ≥ 2 s compared to < 2 s
- Task duration of ≥ 4 s compared to < 4 s
- Task duration of ≥ 6 s compared to < 6 s
- Task duration of ≥ 8 s compared to < 8 s
- Task duration of ≥ 10 s compared to < 10 s

The frequency of these secondary task durations occurring in the last 15 s of the case-crossover baseline epochs were then compared to the frequency of these task duration times occurring in the 15 s preceding the crashes and near-crashes. The last 15 s of the baseline epochs were used because this was the point at which the matched temporal and geographic factors occurred. The ORs for engaging in tasks for these durations are shown in Figure 18. The results show a fairly flat OR calculation in which task duration is significantly less than 1.0 and does not appear to increase as task duration increases. These results are somewhat surprising in that previous research shows increased task duration time to be inversely related to driving performance (Green, 1999; LeBlanc et al., 2006). Some studies have also shown that total task time is the most important metric when determining when a task is too dangerous for drivers to engage in (Green, 2004; Farber et al., 1999). This particular analysis, however, uses all types of secondary tasks that occur in the vehicle.

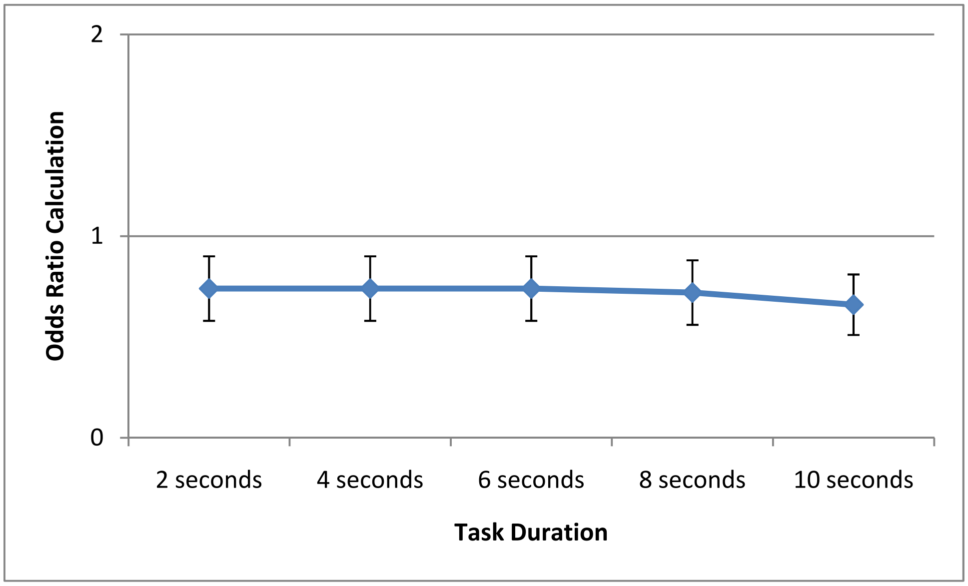

Figure 18. Odds Ratio Calculations for Secondary Task Duration for All Tasks

The secondary tasks of talking with a passenger, singing, personal hygiene (other), or adjusting the radio were shown by Klauer et al. (2006) to possess ORs of less than 1.0. Figure 15 shows that talking to passengers (adjacent or rear), singing, personal hygiene (other), and adjusting the radio all contribute to over 50 percent of the case-crossover baseline epochs. These high frequencies could be responsible for the overall protective ORs as shown in Figure 18.

Typically, when safety researchers discuss total task time as playing a significant role in the assessment of the safety of a particular task, the tasks are complex, multi-step, and involve multiple eyeglances away from the forward roadway. Therefore, a second analysis was conducted looking at only the complex secondary tasks.

Complex secondary task duration was broken into three comparison groups:

- Task duration of ≥ 2 s compared to < 2 s
- Task duration of ≥ 4 s compared to < 4 s
- Task duration of ≥ 6 s compared to < 6 s

Complex task durations of greater than 6 s were too infrequent (less than N = 10) to be included in analyses for crashes and near-crashes; thus, 6-second durations were the longest that could be properly assessed. The frequency of complex secondary tasks occurring in each of these bins of duration for the case-crossover baseline data were then compared to the frequency of these task duration times occurring in the 15 s preceding the crashes and near-crashes. The ORs for engaging in tasks for these durations are shown in Figure 19. While the point estimates for each of these odds is greater than 1.0, the results show that none of the ORs for task durations are significantly greater than 1.0 (note that the confidence intervals include 1.0). Thus, complex task duration does not appear to affect or be a factor in the increased risk for these types of tasks.

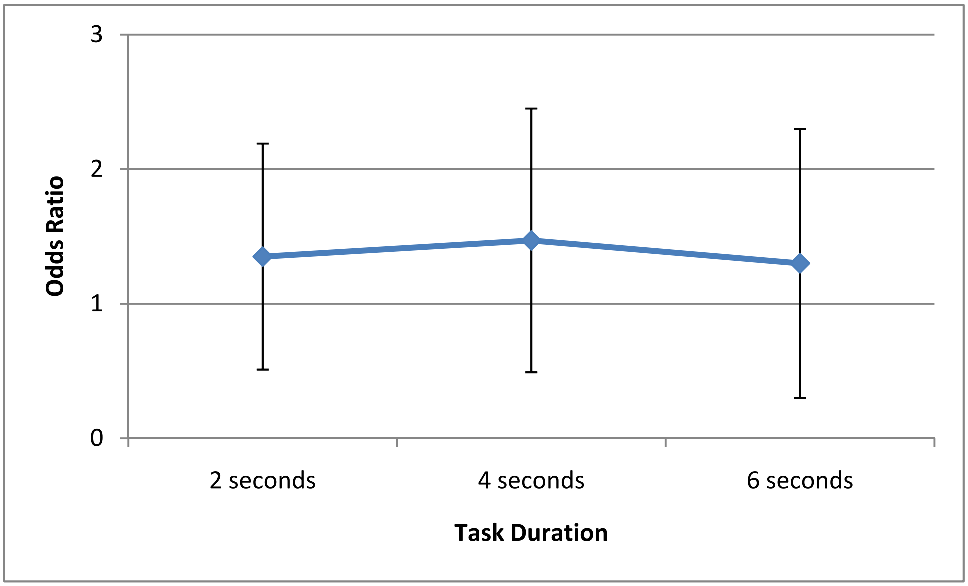

Figure 19. Odds Ratios for Three Task Durations for Complex Tasks

Research Question 3: Characterize eyeglance behavior while using wireless devices.
To address this research objective, the case-crossover baseline data set was used. Those baseline epochs in which a driver was talking on a cell phone were compared to a baseline epoch for the same driver, duration, and same corresponding crash/near-crash event (similar geographic location, time of day, and day of week) in which the driver was not engaging in any secondary task. The total TEOR and number of mirror glances were assessed and t-tests were conducted to determine whether significant differences in eyeglance behavior existed when drivers were on the cell phone and when they were not. PROC ANOVA in SAS v. 9.1 was used to calculate the t-tests as the two groups were equally balanced (244 epochs with the driver talking on a cell phone and 244 epochs in which the same driver was not engaging in any secondary tasks).

The results of the t-tests indicated that drivers who are not engaging in secondary tasks ($M = 3.3$ s, $SD = 3$ s) had a significantly longer total TEOR than did those drivers who were talking on their cell phone ($M = 2.4$ s, $SD = 2.3$ s), $t(486) = 16.20$, $p < 0.0001$. The drivers who were not engaged in secondary tasks also had a higher frequency of glances to mirrors ($M = 1.9$, $SD = 2.3$) than did the drivers who were talking on their cell phone ($M = 1.5$, $SD = 1.9$), $t(486) = 5.46$, $p > 0.01$. Thus, drivers on cell phones may have less awareness of their general surroundings in traffic than do those drivers who are not engaged in secondary tasks. This result supports previous research that has shown that when talking on cell phones, drivers tend to reduce their eye scanning patterns and only look directly ahead (Harbluk et al., 2007). While these previous studies were conducted in instrumented vehicles, simulators, and test tracks, it appears that drivers in real-world environments also reduce the time they spend checking mirrors and scanning the environment when talking on a cell phone while driving.

This result should not be seen as a contradiction to the risks associated with long total TEOR durations of 2 s or greater, as discussed previously in this report. The comparison here is assessing the eyeglance patterns of drivers talking on cell phones to the eyeglance patterns of alert drivers. Alert drivers typically make brief (less than 1 s) and systematic glances to mirrors and surrounding traffic. These types of glances were found in the Klauer et al. (2006) report to have odds ratios of significantly less than 1.0 and were shown to have a protective effect. Drivers who talk on their cell phones had an odds ratio of 1.3 which shows a slightly elevated risk but was not statistically different from 1.0. Thus, this slight increased risk might be explained by the reduction in the brief and systematic scanning of the traffic environment.

CHAPTER 5. CONCLUSIONS

The power of the 100-Car Naturalistic driving data primarily resides in the detailed driving behavior data recorded in the seconds leading up to crashes and near-crashes as compared to data from normal, baseline driving. These assessments allow safety researchers to calculate which of those behaviors actually increase risk of crash/near-crash involvement as well as assess the frequency, duration, and impact on eyeglance behavior for each of these tasks. Use of these new and unique data sources is a critical step not only towards furthering our knowledge of the types of behaviors that actually increase drivers' crash/near-crash risk but also in directing research towards the mitigation of these behaviors to most effectively save lives.

The slight drop in the ORs for secondary task engagement was expected given that all of the baseline epochs were matched on specific temporal, environmental, and driver factors. This drop could potentially be explained by the fact that driver characteristics, especially those characteristics that are known risk factors (such as age), were carefully controlled in the case-crossover study. The previous crude OR calculations using the case-control baseline did not control or account for driver age. The case-crossover design may be a more precise estimate for the risk associated with *only* secondary task engagement. Similarly, all of the other matching factors (time of day and geographic location) are also accounted for in the design. Future naturalistic studies may also allow researchers to calculate the ORs for secondary task engagement for subsets of the driving population as these ORs may be much higher for teenaged drivers and lower for more experienced drivers.

The ORs calculated for total TEOR confirmed the riskiness of looking away from the forward roadway, even for fairly brief periods of time or for repeated brief glances away from the forward roadway. This is an important result when compared with the ORs calculated for task duration whereby the ORs suggested that an increase in task duration does not increase risk of secondary task engagement. These two results may at first appear to be contradictory, but when combined with the literature, these results may actually suggest that while task duration is important when assessing the safety of a particular task, it is the increase in total TEOR that is most directly responsible for the increase in crash/near-crash risk. Thus, tasks with intermittent, repeated glances away from the forward roadway (e.g., text messaging or dialing a cell phone) are riskier than those tasks that require less time and fewer eyeglances away from the forward roadway (e.g., inserting a CD, talking on the cell phone).

One possible and important application of the total TEOR OR analysis is that total TEOR should also be reviewed and evaluated by in-vehicle display designers in conjunction with task duration and single glance duration. The "2-second rule" (as suggested by AAM) and the "15-second rule" (as suggested by SAE) are not based upon associations with actual crash/near-crash risk. Given the results presented here for both the ORs associated with total TEOR over 15 s, complex tasks that require multiple eyeglances or a single eyeglance of 2 s indicates that crash/near-crash risk has already started to increase when these two rules indicate that a task is not safe. Thus, total TEOR should be an additional metric used to assess the safety of new devices. The riskiness of even very brief total TEOR over a 15-second duration of time (or a 15-second task duration) suggests that efficient voice-activated commands may be critical to the overall safety of any device. Further research is needed to examine the distribution of the number of glances for each of these total TEOR durations as well as the degree of eccentricity from the forward roadway which can substantially increase practical total TEOR time for older drivers who take longer to accommodate to changes in focal distance.

The task duration analysis also provided the opportunity to calculate an estimate of the amount of time that the drivers in the 100-Car Study engaged in secondary tasks while driving. The average percentage of time that drivers were engaged in some secondary task for all 10,006 baseline epochs is 23.5 percent. This is 40 percent higher than the 16 percent reported by Stutts et al. in their 2003 report, which could be explained by the increased use of cell phones (Traffic Safety Facts, 2008). While both the Stutts et al. (2003) and Green (1999; 2004) studies were helpful and informative in developing new operational definitions for secondary task engagement, neither list adequately captured the types of tasks that were observed in the 100-Car Study and, thus, are probably only comparable for similar tasks.

The ORs that were calculated for task duration also demonstrated some important differences between real-world driving and driving safety studies conducted in simulators. Complex tasks such as destination entry into navigation devices have been studied extensively in simulators and have shown direct links between long task duration and decreased driving performance metrics. These types of tasks were not observed in the 100-Car Study, whereas relatively simple, shorter tasks (such as heating, ventilating, and air-conditioning [HVAC] adjustment, eating, and talking on a cell phone) were frequently observed. The OR calculations were not significantly different from 1.0 as task duration increased, suggesting that task duration does not affect driving risk. For the tasks observed in the 100-Car Study, this may be true; however, for these longer, more complex tasks, future naturalistic driving studies will need to be conducted. One possible study is the SHRP 2 Naturalistic Driving Study, which will be better suited to directly calculate the ORs for these types of tasks.

It has repeatedly been found in controlled experiments that, while talking on cell phones, drivers typically scan their environment less than they do when not engaged in any secondary tasks (Harbluk et al., 2007; Hancock, Lesch, & Simmons, 2003). The results of this study support these previous findings and validate that previous results are generalizable to everyday driving. Total TEOR and number of mirror glances while driving when using a cell phone versus driving while attentive indicated that drivers significantly reduce scanning their environment when using a cell phone. This result should not be seen as a contradiction to the risks associated with long total TEOR durations of 2 s or greater, as discussed previously in this report. The comparison here is assessing the eyeglance patterns of drivers talking on cell phones to the eyeglance patterns of alert drivers. Alert drivers typically make brief (less than 1 s) and systematic glances to mirrors and surrounding traffic. These types of glances were found in the Klauer et al. (2006) report to have ORs of significantly less than 1.0 and were shown to have a protective effect. Drivers who talk on their cell phones had an OR of 1.3 which shows a slightly elevated risk but was not statistically different from 1.0. Thus, this slight increased risk might be explained by the reduction in the brief and systematic scanning of the traffic environment.

Limitations of Current Research and Directions for Future Research

There are a few caveats that need to be discussed regarding the above analyses. First, the ORs calculated using the case-control baseline were calculated using Equation 2 (also referred to as a 'crude odds ratio') which does not adjust for driver or other effects. The reason for this is that the original calculation was conducted as an exploratory analysis to: 1) assess whether ORs could be calculated using naturalistic driving data, and 2) provide a very simple and understandable calculation of risk when drivers engage in these secondary tasks. A conditional logistic regression model was used for the case-crossover analysis because of the statistical power that such a model provides when the controls are matched to each case. The process of matching the baseline epochs to the crashes and near-crashes – and then not utilizing a model to control for the driver, temporal, and environmental factors – would negate the power provided by using this matching process. Further research should be conducted to calculate these same ORs using a logistic regression model with the case-control baseline to assess whether the OR point estimates also are slightly lowered when driver age is accounted for in the model. While it may be possible that the proportion of young drivers to older drivers cannot fully be accounted for in a statistical model, this is the next logical step in this line of research.

Second, both crashes and near-crashes were used in the calculation of ORs to increase the statistical power of these calculations. Analyses by Dingus et al. (2006) indicated that the kinematic signatures of crashes and near-crashes were similar and thus could be combined for relative risk calculations. However, most of these crashes (and all of the near-crashes) are of less severity (i.e., no fatalities) than crashes recorded in crash databases. While this may at first appear to be a severe limitation, the collection of these data provides unique opportunities given that these represent some form of vehicular loss of control and are not collected or analyzed in any other area of transportation safety. Third, only the crashes and near-crashes where the driver was considered at fault or partially at fault were used in the calculation of the ORs. At fault or partial fault was a judgment made by the project manager or the data reduction manager where they considered whether the actions of the driver (both in the handling of the vehicle as well as driver state) contributed to the occurrence of the crash or near-crash. These judgments were verified by expert data reductionists when these events were reviewed, with fewer than 10 of 830 events being reclassified. It is important to remember that these are subjective judgments but the precision of the video and temporal data greatly increases the reliability and validity of these judgments.

It is also possible that the matching factors selected for the case-crossover baseline epochs were not comprehensive and that an important factor was missed or overlooked. Potential examples include traffic density or number of lanes, both of which could easily impact crash/near-crash risk when driving inattentively. In higher traffic densities, unexpected traffic slowing and stoppages can catch an inattentive driver by surprise. More lanes typically mean higher traffic densities as well as more complex traffic situations with lane changes and merging traffic. Again, all unexpected traffic maneuvers can surprise an inattentive driver. While matching on these variables would have increased the data reduction effort substantially, it is possible that these variables could affect the OR calculation. It is also possible with this naturalistic driving database to more precisely match on a variety of variables and that more precision could potentially be gained by matching on other variables of interest.

Other potential but unlikely limitations are that neither the case-control nor the case-crossover baseline samples are stable, or are too small to reliably calculate ORs for driver inattention. This is unlikely since the estimates are not dramatically different, except in the case of driver drowsiness (which was explained by key differences in the baseline sample).

If the assumption that the ORs calculated with the case-crossover baseline are more precise estimates for secondary task engagement, it may make sense to reassess the groupings or operational definitions of complex, moderate, and simple secondary task engagement. Recall that these definitions were based upon research done by Dingus, Antin, Hulse, & Wierwille (1989). Future research should define each occurrence of these secondary tasks and designate each task as complex, moderate, or simple based upon the actual number of eyeglances away from the forward roadway and/or button presses performed by the driver. It has been shown in previous research (Klauer et al., 2006) that some of the simple secondary tasks demonstrate a protective effect (talking to a passenger) whereas others do not. This research should also be further extended with larger naturalistic driving studies to assess the combined risk of age plus secondary task engagement to truly assess whether the risk of secondary task engagement changes across age groups.

The application of these results to future naturalistic driving studies, those both smaller and larger than the 100-Car Study, may suggest that using a case-crossover approach with naturalistic driving data may not be the best method for identifying and recording data on normal, baseline driving. Other approaches, such as case-control approach, may also be conducted with a more efficient use of resources, given that a naturalistic study is comprised of massive amounts of un-coded video data which requires viewing and coding, typically by human researchers. In addition, the case-control approach may provide more generalizable data that can be used to not only accurately assess the prevalence of various driving behaviors but also could be used to calculate a wider variety of relative risk calculations and answer a wider range of research questions than is possible with the matched case-crossover baseline. Regardless, this was an important and critical task given the novel and uncharted area of research that naturalistic driving data represent. It was virtually impossible to predict the difficulties encountered when matching baselines or how this matching would impact the OR calculations until this task was attempted. It is hoped that these analyses will be used in the future to provide guidance to those researchers also attempting to understand and improve driver safety.

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APPENDIX A. Data Reduction Variables Used in the Crash/Near-Crash Reduction (and Baseline/Control Reduction Where Appropriate)

1. Vehicle Number

Comment: Each vehicle will be assigned a vehicle number. Information will originate in the raw data stream.

FORMAT: Integer value.

2. Epoch Number

The Epoch file number is arranged by vehicle identification number, date and time. The first three numbers represent the vehicle identification number, the next two numbers represent the year (Ex. 03 for 2003), the next two numbers represents the month (Ex. 03 for March), the next two numbers represent the day of the month, the next four numbers represent the time in military time. The last six numbers are the epoch ID

002 03 02 28 1209 000000

Comment: Each valid driving performance trigger will be assigned to an epoch. An epoch will consist of 1 minute of video prior and 30 s of video after the initial onset of a trigger. If a second trigger occurs within this 1.5 minute segment, the epoch will extend to include a full 1 minute prior to the onset of the initial trigger and 30 s after the onset of the last trigger.

3. Event Severity – A general term referring to all valid triggered occurrences of an incident, near-crash, or crash that begins at the precipitating event and ends when the evasive maneuver has been completed.

- Invalid trigger – Any instance where a trigger appears but no safety-relevant event is present.
    - Non-participant conflict - Any safety-relevant event captured on video (incident, near-crash, or crash) that does not involve the driver.

- Non-conflict - Any event that increases the level of risk associated with driving, but does not result in a crash, near-crash, or incident, as defined below. Examples include: driver control error without proximal hazards being present; driver judgment error such as unsafe tailgating or excessive speed; or cases in which drivers are visually distracted to an unsafe level.

- Proximity Event - Any circumstance resulting in extraordinarily close proximity of the participant vehicle to any other vehicle, pedestrian, pedalcyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, pedalcyclists or animals, there is no avoidance maneuver or response. Extraordinarily close proximity is defined as a clear case where the absence of an avoidance maneuver or response is inappropriate for the driving circumstances (including speed, sight distance, etc.).

- Crash-Relevant - Any circumstance that requires a crash avoidance response on the part of the participant vehicle. Any other vehicle, pedestrian, pedalcyclist, or animal that is less severe than a rapid evasive maneuver (as defined above), but greater in severity than a “normal maneuver” to avoid a crash. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. A “normal maneuver” for the participant vehicle is defined as a control input that falls inside of the 99% confidence limit for control input as measured for the same participant.

- Near-crash - Any circumstance that requires a rapid, evasive maneuver by the participant vehicle, or any other vehicle, pedestrian, pedalcyclist, or animal to avoid a crash. A rapid, evasive maneuver is defined as steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities. As a guide: participant vehicle braking greater than 0.5 g, or steering input that results in a lateral acceleration greater than 0.4 g to avoid a crash, constitutes a rapid maneuver.

- Crash - Any contact with an object, either moving or fixed, at any speed, in which kinetic energy is measurably transferred or dissipated. Includes other vehicles, roadside barriers, objects on or off the roadway, pedestrians, pedalcyclists or animals.

Comment: Initial coding step. Invalid events result in no further coding. Non-participant and non-conflicts will only result in a brief narrative written, but no other coding. Other coding choices will determine which specific subset of variables that will be coded. Specified at early onset of data reduction software.

4. Trigger Type (C-N-I)

The triggers were specific data signatures that were specified during the sensitivity analysis performed after 10% of the data were collected. The specific data signatures that were used to identify valid events are as follows:

- Lateral acceleration - Lateral motion equal to or greater than 0.7 g.
- Longitudinal acceleration - Acceleration or deceleration equal to or greater than 0.6 g.
- CI button – Activated by the driver upon pressing a button located on the dashboard when an incident occurred that he/she deemed critical.
- Forward Time To Collision (FTTC) - Acceleration or deceleration equal to or greater than 0.5 g coupled with a forward TTC of 4 s or less.
- All longitudinal decelerations between 0.4 g and 0.5 g coupled with a forward TTC value of ≤ 4 s and that the corresponding forward range value at the minimum TTC is not greater than 100 ft.
- Rear Time To Collision (RTTC) - Any rear TTC trigger value of 2 s or less that also has a corresponding rear range distance of ≤ 50 ft. AND any rear TTC trigger value where the absolute acceleration of the following vehicle is greater than 0.3 g.
- Side object detection – Detects presence of other vehicles/objects in the adjacent lane.
- Lane change cut-off – Identifies situations in which the participant vehicle cuts in too close either behind or in front of another vehicle by using closing speed and forward TTC.
- Yaw rate – Any value greater than or equal to a plus AND minus 4 deg change in heading (i.e., vehicle must return to the same general direction of travel) within a 3 s window of time.

5. Driver Participant Number (C-N-I-B)

All primary drivers' participant number will be a 3 digit number followed by the letter 'A'. Any secondary drivers should be given the same 3 digit number followed by the letters 'B', 'C', and so on.

6. Onset of Precipitating Factor

Using video frame numbers, the reductionists will determine the onset of the precipitating event (i.e., onset of lead vehicle brake lights for a lead vehicle conflict).

7. Resolution of the Event

Using video frame numbers, the reductionists will determine when the evasive maneuver (or lack thereof) has been executed and the level of danger has returned to normal.

Event Variables

1. Event Nature (C-N-I)

This variable specified the type of crash, near-crash, or incident that occurred. The reductionists chose from the following variables that were modified from GES variables 'Manner of Collision' and 'Most Harmful Event'.

1=Conflict with a lead vehicle

2=Conflict with a following vehicle
3=Conflict with oncoming traffic
4=Conflict with a vehicle in adjacent lane
5=Conflict with a merging vehicle
6=Conflict with a vehicle turning across participant vehicle's path (same direction)
7=Conflict with a vehicle turning across participant vehicle's path (opposite direction)
8=Conflict with a vehicle turning into participant vehicle's path (same direction)
9=Conflict with a vehicle turning into participant vehicle's path (opposite direction)
10 =Conflict with a vehicle moving across participant vehicle's path (through intersection)
11=Conflict with a parked vehicle
12=Conflict with a pedestrian
13=Conflict with a pedalcyclist
14=Conflict with an animal
15=Conflict with an obstacle/object in roadway
16=Single vehicle conflict
17=Other
18=No known conflict (for RF sensor trigger)
99=Unknown conflict

2. Incident Type (Coded for Crashes and Near-Crashes only)

1 = Rear-end, striking

2 = Rear-end, struck

3 = Road departure (left or right)

4 = Road departure (end)

5 = Sideswipe, same direction (left or right)

6 = Opposite direction (head-on or sideswipe)

7 = Violation of stop sign or signal at intersection

8 = Straight crossing path, not involving sign/signal violation

9 = Turn across path

10 = Turn into path (same direction)

11 = Turn into path (opposite direction)

12 = Backing, fixed object

13 = Backing into traffic

14 = Pedestrian

15 = Pedalcyclist

16 = Animal

17 = Other (specify)

99 = Unknown

3. Pre-Event Maneuver (GES Variable Vehicle 1 Maneuver Prior to Event)

This represents the last action that the participant vehicle driver engaged in just prior to the point that the driver realized impending danger. Note that the variables in italics are those GES variables that were expanded.

1a = Going straight, constant speed

1b = Going straight ahead, accelerating

1c = Going straight, but with unintentional "drifting" within lane or across lanes

2 = Decelerating in traffic lane

3 = Accelerating in traffic lane

4 = Starting in traffic lane

5 = Stopped in traffic lane

6 = Passing or overtaking another vehicle

7 = Disabled or parked in travel lane

8 = Leaving a parked position

9 = Entering a parked position

10 = Turning right

11 = Turning left

12 = Making U-turn

13 = Backing up (other than for parking purposes)

14 = Negotiating a curve

15 = Changing lanes

16 = Merging

17 = Successful corrective action to previous action

18a = Maneuvering to avoid an animal

18b = Maneuvering to avoid a pedestrian/pedalcyclist

18c = Maneuvering to avoid an object

18d = Maneuvering to avoid a vehicle

97 = Other

99 = Unknown

Source/comment: GES Variable V21, Movement Prior to Critical Event. Also, very similar to VA PAR Variable 19/20.

FORMAT: Integer value as listed above.

4. Judgment of Vehicle 1 Maneuver Prior to Event

This variable provided additional information about the pre-event maneuver as to whether this maneuver was either safe or legal.

1 = Safe and legal

2 = Unsafe but legal

3 = Safe but illegal

4 = Unsafe and illegal

99 = Unknown

5. Precipitating Factor (GES Variable V26, Critical Event)

The driver behavior or state of the environment that begins the event and the subsequent sequence of actions that result in a crash, near-crash, or incident, independent of who caused the event (driver at fault). The precipitating factor occurs outside the vehicle and does not include driver distraction, fatigue, or disciplining child while driving.

A. This Vehicle Loss of Control Due to:

001 = Blow-out or flat tire

002 = Stalled engine

003 = Disabling vehicle failure (e.g., wheel fell off)

004 = Minor vehicle failure

005 = Poor road conditions (puddle, pothole, ice, etc.)

006 = Excessive speed

007 = Other or unknown reason

008 = Other cause of control loss

009 = Unknown cause of control loss

B. This Vehicle Traveling:

018a = Ahead, stopped on roadway more than 2 s

018b = Ahead, decelerated and stopped on roadway 2 s or less

021 = Ahead, traveling in same direction and decelerating

022 = Ahead, traveling in same direction with slower constant speed

010 = Over the lane line on the left side of travel lane

011 = Over the lane line on right side of travel lane

012 = Over left edge of roadway

013 = Over right edge of roadway

014 = End departure

015 = Turning left at intersection

016 = Turning right at intersection

017 = Crossing over (passing through) intersection

019 = Unknown travel direction

020a = From adjacent lane (same direction), over left lane line behind lead vehicle, rear-end crash threat

020b = From adjacent lane (same direction), over right lane line behind lead vehicle, rear-end crash threat

C. Other Vehicle in Lane:

050a = Ahead, stopped on roadway more than 2 s

050b = Ahead, decelerated and stopped on roadway 2 s or less

051 = Ahead, traveling in same direction with slower constant speed

052 = Ahead, traveling in same direction and decelerating

053 = Ahead, traveling in same direction and accelerating

054 = Traveling in opposite direction

055 = In crossover

056 = Backing

059 = Unknown travel direction of the other motor vehicle

D. Another Vehicle Encroaching into This Vehicle's Lane:

060a = From adjacent lane (same direction), over left lane line in front of this vehicle, rear-end crash threat

060b = From adjacent lane (same direction), over left lane line behind this vehicle, rear-end crash threat

060c = From adjacent lane (same direction), over left lane line, sideswipe threat

060d = From adjacent lane (same direction), over right lane line, sideswipe threat

060e = From adjacent lane (same direction), other

061a = From adjacent lane (same direction), over right lane line in front of this vehicle, rear-end crash threat

061b = From adjacent lane (same direction), over right lane line behind this vehicle, rear-end crash threat

061c = From adjacent lane (same direction), other

062 = From opposite direction over left lane line.

063 = From opposite direction over right lane line

064 = From parallel/diagonal parking lane

065 = Entering intersection—turning in same direction

066 = Entering intersection—straight across path

067 = Entering intersection – turning into opposite direction

068 = Entering intersection—intended path unknown

070 = From driveway, alley access, etc. – turning into same direction

071 = From driveway, alley access, etc. – straight across path

072 = From driveway, alley access, etc. – turning into opposite direction

073 = From driveway, alley access, etc. – intended path unknown

074 = From entrance to limited access highway

078 = Encroaching details unknown

E. Pedestrian, Pedalcyclist, or other Non-Motorist:

080 = Pedestrian in roadway

081 = Pedestrian approaching roadway

082 = Pedestrian in unknown location

083 = Pedalcyclist/other non-motorist in roadway

084 = Pedalcyclist/other non-motorist approaching roadway

085 = Pedalcyclist/or other non-motorist unknown location

086 = Pedestrian/pedalcyclist/other non-motorist—unknown location

F. Object or Animal:

087 = Animal in roadway

088 = Animal approaching roadway

089 = Animal unknown location

090 = Object in roadway

091 = Object approaching roadway

092 = Object unknown location

099 = Unknown critical event

6. Evasive Maneuver (GES Variable V27 Corrective Action Attempted)

The participant vehicle driver’s reaction to the precipitating factor.

0 = No driver present

1 = No avoidance maneuver

2 = Braking (no lockup)

3 = Braking (lockup)

4 = Braking (lockup unknown)

5 = Releasing brakes

6 = Steered to left

7 = Steered to right

8 = Braked and steered to left

9 = Braked and steered to right

10 = Accelerated

11 = Accelerated and steered to left

12 = Accelerated and steered to right

98 = Other actions

99 = Unknown if driver attempted any corrective action

7. Vehicle Control After Corrective Action (GES Variable V28—Coded only for Near-crashes and crashes):

0 = No driver present

1 = Vehicle control maintained after corrective action

2 = Vehicle rotated (yawed) clockwise

3 = Vehicle rotated (yawed) counter-clockwise

4 = Vehicle slid/skid longitudinally – no rotation

5 = Vehicle slid/skid laterally – no rotation

9 = Vehicle rotated (yawed) unknown direction

20 = Combination of 2-9

94 = More than two vehicles involved

98 = Other or unknown type of vehicle control was lost after corrective action

99 = Unknown if vehicle control was lost after corrective action.

Contributing Factors

1. Driver Behavior: Driver 1 Actions/Factors Relating to the Event (**VA PAR Variable 17/18)**

This variable provides a descriptive label to the driver's actions that may or may not have contributed to the event.

0 = None

1 = Exceeded speed limit

2= Inattentive or distracted

3 = Exceeded safe speed but not speed limit

4 = Driving slowly: below speed limit

5 = Driving slowly in relation to other traffic: not below speed limit

6 = Illegal passing (i.e., across double line)

7 = Passing on right

8 = Other improper or unsafe passing

9 = Cutting in, too close in front of other vehicle

10 = Cutting in, too close behind other vehicle

11 = Making turn from wrong lane (e.g., across lanes)

12 = Did not see other vehicle during lane change or merge

13 = Driving in other vehicle's blind zone

14 = Aggressive driving, specific, directed menacing actions

15 = Aggressive driving, other, i.e., reckless driving without directed menacing actions

16 = Wrong side of road, not overtaking

17 = Following too close

18 = Failed to signal, or improper signal

19 = Improper turn - wide right turn

20 = Improper turn - cut corner on left turn

21 = Other improper turning

22 = Improper backing, did not see

23 = Improper backing, other

24 = Improper start from parked position

25 = Disregarded officer or watchman

26 = Signal violation, apparently did not see signal

27 = Signal violation, intentionally ran red light

28 = Signal violation, tried to beat signal change

29 = Stop sign violation, apparently did not see stop sign

30 = Stop sign violation, intentionally ran stop sign at speed

31 = Stop sign violation, “rolling stop”

32 = Other sign (e.g., Yield) violation, apparently did not see sign

33 = Other sign (e.g., Yield) violation, intentionally disregarded

34 = Other sign violation

35 = Non-signed crossing violation (e.g., driveway entering roadway)

36 = Right-of-way error in relation to other vehicle or person, apparent recognition failure (e.g., did not see other vehicle)

37 = Right-of-way error in relation to other vehicle or person, apparent decision failure (i.e., did see other vehicle prior to action but misjudged gap)

38 = Right-of-way error in relation to other vehicle or person, other or unknown cause

39 = Sudden or improper stopping on roadway

40 = Parking in improper or dangerous location, e.g., shoulder of Interstate

41 = Failure to signal with other violations or unsafe actions

42 = Failure to signal, without other violations or unsafe actions

43 = Speeding or other unsafe actions in work zone

44 = Failure to dim headlights

45 = Driving without lights or insufficient lights

46 = Avoiding pedestrian

47 = Avoiding other vehicle

48 = Avoiding animal

49 = Apparent unfamiliarity with roadway

50 = Apparent unfamiliarity with vehicle, e.g., displays and controls

51 = Apparent general inexperience driving

52 = Use of cruise control contributed to late braking

53 = Other, specify

2. Driver 1 Physical/Mental Impairment (GES Variable D3: Driver Physical/Mental Condition)

0 = None apparent

1 = Drowsy, sleepy, asleep, fatigued

2 = Ill, blackout

3a = Angry

3b = Other emotional state

4a = Drugs-medication

4b = Drugs-Alcohol

5 = Other drugs (marijuana, cocaine, etc.)

6 = Restricted to wheelchair

7 = Impaired due to previous injury

8 = Deaf

50 = Hit and run vehicle

97 = Physical/mental impairment – no details

98 = Other physical/mental impairment

99 = Unknown physical/mental condition

Source: GES D3, Driver Physical/Mental Condition. Element 3 expanded to separate anger from other emotions. Element 50 not applicable.

Coded in General State Variables: Driver's General State, Causal/Contributing Factors, & Precipitating Event. FORMAT: 16-bit encoded value(s) as listed above.

3. Driver 1 Distracted By (GES Variable D7: Driver Distracted By)

This variable was recorded if the reductionists observed the drivers engaging in any of the following secondary tasks 5-10 s prior to the onset of the precipitating factor. For a complete definition of these tasks, see Appendix D.

00 = Not Distracted

15 = Cognitive distraction

97 = Lost in thought

01 = Looked but did not see

15a = Reading

15b = Talking/singing without obvious passenger

15c = Dancing to the radio

15d = Reading

03 = Passenger in vehicle

3a = Passenger in adjacent seat

3b = Passenger in rear seat

3c = Child in adjacent seat

3d = Child in rear seat

04 = Object/Animal/Insect in Vehicle

4a = *Moving object in vehicle (i.e. object fell off seat when driver stopped hard at a traffic light)*

4b = Insect in vehicle

4c = Pet in vehicle

4d = Object dropped by driver

4e = Reaching for object in vehicle (not cell phone)

5 = Cell phone operations

05a = Talking/listening

06a = Dialing hand-held cell phone

06b = Dialing hand-held cell phone using quick keys

06c = Dialing hands-free cell phone using voice-activated software

06d = Locating/reaching/answering cell phone

17 = PDA operations

15a = Locating/reaching PDA

15b = Operating PDA

15c = Viewing PDA

16 = In-vehicle system operations

7 = Adjusting climate control

8a = Adjusting the radio

8b = Inserting/retrieving cassette

8c = Inserting/retrieving CD

9 = Adjusting other devices integral to vehicle (unknown which device)

9a = Adjusting other known in-vehicle devices (text box to specify)

12 = External Distraction

12a = Looking at previous crash or highway incident

12b = Pedestrian located outside the vehicle

12c = Animal located outside the vehicle

12d = Object located outside the vehicle

12e = Construction zone

13 = Dining

13a = Eating with a utensil

13b = Eating without a utensil

13c = Drinking from a covered container (i.e., with a straw)

13d = Drinking from an uncovered container

14 = Smoking

14a = Reaching for cigar/cigarette

14b = Lighting cigar/cigarette

14c = Smoking cigar/cigarette

14d = Extinguishing cigar/cigarette

18. Personal Hygiene

18a = Combing/brushing/fixing hair

18b = Applying makeup

18c = Shaving

18d = Brushing/flossing teeth

18e = Biting nails/cuticles

18f = Removing/adjusting jewelry

18g = Removing/inserting contact lenses

18h = Other

19. Inattention to the Forward Roadway

19a = Left window

19b = Left rearview mirror

19c = Center rearview mirror

19d = Right rearview mirror

19e = Right passenger window

3a. Time Distraction Began

Reductionists entered the video frame number corresponding to the time at which the driver became distracted or began to engage in the distracting task.

3b. Time Distraction Ended

Reductionists entered the video frame number corresponding to the time at which the driver disengaged from the distracting task or the driver's attention returned to the forward roadway.

3c. Outcome (of Incident) Impacted

Reductionists also marked whether they believed that the secondary task that was present at the onset of the precipitating factor impacted the severity or the outcome of the event. Note that all distraction analyses conducted in this report only used those secondary tasks that were marked 'yes' or 'not able to determine'.

1 = Yes

2 = No

3 = Not able to determine

99 = Unknown

4. Willful Behavior

Reductionists marked this variable when they believed that the driver was aware or cognizant of their poor behavior. There were three options, written in sequential order of increasingly willful or aggressive behavior.

1 = Aggressive driving

2 = Purposeful violation of traffic laws

3 = Use of vehicle for improper purposes (Intimidation/weapon)

99 = Unknown

Source/comment: This variable came from the Light/Heavy Vehicle Interaction Study Taxonomy.

5. Driver Proficiency

Reductionists marked this variable when it was believed that the driver was generally unaware of their poor driving behavior. There are four options, written in order of decreasing levels of proficiency (the last is the most drastic measure of poor driving proficiency).

1 = Violation of traffic laws

2 = Driving techniques (incompetent to safely perform driving maneuver)

3 = Vehicle kinematics (incompetent handling of the vehicle)

4 = Driver capabilities (incompetent on what maneuvers are safe and appropriate)

Source/comment: This variable came from the Light/Heavy Vehicle Interaction Study Taxonomy.

6. Driver 1 Drowsiness Rating (Coded for Crashes and Near-Crashes only)

An observer rating of drowsiness will be assigned for the 30 s prior to the event based on review of driver videos. For drowsiness levels above a criterion level of an ORD of 60 or above, a manual calculation of PERCLOS will be measured by the analyst. This variable will be coded for all crashes and near-crashes (Wierwille and Ellsworth, 1994).

7. Driver 1 Vision Obscured by (GES Variable D4: Vision Obscured by)

Reductionists will ascertain to the best of their ability whether the driver's vision was obscured by any of the following:

0 = No obstruction

1 = Rain, snow, fog, smoke, sand, dust

2a = Reflected glare

2b = Sunlight

2c = Headlights

3 = Curve or hill

4 = Building, billboard, or other design features (includes signs, embankment)

5 = Trees, crops, vegetation

6 = Moving vehicle (including load)

7 = Parked vehicle

8 = Splash or spray of passing vehicle [any other vehicle]

9 = Inadequate defrost or defog system

10 = Inadequate lighting system

11 = Obstruction interior to vehicle

12 = Mirrors

13 = Head restraints

14 = Broken or improperly cleaned windshield

15 = Fog

50 = Hit & run vehicle

95 = No driver present

96 = Not reported

97 = Vision obscured – no details

98 = Other obstruction

99 = Unknown whether vision was obstructed

8. Vehicle Contributing Factors (GES Variable V12, Vehicle contributing factors)

Reductionists will determine if any of the following contributed to the severity or the presence of an event.

0 = None

1 = Tires

2 = Brake system

3 = Steering system

4 = Suspension

5 = Power train

6 = Exhaust system

7 = Headlights

8 = Signal lights

9 = Other lights

10 = Wipers

11 = Wheels

12 = Mirrors

13 = Driver seating and controls

14 = Body, doors

15 = Trailer hitch

50 = Hit and run vehicle

97 = Vehicle contributing factors, no details

98 = Other vehicle contributing factors

99 = Unknown if vehicle had contributing factors

Environmental Factors: Driving Environment

1. Weather (GES Variable A20I, Atmospheric condition and VA PAR Variable 4)

Reductionists will determine the type of weather using the video and record as part of the data reduction process.

1 = Clear

2 = Cloudy

3 = Fog

4 = Mist

5 = Raining

6 = Snowing

7 = Sleeting

8 = Smoke dust

9 = Other

99 = Unknown

2. Light (GES Variable A19I, Light Condition and VA PAR Variable 7)

Reductionists will determine the type of ambient light conditions that are present using the video and record as part of the data reduction process.

1 = Dawn

2 = Daylight

3 = Dusk

4 = Darkness, lighted

5 = Darkness, not lighted

99 = Unknown

3. Windshield Wiper Activation

Analysts will determine the windshield wiper activation through video reduction.

0 = Off

1 - On

99 = Unknown

4. Surface Condition (VA PAR Variable 5)

Reductionists will determine the type of surface condition at the onset of the precipitating factor and record as part of the data reduction process.

1 = Dry

2 = Wet

3 = Snowy

4 = Icy

5 = Muddy

6 = Oily

7 = Other

99 = Unknown

5. Traffic Density (Level of Service)

Reductionists will determine the level of traffic density at the time of the precipitating factor and record as part of the data reduction process.

1 = LOS A: free flow

2 = LOS B: Flow with some restrictions

3 = LOS C: Stable flow, maneuverability and speed are more restricted

4 = LOS D: Unstable flow – temporary restrictions substantially slow driver

5 = LOS E: Flow is unstable, vehicles are unable to pass, temporary

stoppages, etc.

6 = LOS F: Forced traffic flow condition with low speeds and traffic volumes that are below capacity. Queues forming in particular locations.

99 = Unknown

Driving Environment: Infrastructure

1. Kind of Locality (VA PAR Variable 8)

Reductionists will determine the kind of locality at the onset of the precipitating factor and record as part of the data reduction process.

1 = School

2 = Church

3 = Playground

4 = Open Country

5 = Business/industrial

6 = Residential

7 = Interstate

8 = Other

9= *Construction Zone (Added)*

99 = Unknown

2. Relation to Junction (GES Variable A9)

Reductionists will determine the whether the precipitating factor occurred near a roadway junction and record as part of the data reduction process.

Non-Interchange Area

00 = Non-Junction

01 = Intersection

02 = Intersection-related

03 = Driveway, alley access, etc.

04 = Entrance/exit ramp

05 = Rail grade crossing

06 = On a bridge

07 = Crossover related

08 = Other, non-interchange area

09 = Unknown, non-interchange

20 = Parking lot [Added]

FORMAT: Integer value as listed above.

Interchange Area

10 = Non-Junction

11 = Intersection

12 = Intersection-related

13 = Driveway, alley access, etc.

14 = Entrance/exit ramp

16 = On a bridge

17 = Crossover related

18 = Other location in interchange area

19 = Unknown, interchange area

99 = Unknown if interchange

3. Trafficway Flow (GES Variable A11)

Reductionists will determine the whether the roadway was divided at the time of the precipitating factor and record as part of the data reduction process.

1 = Not divided

2 = Divided (median strip or barrier)

3 = One-way traffic

99 = Unknown

4. Number of Travel Lanes (GES Variable A12)

Reductionists will determine the number of travel lanes at the time of the precipitating factor and record as part of the data reduction process.

1 = 1

2 = 2

3a = 3 lanes in direction of travel (divided or one-way trafficway)

3b = Undivided highway, 3 lanes total, 2 in direction of travel

3c = Undivided highway, 3 lanes total, 1 in direction of travel

4 = 4

5 = 5

6 = 6

7 = 7+

99 = Unknown

5. Traffic Control (VA PAR Variable 1)

Reductionists will determine whether there was a traffic control device present and record as part of the data reduction process.

1 = No traffic control

2 = Officer or watchman

3 = Traffic signal

4 = Stop sign

5 = Slow or warning sign

6 = Traffic lanes marked

7 = No passing signs

8 = Yield sign

9 = One way road or street

10 = Railroad crossing with markings or signs

11 = Railroad crossing with signals

12 = Railroad crossing with gate and signals

13 = Other

99 = Unknown

Source: VA PAR Variable 1.

Coded in General State Variables: Road/Traffic Variables.

FORMAT: Integer value as listed above.

6. Alignment (VA PAR Variable 3)

Reductionists will determine what the road alignment was at the onset of the precipitating factor and record as part of the data reduction process.

1 = Straight level

2 = Curve level

3 = Grade straight

4 = Grade curve

5 = Hillcrest straight

6 = Hillcrest curve

7 = Dip straight

8 = Up curve [need definition]

9 = Other

99 = Unknown

Driver State Variables

1. Driver 1 Hands on Wheel (C-N-I-B)

Reductionists will determine the number of hands the driver had on the steering wheel at the time of the precipitating factor and record as part of the data reduction process.

0 = None

1 = Left hand only

2 = Both hands

3 = Right hand only

99 = Unknown

2. Occupant Safety Belt Usage (C)

Reductionists will determine whether the driver had a seatbelt fastened at the time of the precipitating factor and record as part of the data reduction process.

1 = Lap/shoulder belt

2 = Lap belt only

3 = Shoulder belt only

5 = None used

99 = Unknown if used.

3. Driver 1 Alcohol Use (GES Variable V92)

Reductionists will determine whether drivers were using alcohol or under the influence of alcohol at the time of the precipitating factor and record as part of the data reduction process.

1a = Use observed in vehicle without overt effects on driving

1b = Use observed in vehicle with overt effects on driving

1c = Use not observed but reported by police

1d = Use not observed or reported, but suspected based on driver behavior.

2 = None known

99 = Unknown

4. Fault Assignment

1 = Driver 1 (participant vehicle)

2 = Driver 2

3 = Driver 3

4 = Driver 4

5 = Driver 5

6 = Driver 6

7 = Driver 7

8 = Driver 8

9 = Driver 9

10 = Driver 10

11 = Other (textbox)

99 = Unknown

5. Average PERCLOS (Percentage Eyes Closed) (C, N)

For crashes and near-crashes where the driver's observer rating of drowsiness is above a criterion level (an ORD of 60), the average PERCLOS value for the 30 s pre-event period will be obtained through video reduction.

6. Driver 1 Eye Glance Reconstruction (C-N)

Eye glances for the previous 30 s will be classified using the following categories and described as a timed, narrative sequence of the following numbers:

1 = Center forward

2 = Left forward

3 = Right forward

4 = Left mirror

5 = Right mirror

6 = Left window

7 = Right window

8 = Instrument panel

9 = Passenger

10 = Object

11 = Cell Phone

12 = Other

Comment: The analysis will include a recording of time the driver's eyes were not "on the road," i.e., straight ahead, forward right, or forward left. When possible, eye glances will be characterized in greater detail than the general directions and areas listed above; e.g., when known, the specific object of regard will be noted in the narrative. For the instrument panel, for example, specific components such as the radio/CD will be noted in the narrative. When applicable and possible, the eye glance reconstruction will also include an assessment of driver reaction time to a stimulus, e.g., braking reaction time following a potential crash-precipitating event.

Driver/Vehicle 2

1. Number of other Vehicle(s)/Person(s)

Reductionists will identify the number of vehicles in the immediate environment .

2. Location of other Vehicle/Persons

Reductionists will identify the location of vehicles in the immediate environment with respect to the participant vehicle and then record the following variables.

A = In front of participant vehicle

B = In front and to the immediate right of the participant vehicle

C = On the right side of the participant vehicle, closer to front seat of the vehicle

D = On the right side of the participant vehicle, closer to rear seat of the vehicle

E = Behind and to the immediate right of the participant vehicle

F = Behind the participant vehicle

G = Behind and to the immediate left of the participant vehicle

H = On the left side of the participant vehicle, closer to the rear seat of the vehicle

I = On the left side of the participant vehicle, closer to the front seat of the vehicle

J = In front and to the immediate left of the participant vehicle

3. Vehicle/Person 2 Type (Modified version of GES Variable V5, Body Type)

Data reductionists will record what type of vehicles are in the participant vehicle's immediate surroundings.

1 = Automobile

14 = Sport Utility vehicles

20 = Van-based truck (minivan or standard van)

30 = Pickup truck

50 = School Bus

58a = Transit bus

58b = Greyhound bus

58c = Conversion bus

64a = Single-unit straight truck: Multi-stop/Step Van

64b = Single-unit straight truck: Box

64c = Single-unit straight truck: Dump

64d = Single-unit straight truck: Garbage/Recycling

64e = Single-unit straight truck: Concrete Mixer

64f = Single-unit straight truck: Beverage

64g =Single-unit straight truck: Flatbed

64h =Single-unit straight truck: Tow truck

64i = Single-unit straight truck: Other

64j = Single-unit straight truck: Unknown

64k = Straight Truck + Trailer

66 = Tractor only

66a = Tractor-trailer: Enclosed box

66b = Tractor-trailer: Flatbed

66c = Tractor-trailer: Tank

66d = Tractor-trailer: Car carrier

66e = Tractor-trailer: Livestock

66f = Tractor-trailer: Lowboy trailer

66g = Tractor-trailer: Dump trailer

66h = Tractor-trailer: Multiple trailers/Enclosed box

66i = Tractor-trailer: Multiple trailers/grain

66e = Tractor-trailer: Other

93 = Other Large Construction Equipment

8 = Motorcycle or moped

9a = Ambulance

9b = Fire truck

9c = Police

10 = Other vehicle type

11 = Pedestrian

12 = Pedalcyclist

13 = Animal

99 = Unknown vehicle type

4. Vehicle 2 Maneuver (GES Variable V21, Movement Prior to Critical Event)

Reductionists will record what the other vehicle's actions were just prior to the onset of the precipitating factor.

1 = Going straight ahead

2 = Making right turn

3 = Making left turn

4 = Making U-turn

5 = Slowing or stopping

6 = Starting in traffic lane

7 = Starting from parked position

8 = Stopped in traffic lane

9 = Ran off road right

10 = Ran off road left

11 = Parked

12 = Backing

13 = Passing

14 = Changing lanes

15 = Other

16 = Accelerating in traffic lane

17 = Entering a parked position

18 = Negotiating a curve

19 = Merging

99 = Unknown

5. Driver/Vehicle 2 Corrective Action Attempted (GES V27, Corrective Action Attempted)

Reductionists will record the corrective action attempted for each vehicle immediately surrounding the participant vehicle.

0 = No driver present

1 = No avoidance maneuver

2 = Braking (no lockup)

3 = Braking (lockup)

4 = Braking (lockup unknown)

5 = Releasing brakes

6 = Steered to left

7 = Steered to right

8 = Braked and steered to left

9 = Braked and steered to right

10 = Accelerated

11 = Accelerated and steered to left

12 = Accelerated and steered to right

98 = Other actions

99 = Unknown if driver attempted any corrective action

Coded: From PAR and/or video.

Source: GES V27, Corrective Action Attempted.

Coded in General State Variables: Driver/Vehicle 2.

FORMAT: Integer value as listed above.

6. Driver/Vehicle 2 Physical/Mental Impairment (GES D3, Driver Physical/Mental Condition)

Reductionists will mark only for those crashes when a police accident report form is collected from the participant.

0 = None apparent

1 = Drowsy, sleepy, asleep, fatigued

2 = Ill, blackout

3a = Angry

3b = Other emotional state

4 = Drugs-medication

5 = Other drugs (marijuana, cocaine, etc.)

6 = Restricted to wheelchair

7 = Impaired due to previous injury

8 = Deaf

50 = Hit and run vehicle

97 = Physical/mental impairment – no details

98 = Other physical/mental impairment

99 = Unknown physical/mental condition

7. Driver 2 Actions/Factors Relating to Crash/Incident (VA PAR Variable 17/18)

Reductionists will code this for crashes and near-crashes only for each vehicle immediately surrounding the participant vehicle.

0 = None

1 = Exceeded speed limit

2 = Inattentive or distracted (coded in previous variable)

3 = Exceeded safe speed but not speed limit

4 = Driving slowly: below speed limit

5 = Driving slowly in relation to other traffic: not below speed limit

6 = Illegal passing (i.e., across double line)

7 = Passing on right

8 = Other improper or unsafe passing

9 = Cutting in, too close in front of other vehicle

10 = Cutting in, too close behind other vehicle

11 = Making turn from wrong lane (e.g., across lanes)

12 = Did not see other vehicle during lane change or merge

13 = Driving in other vehicle's blind zone

14 = Aggressive driving, specific, directed menacing actions

15 = Aggressive driving, other; i.e., reckless driving without directed menacing actions

16 = Wrong side of road, not overtaking

17 = Following too close

18 = Failed to signal, or improper signal

19 = Improper turn: wide right turn

20 = Improper turn: cut corner on left turn

21 = Other improper turning

22 = Improper backing, did not see

23 = Improper backing, other

24 = Improper start from parked position

25 = Disregarded officer or watchman

26 = Signal violation, apparently did not see signal

27 = Signal violation, intentionally ran red light

28 = Signal violation, tried to beat signal change

29 = Stop sign violation, apparently did not see stop sign

30 = Stop sign violation, intentionally ran stop sign at speed

31 = Stop sign violation, “rolling stop”

32 = Other sign (e.g., Yield) violation, apparently did not see sign

33 = Other sign (e.g., Yield) violation, intentionally disregarded

34 = Other sign violation

35 = Non-signed crossing violation (e.g., driveway entering roadway)

36 = Right-of-way error in relation to other vehicle or person, apparent recognition failure (e.g., did not see other vehicle)

37 = Right-of-way error in relation to other vehicle or person, apparent decision failure (i.e., did see other vehicle prior to action but misjudged gap)

38 = Right-of-way error in relation to other vehicle or person, other or unknown cause

39 = Sudden or improper stopping on roadway

40 = Parking in improper or dangerous location, e.g., shoulder of Interstate

41 = Failure to signal with other violations or unsafe actions

42 = Failure to signal, without other violations or unsafe actions

43 = Speeding or other unsafe actions in work zone

44 = Failure to dim headlights

45 = Driving without lights or insufficient lights

46 = Avoiding pedestrian

47 = Avoiding other vehicle

48 = Avoiding animal

49 = Apparent unfamiliarity with roadway

50 = Apparent unfamiliarity with vehicle, e.g., displays and controls

51 = Apparent general inexperience driving

52 = Use of cruise control contributed to late braking

53 = Other, specify

APPENDIX B. Distraction Reduction Variables Used in Crash/Near-Crash, Baseline, and Control Reductions

List	*Code*	*Distraction Category*	*Category Definitions*	*Examples and Hints*	*Distraction Start Point*	*Distraction End Point*
		Not Distracted	There are no observable signs of driver distraction			
A	**q**	Lost in thought	Driver is looking at, or near, the location of the incident but exhibits an obviously delayed or slow response	Can be characterized by random, quick eye glances around the environment, but not at anything in particular.	When incident first presents itself (i.e., vehicle ahead of driver applies brakes)	When driver first responds to incident (i.e., facial expression changes, applies brakes, moves steering wheel in an evasive maneuver).
A	**1**	Looked but did not see	Driver is looking right at where incident is occurring, but shows no reaction; that is, clearly does not recognize that the incident is occurring or the hazard is present		When incident first presents itself (i.e., vehicle ahead of driver applies brakes)	When driver first responds to incident (i.e., facial expression changes, applies brakes, moves steering wheel in an evasive maneuver).

A	**s**	Singing/Talking	When driver is moving lips as if singing a song or talking to self.	Mark this if driver is singing and there is no other passenger visible in the car. Only use this distraction if you cannot see a passenger in the camera or the driver is talking and not looking in the direction of a passenger seat and does not turn head as if communicating with someone.	When driver first starts to open mouth, forming first word.	When driver stops moving mouth for last time. This does not include driver screaming or cursing in reaction to an incident.
A	**a**	Dancing	This could be when the driver is using his/her arms to go with the beat of the music or moving head or torso.		When body part first starts moving in a rhythmic motion.	When body stops moving in a rhythmic motion for the last time.
A	**r**	Reading	This is reading material that is in the vehicle, but not a part of the vehicle (i.e., not reading external signs, or radio display). This could be reading directions, paper material, packaging. If reading a phone number, record as dialing cell phone.		When eyes first glance at what the driver is reading.	The point when the eyes transition back to the driving task after being fixated on the reading material for the last time. If less than 5 seconds, it is the same task. If 5 seconds or greater, separate task.

A	**w**	Writing	Driver is writing using a pen or pencil on some kind of notepad or object. Does not include using a stylus for a PDA or similar device, or typing as in texting or other activity		When the driver first glances at the pen/pencil or notepad, or begins to reach for them without glancing away from the roadway.	When eyes have fixated on the writing task or person for the last time and then fixate somewhere else. If time between writing is less than 5 seconds, then keep as same task. If time between writing is 5 seconds or greater, then it is two separate writing tasks.
A	**e**	Emotional distraction	Includes when driver is obviously emotionally upset, angry, crying, or other activity that requires the driver to be thinking about something other than driving	If the driver is crying throughout the trip, label the entire trip as emotional distraction.	When eyes first glance at what the driver is angry at, etc.	When eyes have fixated on what the driver is angry at for the last time and then fixate somewhere else.
A	**2**	Passenger(s) Present*	When a passenger is clearly present either in adjacent and/or the rear seat but the driver is not actively engaging in conversation with passenger.	Use this category when there is a passenger present in any seat in the vehicle but no active conversation is occurring.	Begin sync is the beginning frame of event.	End sync is the end sync of event.

A	**3**	Passenger Adjacent Seat/Driver Interaction	The driver is clearly interacting with a passenger (other than a child) in the adjacent seat. This could be talking, listening, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person).	Use this distraction if you can see the passenger (other than a child) in the camera or the driver is talking and looking in the direction of the passenger seat. Entire trip file or segment may be used to look for evidence of passenger. Consider this distraction as long as the driver and passenger remain in the vehicle (even if the car stops or is idling).	The first frame number when driver interacts with a passenger in the adjacent seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her.	The last frame number when driver interacts with a passenger in the adjacent seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her. If there is a clear break in the interaction for more than 5 seconds, code as the end of the current task.

A	**4**	Passenger in Rear seat/Driver Interaction	The driver is clearly interacting with a passenger (other than a child) in the rear seat. This could be talking, listening, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person).	Use this distraction if you can see the passenger (other than a child) in the camera or the driver is talking and looking in the direction of the rear seat.	The first frame number when driver interacts with a passenger in the rear seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her.	The last frame number when driver interacts with a passenger in the rear seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her. If there is a clear break in the interaction for more than 5 seconds, code as the end of the current task.

A	**5**	Child in adjacent seat/Driver interaction	The driver is clearly interacting with a child in the adjacent seat. This could be talking, listening, reacting to (i.e., laughing), moving toward or away from the child (i.e., reaching for a child, not object, or avoiding a pat from the child). If the child is visible (even if the driver is not interacting at a given time), code this distraction.	Use this distraction if you can see the child in the camera or the driver is talking and looking in the direction of the adjacent seat, handing bottles/toys, etc. Entire trip file or segment may be used to look for evidence of passenger. Consider this distraction as long as the driver and passenger remain in the vehicle (even if the car stops or is idling).	The first frame number when driver interacts with a child in the adjacent seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for a child, not object, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing them. If the driver exits the car and re-enters, event start would begin when the driver enters the vehicle again with the passenger also in the vehicle.	The last frame number when driver interacts with a child in the adjacent seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her. If there is a clear break in the interaction for more than 5 seconds, code as the end of the current task.

A	**6**	Child in rear seat/Driver interaction	The driver is clearly interacting with a child in the rear seat. This could be talking, listening, reacting to (i.e., laughing), moving toward or away from the child (i.e., reaching for a child, not object, or avoiding a pat from the child). If the child is visible (even if the driver is not interacting at a given time), code this distraction.	Use this distraction if you can see the child in the camera or the driver is talking and looking in the direction of the rear seat, handing bottles/toys, etc. If the driver is looking at the rear passenger using the rearview mirror, then that would be coded as passenger in rear seat AND center rearview mirror. Entire trip file or segment may be used to look for evidence of passenger. Consider this distraction as long as the driver and passenger remain in the vehicle (even if the car stops or is idling).	The first frame number when driver interacts with a child in the back seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for a child, not object, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing them. If the driver exits the car and re-enters, event start would begin when the driver enters the vehicle again with the passenger also in the vehicle.	The last frame number when driver interacts with a child in the rear seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her. If there is a clear break in the interaction for more than 5 seconds, code as the end of the current task.

A	**m**	Moving object in vehicle	When any object moves unexpectedly in the vehicle that draws the driver's attention immediately away from the prior activity; including driving only, or driving plus other.	Ex. object is falling off seat when driver stopped hard at a traffic light; drink spilling or turning over, food dripping, cell phone dropped	When driver first shifts gaze or starts to move hand to reach for the object.	When driver puts down object, or if he/she holds onto it, then the end frame would be when the driver stops moving his/her hand and the driver's gaze has returned to tne roadway.
A	**b**	Insect in vehicle	Swatting at insect, moving body to avoid insect, looking around trying to locate insect.		When driver first responds to insect (i.e., looks away from driving scene)	When driver goes back to normal driving behavior (i.e., looking at driving scene) and stops interacting with the insect. If there is a clear break of 5 seconds where the driver does not interact with the insect, code as separate events.

A	**n**	Pet in vehicle	Any interaction with pet, including petting, talking to, or moving pet or pet carrier.	Only code if animal/pet is visible at some point in the trip file or if there is history/context with the driver and the driver is exhibiting behaviors that are appropriate to having a pet in the vehicle.	When driver first interacts with pet. This could be first glance away from driving scene when looking for or at pet. Or if driver first speaks and then looks at pet, then the beginning frame number would be when first word is formed.	When driver stops interacting with pet. This would be the point in time when the driver's gaze or hand has returned to the driving task after the driver has last glanced at pet, takes hand off of pet if not looking at pet, or stops talking to pet. If there is a clear break in the interaction with pet greater than 5 seconds, code as separate tasks.

A	**h**	Reaching for object (not cell phone)	When driver reaches to pick up an object, other than a cell phone, or is setting the object down/putting away.	Once the driver has finished reaching for the object and has it in hand, then it becomes 'object in vehicle_other', as long as it doesn't fit into any of the other categories (i.e., eating or drinking).	When driver first starts to move hand to reach for object/when the driver begins to move the object to set it down or put it away.	When driver retrieves the object and first begins to use it; or shifts gaze or hand back to the driving task. Could also end when driver places object and it no longer is in his/her hands.
A	**l**	Looking at object in Vehicle	When a driver clearly is looking at a visible object or thing located in the vehicle, other than those listed in other categories. Driver does not necessarily need to handle or manipulate for this category.		Begins when the driver first gazes at object.	Ends when gaze returns to the driving task for the last time.
A	**k**	In vehicle - Other	When a driver is doing something in the vehicle that is not covered by other options. This may include holding an object (other than cell phone) such as a pen, without interacting with it.		Begins when the secondary task first begins (e.g., driver has picked up object, coded as Reach for Object, and is holding it but not interacting with it).	Ends when the secondary task ends (e.g., driver reaches out to put object down, at which point it becomes Reach for Object).

A	**c**	Talking/listening on cell phone	When a driver is talking or has phone up to ear as if listening to a phone conversation or waiting for person they are calling to pick up the phone. If driver has ear piece, reductionist must observe the driver talking repeatedly.	Cell phone use is always categorized as Distraction	Begins when the phone is at the driver's ear. If using an earpiece, it begins when the driver has pushed the last button on his/her phone.	Ends when the driver moves the phone away from his/her ear and has let go of the phone, or once the phone is away from the driver's ear, when the phone is no longer moving (i.e., driver puts the phone down in his/her lap or holds on steering wheel, but doesn't let go of the phone). Once they put the phone in their lap and still hold it, this should be recorded as "other." If they are using an earpiece, it is when they push a button on their phone to end the call.

A	**d**	Dialing hand-held cell phone	When a driver is pushing buttons on a cell phone to dial a number or check something else on their cell phone. This would also include reading a phone number from a sheet of paper.		For flip phones it begins when phone is fully opened. For non-flip phones it begins when first button on keypad is depressed or glance at cell phone begins just prior to pushing a button, whichever comes first. If driver reads phone number from a piece of paper, the first frame number would be when the driver picks up the piece of paper and glances at it.	Ends when last button is depressed and hand stops moving when the phone is up to the driver's ear. Or if not completing a call, it would be when he/she closes the phone and/or lets it go or puts it in his/her lap, or last glances at it.

A	**x**	Dialing hand-held cell phone using quick keys	When a driver is pushing buttons on a cell phone to dial a number or check something else on their cell phone.		For flip phones it begins when phone is fully opened. For non-flip phones it begins when first button on keypad is depressed or glance at cell phone begins just prior to pushing a button, whichever comes first.	Ends when last button is depressed and hand stops moving when the phone is up to the driver's ear. Or if not completing a call, it would be when he/she closes the phone and/or lets it go or puts it in his/her lap, or last glances at it.
A	**f**	Dialing hands-free cell phone using voice-activated software	When a driver speaks into open or activated cell phone with long, prior delay of no speaking into device and no button presses (i.e., most likely not in prior conversation).		Begins when driver begins to speak toward open cell phone or in ear piece.	Ends when the driver continually speaks, as if in conversation or presses button on cell phone (hangs up).

A	**5**	Child in adjacent seat/Driver interaction	The driver is clearly interacting with a child in the adjacent seat. This could be talking, listening, reacting to (i.e., laughing), moving toward or away from the child (i.e., reaching for a child, not object, or avoiding a pat from the child). If the child is visible (even if the driver is not interacting at a given time), code this distraction.	Use this distraction if you can see the child in the camera or the driver is talking and looking in the direction of the adjacent seat, handing bottles/toys, etc. Entire trip file or segment may be used to look for evidence of passenger. Consider this distraction as long as the driver and passenger remain in the vehicle (even if the car stops or is idling).	The first frame number when driver interacts with a child in the adjacent seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for a child, not object, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing them. If the driver exits the car and re-enters, event start would begin when the driver enters the vehicle again with the passenger also in the vehicle.	The last frame number when driver interacts with a child in the adjacent seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her. If there is a clear break in the interaction for more than 5 seconds, code as the end of the current task.

A	**3**	Passenger Adjacent Seat/Driver Interaction	The driver is clearly interacting with a passenger (other than a child) in the adjacent seat. This could be talking, listening, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person).	Use this distraction if you can see the passenger (other than a child) in the camera or the driver is talking and looking in the direction of the passenger seat. Entire trip file or segment may be used to look for evidence of passenger. Consider this distraction as long as the driver and passenger remain in the vehicle (even if the car stops or is idling).	The first frame number when driver interacts with a passenger in the adjacent seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her.	The last frame number when driver interacts with a passenger in the adjacent seat. This could be talking, reacting to (i.e., laughing), moving toward or away from the passenger (i.e., reaching for the passenger, or avoiding a pat from the person) or glancing at the passenger or something the passenger is showing him/her. If there is a clear break in the interaction for more than 5 seconds, code as the end of the current task.

A	**0**	Locating/reaching PDA	When driver reaches or starts to glance around for PDA.		When driver first starts to move hand to reach for PDA or glances in that direction followed by hand moving for PDA	When driver first touches the PDA. If driver doesn't touch PDA, then it is when driver stops looking at PDA.
A	**9**	Operating PDA	When driver is pressing buttons on the PDA.		When driver first presses a button on the PDA	The last button press on the PDA
A	**8**	Viewing PDA	When driver is looking at PDA, but not pressing any buttons		When driver first looks in the direction of the PDA location.	When driver looks away from the PDA and fixates on another location.
A	**7**	PDA - Other	When a driver is interacting with a PDA in some manner; i.e., looking at PDA and/or holding the PDA while driving.		When driver first looks at screen and is not pressing any buttons on PDA or after driver has held the PDA for a few seconds.	When driver looks away from PDA and fixates somewhere else and/or puts the PDA down.
A	**t**	Adjusting climate control	When driver interacts with climate control either by touching the climate control buttons, or glancing at the climate control on dashboard.		When driver's hand moves in the direction of the control or driver first glances at climate control.	When driver's hand has last interaction adjusting knobs or any controls for that device or driver glances at device for the last time.

A	**g**	Adjusting radio	When driver interacts with radio either by touching the radio buttons on dashboard or steering wheel, or just glancing at the radio on dashboard.		When driver's hand moves in the direction of the control or driver first glances at the radio.	When driver's hand has last interaction adjusting knobs or any controls for that device or driver glances at device for the last time.
A	**y**	Inserting/retrieving cassette	When driver picks up cassette in vehicle and pushes it into cassette slot and presses any subsequent buttons to get cassette to play/rewind/fast forward and then play, or when driver presses button to eject cassette and then places it somewhere in vehicle.		When driver's hand moves in the direction of the cassette to insert it into player OR when driver's hand moves in the direction of the player to extract a cassette OR driver first glances at cassette (case) or direction of the cassette player.	When driver's hand has last interaction with player (i.e., pushing play) or driver puts cassette that has been retrieved either in a case or puts it down or driver has a last glance at device or cassette.

A	**u**	Inserting/retrieving CD	When driver picks up CD in vehicle and pushes it into CD slot and presses any subsequent buttons to get CD to play/rewind/fast forward and then play, or when driver presses button to eject CD and then places it somewhere in vehicle.		When driver's hand moves in the direction of the CD to insert it into player OR when driver's hand moves in the direction of the player to extract a CD OR driver first glances at case or direction of the CD player.	When driver's hand has last interaction with player (i.e., pushing play) or driver puts CD that has been retrieved either in a case or puts it down or driver has a last glance at device or CD.
A	**o**	Adjusting other devices integral to vehicle	When driver interacts with a manufacturer-installed device other than those listed in other categories, either by touching or glancing at the device.	Includes interaction with seat belt, door locks, etc.	When driver's hand moves in the direction of the device or driver first glances at that device.	When driver's hand has last interaction touching that device OR driver glances at that device for the last time.

B	**q**	Looking at previous crash or incident	When a driver is looking outside of the vehicle in the direction of what is obviously an accident or incident.	Only mark if it is clear that the driver is tracking a specific external distraction as he/she drives by--mark what you see the driver doing (ex., mark inattention: rear-view mirror, if driver is looking at mirror)/quick glances are not categorized in this category, code these according to where the driver is glancing (ex., mirror or window)	When driver's glance is first directly on the accident or something related to the accident (i.e., police officer standing on the side of the road)	When driver has taken his/her last direct glance at the accident.
B	**w**	Looking at pedestrian	When a driver is looking outside of the vehicle in the direction of a pedestrian (not in a construction zone) either on the side of the road or in front of them (i.e. using a crosswalk or riding a bike at a red light).		When driver first glances at pedestrian.	When driver has taken his/her last glance at the pedestrian.
B	**a**	Looking at animal	When a driver is looking outside of the vehicle in the direction of an animal on either side of the road. This would not be used for an animal crossing the road.		When driver first glances at the animal.	When driver has taken his/her last glance at the animal.

B	**s**	Looking at an object	When a driver is looking outside of the vehicle in the direction of an object (not in a construction zone) on the side of the road (e.g.., a box).		When driver first glances at the object.	When driver has taken his/her last glance at the object.
B	**d**	Distracted by construction	When a driver is looking outside of the vehicle in the direction of a construction zone. A construction zone would be defined as seeing a barrel, person in a hard hat, construction equipment, or vehicles.		When driver first glances at an object or person in the construction zone.	When driver has taken his/her last glance at an object or person in the construction zone.
B	**e**	Other external distraction	When a driver is looking outside of the vehicle for purposes not described in previous categories.		When driver first glances at an object or person outside the vehicle.	When driver has taken his/her last glance at an object or person outside of the vehicle.

B	**p**	Eating with utensils	When a driver has food that will be put into his/her mouth via a utensil like a fork, spoon, knife, chopsticks, etc.		When driver first picks up the food to be eaten or the utensil to eat it with.	When driver does the last of one of the following: (1) finishes chewing, (2) puts food or utensil down and lets go of it or hand that is holding food/utensil is still for 5 seconds (i.e., in lap or on steering wheel)
B	**o**	Eating without utensils	When a driver has food that will be put into his/her mouth and a utensil is not used to place the food in the driver's mouth.		When driver first picks up the food to be eaten.	When driver does the last of one of the following: (1) finishes chewing, (2) puts food down and lets go of it or hand that is holding food is still for 5 seconds (i.e., in lap or on steering wheel)

B	**i**	Drinking with lid and straw	When a driver uses a straw to drink from a container that has a cover on it and cannot easily spill if it tips over	Ex. Fountain drink with lid and straw, sippy water bottle	When driver first picks up the drink to be drunk.	When driver puts drink down and lets go of it or hand that is holding the drink is still for 5 seconds (i.e., in lap or on steering wheel)
B	**u**	Drinking with lid, no straw	When a driver drinks from a container that has a cover on it and cannot easily spill if it tips over (not using a straw)	Ex. Coffee mug with lid that closes	When driver first picks up the drink to be drunk.	When driver puts drink down and lets go of it or hand that is holding the drink is still for 5 seconds (i.e., in lap or on steering wheel)
B	**y**	Drinking with straw, no lid	When a driver uses a straw to drink from a container that does not have a lid	Ex. Uncovered fountain drink with a straw	When driver first picks up the drink to be drunk.	When driver puts drink down and lets go of it or hand that is holding the drink is still for 5 seconds (i.e., in lap or on steering wheel)

B	**t**	Drinking from an open container	When a driver drinks from a container that does not have a lid (not using a straw)	Ex. Uncovered cup, coffee cup, water bottle with lid off, soda can	When driver first picks up the drink to be drunk.	When driver puts drink down and lets go of it or hand that is holding the drink is still for 5 seconds (i.e., in lap or on steering wheel)
B	**c**	Reaching for cigar/cigarette	When driver reaches or starts to glance around for cigar/cigarette.		When driver first starts to move hand to reach for cigar/cigarette or glances in that direction followed by hand moving for cigar/ cigarette.	When driver puts the cigar/ cigarette in mouth and last touches cigar/ cigarette before the process of lighting it has begun.
B	**v**	Lighting cigar/cigarette	When driver is reaching for and/or lighting cigar/cigarette.		When driver first starts to move hand to reach for lighter or glances in that direction followed by hand moving for lighter.	When driver starts to let go of lighter, OR in the case of an in-dash lighter, when lighter is placed back in dashboard and driver lets go of it OR last glance to either of these devices, whichever is last.

B	**z**	Smoking cigar/cigarette	When driver has a lit cigar/cigarette in their mouth or hand.		When driver lets go of lighter and driver has a lit cigar/cigarette in mouth or hand.	This would be the last frame number before driver starts to move cigar/ cigarette towards ashtray or device for extinguishing cigar/ cigarette.
B	**x**	Extinguishing cigar/cigarette	When driver puts out his/her cigar/cigarette, or hands it to someone else.		When driver's hand starts to move cigarette towards extinguishing device.	When driver last touches cigar/ cigarette.
B	**1**	Combing/brushing/ fixing hair	Any touching, adjusting, or combing/brushing of hair.	Picking up comb/hairbrush would go under object/animal/ insect in vehicle: reaching for object	When driver's hand first moves towards hair (would not include reaching for hairbrush, would be after having hairbrush in hand).	When driver's hand/brush/ comb last touches hair.

B	**2**	Applying makeup	Applying any body product to body. This would include lotions.	Picking up makeup would go under object/animal/ insect in vehicle: reaching for object	When driver's hand first moves towards makeup in such a manner that it will be applied to body (would not include getting makeup out of purse, would be after having makeup in hand and hand moving in the direction of opening up makeup container; i.e., flipping a compact lid open, or taking top off of lip gloss)	When driver last touches body to apply makeup and/or last checks self in mirror, whichever step comes last. This would include smoothing out makeup that was just applied.
B	**3**	Shaving	Using any appliance to remove hair from body. This does not include tweezing.	Picking up razor would go under object/animal/ insect in vehicle: reaching for object. Using tweezers would go under Personal hygiene: other.	When driver has the razor in hand and hand moves towards face.	When razor last touches face and/or driver last checks self in mirror, whichever step comes last.

B	**4**	Brushing/flossing teeth	Using any appliance to brush, floss, or otherwise clean teeth or mouth.		When driver has toothbrush, floss, or oral hygiene product in hand. For floss this would start when the package is in hand, before the driver actually gets the piece of floss out.	When toothbrush, floss, or oral hygiene product last touches driver's mouth and/or driver spits out toothpaste and/or driver checks teeth in mirror, whichever step comes last.
B	**5**	Biting nails/cuticles	When driver bites nails or cuticles		When driver's hand first moves towards mouth.	When driver's hand last touches mouth and/or removing nail or cuticle bitten off finger nail from driver's mouth.
B	**6**	Removing/adjusting jewelry	When driver removes or adjusts jewelry, including watches.		When driver's hand first moves towards jewelry.	When driver's hand last touches jewelry if adjusting jewelry or the driver lets go of jewelry if removing jewelry, whichever step comes last.

B	**7**	Removing or putting on glasses/sunglasses	When driver is putting on or taking off glasses or sunglasses	If driver is simply adjusting glasses, this should not be coded as a distraction.	When driver's hand first moves towards glasses.	When driver's hand last touches glasses.
B	**8**	Removing /inserting contact lenses	When driver is removing or inserting contact lens(es) from eye(s)		When driver's hand first moves towards eye to remove contact or interact with contact OR if inserting contact it would be when driver first opens contact lens case to expose contact.	When driver's hand last touches eyeball if inserting contact OR when driver last touches contact if removing it or adjusting it in the eye, whichever step comes last.
B	**9**	Other personal hygiene*	Other personal hygiene activities not described in previous categories	These might include scratching face, adjusting clothing, checking oneself in mirror without the preceding tasks, trying to get something out of one's eye	When driver has first interaction.	When driver has last interaction.

*These tasks were not included in any of the analyses in this report because these tasks were not distracting to the driver.

APPENDIX C. Frequency and Percent of Observed Drowsiness and Secondary Task Use in the Crash/Near-Crash Data Set and Case-Crossover Baseline

Frequency Percent Row Percent Column Percent	Crashes/Near-Crashes : No Drowsiness Present	Crashes/Near-Crashes : Drowsiness Present	**Crashes/Near-Crashes :** **Totals**	Case-Crossover Baseline: No Drowsiness Present	Case-Crossover Baseline: Drowsiness Present	**Case-Crossover Baseline:** **Totals**
Complex Secondary Task	26 4.6% 100.0% 5.5%	0 0% 0% 0%	26 4.6%	175 2.6% 100% 2.6%	0 0% 0% 0%	175 2.6%
Moderate Secondary Task	119 21.1% 92.5% 25.2%	10 1.8% 7.8% 10.9%	129 22.8%	1,449 21.7% 99.7% 21.8%	5 0.1% 0.3% 18.5%	1,454 21.8%
Simple Secondary Task	120 21.2% 87.0% 25.4%	18 3.2% 13.0% 19.6%	138 24.4%	1,929 28.9% 99.8% 29.0%	3 0.04% 0.2% 11.1%	1,932 29.0%
No Secondary Task	208 36.8% 76.5% 44.0%	64 11.3% 23.5% 69.6%	272 48.1%	3,090 46.3% 99.4% 46.5%	19 0.3% 0.6% 70.4%	3,109 46.6%
Totals	473 83.7%	92 16.3%	565 100%	6,643 99.6%	27 0.4%	6,670 100%

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