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The Impact of Driver Inattention On Near-Crash/Crash Risk:

An Analysis Using the 100-Car Naturalistic Driving Study Data

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16. Abstract
The purpose of this report was to conduct in-depth analyses of driver inattention using the driving data collected in the 100-Car Naturalistic Driving Study. An additional database of baseline epochs was reduced from the raw data and used in conjunction with the crash and near-crash data identified as part of the original 100-Car Study to account for exposure and establish near-crash/crash risk. The analyses presented in this report are able to establish direct relationships between driving behavior and crash and near-crash involvement. Risk was calculated (odds ratios) using both crash and near-crash data as well as normal baseline driving data for various sources of inattention. The corresponding population attributable risk percentages were also calculated to estimate the percentage of crashes and near-crashes occurring in the population resulting from inattention. Additional analyses involved: driver willingness to engage in distracting tasks or driving while drowsy; analyses with survey and test battery responses; and the impact of driver's eyes being off of the forward roadway.

The results indicated that driving while drowsy results in a four- to six-times higher near-crash/crash risk relative to alert drivers. Drivers engaging in visually and/or manually complex tasks have a three-times higher near-crash/crash risk than drivers who are attentive. There are specific environmental conditions in which engaging in secondary tasks or driving while drowsy is more dangerous, including intersections, wet roadways, and areas of high traffic density. Short, brief glances away from the forward roadway for the purpose of scanning the driving environment are safe and actually decrease near-crash/crash risk. Even in the cases of secondary task engagement, if the task is simple and requires a single short glance the risk is elevated only slightly, if at all. However, glances totaling more than 2 seconds for any purpose increase near-crash/crash risk by at least two times that of normal, baseline driving.

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EXECUTIVE SUMMARY

INTRODUCTION

The purpose of this report was to conduct in-depth analyses of driver inattention using the driving data collected in the 100-Car Naturalistic Driving Study. These data provide unique opportunities for transportation researchers as data were collected over an 18-month period and represent normal, daily driving with all the stress and pressures that occur in a metropolitan environment.

This analysis also demonstrates one of the primary strengths of large-scale naturalistic driving data in that analytical methods from epidemiology, empirical research, and qualitative research can all be employed to answer research questions. Figure ES.1 shows the relationship of naturalistic data to empirical and epidemiological data. Naturalistic data can help complete gaps in the transportation research between epidemiology and empirical methods by collecting enough data to conduct epidemiological analyses while still collecting detailed driver behavior and driving performance data.

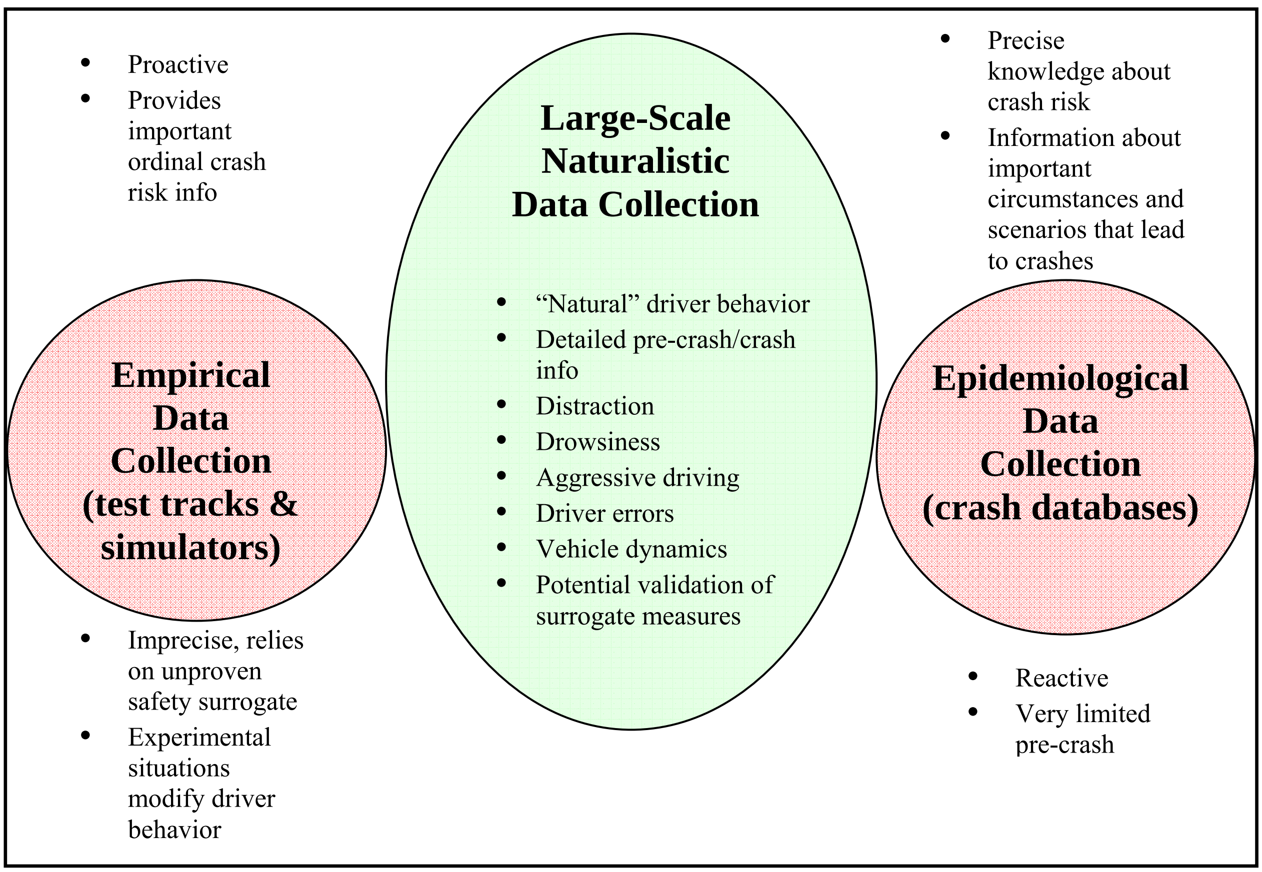

Figure ES.1. The relationship between empirical, naturalistic, and epidemiological methods in driving safety research.

The following analyses are able to establish direct relationships between driving inattention and crash and near-crash involvement because of the extensive real-world observations of drivers' behavior. Relative near-crash/crash risk was calculated (odds ratios) using both crash and near-crash data compared to normal, baseline driving data for various sources of inattention. Crashes and near-crashes were used because it was found that the kinematic signatures of both are similar and using both increased statistical power. The corresponding population attributable risk percentage calculations were used to determine what percentage of crashes and near-crashes occurring in the population are attributable to inattention. The relative near-crash/crash risk and population attributable risk percentage calculations provide useful counterpoint assessments of the crash-risk problem. The odds ratio provides the increased risk of each source of inattention per individual whereas the population attributable risk percentage provides an assessment of how this individual risk translates to a percentage of crashes and near-crashes in the population at-large.

METHOD

For these analyses, two reduced databases were used: the 100-Car Study *event database* that consists of the reduced crashes, near-crashes, and incidents; and the *baseline database*. The *baseline database* was created specifically for this analysis by stratifying the entire dataset based upon the number of crashes, near-crashes, and incidents each vehicle was involved in and then randomly selecting 20,000 6-second segments from the 6.3 terabytes of driving data. For example, a vehicle involved in over 3 percent of all the total crashes, near-crashes, and incidents would also represent 3 percent of the baselines. Vehicles that were not involved in any crashes, near-crashes, or incidents were not represented in the baseline database. This stratification of the baseline epochs was performed to create a *case-control* data set where there are multiple baseline epochs per each crash or near-crash event to allow for more accurate calculation of odds ratios.

The variables that were recorded for the 20,000 baseline epochs included the vehicle, environmental, and most drivers' state variables. In addition, eyeglance analyses were performed for 5,000 of these baseline epochs. The event variables were not recorded for the baseline epochs as these variables (e.g., precipitating factor, evasive maneuver) were not present when an incident, near-crash, or crash did not occur. Table ES.1 shows the breakdown of the type of data that currently exists as part of the original 100-Car Study event database and the baseline database.

Table ES.1. Description of the Databases Created for the Distraction Analysis

	100-Car Study Event Database	**Baseline Database (epochs)**
1.	Vehicle variables	Vehicle variables
2.	Event variables	N/A
3.	Environmental Variables	Environmental Variables
4.	Driver's State Variables	Driver's State Variables
	Eyeglance data (crashes, near-crashes, and incidents)	Eyeglance data on 5,000 randomly selected baseline distraction events.
	Observer Rating of Drowsiness (ORD) for crashes and near-crashes	Drowsiness was marked yes/no with "yes" = ORD of 60 or above.
5.	Driver/Vehicle 2	N/A
10.	Narrative	N/A

The questionnaire data collected during the 100-Car Study was also used in these analyses. Table ES.2 presents a list of all the surveys and test batteries that were administered to the primary drivers.

Table ES.2. Description of questionnaire and computer-based tests used for the 100-Car Study.

	Name of Testing Procedure	Type of Test	Time test was administered	Brief description
1.	Driver demographic information	Paper/pencil	In-processing	General information on driver age, gender, etc.
2.	Driving History	Paper/pencil	In-processing	General information on recent traffic violations and recent collisions.
3.	Health assessment questionnaire	Paper/pencil	In-processing	List of variety of illnesses/medical conditions/or any prescriptions that may affect driving performance.
4.	Dula Dangerous Driving Index	Paper/pencil	In-processing	One score that describes driver's tendencies toward aggressive driving.
5.	Sleep Hygiene	Paper/pencil	In-processing	List of questions that provide information about driver's general sleep habits/substance use/sleep disorders.
6.	Driver Stress Inventory	Paper/Pencil	In-processing	One score that describes the perceived stress levels drivers experience during their daily commutes.
7.	Life Stress Inventory	Paper/pencil	In-processing/Out-processing	One score that describes drivers stress levels based upon the occurrence of major life events.
8.	Useful Field-of-View	Computer-based test	In-processing	Assessment of driver's central vision and processing speed, divided and selective attention.
9.	Waypoint	Computer-based test	In-processing	Assessment of the speed of information processing and vigilance.
10.	NEO-FFI	Paper/pencil	In-processing	Personality test.
11.	General debrief questionnaire	Paper/pencil	Out-processing	List of questions ranging from seatbelt use, driving under the influence, and administration of experiment.

MAJOR CONCLUSIONS

The analyses reported in this document are derived from direct measurements of driver inattention immediately prior to a crash or near-crash. The analytical methods that were used in this report were borrowed from epidemiology, empirical research, and qualitative research. The application of these analytical methods demonstrates the power of naturalistic driving data and its importance in relating driving behavior to crash and near-crash involvement.

Driver inattention was defined for this report as one of the following:

1) Driver engagement in secondary tasks (those tasks not necessary to the primary task of driving)
2) Driver drowsiness
3) Driving-related inattention to the forward roadway
4) Non-specific eyeglance away from the forward roadway

These four types of inattention, singly or in combination, were used to answer the research questions addressed in this report. Some of the important findings are presented below:

- This study allowed for the calculation of relative near-crash/crash risk of engaging in various types of inattention-related activities. Some of the primary results were that driving while drowsy increases an individual's near-crash/crash risk by four to six times, engaging in complex secondary tasks increases risk by three times, and engaging in moderate secondary tasks increases risk by two times that of normal, baseline driving. *Driving-related inattention to the forward roadway* was actually shown to be safer than normal, baseline driving (odds ratio of 0.45). This was not surprising as drivers who are checking their rear-view mirrors are generally alert and engaging in environmental scanning behavior.

- This study also allowed for the calculation of population attributable risk percentages. This calculation produces an estimate of the percentage of crashes and near-crashes in the population where the specific inattention-related activity was a contributing factor. The results of this analysis indicated that driving while drowsy was a contributing factor for 22 to 24 percent of the crashes and near-crashes and secondary-task distraction contributed to over 22 percent of all crashes and near-crashes. This is a useful metric since odds ratios estimate risk on a per-task (or drowsiness episode) basis while the population attributable risk percentage accounts for the frequency of occurrence. Thus, some inattention-related activities that indicated high relative near-crash/crash risk had corresponding population attributable risk percentages indicating low total percentages. This was due to lower frequency of occurrence. Conversely, other more frequently performed inattention activities, while obtaining lower relative near-crash/crash risks, obtained higher population attributable risk percentages.

- The prevalence of driving inattention was analyzed by using normal, baseline driving (i.e., no event crash, near-crash, or incident present) as established by the baseline distraction database. The four types of inattention were recorded alone and in combination with the other types of inattention. The percent of the total baseline epochs in which drivers were engaged in each type of inattention is as follows:
  secondary tasks – 54 percent of baseline epochs
  driving-related inattention – 44 percent of baseline epochs
  drowsiness – 4 percent of baseline epochs
  non-specific eyeglance – 2 percent of baseline epochs

  Note that the total is higher than 100 percent since drivers engaged in multiple types of inattention activities at one time. *Non-specific eyeglance* was most frequently recorded as associated with the other types of inattention but accounts for only 2 percent of the baseline epochs, singularly. Given that the baseline epochs most closely represent "normal, baseline driving," these results suggest that drivers frequently engage in inattention-related tasks.

- The analysis of eyeglance behavior indicates that total eyes-off-road durations of greater than 2 seconds significantly increased individual near-crash/crash risk whereas eyeglance durations less than 2 seconds did not significantly increase risk relative to normal, baseline driving. The purpose behind an eyeglance away from the roadway is important to consider. An eyeglance directed at a rear-view mirror is a safety-enhancing activity in the larger context of driving while eyeglances at objects inside the vehicle are not safety-enhancing. It is important to remember that scanning the driving environment is an activity that enhances safety as long as it is systematic and the drivers' eyes return to the forward view in under 2 seconds.

- The results for the analysis investigating the impact of driver drowsiness on environmental conditions resulted in many interesting results. First, driver drowsiness may vary depending on time of day or ambient lighting conditions. Drowsiness was also seen to slightly increase in the absence of high roadway or traffic demand. A higher percentage of drowsiness-related baseline epochs were found during free-flow traffic densities on divided roadways and areas free of roadway junctions.

- The results of the analysis investigating the impact of complex or moderate secondary task engagement on various environmental conditions were more varied. Each of the eight environmental conditions resulted in odds ratios greater than 1.0 when engaging in complex secondary tasks. Engaging in moderate secondary tasks rarely resulted in odds ratios significantly greater than 1.0 which indicates that these behaviors are not as risky as driving while engaging in complex secondary tasks.

- The most frequent type of secondary task engagement, hand-held device use, also obtained odds ratios greater than 1.0 for both *dialing hand-held device* (OR = 2.8; CL = 1.6 – 4.9) and *talking/listening to a hand-held device* (OR = 1.3; CL = 0.9 – 1.8). *Talking/listening to a hand-held device* was not significantly different than 1.0, indicating that this task was not as risky as *dialing a hand-held device*. Despite the differences in these odds ratios, the *hand-held-device-related* secondary tasks had nearly identical population attributable risk percentages (each contributing to 3.6 percent of crashes and near-crashes). This is because drivers were talking/listening to hand-held devices a much larger percentage of time than they were dialing hand-held devices. Thus, the percentage of crashes and near-crashes that were attributable to these two actions was similar due to the fact that dialing was more dangerous but was performed less frequently whereas talking/listening was less dangerous but performed more frequently.

- The results from the survey and test battery response analyses indicated that drivers with high involvement in inattention-related crashes and near-crashes were significantly younger and possessed less driving experience than the drivers who were involved in fewer inattention-related crashes and near-crashes. The high-involvement drivers also self-reported significantly more traffic violations and being involved in more accidents prior to the beginning of the study. Other test scores demonstrated that the high-involvement drivers were more often drowsy and scored significantly lower on selected personality inventories than did the drivers that were involved in fewer inattention-related crashes and near-crashes.

- A clear relationship between involvement in inattention-related crashes and near-crashes and engaging in inattention-related activities during baseline driving was observed. A correlation of 0.72 was obtained suggesting that those drivers who are frequently involved in inattention-related crashes and near-crashes are not simply getting "caught" at inopportune moments. These drivers engage in inattention-related activities frequently. Those drivers who are not frequently engaging in inattention-related tasks are therefore not involved in as many inattention-related crashes and near-crashes.

GLOSSARY OF TERMS

ANOVA – Analysis of variance.

Additional driver – Family or friends of the primary driver who drove the subject's vehicle and were 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.

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 subject vehicles.

Contributing factors – Any circumstance that leads up to or has an impact on 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, objects on or off the roadway, pedestrians, cyclists, or animals.

Crash-Relevant Event – A subjective judgment of any circumstance that requires, but is not limited to, a crash avoidance response on the part of the subject-vehicle driver, any other vehicle, pedestrian, cyclist, or animal that is less severe than a rapid evasive maneuver (as defined in near-crash event), 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 subject vehicle is defined as a control input that falls outside of the 95 percent confidence limit for control input as measured for the same subject.

Conflict Type – All crashes, near-crashes, crash-relevant conflicts and proximity conflicts were categorized based on the initial conflict that lead to the crash that occurred or would have occurred in the case of near-crashes and incidents. 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, cyclist, animal, obstacle/object in roadway, single-vehicle conflict, other, no known conflict, unknown conflict. This list was primarily from National Automotive Sampling System (NASS) General Estimates System (GES) Accident Types.

DAS – Data Acquisition System.

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

Driver distraction - When a driver has chosen to engage in a secondary task that is not necessary to perform the primary driving task.

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

Driver Proficiency – Whether the individual's driving skills, abilities, or knowledge are inadequate. This specifically refers to whether the driver appeared to be aware of specific traffic laws (i.e., no U-turn), whether the driver was incompetent to safely perform a driving maneuver (i.e., check for traffic before pulling out on a roadway), unaware of the vehicle's turning radius, or performs driving maneuvers under the incorrect assumption that it is safe, (i.e., drives over a concrete median).

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

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

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

Drowsiness – Refers to a driver who is either moderately to severely drowsy, as defined by Wierwille and Ellsworth (1994). A driver who is moderately drowsy will exhibit slack musculature in the facial muscles and limited overall body movement as well as a noticeable reduction in eye scanning behaviors. A severely drowsy driver will exhibit all the above behaviors as well as extended eye lid closures and will have difficulties keeping his/her head in a lifted position.

EDR – Electronic data recorder.

Epoch – Typically, a 6-second period of time that was selected randomly to allow for the observation of normal, baseline driving.

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, and non-conflict.

FARS – Fatality Analysis Reporting System.

FOV – Field of view.

FV – Following vehicle**.**

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

Inattention – Any event or epoch where drowsiness, driver-related inattention to the forward roadway, driver secondary tasks, or non-specific eyeglance away from the forward roadway were identified as a contributing factors to the event.

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

IVI – Intelligent Vehicle Initiative**.**

IR LEDs – Infrared light-emitting diode.

Invalid Trigger – Any instance where a prespecified signature in the driving performance data stream is observed but no safety-relevant event is present. See Appendix C for a more complete definition of triggers.

LV – Lead vehicle.

MVMT – Million vehicle miles traveled.

NHTSA – National Highway Traffic Safety Administration.

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

Near-crash – A subjective judgment of any circumstance that requires, but is not limited to, a rapid, evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, cyclist, 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.

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. 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, crash-relevant conflict, near-crash, or crash that is captured on video but does not involve the subject driver. Labeled as a non-subject conflict but data reduction was not completed.

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

ORD – Observer Rating of Drowsiness; measured on a scale from 0 to 100 in increasing severity of drowsiness. Based on Wierwille and Ellsworth (1994), who developed this procedure where observable behaviors were identified to allow data reductionists to reliably and consistently rate the drowsiness of drivers using post-hoc video data reduction.

Precipitating factor – The driver behavior or state of the environment that initiates the crash, near-crash, or incident, and the subsequent sequence of actions that result in an incident, near-crash, or crash.

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

Proximity Event – Any circumstance resulting in extraordinarily close proximity of the subject vehicle to any other vehicle, pedestrian, cyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, cyclists, or animals, there is no avoidance maneuver or response attempted. 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.).

Pre-Incident Maneuver – The maneuver that the driver was performing immediately prior to the event. The importance of this is to record what the driver was doing before the precipitating event occurred.

Precipitating Factor – The action of a driver that begins the chain of events leading up to the 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).

Secondary Task – Task, unrelated to driving, which requires subjects to divert attention resources from the driving task, e.g., talking on the hand-held device, talking to passenger, eating, etc.

Rear-end striking – Refers to the subject vehicle striking a lead vehicle.

Rear-end struck - Refers to the subject vehicle being struck by a following vehicle.

Sideswipe – Refers to either a vehicle in the adjacent lane changing lanes into the subject vehicle lane or the subject vehicle changing lanes into an already occupied adjacent lane.

SV – Subject vehicle.

Time-to-Collision (TTC) – A calculation that estimates the moment of impact. This calculation uses radar data (either forward or rear) to obtain measures of range and range-rate.

Trigger/Trigger Criteria – A signature in the data stream that, when exceeded, 90 seconds of video data (60 seconds prior and 30 seconds after the data excedence) and the corresponding driving performance data are copied and saved to a database. Trained data reductionists assessed these segments of video and driving performance data to determine whether this segment of data contained a safety-relevant conflict (i.e., crash, near-crash, or incident) or not. Examples of triggers include a driver braking at 0.76 *g* longitudinal deceleration or swerving around an obstacle, obtaining a 0.8 *g* lateral acceleration. For a more complete description of triggers, see Appendix C.

US DOT – United States Department of Transportation.

Valid Event or Valid Trigger – Those events where a specific signature in the data stream was identified and viewed by a data reductionist and deemed to contain a safety-relevant scenario. Data reductionists recorded all relevant variables and stored this data in the 100-Car Study database.

Vehicle Run-Off-Road – Describes a situation when the subject vehicle departed the roadway.

VDOT – Virginia Department of Transportation.

Virginia Tech Motor Pool – An extension of the Virginia Tech Office of Transportation.

VTTI – Virginia Tech Transportation Institute.

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

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

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CHAPTER 1: INTRODUCTION AND METHOD

BACKGROUND

Transportation researchers have long been aware of the negative effects of driver distraction and inattention on driving performance. Researchers have devised clever experimental designs on test tracks and simulators to gain greater understanding of the effects of various sources of driver inattention on reaction time, lateral deviations, time-to-collision (TTC), etc., in both normal and unexpected driving environments. While this research is important and useful to understanding whether these behaviors impact driving performance, it is largely unknown whether driver inattention actually decreases safety and relative crash risk on roadways (Hancock, Lesch, and Simmons, 2003; Dingus, 1995).

Crash database research has found that driver inattention is a contributing factor in approximately 25 to 30 percent of all actual crashes on roadways (Wang, Knipling, and Goodman, 1996). Unfortunately, this statistic is based upon police accident reports that were completed at the scene of crashes. The investigating police officer would only mark distraction or inattention if the driver admitted guilt or an eyewitness observed that the driver was inattentive. Given the source of this information and the potential for inaccurate information to be recorded, most transportation researchers believe that the actual percentage is much higher. Regardless of beliefs, the true effects of driving inattention on crash rates are unknown.

While both empirical and epidemiological research are useful to understanding aspects of the problem of driving inattention, there are significant questions that still need to be addressed. The 100-Car Naturalistic Driving Study (Dingus et al., 2005) provides the type of pre-crash driver behavior data that is necessary to take initial steps at calculating measures such as:

- The increased relative near-crash/crash risk for various types of driver inattention
- The frequency and prevalence of driver inattention in a normal roadway environment
- The types of environmental conditions in which drivers choose to engage in driving inattention
- The impact of eyeglance behavior on near-crash/crash risk

Also, using questionnaire data from the participating drivers, initial attempts to characterize those drivers who are involved in inattention-related crashes versus those drivers who are not involved in inattention-related crashes can also be performed.

The purpose of this report was to conduct in-depth analyses of driver inattention using the driving data collected in the 100-Car Study. These data provide unique opportunities for transportation researchers, as data were collected in 109 cars for a period of 12 to 13 months per car. The data represent normal, baseline driving with all the natural stress and pressures that occur in an urban environment.

For the analyses conducted in this report, two reduced databases were used: the 100-Car Study *event database* and the *baseline database*.

For the original 100-Car Study analyses, the *event database* consisted of crashes, near-crashes, and incidents, which were defined as follows:

- Crash: Any physical contact between the subject vehicle and another vehicle, fixed object, pedestrian, cyclist, animal, etc., as assessed by either the lateral or longitudinal accelerometers.
- Near-crash**:** A conflict situation requiring a rapid, severe, evasive maneuver to avoid a crash.
- Incident**:** A conflict requiring an evasive maneuver, but of lesser magnitude than a near-crash.

The *baseline database* was created specifically for this analysis by randomly selecting a stratified sample of 20,000 6-second segments, referred to as *baseline epochs*. The method used to randomly stratify this sample will be discussed in detail below.

This report will use the *event database*, the *baseline database*, and the questionnaire data to answer the following six research objectives:

Objective 1. What are the prevalence as well as the types of driver inattention in which drivers engage during their daily driving? What is the relative risk of a crash or near-crash while engaging in an inattentive task? Does the relative risk differ for different types of secondary tasks?

Objective 2. What are the environmental conditions associated with a drivers' choice of engaging in secondary tasks or driving while drowsy? What are the relative risks of a crash or near-crash while engaging in driving inattention while encountering these environmental conditions (e.g., time of day, road type, weather conditions, passengers in the vehicle, etc.)?

Objective 3. Determine the differences in demographic data, test battery results, and performance-based measures between inattentive and attentive drivers? How might that knowledge be used to mitigate the potential negative consequences of inattentive driving behaviors? Could this information be used to improve driver education courses or traffic schools?

Objective 4. What is the relationship between measures obtained from pretest batteries (e.g., a life stress test) and the frequency of engagement in distracting behaviors while driving? Does there appear to be any correlation between willingness to engage in distracting behaviors and life stress scores, personality characteristics, or ability to focus attention?

Objective 5. Are there differences in driving performance for drivers who are engaging in an inattentive task versus those drivers who are attending solely to the forward roadway?

Objective 6. Are there differences in driving performance for drivers who are engaging in a distraction task versus those drivers who are attending to driving? Are some of the safety surrogate measures more sensitive to driving performance differences when driving while distracted versus other safety surrogate measures?

Each of these six research objectives will be presented in a separate chapter with results from the data analysis and conclusions. The last chapter of the report will summarize all key results and conclusions from this analysis and outline future directions for this research.

For a complete description of the 100-Car Study method, instrumentation, and data collection procedure, refer to Dingus et al. (2005). In order to provide an abbreviated description, the following description is provided from the Neale, Klauer, Dingus, and Goodman (2005) report.

METHOD

Instrumentation

The 100-Car Study instrumentation package was engineered by the Virginia Tech Transportation Institute (VTTI) to be rugged, durable, expandable, and unobtrusive. It constituted the seventh generation of hardware and software developed over a 15-year period that has been deployed for a variety of purposes. The system consisted of a Pentium-based computer that receives and stores 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 before requiring data downloading.

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 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 1.1.

The modular aspect of the data collection system allowed for integration of instrumentation that was not essential for data collection, but provided the research team with additional and important information. These subsystems included: automatic collision notification that informed the research team of the possibility of a collision; cellular communications that were used by the research team to communicate with vehicles on the road to determine system status and position; system initialization equipment that automatically controlled system status; and a Global Positioning System (GPS) subsystem that collected information on vehicle position. The GPS subsystem and the cellular communications were often used in concert to allow for vehicle localization and tracking.

Figure 1.1. 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 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 1.2) and behind the rear seat in the SUVs.

Doppler radar antennas were mounted behind special plastic license plates on the front and rear of the vehicle (Figure 1.3). The location behind the plates allowed the vehicle instrumentation to remain inconspicuous to other drivers.

Figure 1.2. The main DAS unit mounted under the "package shelf" of the trunk.

Figure 1.3. Doppler radar antenna mounted on the front of a vehicle, covered by a mock-up of one of the plastic license plates used for the study.

The final major components in the 100-Car Study hardware installation were mounted above and in front of the center rear-view mirror. These components included an "incident" pushbutton box which housed a momentary pushbutton that the subject could press whenever an unusual event happened in the driving environment. Pressing the incident button would open an audio channel which recorded the driver's voice explaining the nature of the incident. Also contained in the housing was 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.

Mounted behind the center mirror were the forward-view camera and the glare sensor (Figure 1.4). This location was selected to be as unobtrusive as possible and did not occlude the driver’s normal field of view.

Figure 1.4. The incident pushbutton box mounted above the rear-view mirror. The portion on the right contains the driver-face/left-vehicle side camera hidden by a smoked plexiglass cover.

Subjects

One-hundred drivers who commuted into or out of the Northern Virginia/Washington, DC, metropolitan area 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 as well as by placing announcements in the classified section of local newspapers. Drivers who had their private vehicles instrumented (78) received $125 per month and a bonus at the end of the study for completing necessary paperwork. Drivers who received a leased vehicle (22) received free use of the vehicle, including standard maintenance, and the same bonus at the end of the study for completing 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 would occasionally drive 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 subjects 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 of drivers who drove more than the average number of miles. The age by gender distribution of the primary drivers is shown in Table 1.1. The distribution of miles driven by the subjects during the study appears as Table 1.2. As presented, the data are somewhat 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 that needs to be understood is that the data were collected in only one region (i.e., Northern Virginia/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, are not well represented.

Table 1.1. Driver age and gender distributions.

	Gender		
Age	**Female** N Percent	**Male** N Percent	**Grand Total**
18-20	9 8.3%	7 6.4%	16 14.7%
21-24	11 10.1%	10 9.2%	21 19.3%
25-34	7 6.4%	12 11.0%	19 17.4%
35-44	4 3.7%	16 14.7%	20 18.3%
45-54	7 6.4%	13 11.9%	20 18.3%
55+	5 4.6%	8 7.3%	13 11.9%
Total N Total %	43 39.4%	66 60.6%	109 100.0%

Table 1.2. Actual miles driven during the study.

Actual miles driven	Number of Drivers	Percent of Drivers
0-9,000	29	26.6%
9,001-12,000	22	20.2%
12,001-15,000	26	23.9%
15,001-18,000	11	10.1%
18,001-21,000	8	7.3%
More than 21,000	13	11.9%

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 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

PROCEDURE FOR DATA REDUCTION: 100-CAR STUDY EVENT DATABASE

Data reduction for the 100-Car Naturalistic Driving Study as well as for these current analyses refers to a process of recording specific variables based upon review of the video. This data reduction process will be discussed in detail in the following sections.

Sensitivity Analysis

As stated in Dingus et al. (2005), data were collected continuously on board 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 TTC value > 3 seconds 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 an incident, near-crash, or crash.

Figure 1.5 shows the data reduction plan in a flow chart format. Raw data from each vehicle was saved on the network attached storage (NAS) unit at VTTI until approximately 10 percent of the data was collected. At that time, a sensitivity analysis was performed to establish post-hoc trigger criteria.

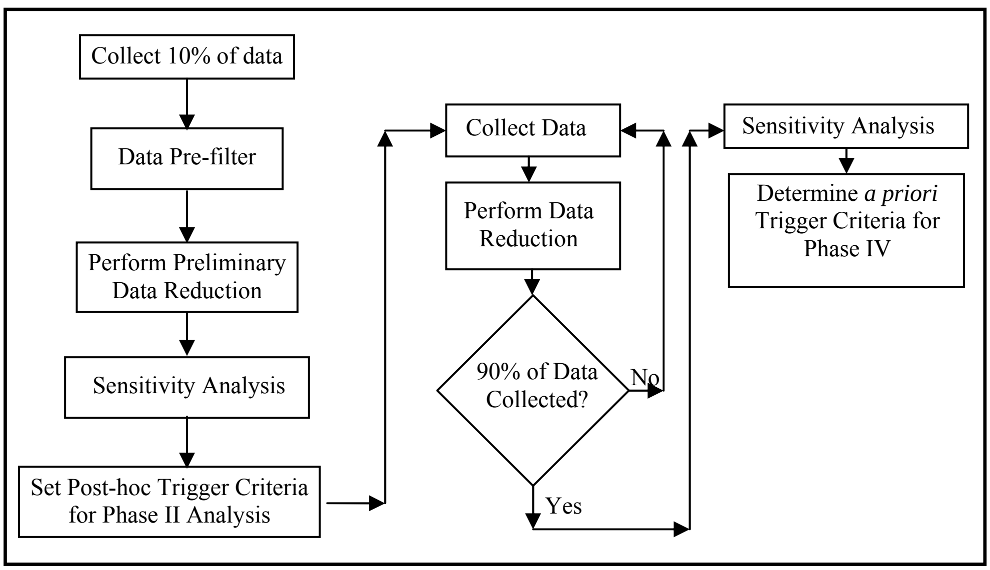

Figure 1.5. Flow chart of the data reduction process.

The sensitivity analysis was performed by setting the trigger criteria to a very liberal level, ensuring that the chance of a missed valid event was minimal while allowing a high number of invalid events (false alarms) to be identified (see Figure 1.6). 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.

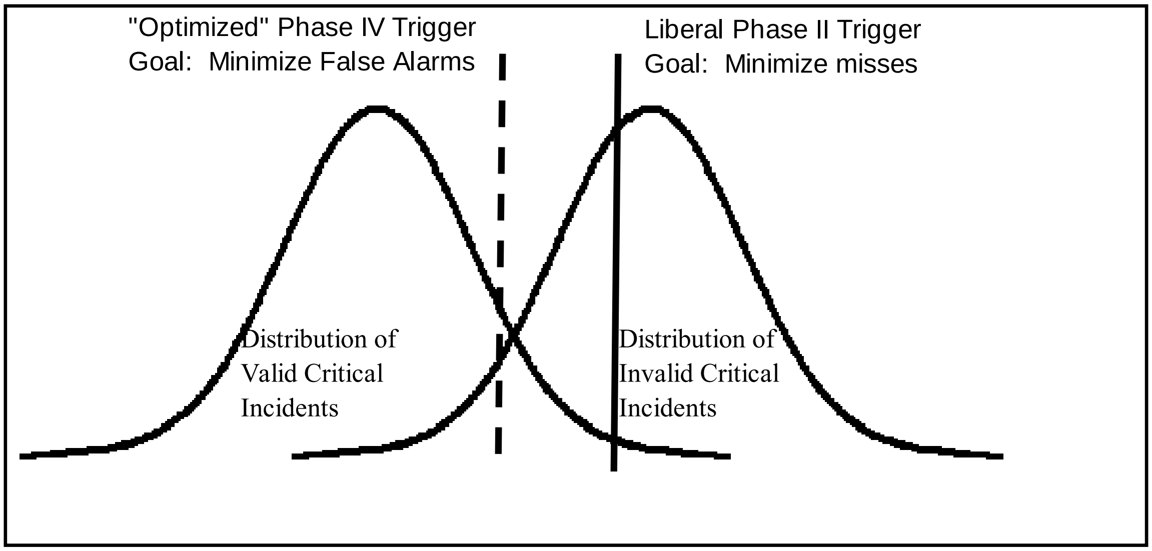

Figure 1.6. Graphical depiction of trigger criteria settings for Phase II and Phase IV using the distribution of valid events. Note that this distribution and criterion placement is unique for each trigger type.

The trigger criteria for each dependent variable was then set to a slightly more conservative level and the resulting number of valid and invalid events was 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 counted and compared until an optimum trigger criteria 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. Therefore, the data reductionists would be presented with nearly all valid events but would have to reject less than 30 percent of the events that they reviewed. The list of dependent variables ultimately used as triggers used to identify crashes, near-crashes, and incidents is presented in Table 1.3.

Table 1.3. 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 equal to or greater than 0.6 *g*. • Acceleration or deceleration equal to or greater than 0.5 *g* coupled with a forward TTC of 4 seconds or less. • All longitudinal decelerations between 0.4 *g* and 0.5 *g* coupled with a forward TTC value of ≤ 4 seconds 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/she deemed critical.
4. Forward time-to-collision	• Acceleration or deceleration equal to or greater than 0.5 *g* coupled with a forward TTC of 4 seconds or less. • All longitudinal decelerations between 0.4 *g* and 0.5 *g* coupled with a forward TTC value of ≤ 4 seconds and that the corresponding forward range value at the minimum TTC is not greater than 100 ft.
5. Rear time-to-collision	• Any rear TTC trigger value of 2 seconds or less that also has a corresponding rear range distance of ≤ 50 feet and any rear TTC trigger value in which the absolute acceleration of the following vehicle is greater than 0.3 *g*.
6. Yaw rate	• Any value greater than or equal to 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.

Based on data from past VTTI studies, it was originally hypothesized that as many as 26 crashes, 520 near-crashes, and over 25,000 incidents (crash-relevant conflicts and proximity conflicts) would be collected. However many of these early estimates were based on long-haul-truck-driving data. It was soon discovered, after the sensitivity analysis process began that the variability in light-vehicle drivers' braking, acceleration, and steering behavior is much larger than with truck drivers. These differences in variability are primarily due to the differences in vehicle dynamics and the more uniform driving skill of commercial truck drivers. While greater variability was expected for light-vehicle drivers, the high degree of variability that was observed was a very interesting result.

Given the variability in light-vehicle driving performance, the sensitivity analysis proved to be challenging. 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 9,125 events. The distribution of the total number of reduced events by severity is shown in Table 1.4.

Table 1.4. The total number of events reduced for each severity level.

Event Severity	Total Number
Crash	69 (plus 13 without complete data)
Near-crash	761
Incidents (Crash-relevant Conflicts and Proximity Conflicts)	8,295

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

Recruiting and Training Data Reductionists

Based upon past experience, it was estimated that reductionists would be able to complete an average of four events per hour. Fourteen data reductionists were recruited by posting flyers and sending notices to various graduate student listservs on the Virginia Tech campus. The data reduction manager interviewed, hired, and trained the data reductionists on how to access the data from the server and operate the data reduction software. Training was also provided on all relevant operational and administrative procedures (approximately 4 hours). The manager gave each data reductionist a data reduction manual to guide him or her in learning the software and reduction procedures. All analyst trainees practiced data reduction procedures with another trained analyst prior to reducing data independently. After each trainee felt comfortable with the process, the trainee worked alone under the supervision of the data reduction manager. Once the trainee and manager felt confident of the analyst's abilities, the analyst began working independently with "spot check" monitoring from the project leader and other reductionists. The data reductionists were responsible for analyzing a minimum number of events per week and were required to attend weekly data reduction meetings to discuss issues that arose during the data reduction process.

The data reductionists performed two general tasks while creating the *event database*. On the first 10 to 15 percent of the data, they performed a preliminary data-reduction task in which they viewed events to determine whether the event was valid or invalid. If invalid, they then determined the severity of the event. After the trigger criteria was set using the results from the sensitivity analysis, the data reductionists validated the data, determined severity, and performed a full data reduction. For the full data-reduction process, they recorded all of the required variables (discussed below) for the event type.

Event Database Reduction Software Framework

The data reduction framework for the *event database* was developed to identify various driving behavior and environmental characteristics for four levels of event severity: crashes, near-crashes, crash-relevant conflicts, and proximity conflicts. The operational definitions for these severity levels are presented in Table 1.5. The variables recorded were selected based upon past instrumented-vehicle studies (Hanowski et al., 2000; Dingus et al., 2002), national crash databases (General Estimates System [GES] and 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 those crashes, near-crashes, and incidents (crash-relevant conflicts and proximity conflicts) identified in this dataset.

Table 1.5. Operational Definitions for All Event Severity Levels

Severity Level	Operational Definition
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, cyclists, animals, etc.
Near-Crash	Any circumstance that requires a rapid, evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash. 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.
Crash-Relevant Conflict	Any circumstance that requires a crash-avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, cyclist, 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 subject vehicle is defined as a control input that falls outside of the 95 percent confidence limit for control input as measured for the same subject.
Proximity Conflict	Any circumstance resulting in extraordinarily close proximity of the subject vehicle to any other vehicle, pedestrian, cyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver, pedestrians, cyclists, 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.).

The general method for data reduction was to have trained data reductionists view the video data and record the battery of variables for all valid events. The data reduction manager and project manager performed all data reduction on the near-crashes and crashes. Varying levels of detail were recorded for each type of event. Crash-relevant conflicts and proximity conflicts have the least amount of information recorded and near-crashes and crashes have the most information recorded. A total of four areas of data reduction were recorded for each event type. These four areas include: vehicle variables, event variables, environmental variables, and driver state variables. Table 1.6 defines each area of data reduction, provides examples, and describes additional features of the data reduction. The complete list of all variables reduced during data reduction is shown in Appendix C.

Table 1.6. Areas of data reduction, definition of the area, and examples.

Area of Data Reduction	Definition	Example
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/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.	

Baseline Database Framework

The *baseline database* was comprised of approximately 20,000 6-second segments where the vehicle maintained a velocity greater than 5 mph (referred to as an *epoch*). Kinematic triggers on driving performance data were not used to select these baseline epochs. The epochs were selected at random throughout the 12- to 13-month data collection period per vehicle. A 6-second segment of time was used as this was the time frame used by data reductionists to ascertain 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 5 seconds prior to or 1 second after the onset of the conflict for the activity to be considered a contributing factor to the crash, near-crash, or incident.

Each *baseline epoch* was randomly selected from the 12-13 months of data collected on each vehicle. However, the number of 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 dataset in which multiple baseline epochs are present to compare to each crash and near-crash. Case-control designs are optimal for calculating odds ratios (also referred to as relative near-crash/crash risk) due to the increased power that a case-control data set possesses. Greenberg et al. (2001) argue that using a case-control design allows for an efficient means to study rare events, such as automobile crashes, even though smaller sample sizes are used. Given that relative near-crash/crash risk calculations were an objective of the following analyses, the creation of a case-control data set was deemed important.

Considering that the number of baseline epochs was dependent upon the number of crashes, near-crashes, and incidents of vehicle involvement, not driver involvement, an analysis was conducted to determine the percentage of events and baseline epochs that were attributable to the primary driver and secondary driver. The results indicated that 89.6 percent of all events and 88.2 percent of all baseline epochs were primary drivers. Therefore, even though the baselines were selected based upon vehicle involvement, the vast majority of crashes and near-crashes as well as baseline epochs were primary drivers.

Four vehicles did not have any crashes, near-crashes, or incidents and were therefore eliminated from the baseline database. The reasons that these four vehicles did not contain a single crash, near-crash, or incident included very low mileage due to driver attrition (2 vehicles), frequent mechanical malfunctions (1 vehicle), and excellent driver performance (1 vehicle).

Figure 1.7 shows the number of events that each vehicle was involved (y-axis) and the corresponding number of baseline epochs that were identified for that vehicle (x-axis). Note that the vehicles that were involved in multiple crashes, near-crashes, and incidents also had a larger number of baseline epochs.

There are two data points on the far right side of the figure. These two data points represent two female drivers, 18 and 41 years of age, respectively. The 18-year-old female was involved in 3 crashes, 53 near-crashes, and 401 incidents. The 41-year-old female was involved in 4 crashes, 56 near-crashes, and 449 incidents. Both drivers were over-represented in their crash, near-crash and incident involvement.

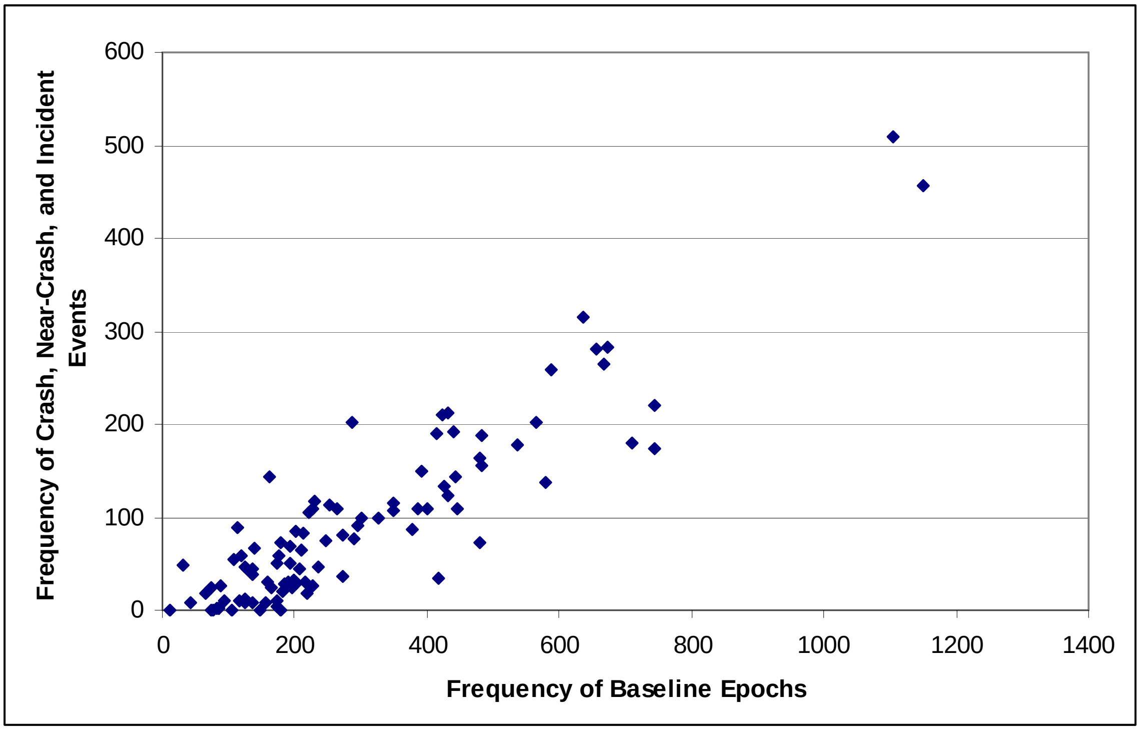

Figure 1.7. The frequency of each vehicle's involvement in crash, near-crash, and incident events versus the number of baseline epochs selected for each vehicle.

The *baseline database* will be used in the assessment of the prevalence of various types of inattentive driving. This will determine the relative near-crash/crash risk for each of these types of inattention as well as the percentage of crashes and near-crashes in the population that are attributable to these types of inattention. While the reader should keep in mind that the baseline epochs were stratified, this does not reduce the generalizability of the data analysis for the following reasons:

1) 99 of 103 vehicles are represented in the 20,000 baseline epochs;
2) 101 out of 109 primary drivers are represented in the baseline epochs;
3) multiple drivers drove each vehicle; and
4) no environmental or driver behavior data was used in the stratification.

The variables that were recorded for the 20,000 *baseline epochs* included 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 primary drivers.

The event variables (number 2 in Table 1.7) were not recorded for the baseline epochs as these variables (e.g., precipitating factor, evasive maneuver) were not present when an incident, near-crash, or crash did not occur. Table 1.7 shows the breakdown of the type of data that currently exists as part of the original 100-Car Study *event database* and the *baseline database*.

Table 1.7. Description of the databases created for the inattention analysis.

	100-Car Study Event Database	**Baseline Database (epochs)**
1.	Vehicle variables	Vehicle variables
2.	Event variables	N/A
3.	Environmental Variables	Environmental Variables
4.	Driver-state Variables	Driver-state Variables
	Eyeglance data (crashes, near-crashes, and incidents)	Eyeglance data on 5,000 randomly selected baseline inattention events.
	Observer Rating of Drowsiness (ORD) for Crashes and Near-crashes	Drowsiness was marked yes/no with "yes" = ORD of 60 or above.
5.	Driver/Vehicle 2	N/A
10.	Narrative	N/A

Data Reduction Inter- and Intra-Rater Reliability for the 100-Car Study Event Database

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.

First, data-reductionist managers performed spot checks of the reductionists' work, monitoring both event validity judgments as well as recording all database variables. Reductionists also performed 30 min of spot-checks of their own or other reductionists' work every week. This was done to ensure accuracy but also to allow reductionists the opportunity to view other reductionists' work. It was anticipated that this would encourage each reductionist to modify his or her own work and to improve consistency in decision-making techniques across all reductionists. Mandatory weekly meetings were held to discuss issues concerning data reduction techniques. Issues were usually identified by the spot-checking activities of the reductionist managers and the reductionists, or specific difficult events that the reductionists had encountered. These meetings provided iterative and ongoing reduction training throughout the entire data reduction process.

To determine how successful these techniques were, an inter- and intra-rater reliability test was conducted during the last 3 months of data reduction. Three reliability tests were developed (each containing 20 events) for which the reductionist was required to make validity judgments. Three of the 20 events were also completely reduced in that the reductionist recorded information for all reduction variables (i.e., event variables, driver-state variables, and environmental variables as opposed to simply marking severity of event). Three of the test events on Test 1 were repeated on Test 2 and three other events were duplicated between Tests 2 and 3 to obtain a measure of intra-rater reliability.

Using the expert reductionists' evaluations of each epoch as a "gold" standard, the percent correct was calculated for each rater's test. The measures for each rater for each testing period, along with a composite measure, can be found in Table 1.8.

Table 1.8. Percentage agreement with expert reductionists.

Rater	Test 1 Percent	Test 2 Percent	Test 3 Percent
1	78.3	87.5	91.3
2	65.2	70.8	78.3
3	100	91.7	95.7
4	100	91.7	87.0
5	100	83.3	87.0
6	95.7	87.5	91.3
7	91.3	87.5	91.3
8	91.3	91.7	91.3
9	95.7	70.8	91.3
10	95.7	91.7	87.0
11	95.7	87.5	100
12	78.3	87.5	87.0
13	87.0	83.3	96.0
14	78.3	83.3	91.3
	Average (across all tests)	88.4	

The Kappa statistic was also used to calculate inter-rater reliability. Although there is controversy surrounding the usefulness of the Kappa statistic, it is viewed by many researchers as the standard for rater assessment (e.g., Cicchetti and Feinstein, 1990). The Kappa coefficient ($K = 0.65$, $p < 0.0001$) indicated that the association among raters is significant. While the coefficient value is somewhat low, given the highly subjective nature of the task, the number of raters involved, and the conservative nature of this statistic, the Kappa calculation probably errs on the low side.

A tetrachoric correlation coefficient is a statistical calculation of inter-rater reliability based on the assumption that the latent trait underlying the rating scale is continuous and normally distributed. Based on this assumption, the tetrachoric correlation coefficient can be interpreted in the same manner as a correlation coefficient calculated on a continuous scale. The average of the pair-wise correlation coefficients for the inter-rater analysis is 0.86. The coefficients for the intra-rater analysis were extremely high with nine raters achieving a correlation of 1.0 among the three reliability tests and five raters achieving a correlation of 0.99.

Given these three methods of calculating inter-rater reliability, it appears that the data reduction training coupled with spot-checking and weekly meetings proved to be an effective method for achieving high inter- and intra-rater reliability.

Baseline Database

Inter-rater reliability tests were also conducted for the baseline events. All trained data reductionists were given a random sample of 25 baseline epochs to view and record the secondary tasks, driving-related inattention behaviors, and moderate to severe drowsiness. The reductionists' responses were then compared to an expert data reductionist's responses. The results indicated an average of 88 percent accuracy among all the data reductionists. Given that the Kappa coefficient and the tetrachoric correlation coefficient did not provide additional information, these tests were not conducted on the baseline inter-rater reliability test.

SURVEYS, QUESTIONNAIRES AND PERFORMANCE-BASED TESTS

As part of the 100-Car Study, the primary drivers were administered questionnaires and performance-based tests either prior to data collection or post data collection (dependent upon the type of test). Table 1.9 provides a list and description of each type of questionnaire and performance-based test that was completed. A copy of all questionnaires and surveys is located in Appendix B.

Table 1.9. Description of questionnaire and computer-based tests used for the 100-Car Study.

	Name of Testing Procedure	Type of Test	Time test was administered	Brief description
1.	Driver demographic information	Paper/pencil	In-processing	General information on drivers age, gender, etc.
2.	Driving History	Paper/pencil	In-processing	General information on recent traffic violations and recent collisions.
3.	Health assessment questionnaire	Paper/pencil	In-processing	List of variety of illnesses/medical conditions/or any prescriptions that may affect driving performance.
4.	Dula Dangerous Driving Index	Paper/pencil	In-processing	One score that describes driver's tendencies toward aggressive driving.
5.	Sleep Hygiene	Paper/pencil	In-processing	List of questions that provide information about driver's general sleep habits/substance use/sleep disorders.
6.	Driver Stress Inventory	Paper/Pencil	In-processing	One score that describes the perceived stress levels drivers experience during their daily commutes.
7.	Life Stress Inventory	Paper/pencil	In-processing/Out-processing	One score that describes drivers stress levels based upon the occurrence of major life events.
8.	Useful Field-of-View	Computer-based test	In-processing	Assessment of driver's central vision and processing speed, divided and selective attention.
9.	Waypoint	Computer-based test	In-processing	Assessment of the speed of information processing and vigilance.
10.	NEO-FFI	Paper/pencil	In-processing	Personality test.
11.	General debrief questionnaire	Paper/pencil	Out-processing	List of questions ranging from seatbelt use, driving under the influence, and administration of experiment.

CHAPTER 2: *OBJECTIVE 1,* WHAT IS THE PREVALENCE AS WELL AS THE TYPES OF DRIVER INATTENTION IN WHICH DRIVERS ENGAGE DURING THEIR DAILY DRIVING? WHAT IS THE RELATIVE NEAR-CRASH/CRASH RISK OF DRIVING WHILE ENGAGING IN AN INATTENTIVE TASK? IS THE RELATIVE NEAR-CRASH/CRASH RISK DIFFERENT FOR DIFFERENT TYPES OF SECONDARY TASKS?

During data reduction it became apparent that there were many rear-end and run-off-road collisions that occurred primarily because the driver looked away from the forward roadway at a critical point. In order to conduct defined analyses on these events, separate categories of driver inattention were developed. Throughout this document, driver inattention is broadly defined as any point in time that a driver engages in a secondary task, exhibits symptoms of moderate to severe drowsiness, or looks away from the forward roadway. These categories of driver inattention are operationally defined as follows.

- *Secondary task distraction* – driver behavior that diverts the driver's attention away from the driving task. This may include talking/listening to hand-held device, eating, talking to a passenger, etc. A complete list of all secondary task distractions is provided in Appendix A.
- *Driving-related inattention to the forward roadway* – driver behavior that is directly related to the driving task but diverts driver's attention away from the forward field of view. This includes reductionists observing drivers checking the speedometer, checking blind spots, observing adjacent traffic prior to or during a lane change, looking for a parking spot, and checking mirrors.
- *Drowsiness* – driver behavior that includes eye closures, minimal body/eye movement, repeated yawning, and/or other behaviors based upon those defined by Wierwille and Ellsworth (1994).
- *Non-specific eyeglance away from the forward roadway* – driver behavior that includes moments when the driver glances, usually momentarily, away from the roadway, but at no discernable object, person, or unknown location. Eyeglance reduction and analysis of these events was done for crashes, near-crashes, incidents, and 5,000 of the baseline events.

The terms *driver inattention* and *driver distraction* have been used throughout the transportation literature separately at times and interchangeably at other times, referring to different types of driver inattention. In this report, the term *driver inattention* will refer to a broader scope of behaviors as defined above. The term *driver distraction,* when used, will refer only to secondary-task engagement.

The frequency of occurrence, the *relative near-crash/crash risk*, and *population attributable risk percentage* for each of these associated types of inattention will be determined in this chapter.

Driver Data Included in the Analysis

For the analyses in this chapter, crashes and near-crashes only will be used (incidents will be excluded from the analyses). In Chapter 6, *Objective 2* of the 100-Car Study Final Report, the analyses indicated that the kinematic signatures of both crashes and near-crashes were nearly identical; whereas the kinematic signature of incidents was more variable. Given this result and the need to increase statistical power, the data from both crashes and near-crashes will be used in the calculation of relative risk.

Please note that secondary tasks, driving-related inattention to the forward roadway, and drowsiness were all recorded for crash and near-crash events as well as baseline epochs. Eyeglance data, on the other hand, was recorded for all events and 5,000 of the baseline epochs (25 percent of the baseline epochs). Therefore, all analyses that are conducted requiring eyeglance data will use only the 5,000 *baseline* epochs. All other analyses utilize the entire baseline database. Please note that the 5,000 baseline epochs that contain eyeglance data also represent 99 vehicles and 101 primary drivers which is identical to the number of vehicles and primary drivers represented in all 20,000 baseline epochs.

Recall from Chapter 1 that the *baseline database* consisted of a stratified random sample of epochs. This stratification was performed to provide a case-control data set which possesses greater statistical power for the calculation of relative near-crash/crash risk.

QUESTION 1. WHAT IS THE RELATIVE FREQUENCY OF A DRIVER BEING LABELED INATTENTIVE VERSUS ATTENTIVE?

To determine the relative frequency of inattention, the baseline epochs were analyzed to assess the frequency in which drivers were engaging in inattention-related tasks during normal, baseline driving. While task duration was not recorded, the fact that 73 percent of all 6-second segments contained at least one form of driving inattention indicates that drivers are engaging in secondary tasks, driving while drowsy, or looking away from the forward roadway very frequently.

QUESTION 2. WHAT IS THE RELATIVE FREQUENCY OF EACH TYPE OF DRIVER INATTENTION BEING LABELED AS A CONTRIBUTING FACTOR FOR CRASHES, NEAR-CRASHES, AND/OR PRESENT IN BASELINE EPOCHS?

Two comparisons were performed on different subsets of data. First, a comparison was conducted of the four types of inattention for the crashes and near-crashes versus the **5,000** *baseline epochs*. Second, a separate comparison of three types of inattention, *secondary task, drowsiness,* and *driving-related inattention to the forward roadway*, for all **20,000** *baseline epochs* and crashes and near-crashes was conducted to assess the frequency analysis for the entire dataset.

Figure 2.1 shows the percentage of the total number of crashes, near-crashes, and baseline epochs that were inattention-related. Please note that 78 percent of all crashes, 65 percent of all near-crashes, and 73 percent of all 20,000 baseline epochs contained at least one of the four types of inattention. Therefore, the sum of all of the bars representing crashes is equal to 78.

Each event and epoch is presented in the figure by type of inattention and/or combination of inattention because many of the events and epochs contained multiple types of driving inattention. Please note that s*econdary task, driving-related inattention*, and *driver drowsiness* were the most frequent contributing factors for the crashes and near-crashes. Also note that *secondary task* and *combinations thereof* were the most frequent types of inattention observed for baseline epochs. Drowsiness occurred far less frequently for the baseline epochs than for the crashes and near-crashes. The *non-specific eyeglance* category occurred most frequently in conjunction with *secondary tasks* and *driving-related inattention*, and only accounted for an additional 2 percent of the baseline epochs by itself.

Figure 2.1 shows that *non-specific eyeglance* most commonly occurred in conjunction with other sources of driver inattention for the baseline epochs. For crashes and near-crashes, there were higher percentages of events where *non-specific eyeglance*, by itself, was a contributing factor. This result will be more fully analyzed later in this chapter.

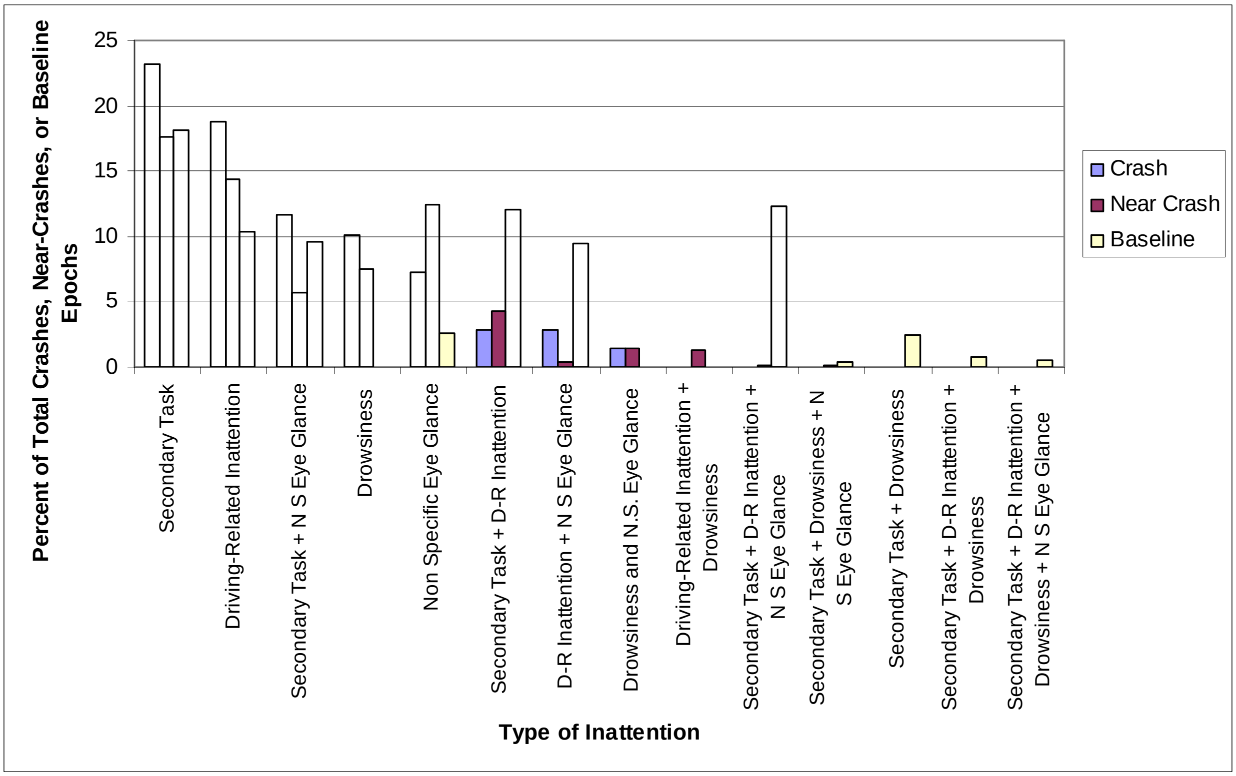

Figure 2.1. The percentage of the total number of crashes and near-crashes identified in the 100-Car Study and the percentage of the total number of baseline epochs in which these four types of inattention were identified as a contributing factor (N = 69 crashes, 761 near-crashes, and 4,977 baseline epochs).

Comparisons were then conducted without the *non-specific eyeglance* inattention category for crashes, near-crashes, and baseline epochs to obtain a complete picture of the frequency of inattention categories for all 20,000 baseline epochs. Without *non-specific eyeglance*, the combinations of inattention-type are fewer. For example, the *secondary task plus non-specific eyeglance* category in Figure 2.1 is now included with the *secondary task* category in Figure 2.2. *Secondary tasks* are still the most frequent type of inattention for crashes and near-crashes, followed by *driving-related inattention to the forward roadway* and *drowsiness*.

Note that the baseline epochs are similar to crashes and near-crashes in that secondary tasks are again the most frequent; followed by *driving-related inattention to the forward roadway* and combinations of these two types of inattention. Drowsiness, however, was observed in less than 2.2 percent of all baseline epochs. This is a very interesting finding when comparing *drowsiness's* low baseline-epoch percentage to the much higher percentage in crashes and near-crashes. This may indicate that driver drowsiness may significantly increase near-crash/crash risk. Also of interest is the high frequency of *driving-related inattention to the forward roadway* for the baseline epochs. This category is present in 27 percent (summed across categories) of the baseline epochs but only 14 percent of the crashes and near-crashes. In this case, relative near-crash/crash risk due to *driving-related inattention to the forward roadway* may be very low. Odds ratios will be presented for all types of inattention in the next section.

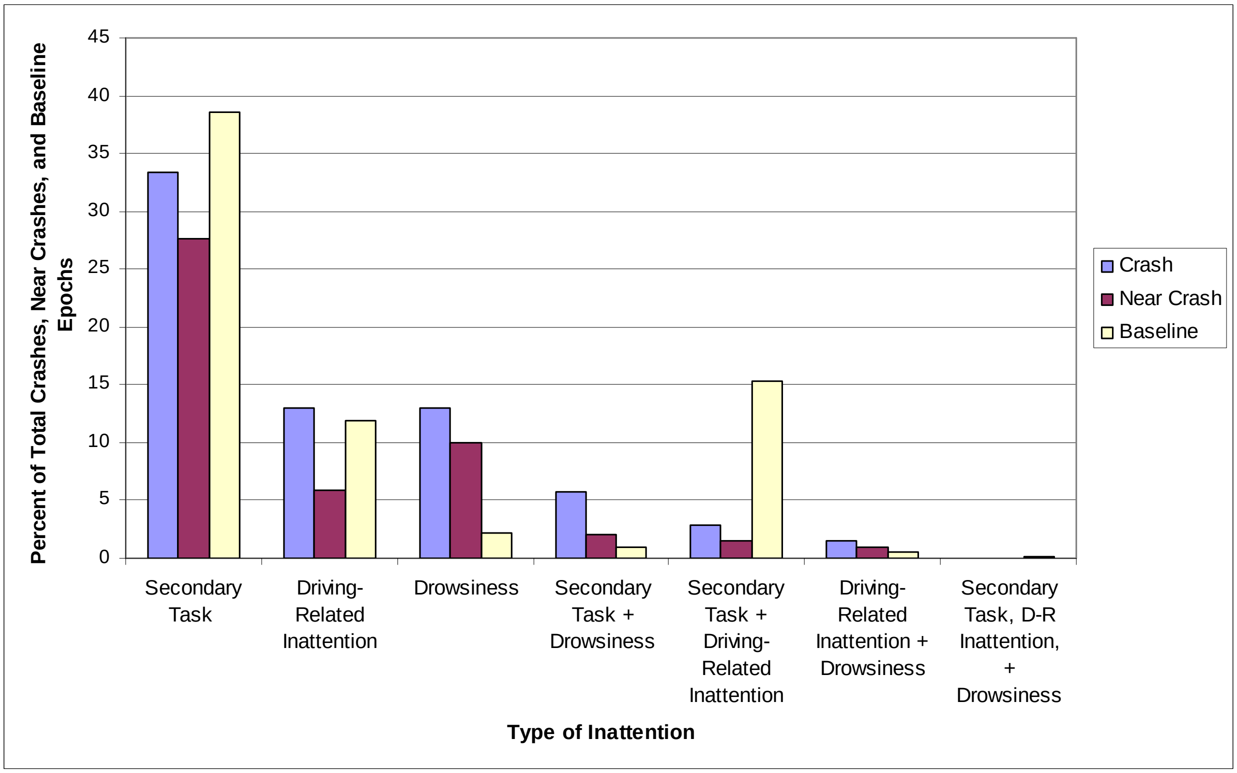

Figure 2.2. The percentage of crashes and near-crashes in which three types of inattention were identified as a contributing factor (N = 69 crashes, 761 near-crashes, and 19,827 baseline epochs).

QUESTION 3. DETERMINE THE RELATIVE NEAR-CRASH/CRASH RISK AND THE POPULATION ATTRIBUTABLE RISK PERCENTAGE FOR EACH TYPE OF INATTENTION. WHAT IS THE RELATIVE RISK FOR DIFFERENT TYPES OF SECONDARY TASKS?

Using the baseline data as a measure of non-event exposure, odds ratios were calculated to obtain an estimate of relative near-crash/crash risk for each of the four types of inattention. In addition, population attributable risk percentages were calculated to determine the percentage of crashes and near-crashes that occur in the general driving population when inattention was a contributing factor.

Both statistics are used because of the complementary information that both provide. While the odds ratio, or relative risk calculation for a crash or near-crash, provides information regarding individual near-crash/crash risk when engaging in a particular behavior, the population attributable risk percentage calculation provides an estimate of the percentage of crashes and near-crashes in the study population that can be attributed to each type of behavior. Therefore, while an individual's near-crash/crash risk may increase while performing a particular task, drivers may not engage in this behavior very often or the behavior requires a brief duration therefore very few crashes in the population are in fact caused by this behavior. On the other hand, if a specific type of behavior does not increase individual near-crash/crash risk greatly in isolation, this behavior may in fact occur frequently and/or for long durations while driving and therefore does account for many crashes in the population.

The following odds ratios are calculated for three levels of *secondary tasks*, two levels of *driving-related inattention*, two levels of *non-specific eyeglances*, and only one level of *drowsiness*. The three levels of secondary tasks are *complex secondary tasks*, *moderate secondary tasks*, and *simple secondary tasks*. The *complex secondary tasks* are defined as a task that requires either multiple steps, multiple eyeglances away from the forward roadway, and/or multiple button presses (Dingus, Antin, Hulse, and Wierwille, 1989). *Moderate secondary tasks* are those that require, at most, two glances away from the roadway and/or at most two button presses. *Simple secondary tasks* are those that require none or one button press and/or one glance away from the forward roadway. Table 2.1 presents the task types that were assigned to each level of complexity. For operational definitions and examples for each of these tasks, please refer to Appendix C.

Table 2.1. 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

There is considerable automotive research indicating that drivers generally do not look away from the forward roadway greater than 1.0 to 1.5 seconds per glance (Wierwille, 1993). Tasks that require longer and more frequent glances decrease safe driving performance. Therefore, the *driving-related inattention to the forward roadway* category, which is operationally defined as eyeglances to one of the rear-view mirrors or windows, was separated into two categories: *total time eyes off the forward roadway: greater than 2 seconds and less than 2 seconds.* The same distinction was used for *non-specific eyeglances away from the forward roadway*. These two inattention categories were separated in this manner to differentiate those short, quick glances that are characteristic of an alert driver scanning his or her environment compared to those drivers who are looking away from the forward roadway longer than a short-duration glance.

This separation of the general categories of inattention was performed since there are many factors present within these categories and an odds-ratio calculation for the entire category of *secondary task*, all durations of *driving-related inattention to the forward roadway*, or all durations of *non-specific eyeglance* would provide misleading information and would not be as useful.

The baseline data was categorized in the same manner, using three levels of *secondary task*, two levels of *driving-related inattention*, and two levels of *non-specific eyeglance* data. Due to the importance of glance length, eyeglance data was required for the separation of *driving-related inattention to the forward roadway* and *non-specific eyeglance*. Therefore, only the 5,000 baseline epochs that contained eyeglance data were used to calculate these odds ratios.

When the frequency counts were conducted for the baseline data, 76 combinations emerged from these eight levels of inattention. These combinations emerged because drivers were eating chips (*moderate secondary task*) and would check their left rear-view mirrors for 0.5 seconds (*driving-related inattention less than 2 seconds*), for example. Very few combinations emerged for the crash and near-crash events. Odds ratios were not calculated for each combination of inattention type as the frequency counts were very low in most instances (resulting in wide confidence limits). Odds ratios were calculated for *drowsiness* as well as *drowsiness* combined with other types of inattention as the correlations between *drowsiness* and other types of inattentive behavior are less compelling than the correlations between *secondary task engagement, driving-related inattention to the forward roadway,* and *non-specific eyeglance*.

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 are defined as the probability of event occurrence divided by the probability of non-occurrence. The 2x2 contingency table in Table 2.2 will be used to illustrate this and related measures.

Table 2.2. An example of a 2x2 contingency table that would be used to calculate inattention-related odds ratios.

	Inattention Present	No Inattention Present	
Reduced Event	n_{11}	n_{12}	$n_{1.}$
Baseline Event	n_{21}	n_{22}	$n_{2.}$
	$n_{.1}$	$n_{.2}$	$n_{..}$

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 (no inattention 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). Odds ratios are used as an approximation of relative near-crash/crash risk in case 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 et al., 2001). Referring to Table 2.2, the odds ratio would be defined as:

$$\theta = \frac{\pi_1 / (1-\pi_1)}{\pi_2 / (1-\pi_2)} = \frac{n_{11}/n_{12}}{n_{21}/n_{22}} = \frac{n_{11} n_{22}}{n_{12} n_{21}}$$ *Equation 2.1*

and is a comparison of the odds of success in row 1 versus the odds of success in row 2 of the table.

Algebraically, this equation can be rewritten as shown below. Basic odds ratios are calculated as shown in Equation 2.2.

Odds Ratio = (A x D)/(B x C) *Equation 2.2*

Where:

A = the number of at-fault* events where <inattention type> was present without any other type of inattention
B = the number of at-fault* events where drivers were attentive
C = the number of baseline epochs where <inattention type> was present without any other type of inattention
D = the number of baseline epochs where drivers were attentive

*At-fault was assessed by the data reductionists to indicate whether the driver's actions were primarily the cause of the crash or near-crash or whether the driver was simply reacting to another vehicles poor driving performance. Only those crashes and near-crashes that the reductionists deemed to be the fault of the driver of the instrumented vehicle were included in these analyses.

To interpret odds ratios, a value of 1.0 indicates no significant danger above normal, baseline driving. An odds ratio less than 1.0 indicates that this activity is safer than normal, baseline driving or creates a protective effect. An odds ratio greater than 1.0 indicates that this activity increases one's relative risk of a crash or near-crash by the value of the odds ratio. For example, if *reading while driving* obtained an odds ratio of 3.0, then this indicates that a driver is three times more likely to be involved in a crash or near-crash while reading and driving than if he or she was just driving normally.

Results of Odds Ratio Calculations. The odds ratio calculations were initially conducted for driving-related inattention to determine whether this behavior increases near-crash/crash risk or is a typical behavior of an alert driver (i.e., does not impact near-crash/crash risk). The odds ratios for *driving-related inattention to the forward roadway less than 2 seconds and greater than 2 seconds* are presented in Table 2.3. Note that both odds ratios are significantly less than 1.0 suggesting that this behavior is actually *protective* in that drivers who are engaging in this behavior are safer than those drivers who are simply driving (i.e., not engaging in any extra type of behavior). Given this result, *driving-related inattention to the forward roadway* will *no longer be included in the operational definition of driving inattention for the remainder of this report.*

Table 2.3. Odds ratio point estimates and 95-percent confidence limit intervals to assess likelihood of at-fault-crash (N = 49) or near-crash (N = 439) involvement in driving-related inattention to the forward roadway.

Type of Inattention	Odds Ratio	Lower CL	Upper CL
Driving-Related Inattention to the Forward Roadway – Greater than 2 seconds	0.45	0.24	0.83
Driving-Related Inattention to the Forward Roadway – Less than 2 seconds	0.23	0.15	0.34

Table 2.4 shows the odds ratio calculations as well as the upper and lower confidence levels for the remaining three types of inattention: *drowsiness*, *secondary task*, and *non-specific eyeglance*. *Drowsiness*, *drowsiness (all combinations)*, *moderate secondary tasks,* and *complex secondary tasks* obtained odds ratios of 6.2, 4.2, 2.1, and 3.1 respectively. This result suggests that drivers who drive while severely drowsy are between 4.5 and 8.5 times as likely to be involved in a crash or near-crash as alert drivers. Drivers who are engaging in *moderate secondary task*s are between 1.6 and 2.7 times as likely to be involved in a crash or near-crash, and drivers engaging in *complex secondary tasks* are between 1.7 and 5.5 times as likely. The odds ratio for *simple secondary task*s was also greater than 1.0, however, the lower confidence limit was less than 1.0, indicating these tasks do not significantly alter the likelihood of crash or near-crash involvement over that of normal, baseline driving. The odds ratios for *non-specific eyeglance - greater than 2 seconds and less than 2 seconds* obtained an odds ratios less than 1 (OR = 0.9 and 0.4) but were also not significantly different than 1.0 (as indicated by the upper and lower confidence limit containing 1.0). This result indicates that these types of eyeglance behaviors are probably just as safe as normal, baseline driving. While they may be just as safe, these eyeglance behaviors do not reduce the likelihood of being involved in a crash or near-crash as do eyeglances to mirrors or checking traffic through windows. Note that all odds ratios that are significantly different than 1.0 are in bold font.

Table 2.4. Odds ratio point estimates and 95% confidence intervals to assess likelihood of at-fault crash (N = 49) or near-crash (N = 439) involvement when engaging in driving inattention.

Type of Inattention	Odds Ratio	Lower CL	Upper CL
Complex Secondary Task	**3.10**	**1.72**	**5.47**
Moderate Secondary Task	**2.10**	**1.62**	**2.72**
Simple Secondary Task	1.18	0.88	1.57
Moderate to Severe Drowsiness (in isolation from other types of inattention)	**6.23**	**4.59**	**8.46**
Moderate to Severe Drowsiness (all occurrences)	**4.24**	**3.27**	**5.50**
Non-specific Eye Glance Away from the Forward Roadway-Greater than 2 seconds	0.85	0.20	3.65
Non-specific Eye Glance Away from the Forward Roadway-Less than 2 seconds	0.43	0.17	1.06

Note: These calculations included frequency of events/epochs that included the type of inattention by itself and not in combination with other types of inattention. Only moderate to severe drowsiness (combination) took into account all events in which drowsiness was a contributing factor regardless of whether another type of inattention was present. Five thousand baseline epochs were used along with all crashes and near-crashes where the driver was at fault.

Table 2.5 provides the odds ratios for each type of secondary task separately. Given that these odds ratios are not dependent upon glance length, all 20,000 baseline epochs were used for these calculations. Also, frequencies were counted when each type of secondary task was present, either alone or in combination with other types of inattention. This modification was conducted due to low statistical power associated with breaking data into smaller subsets. While there were over 40 secondary tasks that were identified by the data reductionists, only those secondary tasks that were observed for crashes and near-crashes as well as baseline epochs will be presented in the table. In other words, some secondary tasks were not observed for either the events or baseline epochs, therefore it was not possible to calculate an odds ratio. Those odds ratios that are significantly different than 1.0 are shown in bold font.

As can be viewed from this table, half of the secondary tasks have odds ratios greater than 1.0. *Reaching for a moving object* was shown to have the highest odds ratio followed by *external distraction, reading, applying makeup,* and *dialing a hand-held device*. Please note that *handling a CD, talking or listening to a hand-held device, an insect in the vehicle*, and *reaching for an object (not moving)* also had odds ratios greater than 1.0 but their lower confidence limits went below 1.0, indicating that these secondary tasks may not actually increase the likelihood of crash or near-crash involvement.

The odds ratio for passenger in adjacent seat was also significantly different from 1.0; however, it was significantly lower than 1.0 indicating that it is actually safer to have a passenger in the vehicle than to drive alone. This may be because passengers are often also scanning the environment for hazards and may alert the driver to a hazard that he or she may have missed.

Table 2.5. Odds ratios point estimates and 95 percent conflict confidence intervals to assess the likelihood of crash (N= 49) or near-crash (N = 439) involvement when engaging in secondary tasks.

Type of Secondary Task	Odds Ratio	Lower CL	Upper CL
Reaching for a moving object	**8.82**	**2.50**	**31.16**
Insect in Vehicle	6.37	0.76	53.13
Looking at external object	**3.70**	**1.13**	**12.18**
Reading	**3.38**	**1.74**	**6.54**
Applying makeup	**3.13**	**1.25**	**7.87**
Dialing hand-held device	**2.79**	**1.60**	**4.87**
Inserting/retrieving CD	2.25	0.30	16.97
Eating	1.57	0.92	2.67
Reaching for non-moving object	1.38	0.75	2.56
Talking/listening to a hand-held device	1.29	0.93	1.80
Drinking from open container	1.03	0.33	3.28
Other personal hygiene	0.70	0.33	1.50
Adjusting radio	0.55	0.13	2.22
Passenger in adjacent seat	**0.50**	**0.35**	**0.70**
Passenger in rear seat	0.39	0.10	1.60
Combing hair	0.37	0.05	2.65
Child in rear seat	0.33	0.04	2.40

Note: Calculation included frequency of events/epochs that included the type of inattention by itself or in combination with other types of inattention. Twenty thousand baseline epochs were used along with all crashes and near-crashes where the driver was at fault.

All drivers in the present study were over the age of 18; however, there were 16 drivers between 18 and 20 years old. A second odds ratio was calculated to assess whether the presence of passengers were not protective for this younger age group. These odds ratios are presented in Table 2.6. The results suggest that the odds ratios for the 18- to 20-year-olds is nearly the same as it is for the drivers who are 20 years of age and older. This result is consistent with research findings by Williams (2003) where 16- to 17-year-old drivers' near-crash/crash risk increased with the number of passengers in the vehicle up to six times that of normal, baseline driving, 18- to 19-year-old drivers showed a very slight increase in near-crash/crash risk, and older drivers demonstrated a protective effect for the presence of passengers.

Table 2.6. Odds ratio calculations and 95 percent confidence intervals for "Passenger Present" for drivers who are younger and older than 20 years of age.

Age Group	Odds Ratio for Passenger Present	Lower CL	Upper CL
18 to 20 Years of Age	0.53	0.33	0.83
Older than 20 Years	0.58	0.39	0.87

Definition of Population Attributable Risk. For those types of inattention with an odds ratio greater than 1.0, population attributable risk percentages (PAR%) were also calculated. This calculation provides an assessment of the percentage of crashes and near-crashes that are occurring in the population at-large that are directly attributable to the specific behavior measured. This is an excellent counterpart to the odds ratio calculation in that the odds ratio is measured at the *individual* level whereas the population attributable risk percentage is measured at the *population* level or for all drivers in the population. Please note that data was collected in only a metropolitan area, thus, some degree of caution should be exercised in the interpretation of these results to the population at large.

Population attributable risk percentage is calculated as follows:

$$PAR\% = [(P_e (OR - 1))/(1 + P_e (OR - 1))] * 100 \qquad \textit{Equation 2.3}$$

Where P_e = population exposure estimate
OR = odds ratio or relative risk estimate for a crash or near-crash

For example, to assess a population attributable risk percentage for complex secondary tasks, the population exposure estimate was calculated by counting the number of baseline epochs where a complex secondary task was present and counting the total number of baseline epochs in equation (# of baseline epochs with complex secondary tasks present + # of baseline epochs where no type of inattention was present), for example:

P_e = 49 baseline epochs with complex secondary tasks/2,273 total baseline epochs = 0.02

The relative risk or odds ratio of a crash or near-crash, as shown in Table 2.4, indicated that the relative risk for complex secondary tasks was 3.10. Thus, the PAR percent was calculated as follows:

$$PAR\% = [(0.02)\ (3.10 - 1.00)/1.00 + (0.02)\ (3.10 - 1.00))]*100 = 4.3$$

For a more complete discussion of the population attributable risk percentage calculations, see Sahai and Khurshid (1996), *Statistics in Epidemiology*.

Results of Population Attributable Risk Percentage Calculations. The population attributable risk percentage calculations are presented in Table 2.7 for all of those types of inattention and secondary tasks with an odds ratio greater than 1.0. A population attributable risk percentage calculation is not applicable to those sources of inattention with an odds ratio of less than 1.0.

The results indicate that *moderate to severe drowsiness* accounts for between 22 and 24 percent of all crashes and near-crashes, and c*omplex, moderate, and simple secondary tasks* account for 23 percent of all crashes and near-crashes. *Dialing a hand-held device, talking on a hand-held device*, and *reading* all contributed to 3.6 percent, 3.6 percent, and 2.9 percent to all crashes and near-crashes, respectively. Interestingly, *dialing a hand-held device* had an odds ratio of 2.8 whereas *talking/listening to hand-held device* had an odds ratio of 1.3 and was not significantly different than 1.0. These two secondary tasks had nearly the identical population attributable risk percentages. One hypothesis for this is that drivers were talking/listening to hand-held devices a much larger percentage of time than they were dialing hand-held devices. Thus, the percent of crashes and near-crashes that were attributable to these two actions was similar due to the fact that dialing was more dangerous but was performed less frequently whereas talking/listening was less dangerous but done more frequently. The rest of the secondary tasks each accounted for less than 3 percent of all crashes and near-crashes. *In total, drowsiness and secondary task engagement are contributing factors in over 45 percent of all crashes and near-crashes.*

Table 2.7. Population attributable risk percentage point estimates and 95 percent confidence intervals for types of inattention and the specific secondary tasks.

Type of Inattention	Population Attributable Risk Percentage (PAR%)	Lower CL	Upper CL
Complex Secondary Task	4.26	3.95	4.57
Moderate Secondary Task	15.23	14.63	15.83
Simple Secondary Task	3.32	2.72	3.92
Moderate to Severe Drowsiness (in isolation from other types of inattention)	22.16	21.65	22.68
Moderate to Severe Drowsiness (all occurrences)	24.67	21.12	25.23
Reaching for moving object in vehicle	1.11	0.97	1.25
Insect in vehicle	0.35	0.27	0.44
Reading	2.85	2.60	3.10
Dialing hand-held device	3.58	3.29	3.87
Applying Makeup	1.41	1.23	1.59
Looking at external object	0.91	0.77	1.05
Inserting/retrieving CD	0.23	0.15	0.32
Eating	2.15	1.85	2.46
Reaching for non-moving object	1.23	0.96	1.50
Talking/listening to hand-held Device	3.56	3.10	4.10
Drinking from open container	0.04	-0.10	0.18

Please note that the population attributable risk percentages of the individual secondary tasks do not sum to the higher level secondary-task categories. Recall that there are other types of secondary tasks that are being calculated for each general level of secondary task. For example, the sum of the population attributable risk percentages for the individual types of secondary tasks will not add up to the population attributable risk percentage for the complex secondary task type.

CONCLUSIONS

The results from these analyses demonstrate the power of large-scale naturalistic driving studies in that the prevalence of driving inattention, the frequency of occurrence, as well as the relative near-crash/crash risk for various types of driver inattention can finally be assessed using pre-crash driving behavior data. While relative risk calculations for a crash or near-crash have been obtained using survey data and/or police accident reports, this study directly observed drivers prior to crashes and near-crashes and compare this behavior to their driving behaviors during normal, routine driving.

To calculate the prevalence and frequency of driver inattention, the baseline driving database was used. This analysis indicated that drivers engaged in one of four types of inattention in over 70 percent of the 20,000 baseline epochs. Interestingly, *secondary task engagement* accounted for 54 percent, *driving-related inattention to the forward roadway* accounted for 27 percent, and *drowsiness* only accounted for 4 percent of the baseline epochs.

The results of the relative near-crash/crash risk calculations indicated that urban drivers are between four and six times as likely to be involved in a crash or near-crash when driving while severely drowsy than if they were attentive. The odds ratios for complex and moderate secondary task type also indicated that drivers were at increased risk when engaging in these types of tasks while driving. Drivers are two times as likely to be involved in a crash or near-crash when engaging in a moderate secondary task and three times as likely when engaging in a highly complex secondary task.

The results of these analyses indicated that all odds ratios for each of the secondary task types indicated that *reaching for a moving object, looking at an external object (i.e., long glance), reading, applying makeup, dialing a hand-held device,* and *eating* all had odds ratios greater than 1.0. This suggests a higher individual near-crash/crash risk when a driver engages in these activities. Interestingly, *driving with a passenger*, *singing to the radio*, and even some engagement with the radio and the heating/air conditioner unit all resulted in odds ratios less than 1.0. These results most likely suggest that these activities are indicative of a relatively alert driver. For drivers over the age of 18, having a passenger in the vehicle is associated with less likelihood of crash or near-crash involvement than if there was no passenger in the vehicle. A possible interpretation of this result is that the passenger is also scanning the environment and can warn a driver of an impending dangerous situation. Please note that there is a substantial body of research on drivers *under* the age of 18 indicating that passengers in the vehicle actually *increase* near-crash/crash risk. The results from this study should not be interpreted as conflicting with results from the teen-driving research. There were no 16- or 17-year-old drivers in this study and therefore, the data can not be applied to the teenage driving population.

Even though the odds ratios for *reaching for a moving object, external distraction, reading, applying makeup,* and *eating* presented greater individual near-crash/crash risk, these factors did not account for a large percentage of actual crashes and near-crashes in an urban population as shown by the population attributable risk percentage calculations. Drowsiness, on the other hand, attributed to between 22 and 24 percent of the crashes and near-crashes in the population, which is much higher than most crash database research has shown (Campbell, Smith, and Najm, 2003). All complexity levels of secondary tasks attributed to 22 percent of the crashes and near-crashes in an urban environment. In total, inattention contributes to over 45 percent of all crashes and near-crashes that occur in an urban environment.

Also of interest was that *dialing a hand-held device* had an odds ratio of approximately 3.0 whereas *talking/listening to hand-held device* had an odds ratio of slightly over 1.0 and was not significantly different than 1.0. These two secondary tasks had nearly the identical population attributable risk percentages (each attributing to 3.6 percent of crashes and near-crashes). One hypothesis for this is that drivers were talking/listening to hand-held devices a much larger percentage of time than they were dialing hand-held devices. Thus, the percent of crashes and near-crashes that were attributable to these two actions was similar due to the fact that dialing was more dangerous but was performed less frequently whereas talking/listening was less dangerous but performed more frequently.

CHAPTER 3: *OBJECTIVE 2,* WHAT ARE THE ENVIRONMENTAL CONDITIONS ASSOCIATED WITH DRIVER CHOICE OF ENGAGEMENT IN SECONDARY TASKS OR DRIVING WHILE DROWSY? WHAT ARE THE RELATIVE RISKS OF A CRASH OR NEAR-CRASH WHEN ENGAGING IN DRIVING INATTENTION WHILE ENCOUNTERING THESE ENVIRONMENTAL CONDITIONS?

This research objective used large-scale naturalistic driving data to determine the environmental conditions in which drivers choose to engage in secondary tasks or to drive while drowsy. The associated relative near-crash/crash risks of either engaging in complex or moderate secondary tasks or driving drowsy during poor environmental conditions was also assessed. Several types of environmental variables were recorded during the data reduction process for both the 100-Car Study event database and the baseline database. A list of these variables, the respective levels of each, and a definition of each variable is presented in Table 3.1. Please note that all of these variables were recorded based solely upon the video observed at the time of the event or epoch. For lighting levels, the corresponding time stamp was also used to distinguish between dawn and dusk.

Table 3.1. A detailed list of the environmental variable names, levels of each, and operational definition.

Variable Name	Levels of Variable	Definition of Variable
Lighting	Daylight Darkness, lighted Darkness, non lighted Dawn Dusk	Ambient lighting levels to denote the time of day.
Weather	Clear Raining Sleeting Snowing Foggy Misty Other	Description of the presence of ambient precipitation and type of precipitation occurring.
Road Type	Divided Not divided One-way Traffic No lanes	Description of the type of roadway and how traffic is separated.
Road Alignment/Road Profile	Straight, level Straight, grade Curve, level Curve, grade	Description of the road profile at the onset of the conflict.
Traffic Density	Free flow Stable flow, speed restricted Unstable flow, temporary restrictions Unstable flow, temporary stoppages Restricted Flow Forced flow with low speeds and traffic volumes	Level of service definitions (NHTSA) to define six levels of traffic density ranging from free flow to stop-and-go traffic.
Surface Condition	Dry Wet Snowy Icy Other	Description of the resulting condition of the roadway in the presence of precipitation.
Traffic Control Device	Traffic signal Stop sign Yield sign Slow, warning sign Traffic lanes marked Officer/watchman Other Unknown None	Denotes the presence of a traffic signal near the onset of the conflict.
Relation to Junction	Intersection Intersection-related Interchange area Entrance/exit ramp Driveway/alley access Parking lot Non-junction Other	Description of the road and whether a junction was present.

DATA INCLUDED IN THESE ANALYSES

Two databases were used for this analysis. The first was the *event database*, which consisted of all the crashes, near-crashes, and incidents identified and reduced as part of the 100-Car Study. Only the crashes and near-crashes were used in these analyses (for a discussion of the reasons for this, please refer to Chapter 2, *Objective 1*). Recall that this data is referred to as *event* data for this report. The second was the *baseline database*, which consisted of 20,000 randomly selected 6-second segments of video that were viewed by trained data reductionists. The random sample was stratified to produce a case-control data set which increased power for odds ratio calculations. For a complete description of the variables that were recorded for the baseline database, please refer to Chapter 1: Introduction and Method.

For the following analyses, the term *inattention-related event* refers only to complex- and moderate-secondary-task engagement. *Simple secondary task engagement* and *driving-related inattention to the forward roadway* were not used in these analysis; as shown in the previous chapter, these two types of inattention were either not significantly different than normal, baseline driving or provided a protective effect. Also, *non-specific eyeglance* was not considered, since its inclusion would have reduced the number of baseline epochs available for analysis, and because it was found to be a relatively redundant source of inattention for the baseline epochs (as shown in the previous chapter).

As the effect of risk factors were to be compared across levels of environmental variables, a different analysis method was used. The odds ratio estimates in the chapter were obtained using maximum likelihood estimates obtained from logistic regression models. The stratified analysis or logistic regression allows for comparable evaluation of risk factors across the levels or strata of an environmental variable of interest. To ascertain whether it is more risky to engage in complex tasks on a dark roadway or to drive while alert on a dark roadway, the interaction of both complex-secondary-task engagement (*inattentive* or *attentive* driver) and ambient light levels (*daylight*, *dusk*, *dawn*, *darkness-lighted*, *darkness-not-lighted*) must be assessed. Logistic regression models provide a point estimate for the odds of a crash or near-crash based upon the driver engaging in a secondary task (or driving attentively) and driving environment.

Three independent odds ratio calculations were conducted to assess the relative near-crash/crash risk in various weather, roadway, and traffic environments. These three odds ratio calculations assess the following:

1) Is driving drowsy during <*environmental variable level*> riskier than driving alert in <*environmental level*>?
2) Is engaging in complex secondary tasks during < *environmental variable level*> riskier than driving alert in <*environment level* >?
3) Is engaging in moderate secondary tasks during < *environmental variable level*> riskier than driving alert in <*environment level*>?

Only *drowsiness*, *complex*, and *moderate secondary tasks* were used in the following odds ratio calculations. Recall from the previous chapter that complex and moderate secondary task engagements were operationally defined based upon the frequency of eyeglances away from the forward roadway and/or button presses that were necessary to complete the task. Complex secondary tasks required more than three button presses and/or eyeglances away from the forward roadway to complete the task, while moderate secondary tasks required two eyeglances or button presses. It was also demonstrated in the previous chapter that these two types of *secondary tasks*, as well as *drowsiness*, had higher relative near-crash/crash risks than normal, baseline driving, whereas simple secondary tasks were found to not be significantly riskier than normal, baseline driving. Therefore, only *drowsiness*, *complex*, and *moderate secondary tasks* were used in these calculations.

AMBIENT LIGHT/WEATHER CONDITIONS

Lighting Level

To record light levels for this analysis, data reductionists used the video footage and the time stamp corresponding to the epochs or events to make determinations of the ambient lighting levels. Table 3.2 presents the number of *drowsiness*- and *secondary-task*-related crashes, near-crashes, and baseline epochs observed for each of these lighting levels.

Table 3.2 The frequency of drowsiness- and secondary-task-related events and epochs that were recorded for each type of lighting level.

Lighting Level	Frequency of Drowsiness-Related Crash and Near-Crash Events	Frequency of Secondary-Task-Related Crash and Near-Crash Events	Frequency of Drowsiness-Related Baseline Epochs	Frequency of Secondary-Task-Related Baseline Epochs
Darkness-Lighted	27	42	2	13
Darkness- Not Lighted	18	17	279	3021
Dawn	2	5	51	205
Daylight	52	143	240	571
Dusk	13	20	183	305
Total	308	277	755	4115

Using only the baseline data, the percent of inattention-related epochs and the percent of the total number of baseline epochs were used to determine: (1) the percentage of baseline epochs that drivers engaged in secondary tasks or drove while drowsy during each of these lighting conditions, and (2) whether these percentages differed from the total number of baseline epochs that drivers encountered or were exposed to for each of these lighting conditions. These percentages were calculated by dividing the number of baseline epochs where drivers were engaging in a secondary task at a particular lighting level by the total number of epochs where the drivers engaged in a secondary task. For example, the number of baseline epochs where the driver was engaging in a complex or moderate secondary task during daylight was divided by the total number of baseline epochs where the driver was engaging in a complex or moderate secondary task.

Figure 3.1 presents the baseline data percentages for secondary-task-related epochs (N = 4,115), drowsiness-related epochs (N = 755), and total number of epochs (N = 19,467) for each level of lighting. The majority of complex- and moderate-secondary-task-related events and total baseline epochs occurred during daylight hours; this replicates findings from many previous instrumented-vehicle studies (e.g., Lee, Olsen, and Wierwille, 2003; Dingus et al., 2001). The percentages are very similar for the secondary-task-related epochs and the total number of epochs, suggesting that drivers are not selecting to engage in secondary tasks differently based on ambient lighting conditions. Drivers are experiencing drowsiness differently across the ambient lighting conditions, which is to be expected as ambient lighting levels are associated with time of day and daily wake/sleep cycles. Lower percentages of *drowsiness* were observed during the day, whereas higher percentages of *drowsiness* were observed at night compared to the total baseline epochs.

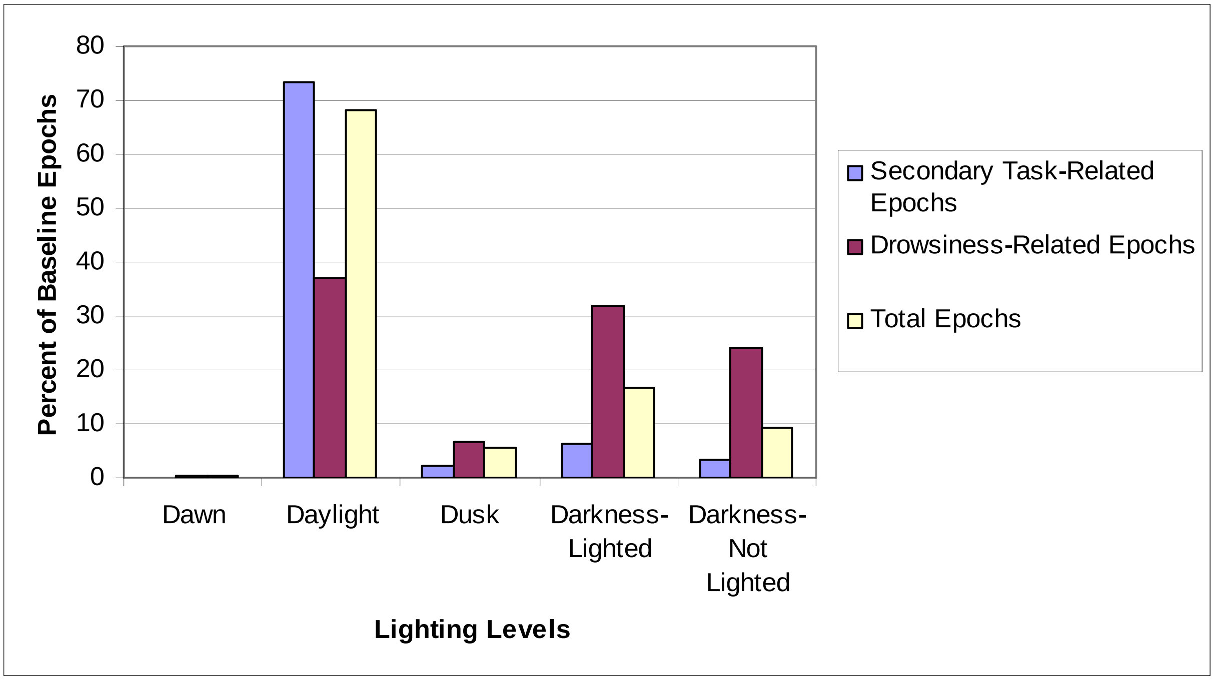

Figure 3.1. Percentage of secondary-task-related, drowsiness-related, and total baseline epochs for the different lighting levels observed.

As shown in Table 3.3, driving drowsy in any of the ambient lighting levels is riskier than driving while alert during similar lighting levels. However, it appears that driving drowsy during the *daylight* may be slightly riskier than driving drowsy in the *dark*. While it is commonly thought that most drowsiness-related crashes occur at night, a majority of the drowsiness-related crashes in this study occurred during the daytime in heavy traffic (during morning and evening commutes). Thus, the risks of driving drowsy during the day may be slightly higher than at night due to higher traffic density.

Table 3.3. Odds ratio point estimates and 95 percent confidence intervals for the interaction of drowsiness by type of lighting.

Type of Lighting	Odds Ratio	Lower CL	Upper CL
Dawn	2.43	0.96	6.17
Daylight	5.27	3.55	7.82
Dusk	6.99	3.82	12.80
Darkness-Lighted	3.24	1.92	5.47
Darkness-Not Lighted	3.26	1.82	5.86

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Relative near-crash/crash risks for the complex- and moderate-secondary-task engagement showed that engaging in complex tasks for all levels of ambient lighting were significantly more risky than driving alert at the same lighting levels (Tables 3.4 and 3.5). This was especially true for engaging in complex tasks at night, as these relative near-crash/crash risks were higher than during *dawn*, *dusk*, or *daylight*. The relative near-crash/crash risks for engaging in moderate secondary tasks were all near 1.0, but not significantly different than 1.0, which suggests that engaging in these tasks is not nearly as risky as engaging in complex tasks or driving while drowsy.

Table 3.4. Odds ratio point estimates and 95 percent confidence intervals for the interaction of complex secondary tasks by type of lighting.

Type of Lighting	Odds Ratio	Lower CL	Upper CL
Dawn	N/A	N/A	N/A
Daylight	**3.06**	**1.84**	**5.06**
Dusk	**8.91**	**4.41**	**18.03**
Darkness-Lighted	**4.58**	**2.46**	**8.52**
Darkness-Not Lighted	**24.43**	**12.40**	**48.10**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.5. Odds ratio point estimates and 95 percent confidence intervals for the interaction of moderate secondary tasks by type of lighting.

Type of Lighting	Odds Ratio	Lower CL	Upper CL
Dawn	0.71	0.21	2.39
Daylight	0.80	0.59	1.08
Dusk	1.55	0.87	2.76
Darkness-Lighted	0.98	0.61	1.56
Darkness-Not Lighted	0.98	0.61	1.56

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Weather

Reductionists used the video to assess the weather conditions outside the vehicle. Table 3.6 presents the frequency counts of the number of drowsiness- and secondary-task-related events and baseline epochs that occurred during the different weather conditions. A majority of events and epochs occurred during clear weather.

Table 3.6. The frequency of drowsiness-related and secondary-task-related events and epochs that were recorded for each type of weather.

	Type of Weather	Frequency of Drowsiness-Related Crash and Near-Crash Events	Frequency of Secondary-Task-Related Crash and Near-Crash Events	Frequency of Drowsiness-Related Baseline Epochs	Frequency of Secondary-Task-Related Baseline Epochs
1.	**Clear**	92	181	669	3,624
3.	**Rain**	20	45	79	462
4.	**Sleet**	0	0	1	4
5.	**Snow**	0	0	3	12
6.	**Fog**	0	0	2	6
7.	**Mist**	0	0	1	5
8.	**Other**	0	0	0	2
	Total	112	226	755	4,115

Figure 3.2 presents the percent of drowsiness-related, secondary-task-related, and total baseline epochs for each weather type. Nearly all of the epochs occurred during *clear weather*, with 11 percent occurring during *rainy weather*. The percentages are nearly identical for secondary-task-related, drowsiness-related, and total baseline epochs for all weather conditions, indicating that drivers were not engaging in secondary tasks or driving drowsy substantially more often during any particular type of weather. The total number of events and epochs that occurred during *sleet*, *snow*, *fog, mist*, and *other* weather conditions was very small (the sample size was perhaps not large enough to adequately address the issue of secondary-task engagement during these types of weather).

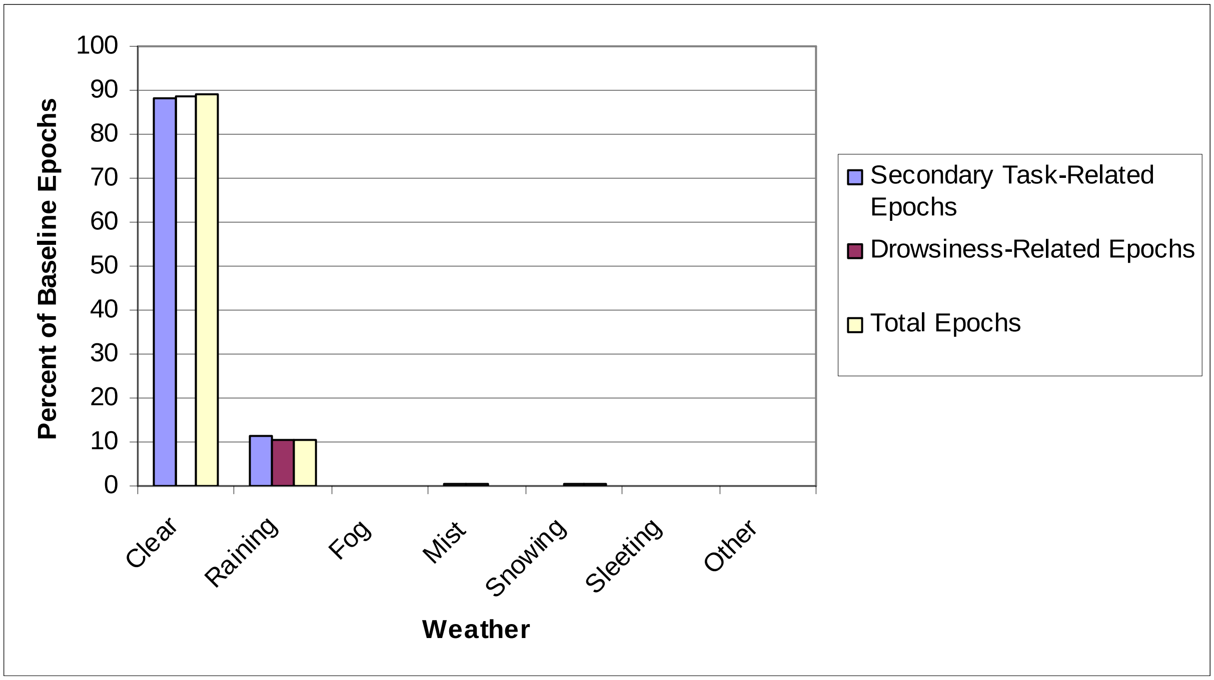

Figure 3.2. Percentage of secondary-task-related, drowsiness-related, and total baseline epochs for each type of weather.

Table 3.7 presents the odds ratio calculations for the different types of weather. Driving while drowsy during both *rainy* and *clear* weather is significantly more risky than driving alert during the same conditions. Interestingly, the elevated near-crash/crash risk is the same for both, suggesting that driving drowsy is very dangerous, regardless of roadway conditions. Unfortunately, the other weather conditions could not be assessed due to low statistical power.

Table 3.7. Odds ratio point estimates and 95 percent confidence intervals for the interaction of drowsiness by type of weather.

Type of Weather	Odds Ratio	Lower CL	Upper CL
Clear	**4.34**	**3.22**	**5.86**
Rain	**4.41**	**2.41**	**8.08**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

The relative risk calculations for a crash or near-crash for complex secondary tasks also suggest that engaging in complex secondary tasks is significantly more risky than driving alert in similar conditions (Table 3.8). The relative near-crash/crash risk estimate is higher for rain, suggesting that it may be riskier to engage in complex secondary tasks during the rain than in clear weather. Some caution is urged in this interpretation because the confidence limit surrounding the odds ratio for engaging in a complex task during the rain is also larger than it is for clear weather.

Table 3.8. Odds ratio point estimates and 95 percent confidence intervals for the interaction of complex secondary tasks by type of weather.

Type of Weather	Odds Ratio	Lower CL	Upper CL
Clear	**3.68**	**2.29**	**5.92**
Rain	**5.11**	**1.86**	**14.07**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

The odds ratio for engaging in moderate secondary tasks indicates that it may be safer to engage in moderate secondary tasks than complex secondary tasks (Table 3.9). Most of the odds ratios for moderate secondary tasks were not significantly different than 1.0 suggesting that engaging in moderate secondary tasks are not protective but rather are simply not riskier than driving while drowsy or engaging in complex secondary tasks.

Table 3.9. Odds ratio point estimates and 95 percent confidence limits for the interaction of moderate secondary tasks by type of weather.

Type of Weather	Odds Ratio	Lower CL	Upper CL
Clear	0.86	0.65	1.13
Rain	0.65	0.37	1.15

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

ROADWAY AND SURFACE CONDITIONS

Road Type

Road Type (called "Traffic Flow" in the GES Database) primarily refers to whether there is a physical barrier between traffic. The No Lanes category was added for parking lots and should be interpreted as "no barrier." One-way streets possess a barrier since all traffic is flowing in one direction. Table 3.10 shows the distribution of drowsiness- and secondary-task-related events and epochs that occurred on each type of traffic-flow roadway. Most secondary-task-related events and epochs occurred on divided roadways.

Table 3.10. The frequency of secondary-task-related events and epochs that were recorded for each road type.

Road Type	Frequency of Drowsiness-Related Crash and Near-Crash Events	Frequency of Secondary Task-Related Crash and Near-Crash Events	Frequency of Drowsiness-Related Baseline Epochs	Frequency of Secondary-Task-Related Baseline Epochs
Divided	64	118	530	2,612
Undivided	43	95	199	1248
One-way	4	11	17	114
No Lanes	1	2	9	141
Total	112	226	755	4,115

Figure 3.3 presents the percent of total drowsiness-related epochs, secondary-task-related epochs, and total baseline epochs for the various road types. While divided roadways were most frequent for all categories, a substantial number of epochs also occurred on undivided roadways as well. One-way roadways and/or parking lots were represented in a smaller percentage of epochs. There were no practical differences between the percent of secondary task or drowsiness epochs as compared to total baseline epochs, which suggests that drivers are engaging in secondary tasks regardless of type of roadway that they happen to be navigating at the time. There was a slightly higher percent of occurrence for drowsiness-related epochs on divided roadways than on undivided roadways. One possible hypothesis for this result is that drivers are more relaxed and less active on divided roadways (i.e., interstates) because they do not have to monitor cross traffic as frequently as on undivided roadways. This feeling of relaxation may result in higher occurrence of drowsiness.

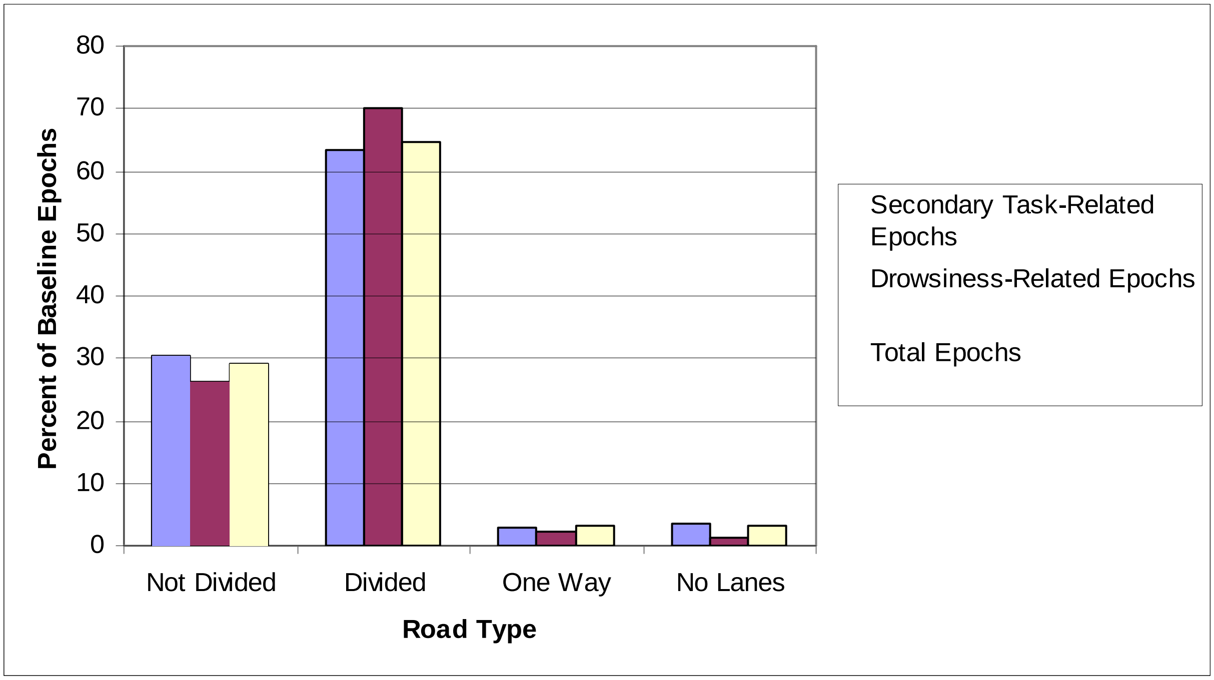

Figure 3.3. Percentage of secondary-task-related, drowsiness-related, and total baseline epochs by type of roadway.

Even though drivers appear to be engaging in secondary tasks or driving drowsy on these types of roadways equally, that does not necessarily mean that it is equally safe to do so. Odds ratios for drowsiness, complex-secondary-task and moderate-secondary-task engagement were calculated for each road type and are presented in Tables 3.11 through 3.13. All of the odds ratios for the interaction of drowsiness and road type were greater than 3.0, suggesting that driving while drowsy on any of these road types increases near-crash/crash risk by at least three times that of driving alert on the same types of roadways with the highest risk associated with undivided roadways.

Engaging in complex secondary tasks while driving on undivided roadways was slightly less dangerous than engaging in complex secondary tasks while driving on a divided roadway. While this may not make intuitive sense, this result may be an artifact of the higher percentage of driving on divided roadways and the higher traffic densities occurring on these roadways given the metropolitan environment where these data were collected. The odds ratios for engaging in moderate secondary tasks were not significantly different from 1.0 indicating that engaging in moderate secondary tasks is less risky than engaging in complex secondary tasks or driving drowsy.

Table 3.11. Odds ratio point estimates and 95 percent confidence intervals for the interaction of drowsiness by road type.

Road Type	Odds Ratio	Lower CL	Upper CL
Divided	**3.73**	**2.61**	**5.34**
Undivided	**5.54**	**3.47**	**8.84**
One-Way	**3.40**	**1.76**	**6.59**
Parking Lots	N/A	N/A	N/A

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.12. Odds ratio point estimates and 95 percent confidence intervals for the interaction of complex secondary tasks by road type.

Road Type	Odds Ratio	Lower CL	Upper CL
Divided	**4.20**	**2.40**	**7.33**
Undivided	**3.60**	**1.89**	**6.79**
One-Way	**3.66**	**1.63**	**8.18**
Parking Lots	N/A	N/A	N/A

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.13. Odds ratio point estimates and 95 percent confidence intervals for the interaction of moderate secondary tasks by road type.

Road Type	Odds Ratio	Lower CL	Upper CL
Divided	0.79	0.57	1.10
Undivided	0.85	0.54	1.35
One-Way	0.94	0.48	1.84
Parking Lots	0.68	0.25	1.85

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Roadway Alignment

Roadway alignment is a GES Crash Database variable that refers to both the curvature and percent grade of the roadway. Both curvature and percent grade can dramatically shorten the driver's sight distance of the roadway and traffic patterns in front of them. Coupled with driver inattention or drowsiness, specific types of roadway alignment may increase near-crash/crash risk. Given reduced sight distance, do drivers tend not to engage in secondary tasks or attempt to become more alert, if even for a brief time?

Table 3.14 presents the frequency of secondary-task-related events and baseline epochs that were observed for each type of roadway alignment. Most events and epochs occurred on straight and level roadways. This is most likely an artifact of the geographic location where the data were collected (Northern Virginia/Washington, DC, metro area).

Table 3.14. The frequency of drowsiness and secondary-task-related events and epochs that were recorded for each type of roadway alignment.

Type of Roadway Alignment	Frequency of Drowsiness-Related Crash and Near-Crash Events	Frequency of Secondary-Task-Related Crash and Near-Crash Events	Frequency of Drowsiness-Related Baseline Epochs	Frequency of Secondary-Task-Related Baseline Epochs
Curve Grade	0	6	7	41
Curve Level	20	31	73	387
Straight Grade	1	4	15	95
Straight Level	90	184	659	3,587
Straight Hill Crest	0	0	0	1
Curve Hill Crest	0	0	0	0
Other	0	0	0	1
Total	111	225	754	4,112

Figure 3.4 compares the percentage of drowsiness-related, secondary-task-related, and total baseline epochs for different levels of roadway alignment. While 90 percent of drowsiness-, secondary-task-related, and total baseline epochs occur on straight and level roadways, other roadway alignments did occur in the dataset. The percentages for each type of alignment were nearly identical for all three groups. This suggests that drivers are not selecting to engage in secondary-task-related activities based upon the alignment of the roadway, nor are there differences in driver drowsiness on these different roadway alignments.

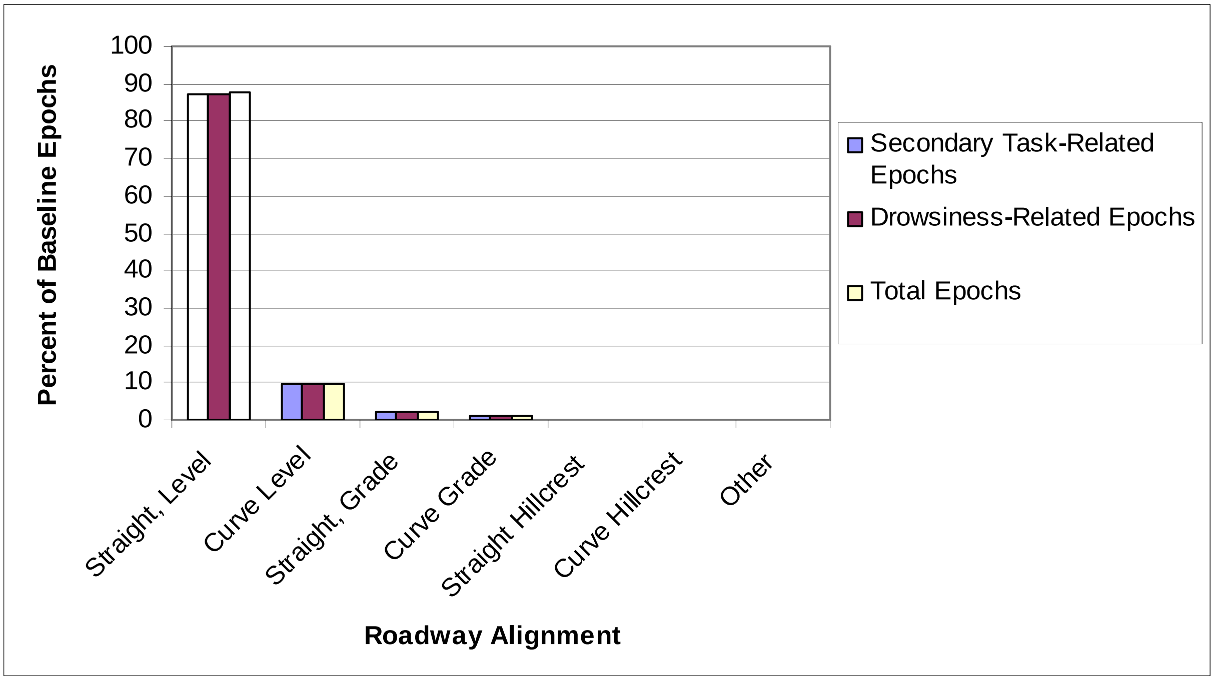

Figure 3.4. Percentage of secondary-task-related, drowsiness-related, and total baseline epochs by type of roadway alignment.

To determine whether there is increased individual near-crash/crash risk for driving drowsy or engaging in secondary-task-related activities for particular types of roadway alignment, odds ratios were calculated and are presented in Tables 3.15 through 3.17. The odds ratio calculation for straight, grade had the highest near-crash/crash risk, suggesting that drowsy drivers are over six times as likely to be involved in a crash or near-crash as an alert driver on a straight, grade roadway (Table 3.15). The odds ratio for the straight, grade was not significantly higher than for curve, level or straight, level (since the confidence limits of all three roadway alignments overlap).

Engaging in complex secondary tasks on these four roadway alignments was also shown to be riskier than driving alert on the same roadway types (Table 3.16). The odds ratio for curve, level was nearly the same as the odds ratio for straight, level, suggesting that these two are equally riskier than driving while alert. The odds ratios for straight, grade was significantly higher than the other road alignments (except for straight, grade), suggesting that this road alignment is a riskier road environment for engaging in complex secondary tasks. The odds ratio for curve, grade was not significantly different than curve, level and straight, level. Driving while performing complex secondary tasks was at least three times riskier than driving while alert for all of these road alignments.

The odds ratios for moderate secondary tasks indicate that these types of tasks are not as risky as engaging in complex secondary tasks or driving drowsy on these road alignments.

Table 3.15. Odds ratio point estimates and 95 percent confidence intervals for the interaction of drowsiness and roadway alignment.

Type of Roadway Alignment	Odds Ratio	Lower CL	Upper CL
Straight, Level	**3.96**	**2.93**	**5.34**
Curve, Level	**5.81**	**3.66**	**9.21**
Straight, Grade	**6.29**	**2.20**	**17.96**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.16. Odds ratio point estimates and 95 percent confidence intervals for the interaction of complex secondary tasks and roadway alignment.

Type of Roadway Alignment	Odds Ratio	Lower CL	Upper CL
Straight, Level	**3.59**	**2.20**	**5.84**
Curve, Level	**3.58**	**1.95**	**6.60**
Straight, Grade	**26.00**	**7.31**	**92.53**
Curve, Grade	**6.75**	**2.08**	**21.89**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.17. Odds ratio point estimates and 95 percent confidence intervals for the interaction of moderate secondary tasks and roadway alignment.

Type of Roadway Alignment	Odds Ratio	Lower CL	Upper CL
Straight, Level	0.79	0.60	1.03
Curve, Grade	1.69	0.56	5.09
Curve, Level	0.88	0.56	1.39
Straight, Grade	1.86	0.56	6.19

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Traffic Density

Traffic density was recorded by the data reductionists using the Transportation Research Board's (TRB) Level of Service (LOS) Definitions (*Highway Capacity Manual*, 2000). The LOS is a scale from 1 to 6 of *increasing* traffic density with 1 being free-flow traffic and 6 being stop-and-go traffic with extended stoppages. The six levels of traffic density are listed in Table 3.18 along with the frequency of drowsiness- and secondary-task-related events and epochs that were recorded at each level of traffic density.

Table 3.18. The frequency of secondary-task-related events and epochs that were recorded at each level of traffic density.

Traffic Density	Frequency of Drowsiness-Related Crash and Near-Crash Events	Frequency of Secondary Task-Related Crash and Near-Crash Events	Frequency of Drowsiness-Related Baseline Epochs	Frequency of Secondary-Task-Related Baseline Epochs
LOS A: Free Flow	44	84	430	2,013
LOS B: Flow with Some Restrictions	31	73	237	1,529
LOS C: Stable Flow – Maneuverability and Speed are more Restricted	20	43	56	391
LOS D: Flow is Unstable – Vehicles are unable to pass with temporary stoppages.	10	19	14	84
LOS E: Unstable Flow- Temporary restrictions, substantially slow drivers	5	7	10	55
LOS F: Forced Traffic Flow Conditions with Low Speeds and Traffic Volumes Below Capacity	2	0	8	43
Total	112	226	755	4,115

Note: inattention is defined as only those events where drivers were involved in secondary tasks or were severely drowsy.

Figure 3.5 presents the percentage of drowsiness-related, secondary-task-related, and total baseline epochs that occurred at each level of traffic density. As traffic density increased, the frequency of drowsiness- and secondary-task-related epochs decreased. The percentage for secondary-task-related epochs and total epochs did not differ, indicating that drivers are not choosing to engage in complex or moderate secondary tasks differently for these traffic densities. The drowsiness-related epochs were slightly different, with more drowsiness-related events occurring during free-flow and fewer occurring during flow with restrictions and stable traffic flow. One hypothesis for this result is that driving in free-flow traffic is less interesting and requires less activity by the driver. Therefore, these types of traffic flow may help induce drowsiness because the driver is under-stimulated.

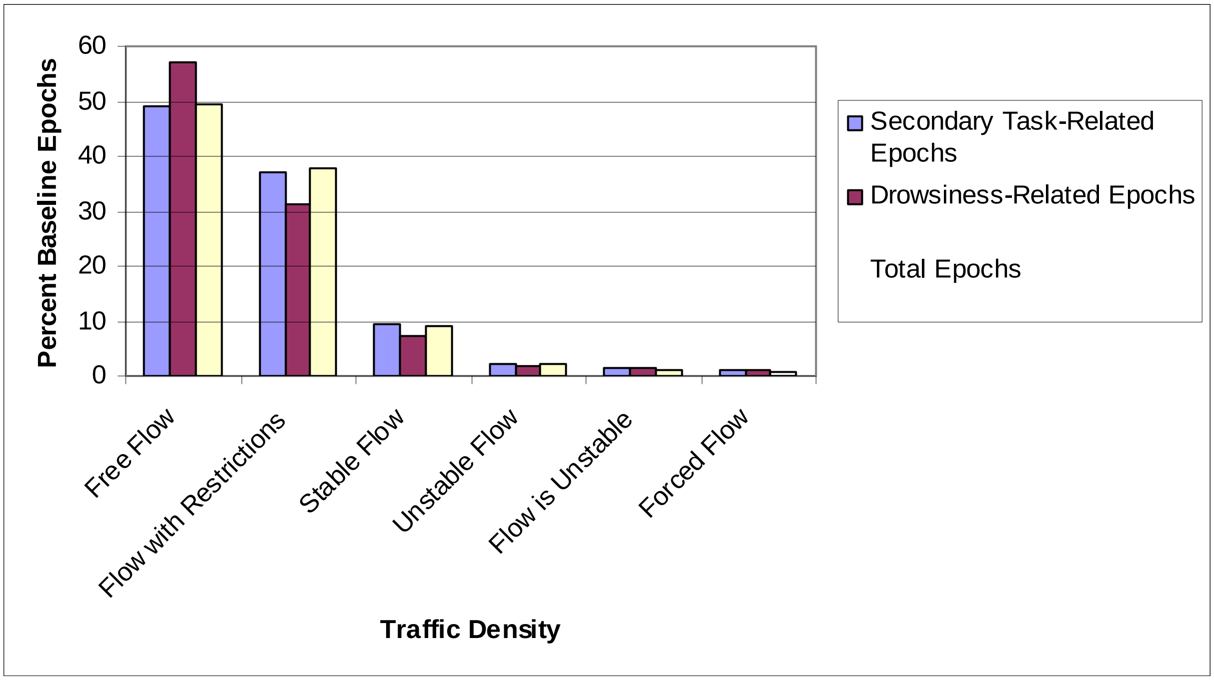

Figure 3.5. Percentage of secondary-task-related, drowsiness-related, and total baseline epochs by type of traffic density.

Odds ratios were calculated to determine if any of these traffic densities present greater individual near-crash/crash risk. Tables 3.19 through 3.21 present the odds ratio calculations for each level of density for drowsiness. The odds ratio calculations for driving drowsy at each level of traffic density suggest that driving drowsy is at least three times riskier than driving while alert during the same level of traffic density. None of the traffic densities were significantly riskier than any another level of traffic density.

Similar results were found for engaging in complex secondary tasks where this activity was found to increase near-crash/crash risk by at least three times that of alert driving during the same traffic density. Again, engaging in complex secondary tasks was equally risky at all levels of traffic density, except for LOS D.

The odds ratios for moderate secondary tasks did not demonstrate similar risk levels and thus engaging in moderate secondary tasks during these traffic levels is not as risky and does not elevate near-crash/crash risk to the extent as driving drowsy or engaging in complex secondary tasks. This result was found to be true across all levels of traffic density for moderate-secondary-task engagement.

Table 3.19. Odds ratio point estimates and 95 percent confidence intervals for the interaction of drowsiness and traffic density.

Type of Traffic Density	Odds Ratio	Lower CL	Upper CL
LOS A: Free Flow	**4.67**	**3.02**	**7.21**
LOS B: Flow with Some Restrictions	**4.81**	**2.70**	**8.58**
LOS C: Stable Flow – Maneuverability and Speed are more Restricted	**3.63**	**2.01**	**6.54**
LOS D: Flow is Unstable – Vehicles are unable to pass with temporary stoppages	**4.29**	**1.88**	**9.80**
LOS E: Unstable Flow-Temporary restrictions, substantially slow drivers	**3.71**	**1.93**	**7.13**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.20. Odds ratio point estimates and 95 percent confidence intervals for the interaction of complex secondary tasks and traffic density.

Type of Traffic Density	Odds Ratio	Lower CL	Upper CL
LOS A: Free Flow	**4.67**	**2.32**	**9.38**
LOS B: Flow with Some Restrictions	**3.67**	**1.65**	**8.19**
LOS C: Stable Flow – Maneuverability and Speed are more Restricted	**3.80**	**1.68**	**8.58**
LOS D: Flow is Unstable – Vehicles are unable to pass with temporary stoppages	1.75	0.61	5.01
LOS E: Unstable Flow-Temporary restrictions, substantially slow drivers	**2.45**	**1.01**	**5.93**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.21. Odds ratio point estimates and 95 percent confidence intervals for the interaction of moderate secondary task and traffic density.

Type of Traffic Density	Odds Ratio	Lower CL	Upper CL
LOS A: Free Flow	0.95	0.63	1.45
LOS B: Flow with Some Restrictions	0.69	0.39	1.23
LOS C: Stable Flow – Maneuverability and Speed are more Restricted	0.69	0.38	1.26
LOS D: Flow is Unstable – Vehicles are unable to pass with temporary stoppages	0.31	0.13	0.76
LOS E: Unstable Flow-Temporary restrictions, substantially slow drivers	1.18	0.59	2.34

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Surface Condition

The surface condition of roadways has been identified as a frequent contributing factor for crashes and near-crashes. Reductionists used the video and driving performance sensors to assess the status of the roadway surfaces. This analysis was conducted to determine whether drivers engaged in inattentive driving on roads with poor surface conditions. Table 3.22 shows the frequency of the drowsiness and secondary-task-related events and baseline epochs for all six surface condition types. Nearly all of the events and epochs occurred on dry pavement.

Table 3.22. The frequency of drowsiness- and secondary-task-related epochs that occurred at each roadway surface condition level.

Surface Condition	Frequency of Drowsiness-Related Crash and Near-Crash Events	Frequency of Secondary-Task-Related Crash and Near-Crash Events	Frequency of Drowsiness-Related Baseline Epochs	Frequency of Secondary-Task -Related Baseline Epochs
Dry	98	197	666	3681
Wet	13	29	83	395
Icy	1	1	0	3
Snowy	0	0	6	35
Muddy	0	0	0	0
Other	0	0	0	1
Total	112	227	755	4115

Figure 3.6 shows the percentages of drowsiness-related, secondary-task-related, and total baseline epochs that occurred for each type of surface condition. Nearly 90 percent of all drowsiness-related, secondary-task-related, and total baseline epochs occurred on dry pavement, while very low percentages occurred on icy, snowy, and muddy roads. Nearly identical patterns

were observed for percent of drowsiness-related and total number of baseline epochs, as well as for secondary-task-related and total number of baseline epochs. This indicates that drivers did not choose to engage in secondary tasks or drive drowsy as a function of the surface condition of the roadway.

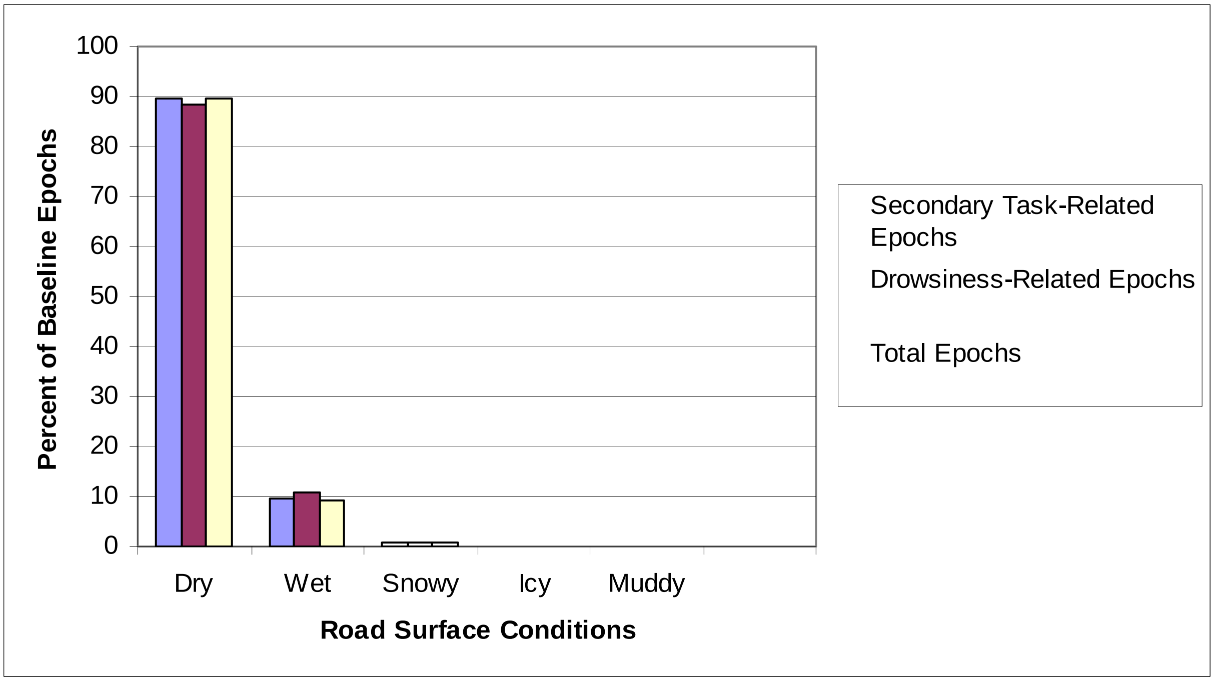

Figure 3.6. Percentage of secondary-task-, drowsiness-related and total baseline epochs for all surface conditions.

Odds ratio calculations were conducted to determine whether the near-crash/crash risks associated with driving drowsy or while engaging in complex or moderate secondary tasks were different as a function of poor surface conditions. Table 3.23 presents the odds ratios calculated for driving drowsy on dry, wet, and icy surface conditions. (Odds ratios were not calculated for the other surface conditions because there were either no baseline epochs or no crash or near-crash events observed for these conditions.) Driving while drowsy on either dry or wet roadways increased near-crash/crash risk by at least three times over that of driving alert on a dry or wet roadway.

The odds ratios for engaging in complex secondary tasks on dry roadways increased near-crash/crash risk by four times over that of driving alert on dry roadways (Table 3.24). The relative near-crash/crash risk of engaging in complex secondary tasks on wet roadways was neither significantly different from 1.0 nor significantly different than driving alert on a wet roadway. This result is also not intuitive, but may be due in part to slower speeds and increased headway distances commonly occurring on rainy roadways.

A similar pattern was found for engaging in moderate secondary tasks, which was found to not be as risky as driving drowsy or while engaging in complex secondary tasks (Table 3.25). Dry and wet roadways were also not significantly riskier than one another, suggesting that the interaction found for the complex secondary task and surface condition is unique to complex-secondary-task engagement.

Table 3.23. Odds ratio point estimates and 95 percent confidence intervals for the interaction of drowsiness and surface condition.

Type of Surface Condition	Odds Ratio	Lower CL	Upper CL
Dry	4.52	3.39	6.03
Wet	**3.17**	**2.03**	**4.95**
Icy	N/A	N/A	N/A

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.24. Odds ratio point estimates and 95 percent confidence intervals for the interaction of complex secondary tasks and surface condition.

Type of Surface Condition	Odds Ratio	Lower CL	Upper CL
Dry	**4.44**	**2.88**	**6.84**
Wet	1.03	0.58	1.80
Icy	N/A	N/A	N/A

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.25. Odds ratio point estimates and 95 percent confidence intervals for the interaction of moderate secondary tasks and surface condition.

Type of Surface Condition	Odds Ratio	Lower CL	Upper CL
Dry	0.85	0.65	1.12
Wet	0.73	0.47	1.15
Icy	N/A	N/A	N/A

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

ROADWAY INFRASTRUCTURE

Traffic Control

The type of traffic control device that a driver needed to heed either 5 seconds prior to or during the course of the crash or near-crash was recorded by trained data reductionists for the events. If a driver needed to heed a traffic control device during the 6-second baseline segment, the reductionist also marked it accordingly. Otherwise, the reductionists recorded *No Traffic Control*.

Table 3.26 presents the frequency of drowsiness- and secondary-task-related events and baseline epochs where the driver was heeding a particular traffic-control device. Most of the events and epochs were marked as *No Traffic Control.*

Table 3.26. The frequency of secondary-task-related crash and near-crash events and baseline epochs that were recorded for each type of traffic-control device.

Type of Traffic Control Device	Frequency of Drowsiness-Related Crash and Near-Crash Events	Frequency of Secondary Task-Related Crash and Near-Crash Events	Frequency of Drowsiness-Related Baseline Epochs	Frequency of Secondary-Task-Related Baseline Epochs
Traffic Signal	13	42	40	614
Stop Sign	2	5	3	73
Traffic Lanes Marked	2	4	28	273
Yield Sign	0	0	2	18
Slow or Warning Sign	0	0	2	7
No Passing Sign	0	0	0	1
One-way road	0	0	0	8
Officer or Watchman	0	0	0	3
No Traffic Control	91	169	676	3,609
Other	3	3	4	15
Total	108	223	755	4,114

Note: inattention is defined as only those events where drivers were involved in secondary tasks or were severely drowsy.

The comparisons between the percent of drowsiness-related, secondary-task-related, and total number of baseline epochs for each type of traffic-control device are shown in Figure 3.7. The percentages are very similar across the board, which indicates that drivers are not choosing to engage in secondary tasks or drive while drowsy differently when encountering any of these traffic control devices. This is not to say that drivers were not engaging in secondary tasks while safely sitting at a stop sign or traffic light. This type of analysis could not be performed because the vehicle needed to be moving during the 6 seconds of the epoch for that segment to qualify as a baseline epoch (as discussed in Chapter 1: Introduction and Method).

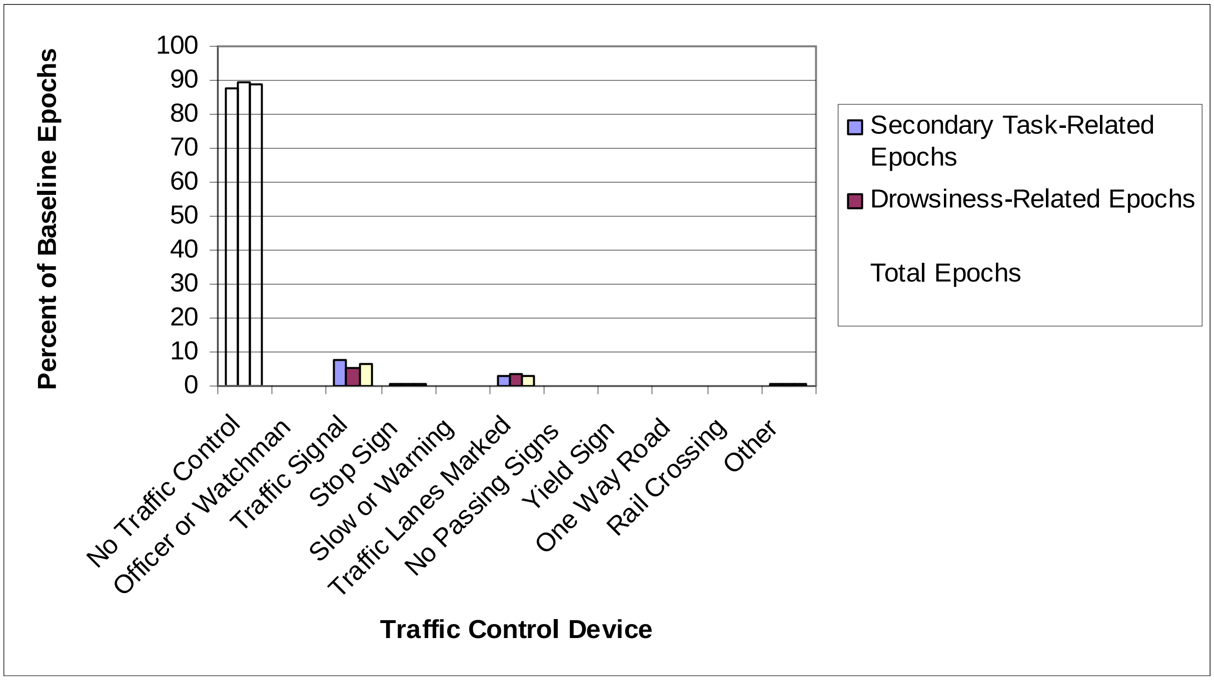

Figure 3.7. Percentage of secondary-task-related, drowsiness-related, and total number of baseline epochs for each type of traffic control device.

Odds ratios were calculated to determine whether engaging in complex or moderate secondary tasks or driving while drowsy while encountering any of these traffic control devices increased an individual's near-crash/crash risk (Tables 3.27 through 3.29). The odds ratio calculations for drowsiness suggest that drowsiness, by itself, increases an individual's risk of being involved in a crash or near-crash by at least 2.7 times over that of an alert driver encountering the same traffic-control device (Table 3.27). None of the traffic-control devices were significantly more risky in the presence of drowsiness than any other traffic-control device.

The odds ratios for complex-secondary-task engagement were similar. Engaging in complex secondary tasks in the presence of a traffic signal, stop sign, or no traffic-control device increased near-crash/crash risk by at least three times over that of an alert driver at a similar traffic-control device (Table 3.28). Stop signs or traffic signals were not significantly riskier than no traffic-control devices. Odds ratios for other traffic-control devices were not available due to low statistical power.

The odds ratios for moderate secondary task engagement were not significantly different from 1.0 except for traffic signal (Table 3.29). The odds ratio for traffic signals actually showed a protective effect, suggesting either that the traffic signal was perhaps able to redirect drivers' attention to the forward roadway or that the presence of a traffic signal was highly correlated with increased traffic, which redirected drivers' attention to the forward roadway. Overall, engaging in moderate secondary tasks is not as risky as driving drowsy or engaging in complex secondary tasks in the presence of any of these traffic-control devices.

Table 3.27. Odds ratio point estimates and 95 percent confidence intervals for the interaction of drowsiness and each type of traffic-control device.

Type of Traffic-Control Device	Odds Ratio	Lower CL	Upper CL
Traffic Signal	**2.71**	**1.90**	**3.85**
Stop Sign	**5.55**	**2.71**	**11.36**
Traffic Lanes Marked	**5.57**	**2.43**	**12.78**
No Traffic Control	**4.83**	**3.60**	**6.48**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.28. Odds ratio point estimates and 95 percent confidence intervals for the interaction of complex secondary tasks and each type of traffic-control device.

Type of Traffic-Control Device	Odds Ratio	Lower CL	Upper CL
Traffic Signal	**3.14**	**2.15**	**4.58**
Stop Sign	**3.27**	**1.38**	**7.75**
No Traffic Control	**4.02**	**2.47**	**6.54**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.29. Odds ratio point estimates and 95 percent confidence intervals for the interaction of moderate secondary tasks and each type of traffic-control device.

Type of Traffic-Control Device	Odds Ratio	Lower CL	Upper CL
Traffic Signal	0.41	0.28	0.59
Stop Sign	0.73	0.34	1.56
Traffic Lanes Marked	2.29	0.98	5.31
No Traffic Control	0.92	0.70	1.22

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Relation to Junction

The *relation to junction* variable was also adapted from the GES Crash Database to refer to whether the driver was in close proximity to a roadway junction. If the onset of a crash or near-crash occurred in or near an intersection, merge ramp, or interchange, the event was recorded as such; otherwise it was recorded as a non-junction. Likewise, if the vehicle passed through an intersection, interchange, or entered a merge ramp during the 6-second segment of the baseline epochs, then the appropriate relation to junction variable was recorded. Otherwise, non-junction was recorded for that baseline epoch. The different types of junctions used by data reductionists are presented in Table 3.30 along with the frequency of secondary-task- and drowsiness-related events and baseline epochs. Note that most events and epochs were not near roadway junctions (i.e., they were "non-junction").

Table 3.30. The frequency of drowsiness- and secondary-task-related events and epochs that were recorded for each type of relation to junction.

Type of Relation to Junction	Frequency of Drowsiness-Related Crash and Near-Crash Events	Frequency of Secondary-Task-Related Crash and Near-Crash Events	Frequency of Drowsiness-Related Baseline Epochs	Frequency of Secondary-Task-Related Baseline Epochs
Intersection	17	42	30	257
Intersection-Related	11	22	28	232
Entrance/Exit Ramp	7	11	15	65
Parking Lot	0	5	4	112
Driveway/Alley Access	0	3	2	15
Interchange	1	2	1	10
Rail Grade Crossing	0	0	0	0
Other	0	0	1	12
Non-Junction	75	140	674	3,412
Total	111	226	755	4,115

Note: inattention is defined as only those events where drivers were involved in secondary tasks or were severely drowsy.

Figure 3.8 presents the percentages of drowsiness-related, inattention-related, and total number of baseline epochs occurring at each of the junction types. Note that non-junction accounted for 84 percent of the secondary-task-related baseline epochs as well as of the total baseline epochs. There were very small differences between the percentages of secondary-task-related and total number of baseline epochs, suggesting that there are only small differences between the percentages of time spent engaging in secondary tasks whereas encountering these junctions and how often drivers encounter these types of junctions. There were slight differences in the percentage of drowsiness-related epochs and total epochs, suggesting that a higher percentage of drowsiness-related epochs occurred at non-junctions than at or near intersections. This may suggest that drivers may be more relaxed (under-stimulated) and may succumb to drowsiness effects more often while navigating through less-demanding environments.

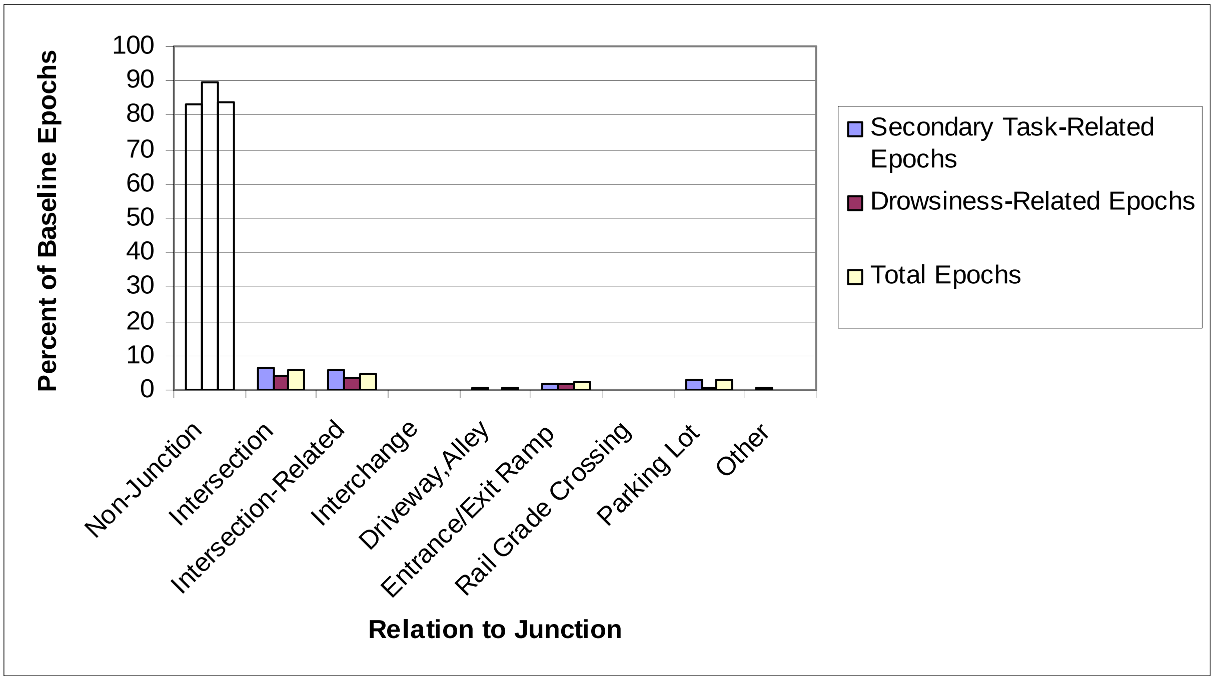

Figure 3.8. Percentage of secondary-task-related, drowsiness-related, and total number of baseline epochs for each relation to junction.

To determine whether any of these types of junctions present higher near-crash/crash risks for inattentive drivers, the odds ratios for each were calculated (Tables 3.31 through 3.33). The results for the drowsiness-related odds ratios indicate that near-crash/crash risk increased by at least three times for drivers who were navigating intersections, entrance ramps, and interchanges than for those drivers who were alert at similar junctions (Table 3.31). Also, driving while drowsy in general (i.e., non-junction) increases a driver's near-crash/crash risk by as much as five times over that of an alert driver encountering similar roadway junctions.

Engaging in complex secondary tasks while in a parking lot or near an intersection increased near-crash/crash risk over that of an alert driver at the junction type (Table 3.32). Somewhat surprisingly, the odds ratio for an intersection did not demonstrate an increased near-crash/crash risk. Drivers may be more careful or even avoid engaging in complex tasks during intersections as these are visually and cognitively demanding environments. The odds ratio for engaging in complex secondary tasks in a parking lot was very high, with an increased near-crash/crash risk of nine times over that of an alert driver in a parking lot. This is somewhat higher than was expected, however, there is a wide confidence interval surrounding this point estimate.

The odds ratios for engaging in moderate secondary tasks showed a similar pattern to complex secondary tasks, in that the odds ratio for intersection was lower than for intersection-related or parking lot (Table 3.33). While the pattern is similar, generally the odds ratios for moderate secondary tasks are not significantly different from 1.0, with the exception of intersection. This suggests that engaging in moderate secondary tasks is not as risky as engaging in complex secondary tasks or driving while drowsy in the presence of these types of roadway junctions.

Table 3.31. Odds ratio point estimates and 95 percent confidence intervals for the interaction of drowsiness and each type of relation to junction.

Type of Relation to Junction	Odds Ratio	Lower CL	Upper CL
Intersection	**3.48**	**2.17**	**5.59**
Intersection-Related	**6.82**	**4.10**	**11.35**
Entrance/Exit Ramp	**3.21**	**1.81**	**5.71**
Interchange	**5.86**	**2.39**	**14.35**
Non-Junction	**5.02**	**3.65**	**6.90**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.32. Odds ratio point estimates and 95 percent confidence intervals for the interaction of complex secondary tasks and each type of relation to junction.

Type of Relation to Junction	Odds Ratio	Lower CL	Upper CL
Intersection	1.59	0.86	2.97
Intersection-Related	**3.32**	**1.73**	**6.38**
Parking Lot	**9.11**	**3.76**	**22.07**

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

Table 3.33. Odds ratio point estimates and 95 percent confidence intervals for the interaction of moderate secondary tasks and each type of relation to junction.

Type of Relation to Junction	Odds Ratio	Lower CL	Upper CL
Intersection	0.50	0.31	0.81
Intersection-Related	0.63	0.37	1.44
Entrance/Exit Ramp	1.12	0.61	2.05
Parking Lot	0.65	0.29	1.44
Driveway/Alley Access	2.00	0.64	6.28
Interchange	2.57	0.89	7.46
Non-Junction	0.95	0.70	1.30

Note: numbers in bold font indicate that the point estimate is significantly different than normal, baseline driving (or an odds ratio of 1.0).

SUMMARY

Two primary research questions were addressed in this chapter:

- Do drivers choose to engage in secondary tasks or drive drowsy during more dangerous or adverse environmental conditions?
- Are any of these environmental conditions riskier than others for inattentive drivers?

Both of these questions were addressed for eight different environmental conditions: ambient lighting, weather, road type, roadway alignment, traffic density, surface condition, traffic-control device, and relation to junction. The results for the first question indicate that far fewer drowsiness-related baseline epochs were observed during the daylight hours than drowsiness-related crashes and near-crashes. Secondly, a greater percentage of drowsiness-related baseline epochs were identified during darkness than drowsiness-related crashes and near-crashes. Drowsiness was also seen to slightly increase in the absence of high roadway or traffic demand. A higher percentage of drowsiness-related baseline epochs were found during free-flow traffic densities, on divided roadways, and areas free of roadway junctions.

The results for the second question were more varied. Each of the eight environmental conditions resulted in odds ratios greater than 1.0 for both drowsiness and engaging in complex secondary tasks. Engaging in moderate secondary tasks rarely resulted in odds ratios significantly greater than 1.0, indicating that these behaviors may not be as risky as driving drowsy or driving while engaging in complex secondary tasks.

In Chapter 2, *Objective 1*, the odds ratio for risk of driving while drowsy was four to six times that of normal, baseline driving, engaging in complex secondary task was three times, and engaging in moderate secondary tasks was two times that of an alert driver. In this chapter, these total odds ratios decreased when comparing across environmental conditions. While a decrease is to be expected when narrowing the focus of the analysis, it should also be noted all three types of tasks are still riskier than attentive driving.

The baseline dataset also provided some interesting results. For example, drivers are operating their vehicles during the daytime, on dry pavement, and on straight, non-junction roadways a majority of the time. While nighttime driving, adverse weather conditions, intersections, and other difficult roadway geometries increase individual near-crash/crash risk, it is important to note that many crashes and near-crashes occur in the *absence* of these adverse conditions.

While many of these results are of interest to human factors researchers, roadway designers, and urban planners, it is important to remember that these data were collected only in a metropolitan, urban driving environment (Northern Virginia/Washington, DC, metropolitan area). The results are only generalizable to other urban/metropolitan driving environments and not to the United States driving population in general.

It is important to note that the 20,000 baseline epochs used in these analyses and calculations of relative near-crash/crash risk were not selected based upon any of the above environmental variables. These epochs were selected at random and these environmental conditions were not used in the sampling procedure. Some degree of caution is suggested in the interpretation of these relative near-crash/crash risks given that the baseline epochs were not selected to specifically assess environmental variables.

While population attributable risk percentages were calculated in Chapter 2 when assessing the general effects of the four types of driver inattention, population attributable risk percentages were not calculated for the environmental conditions discussed in the current chapter. Because the environmental conditions were not considered when selecting the baseline sample, a population attributable risk percentage calculation would only be a gross estimate.

Even after collecting data for 12 months on 100 vehicles, there were still many environmental variables with insufficient statistical power to accurately calculate odds ratios. A larger scale naturalistic driving study is needed to not only obtain accurate and valid measures for many of the variables presented in this chapter, but also for more generalizable results to the United States driving population.

CHAPTER 4: *OBJECTIVE 3*, DETERMINE THE DIFFERENCES IN DEMOGRAPHIC DATA, TEST BATTERY RESULTS, AND PERFORMANCE-BASED MEASURES BETWEEN INATTENTIVE AND ATTENTIVE DRIVERS. HOW MIGHT THIS KNOWLEDGE BE USED TO MITIGATE THE POTENTIAL NEGATIVE CONSEQUENCES OF INATTENTIVE DRIVING BEHAVIORS? COULD THIS INFORMATION BE USED TO IMPROVE DRIVER EDUCATION COURSES OR TRAFFIC SCHOOLS?

For this research objective, statistical analyses were conducted using the frequency of drivers' involvement in inattention-related crashes and near-crashes compared to each driver's composite test battery score or relevant survey response (Table 4.1). The debrief form and the health assessment questionnaires were not included as they are not personality assessment tests. A discussion of how these results could be used to mitigate potential negative consequences of inattentive driving and/or used in traffic schools and drivers education courses will also be addressed in this chapter.

Table 4.1. Description of questionnaire and computer-based tests used for 100-Car Study.

	Name of Testing Procedure	Type of Test	Time test was administered	Brief description
1.	Driver demographic information	Paper/pencil	In-processing	General information on drivers age, gender, etc.
2.	Driving History	Paper/pencil	In-processing	General information on recent traffic violations and recent collisions.
3.	Health assessment questionnaire	Paper/pencil	In-processing	List of variety of illnesses/medical conditions/or any prescriptions that may affect driving performance.
4.	Dula Dangerous Driving Index	Paper/pencil	In-processing	One score that describes driver's tendencies toward aggressive driving.
5.	Sleep Hygiene	Paper/pencil	In-processing	List of questions that provide information about driver's general sleep habits/substance use/sleep disorders.
6.	Driver Stress Inventory	Paper/Pencil	In-processing	One score that describes the perceived stress levels drivers experience during their daily commutes.
7.	Life Stress Inventory	Paper/pencil	In-processing/Out-processing	One score that describes drivers stress levels based upon the occurrence of major life events.
8.	Useful Field-of-View	Computer-based test	In-processing	Assessment of driver's central vision and processing speed, divided and selective attention.
9.	Waypoint	Computer-based test	In-processing	Assessment of the speed of information processing and vigilance.
10.	NEO-FFI	Paper/pencil	In-processing	Personality test.
11.	General debrief questionnaire	Paper/pencil	Out-processing	List of questions ranging from seatbelt use, driving under the influence, and administration of experiment.

DATA INCLUDED IN THESE ANALYSES

For the analyses in this chapter, crashes and near-crashes only will be used (incidents will be excluded from the analyses). In Dingus et al., (2005) the analyses indicated that the kinematic signatures of both crashes and near-crashes were nearly identical; whereas the kinematic signature of incidents were more variable. Given this result and to increase statistical power, the data from both crashes and near-crashes will be used in the comparison of questionnaire data to the frequency of driver involvement in inattention-related crashes and near-crashes.

Note that inattention-related crashes and near-crashes are defined as those events that involve the driver engaging in complex, moderate, or simple secondary tasks or driving while drowsy. Please note that in Chapter 2, *driving-related inattention to the forward roadway* was determined to possess a protective effect and therefore was removed from the definition of driving inattention. *Non-specific eyeglance away from the forward roadway* was also shown to not be significantly different from normal, baseline driving; therefore, these events were also removed from the analysis.

ASSIGNMENT OF INVOLVEMENT LEVEL FOR DRIVERS

The first step to conduct the analyses for this research objective is to logically split the subjects into groups of involvement in inattention-related crashes and near-crashes. Figure 4.1 shows the distribution of all of the primary drivers and the frequency of involvement in inattention-related crashes and near-crashes for this study. The median and mean levels are marked on the figure. Note that there are 36 primary drivers who were not involved in any inattention-related crashes or near-crashes. The rest of the primary drivers were involved in 1 to 15 inattention-related crashes and/or near-crashes.

The mean frequency value was used to separate the drivers into two groups: those drivers who had "high involvement" in inattention-related crashes and near-crashes and those drivers who had "low involvement" in inattention-related crashes and near-crashes. Therefore, any driver who was involved in four or more inattention-related crashes and/or near-crashes was labeled as "high involvement" and drivers who were involved in fewer than four inattention-related crashes and/or near-crashes were labeled as having "low involvement." A separate secondary analysis where the drivers were separated into three levels of involvement will be discussed at the end of this chapter.

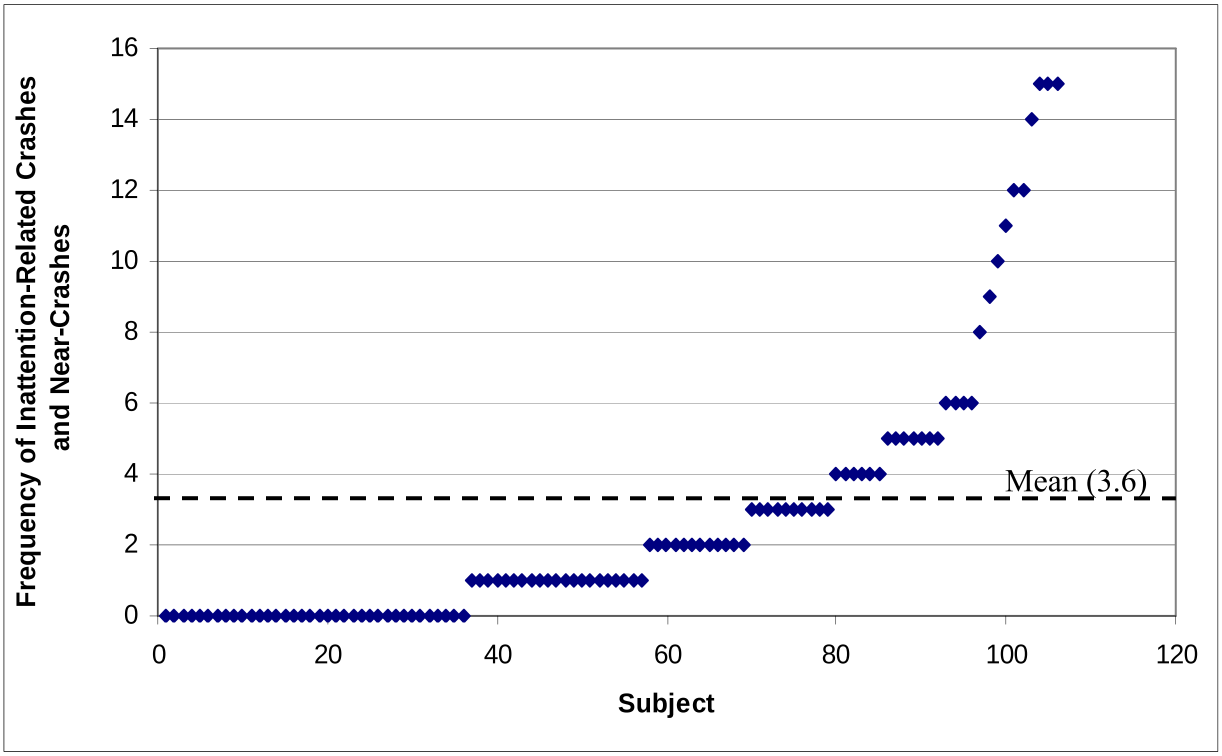

Figure 4.1. The frequency of inattention-related crashes and near-crashes by driver in order from low frequency to high frequency.

While it is apparent that there are several ways to define "high" and "low" levels of involvement in inattention-related crashes and near-crashes, using the mean as a dividing point has been used by many other researchers, and given the exploratory nature of these analyses, it provides a fairly conservative measure upon which to divide the drivers, yet still preserves any differences that may exist between those drivers who have tendencies to be involved in frequent inattention-related crashes and near-crashes and those who exhibit fewer tendencies. Table 4.2 provides the descriptive statistics for the drivers' respective group divisions.

This chapter will first present results using t-tests and correlations to describe any demographic or test battery score differences that exist between drivers with high and low involvement in inattention-related crashes and near-crashes. A separate analysis using analysis of variance and correlations will then be conducted to describe any demographic or test battery differences among high, moderate, and low involvement in inattention-related crashes and near-crashes. Given that these analyses are exploratory in nature, two analyses were conducted to provide a thorough investigation of the demographic and test battery scores for these drivers. Finally, a logistic regression analysis will be presented to assess the predictability of any of these demographic data or test battery scores. After these analyses, a discussion on the usefulness of these test batteries for mitigating distracted driving as well as suggestions for improving driver education programs will be presented.

Table 4.2. Descriptive statistics on drivers labeled "high involvement" and "low involvement" in inattention-related crashes and near-crashes.

Statistic	High Involvement	Low Involvement
Number of drivers	27	78
Mean (# of Inattention-Related Crashes and Near-crashes)	7.6	0.95
Median	6	1
Mode	5	0
Standard deviation	3.9	1.1
Minimum	4	0
Maximum number of events	15	3
Number of crashes	25	14
Number of near-crashes	179	61

ANALYSIS ONE: T-TEST ANALYSIS FOR THE "LOW AND HIGH INVOLVEMENT IN INATTENTION-RELATED CRASHES AND NEAR-CRASHES"

Demographic Data Analyses

The list of driver self-reported demographic data and survey data is shown in Table 4.3.

Table 4.3. Driver self-reported demographic data summary.

	Demographic/Survey Data	Information Presented
1.	Driver Demographic Information	Age Gender Years of driving experience
2.	Driving History	Number of traffic violations in past 5 years Number of accidents in past 5 years
3.	Health Assessment	Frequency of health conditions Frequency of type of health condition
4.	Sleep Hygiene	Daytime sleepiness scale Number of hours of sleep per night

Drivers reported their respective demographic data, driving history (e.g., number of citations received in the past 5 years), health status, and sleep hygiene using four separate surveys. T-tests were conducted to determine if any statistical differences existed between the inattentive and attentive drivers. A complete listing of all t-tests and ANOVA tables is in Appendix D.

Driver Age. Figure 4.2 shows the average age of the high- and low- involvement drivers. A t-test was conducted to determine whether there were significant differences in age between groups. The results suggest that the high-involvement drivers were significantly younger than the low-involvement drivers, t (102) = 7.07, p = 0.009.

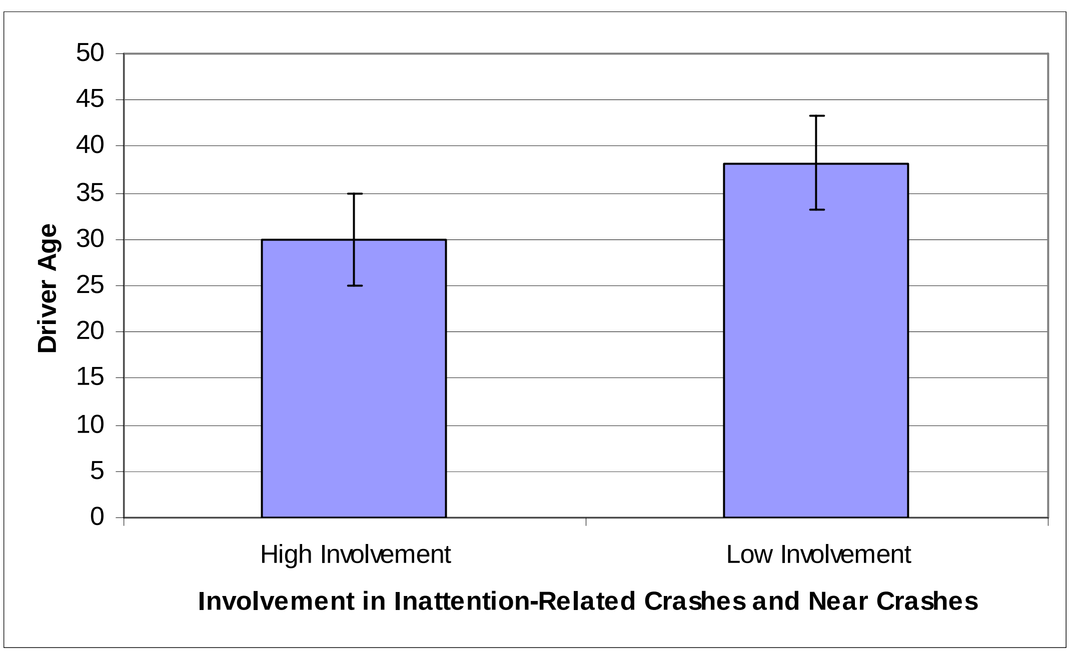

Figure 4.2. Average age of the high- and low-involvement drivers in inattention-related crashes and near-crashes.

To determine whether particular age groups were more likely to drive while inattentive, the drivers were split up into six age groups and the number of events for each group was calculated and plotted in Figure 4.3. Results from a chi-square statistical test indicated that the 18- to 20-year-old drivers had significantly more inattentive events than did any of the other age groups: χ (5) = 39.93, $p > 0.01$.

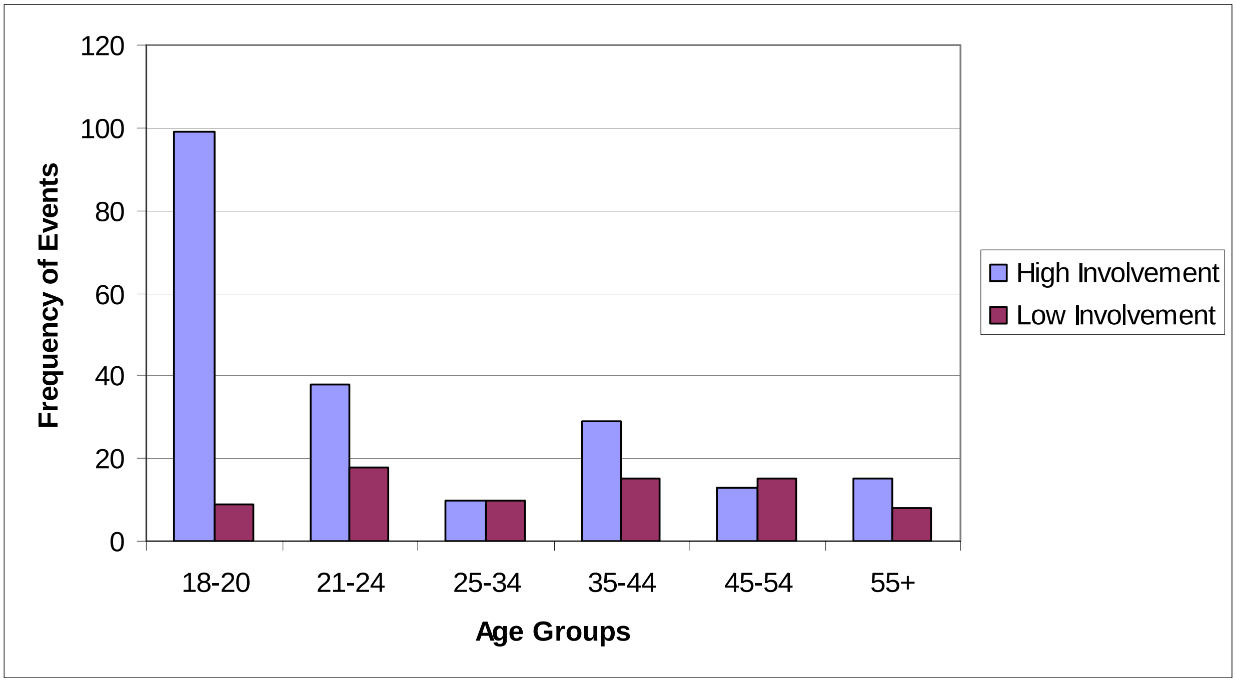

Figure 4.3. The frequency of inattention-related crashes and near-crashes for each age group by involvement group.

Gender. An analysis of the gender make-up of both the high- and low-involvement drivers was also conducted. Note that 60.6 percent of all primary drivers were male and 39.4 percent were female. The breakdown for high- and low-involvement drivers is shown in Figure 4.4. Males were involved in more crashes and near-crashes than were the female drivers. However, it appears that the female drivers were involved in a higher percentage of inattention events than were the male drivers. This suggests that when females are involved in crashes and near-crashes, they are more likely to be inattention-related. Males, on the other hand, have a higher rate of crash and near-crash involvement but a slightly lower likelihood of inattention serving as a contributing factor.

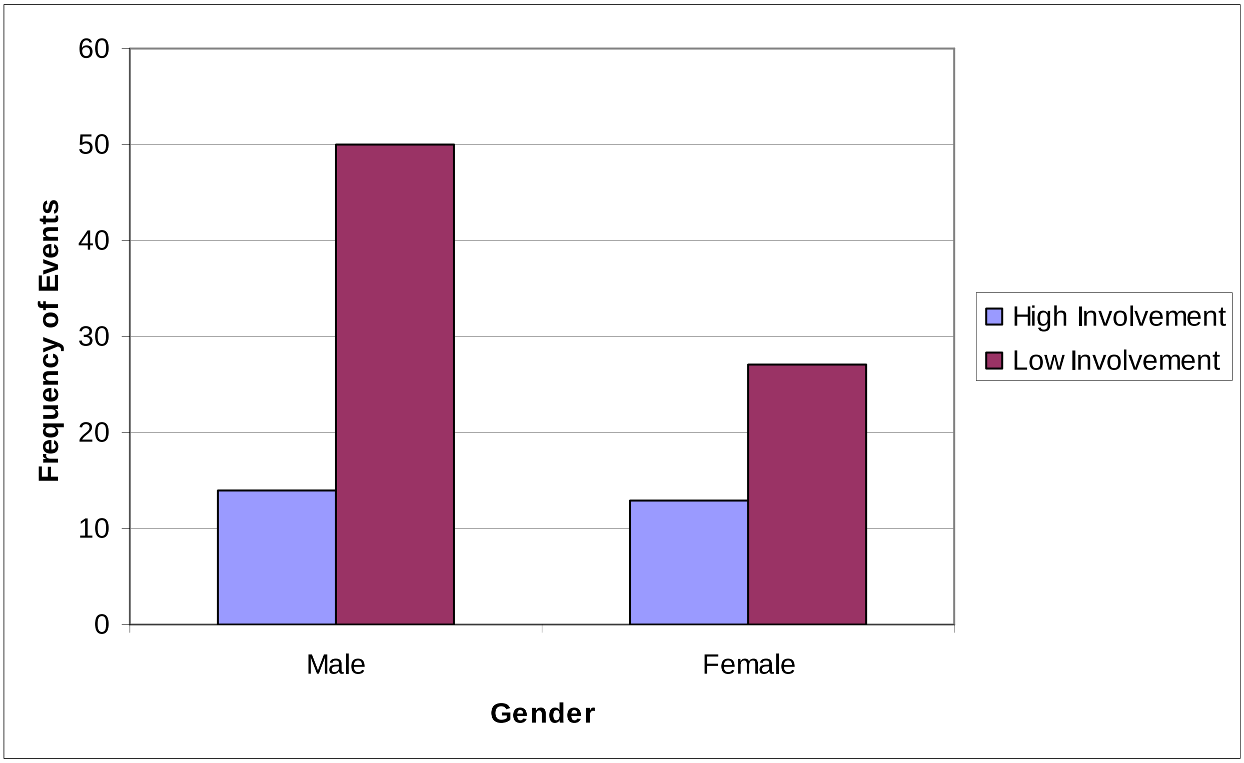

Figure 4.4. Gender breakdown of high-involvement drivers.

Years of Driving Experience. An analysis of the number of years of driving experience was also conducted. Figure 4.5 shows that high-involvement drivers had fewer years of driving experience than did the low-involvement drivers. Again, a t-test was conducted and the results suggest that the high-involvement drivers had significantly fewer years of experience than did the low-involvement drivers: t(99) 7.6, p = 0.007. Given that drivers in the United States generally receive their driver's licenses at age 16, this result is most likely correlated with age.

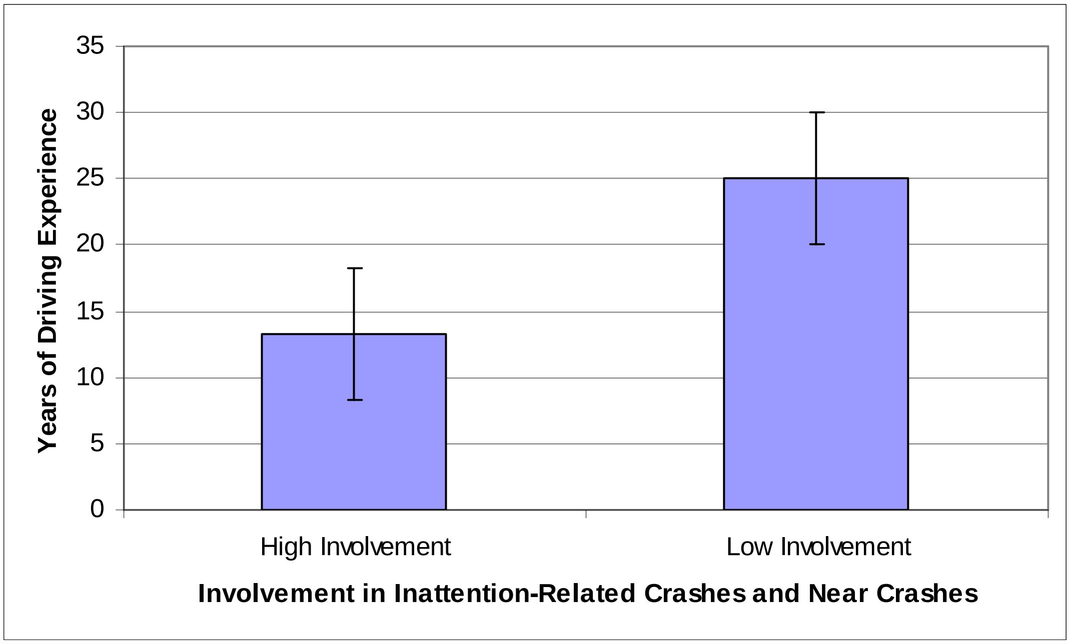

Figure 4.5. Average years of driving experience for drivers with high- and low-involvement in inattention-related crashes and near-crashes.

Drowsiness. Drivers were administered an abbreviated version of the Walter Reed Sleep Hygiene Questionnaire to assess their sleep habits. An abbreviated version was used to reduce the amount of time required of drivers during in-processing. There were 31 questions on this abbreviated questionnaire. This questionnaire was not designed to provide one composite score or rank driver drowsiness on several scales. Therefore, to explore the relevance of this questionnaire to inattention-related events, two of the questions have been identified as the most representative of the entire questionnaire. These two questions are:

1. Rank <on a scale of 1 to 10> the extent to which you currently experience daytime sleepiness?

2. How many hours do you sleep <per night>?

Daytime Sleepiness. The average scores that the high- and low-involvement drivers provided when rating their daytime sleepiness levels on a scale from 1 to 10 indicated that high-involvement drivers rated themselves slightly higher (i.e., more sleepy) than the low-involvement drivers (inattentive = 4.8, attentive drivers = 3.9). While this result was not significant, the t-value approached significance: $t(99) = 3.6$, $p = 0.06$.

Hours of Sleep**.** An analysis of the average number of hours of sleep experienced by high- and low-involvement drivers was also conducted. Both high- and low-involvement drivers' average hours of sleep reported were 7.0 hours, which was not significant. Given that no significant results were obtained for these two questions, no further analyses using this questionnaire were conducted.

Driving History

Number of Traffic Violations. All drivers were asked to report the number of traffic-violation citations that they had received during the 5 years prior to the start of the 100-Car Study. This self-reported value was analyzed by comparing the number of high-involvement driver violations to low-involvement driver violations. Figure 4.6 shows that high-involvement drivers had a higher average number of violations than did the low-involvement drivers. A t-test was conducted which resulted in a significant finding, $t(101)$ 4.9, $p = 0.03$.

Number of Collisions. All drivers were also asked to report the number of collisions that they had been involved during the 5 years prior to the start of the study. Figure 4.6 also shows that high-involvement drivers reported involvement in only slightly more collisions than the low-involvement drivers. This result was not significant at a 0.05 probability level.

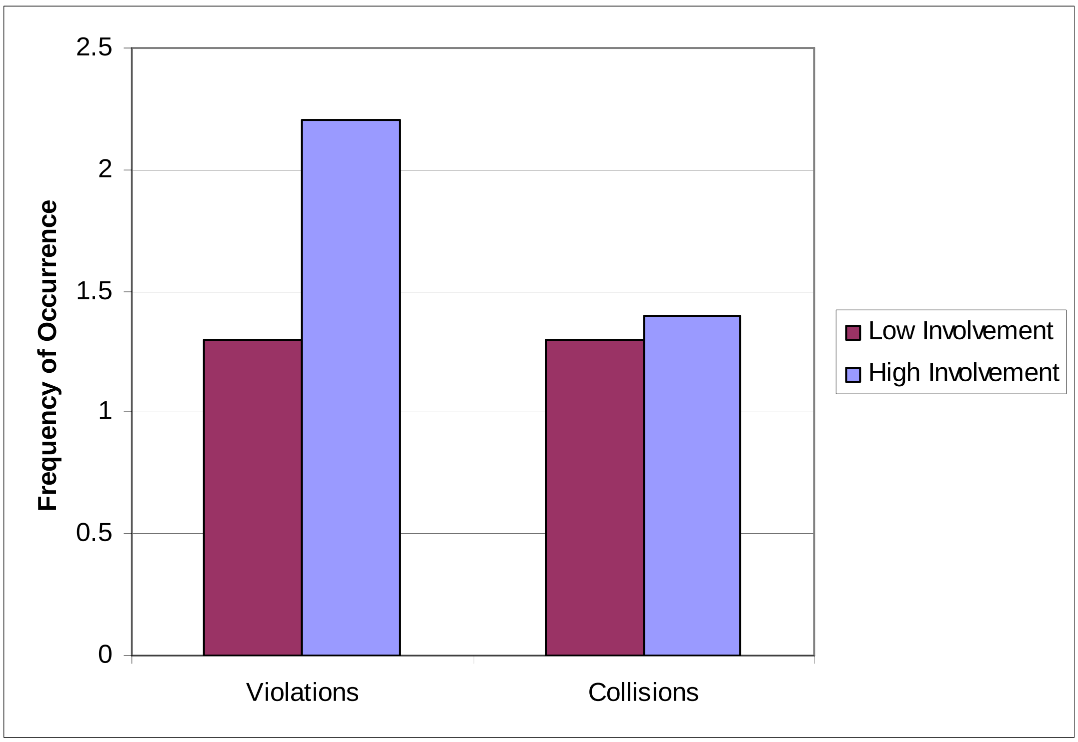

Figure 4.6. Self-reported involvement in traffic violations and collisions for 5 years prior to the onset of the 100-Car Study.

Test Battery Analyses

Table 4.4 provides a list of the test batteries that were administered to the drivers either prior to the onset of the study or at the completion of the study. Analyses of each of these test batteries will follow.

Table 4.4. Test battery names and scores.

Test Battery Name	Test Battery Score
Life Stress Inventory	• Life Stress Score
Driver Stress Inventory	• Aggression • Dislike of Driving • Hazard Monitoring • Thrill-Seeking • Drowsiness-Proneness
Dula Dangerous Driving Inventory	• DDDI Dangerous Driving Total Score • Negative Emotional Driving Subscore • Aggressive Driving Subscore • Risky Driving Subscore
NEO Five Factor Inventory	• Neuroticism • Extroversion • Openness to Experience • Agreeableness • Conscientiousness

Life Stress Inventory. The Life Stress Inventory was administered to the drivers after data collection as the entire questionnaire instructed the drivers to record life stressors experienced during the past 12 months, which corresponded to the duration of data collection. A composite score was then calculated based upon the type of stressors that each driver experienced and an overall life stress score ranged from 0 to 300. Unfortunately, only 65 primary drivers returned after data collection to complete this questionnaire.

T-tests were conducted to determine whether the overall Life Stress Inventory scores were significantly different between the high- and low-involvement drivers. No significant differences were observed as both groups scored in the low stress level category (high-involvement = 154.6 and low-involvement = 125.4). Other descriptive statistics of the Life Stress Inventory are provided in Table 4.5. Note that the highest Life Stress Score was for a low-involvement driver.

Table 4.5. Life Stress Inventory descriptive statistics.

Statistic	High Involvement	Low Involvement
N	15	50
Mean	154.6	125.4
Standard Deviation	104.1	113.0

Driver Stress Inventory. The Driver Stress Inventory was developed by Matthews, Desmond, Joyner, Carcary, and Gilliland (1996) to assess an individual driver's vulnerability to commonplace stress reactions while driving, such as frustration, anxiety, and boredom. The five driver stress factors that the Driver Stress Inventory assesses are (1) aggression, (2) dislike of driving, (3) hazard-monitoring, (4) thrill-seeking, and (5) fatigue proneness. Composite scores for each driver stress factor are provided. The Driver Stress Inventory was originally validated by correlating responses with driver's self-report of violations and collisions, other driver behavior scales (Driver Coping Questionnaire) and the NEO Five-Factor Inventory. The Driver Stress Inventory has been used widely in transportation research.

T-tests were conducted to see whether any significant differences occurred for the high- and low-involvement drivers for each of the five driving stress factor scores. None of the t-tests indicated significant differences between driver groups. One possibility for this result is that these drivers are all urban and may all be fairly uniform on scales such as hazard monitoring and aggressive driving; therefore, no differences existed in this population for these driver assessment scales. Descriptive statistics for each of the five driver stress factors is provided in Tables 4.6 through 4.10 below. These results suggest that the Driver Stress Inventory scores for any of the five driver stress factors show no association with the occurrence of inattention-related crashes and near-crashes.

Table 4.6. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the driver stress factor scale of *aggression*.

Statistic	High Involvement	Low Involvement
N	27	76
Mean	48.5	46.4
Standard Deviation	12.1	15.5

Table 4.7. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the driver stress factor scale of *dislike of driving*.

Statistic	High Involvement	Low Involvement
N	26	76
Mean	33.0	31.9
Standard Deviation	10.1	10.3

Table 4.8. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the driver stress factor scale of *hazard monitoring*.

Statistic	High Involvement	Low Involvement
N	27	76
Mean	64.9	68.9
Standard Deviation	11.2	11.8

Table 4.9. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the driver stress factor scale of *fatigue proneness*.

Statistic	High Involvement	Low Involvement
N	26	76
Mean	39.7	36.7
Standard Deviation	13.6	13.1

Table 4.10. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the driver stress factor scale of *thrill-seeking*.

Statistic	High Involvement	Low Involvement
N	27	75
Mean	28.5	25.1
Standard Deviation	16.6	16.3

Dula Dangerous Driving Inventory. The Dula Dangerous Driving Inventory provides a measure of a driver's likelihood to engage in dangerous behaviors. While the scale maintained strong internal reliability, it was validated using a driving simulator and not any actual driving on a test track or on actual roadways (Dula and Ballard, 2003). The current analysis is one of the first analyses of this inventory using driving data on real roadways and in real traffic conditions. There are four scales that the Dula Dangerous Driving Index measures, these are (1) Overall Dula Dangerous Driving Index, (2) Negative Emotional Driving Subscale, (3) Aggressive Driving Subscale, and (4) Risky Driving Subscale.

T-tests were conducted on each of the four scales to determine whether high-involvement drivers had a significantly different likelihood of engaging in dangerous behavior than did the low-involvement drivers. No significant differences on any of the four scales were observed. The descriptive statistics for each of the four scales are presented in Tables 4.11 through 4.14.

Table 4.11. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the Dula Dangerous Driving Scale for *Dula Dangerous Driving Index*.

Statistic	High Involvement	Low Involvement
N	27	77
Mean	54.04	51.61
Standard Deviation	10.46	11.42

Table 4.12. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the Dula Dangerous Driving Scale *Negative Emotional Driving Index*.

Statistic	High Involvement	Low Involvement
N	27	77
Mean	22.11	21.23
Standard Deviation	4.59	4.9

Table 4.13. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the Dula Dangerous Driving Scale *Aggressive Driving*.

Statistic	High Involvement	Low Involvement
N	27	77
Mean	11.89	11.51
Standard Deviation	4.15	3.78

Table 4.14. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near-crashes for the Dula Dangerous Driving Scale *Risky Driving.*

Statistic	High Involvement	Low Involvement
N	27	77
Mean	20.04	18.94
Standard Deviation	3.88	4.48

NEO Personality Inventory -- Revised. The NEO Five-Factor Inventory is a five-factor personality inventory that obtains individual's ranking on the following five scales: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness.

Extensive research has been conducted correlating the personality scales of neuroticism, extraversion, agreeableness, and conscientiousness to crash involvement (Arthur and Graziano, 1996; Fine, 1963; Loo, 1979; and Shaw and Sichel, 1971). While the hypothesis that drivers with certain personalities would more likely be involved in accidents seems reasonable, the results of this research are mixed. Some of the issues involved with these mixed results are that self-reported driving histories and driving behavior questionnaires have been correlated with personality scales but very little actual driving data has been used.

Neuroticism. The neuroticism scale is primarily a scale contrasting emotional stability with severe emotional maladjustment (depression, borderline hostility). High scorers may be at risk for some kinds of psychiatric problems (Costa and McCrae, 1992).

T-tests were conducted comparing the high- and low-involvement drivers. These results indicated that there were no significant differences with the low-involvement drivers obtaining mean scores of 26.7 and the high-involvement drivers obtaining a mean score of 20.6. The low-involvement drivers' average score of 26.7 places them in the "high" neuroticism category on a scale from Very High (67-75) to Very Low (25-34). The high-involvement drivers average score placed them in the category of "Average" which ranged in scores from 14 to 21.

Extraversion. The extraversion scale is a scale that measures not only sociability but also assertiveness, general optimism and cheerfulness. People who score lower on this scale are not pessimists but rather prefer solitude, are generally more subdued in expressing emotion and demonstrate higher levels of cynicism (Costa and McCrae, 1992).

T-tests conducted on the extraversion scale showed that low-involvement drivers rated significantly higher than did the high-involvement drivers, $t(103) = 7.03$, $p = 0.01$. Figure 4.7

shows the two groups scores with high-involvement drivers ranking as "Average" and the low-involvement drivers ranking "High."

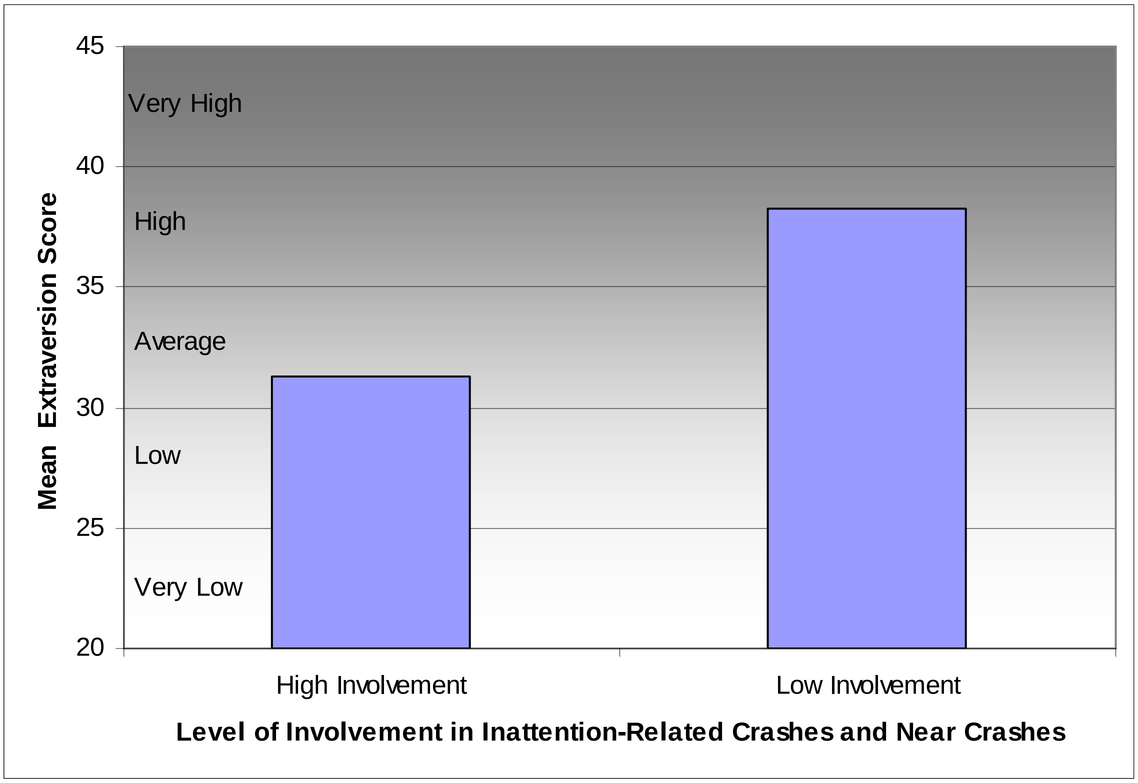

Figure 4.7. Personality scores for the extraversion scale demonstrating significant differences between drivers with high and low involvement in inattention-related crashes and near-crashes.

<u>Openness to Experience</u>**.** The openness to experience scale is a measure of one's willingness to explore, entertain novel ideas, and accept unconventional values. Those who score lower on this scale uphold more conventional values and are more conservative in action and beliefs. While some intelligence measures are correlated with scoring high on the "openness to experience" scale, this is not a measure of intelligence on its own (Costa and McCrae, 1992).

Results from a t-test on the Openness to Experience scale also revealed statistically significant differences between the high- and low-involvement drivers, $t(103) = 4.03$, $p = 0.05$. Figure 4.8 shows mean scores for both groups. These mean scores suggest that the high-involvement drivers scored in the "Average Openness to Experience Range" but that the low-involvement drivers scored in the high range.

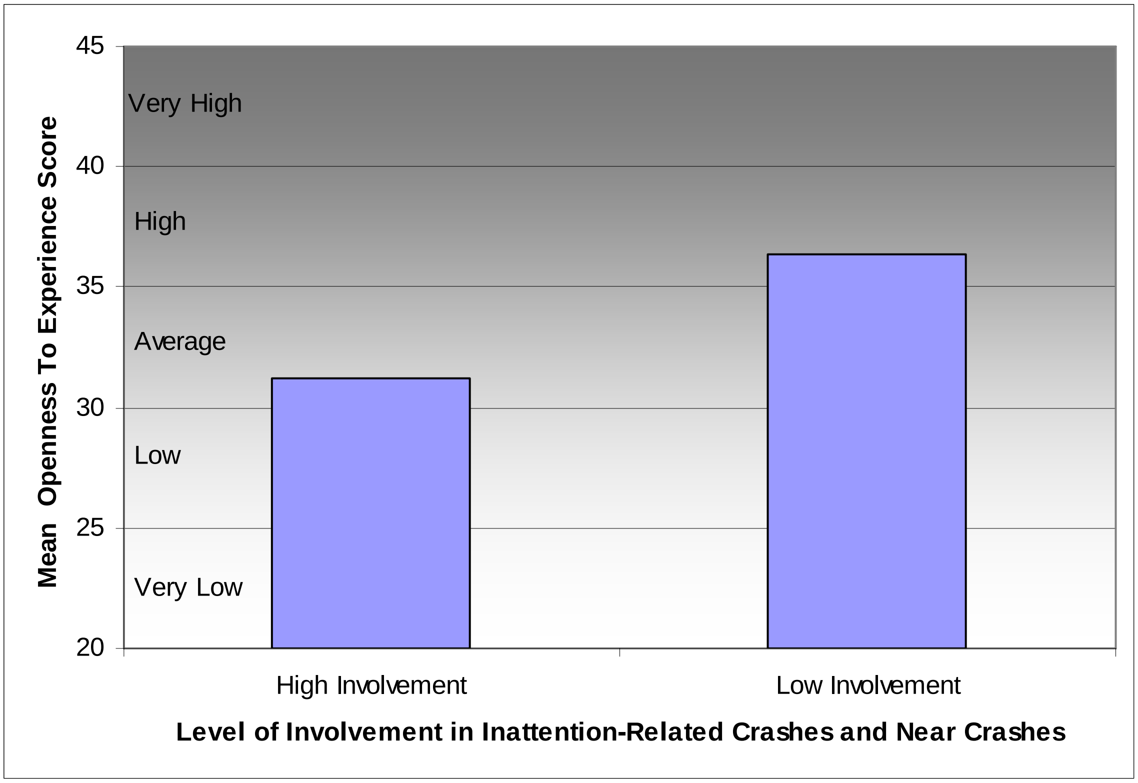

Figure 4.8. Personality scores for the openness to experience scale demonstrating significant differences between drivers with high and low involvement in inattention-related crashes and near-crashes.

Agreeableness. The agreeableness scale is a measure of altruistic and sympathetic tendencies versus egocentric and competitive tendencies. Those drivers who score higher on this scale may be more concerned about the drivers in their vicinity while those who score lower may view driving more as a competition (Costa and McCrae, 1992).

The mean scores on the agreeableness scale for both high- and low-involvement drivers indicated that the low-involvement drivers scored significantly higher on the agreeableness scale than did the high-involvement drivers, $t(102) = 8.26$, $p = 0.005$. High-involvement drivers scored solidly in the middle of the "Average" range while the low-involvement drivers scored near the top of the "High" range (Figure 4.9).

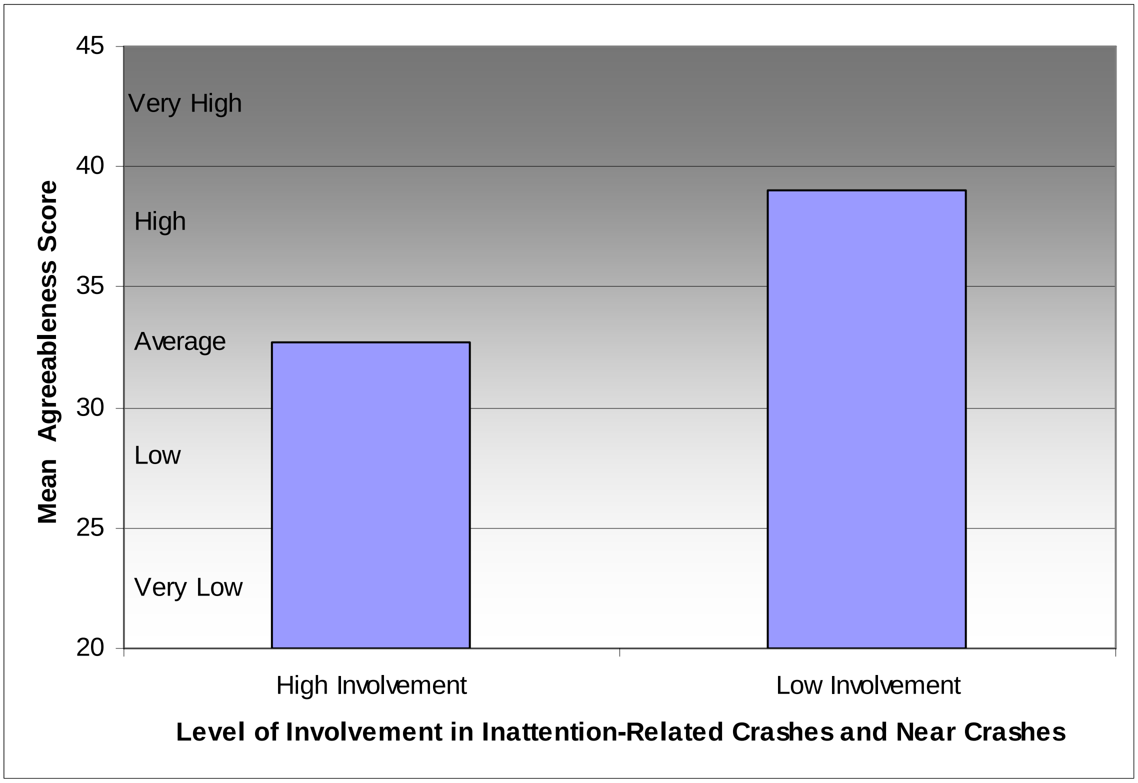

Figure 4.9. Personality scores for the agreeableness scale demonstrating significant differences between drivers with high and low involvement in inattention-related crashes and near-crashes.

Conscientiousness**.** The conscientiousness scale is not as much a measure of self-control but of individual differences in the tendencies and abilities to plan, organize, and perform tasks. Highly conscientious individuals are purposeful, strong-willed, and highly determined individuals who generally fall into categories of highly skilled musicians or athletes. Individuals who score lower on this scale are not as driven to achievement of goals and while they may possess goals, are less likely to maintain schedules and practices that will result in the achievement of these goals (Costa and McCrae, 1992).

The mean conscientiousness scores for both high- and low-involvement drivers also resulted in significant differences, $t(103) = 6.62$, $p = 0.01$. The mean score for the high-involvement group indicated that they scored near the top of "Average" and the low-involvement group scored in the middle of "High" (Figure 4.10).

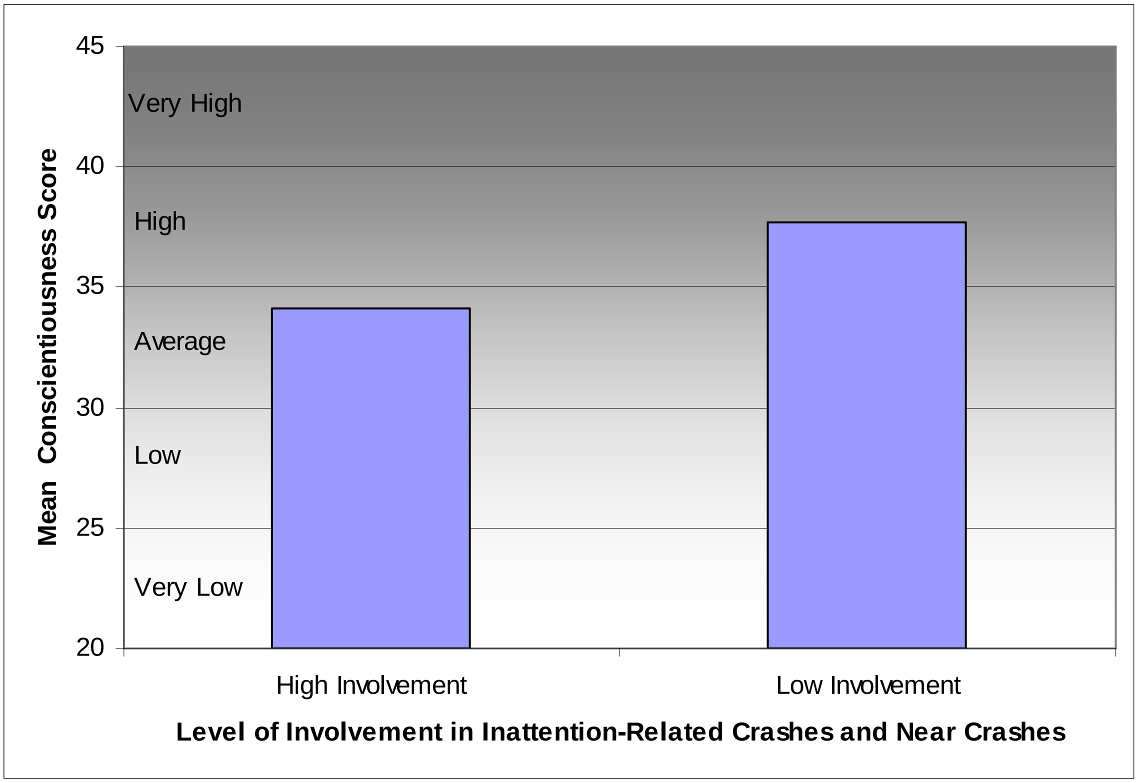

Figure 4.10. Personality scores for the conscientiousness scale demonstrating significant differences between drivers with high and low involvement in inattention-related crashes and near-crashes.

The results of the NEO Five-Factor Inventory suggest that some differences exist between the high- and low-involvement drivers. The low-involvement drivers scored in the "high" or "very high" levels of extroversion, openness to experience, agreeableness, and conscientiousness. The high-involvement drivers scored either "High" or "Average" on all of these scales indicating more moderate tendencies in each of these areas of personality.

Performance-based test analyses

<u>Waypoint.</u> The WayPoint computer-based test provides a composite score on four driver characteristics, as follows:

1. Channel capacity: Speed of information processing.
2. Preventable near-crash/crash risk: Ranks a driver on a scale of 1 to 4 from significantly lower than average (odds ratio of 0.4) to greatly above average (odds ratio of 6.2 or higher).
3. The expected number of moving violations in the next 5 years.
4. Expected seat belt use.

Previous testing by NHTSA indicated that this test could identify high-risk drivers 62.2 percent of the time with a false alarm rate of 19.9 percent; however, these results were based on older drivers. T-tests were conducted to determine whether the high-involvement drivers scored significantly different on any of these four scales than did the low-involvement drivers. None of the t-tests showed significant differences between the high- and low-involvement drivers. This is an interesting result given that drivers' self-reported moving violations were significantly different for these two groups. The descriptive statistics for each of these scales are presented in Tables 4.15 through 4.18.

Table 4.15. Descriptive statistics for the drivers with low and high involvement in inattention–related crashes and near-crashes for the *Channel Capacity Score*.

Statistic	High Involvement	Low Involvement
N	23	69
Mean	5.48	5.31
Standard Deviation	1.86	2.17

Table 4.16. Descriptive statistics for the drivers with low and high involvement in inattention–related crashes and near-crashes for the *Preventable Crash Risk*.

Statistic	High Involvement	Low Involvement
N	23	69
Mean	0.30	1.55
Standard Deviation	1.55	0.76

Table 4.17. Descriptive statistics for the drivers with low and high involvement in inattention–related crashes and near-crashes for the *Expected Number of Moving Violations*.

Statistic	High Involvement	Low Involvement
N	23	69
Mean	1.30	1.31
Standard Deviation	0.63	0.70

Table 4.18. Descriptive statistics for the drivers with low and high involvement in inattention–related crashes and near-crashes for the *Expected Seatbelt Use*.

Statistic	High Involvement	Low Involvement
N	23	67
Mean	1.10	1.15
Standard Deviation	029	0.36

Useful Field of View (UFOV). The Useful Field of View test is also a computer-based performance test that measures an individual's central visual processing speed, divided attention, and selective attention. The participant is required to select rapidly presented target objects that are flashed on a computer monitor while simultaneously attending to other stimuli. Using this test, near-crash/crash risks are assigned to each individual.

T-tests were conducted for the composite UFOV score to determine whether significant differences in the high- versus low-involvement drivers existed in their central visual processing speed, divided attention, and selective attention abilities. No significant differences between the high- and low-involvement drivers were observed for the UFOV test. Descriptive statistics are presented in Table 4.19.

Table 4.19. Descriptive statistics for the drivers with low and high involvement in inattention–related crashes and near-crashes for the UFOV.

Statistic	High Involvement	Low Involvement
N	27	81
Mean	1.78	2.32
Standard Deviation	1.80	2.15

ANALYSIS ONE: CORRELATION ANALYSIS FOR THE HIGH- AND LOW-INVOLVEMENT GROUPS

Spearman correlations were conducted to determine whether there were any linear relationships between the frequency of involvement in inattention-related events and survey responses/test scores for both the high- and low-involvement groups. Table 4.20 presents only those test scores/survey responses that were significant.

Note that none of the low-involvement group's correlations were significant with only accident involvement approaching significance at a 0.06 probability level. The rest of the significant correlation coefficients were for the high-involvement group. Those scores or responses that demonstrated a linear relationship with inattention-related crash and near-crash involvement were Driver Age, Driving Experience, and Neuroticism Scale. Driver age has been found in the past to be highly inversely related to crash involvement. Given that most of the drivers probably received their driver's license in the United States at approximately age 16, these two responses are probably highly correlated with each other. The neuroticism scale has been found in previous research to correspond to drivers self-reported crash involvement; this is an interesting finding in that this demonstrates high correlation to actual crash and near-crash involvement.

Table 4.20. Correlation coefficients and probability values for the test batteries that obtained statistical significance.

	Attentive		Inattentive	
Test Score/Survey Response	Correlation Coefficient	Probability Value	Correlation Coefficient	Probability Value
Driver Age	-0.13	0.24	**-0.37**	**0.05**
Driver History	-0.14	0.24	**-0.49**	**0.01**
Accidents	0.21	0.06	0.18	0.36
Neuroticism	0.07	0.52	**0.45**	**0.02**

Note: Numbers in bold font indicate statistical significant using a 0.05 probability value.

ANALYSIS TWO: F-TEST ANALYSIS FOR THE LOW-, MODERATE-, AND HIGH-INVOLVEMENT GROUPS

As part of the exploratory nature of these analyses, a second analysis using three groups was also conducted. With three groups, some separation between the two tails of the distribution is present so that any differences in those drivers who are the most and least involved in inattention-related crashes and near-crashes may be more easily distinguished. The drivers were grouped into three levels of involvement in inattention-related crashes and near-crashes: low, moderate, and high involvement. These groups were based upon the number of inattention-related crashes and near-crashes that each driver was involved (Figure 4.11). "Low involvement" refers to those drivers who were not involved in any or were involved in one inattention-related crash and/or near-crash. The "moderate involvement" group was involved in two to four inattention-related crashes or near-crashes. The "high involvement" group was involved in five or more inattention-related crashes or near-crashes. Therefore, "high involvement" refers to those drivers with high numbers of inattention-related crashes and/or near-crashes and "low involvement" refers to those drivers with none or only one inattention-related crash and/or near-crash.

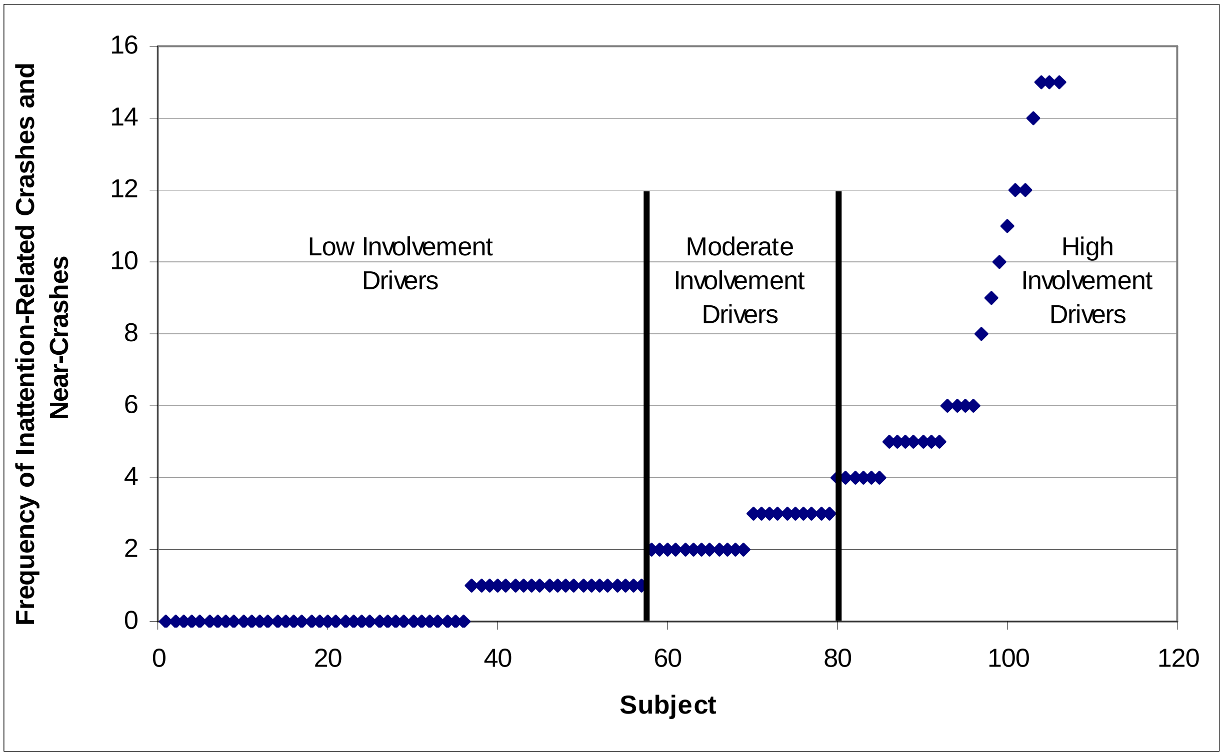

Figure 4.11. The frequency of inattention-related crashes and near-crashes by driver in order for Low, Moderate, and High frequency.

Univariate analyses of variance (ANOVA) tests were conducted using the three levels of inattention-related event involvement. All survey responses and test scores that were appropriate were used as dependent variables. Only those ANOVA tests that were significant will be reported in the following section. Table 4.21 provides the descriptive statistics for the drivers assigned to low-, medium-, and high-involvement groups.

Table 4.21. Descriptive statistics on drivers labeled "low involvement," "moderate involvement," and "high involvement" in inattention-related crashes and near-crashes.

Statistic	Low Involvement	Moderate Involvement	High Involvement
Number of Drivers	58	24	20
Mean (# of Inattention-Related Crashes and Near-crashes)	0.42	2.84	8.57
Median	0	3	6
Mode	0	3	5
Standard Deviation	0.56	0.78	3.88
Minimum	0	2	5
Maximum number of events	2	4	15
Number of crashes	8	9	4
Number of near-crashes	51	18	17

Results

The results of the univariate ANOVA tests using three involvement groups indicated that five of the test scores that were significantly different for the two-group analysis also proved to be significantly different for the three-group analysis. These five test scores/demographic data were mean driver age, years of driving experience, self-reported traffic violations, agreeableness, and conscientiousness. Two other test scores were found to be significantly different using three groups that were not significantly different using two groups: these two test scores were daytime sleepiness score and self-reported accident involvement. The three-group scores on extraversion and openness to experience were not significantly different even though these tests were significantly different with only two groups.

These results indicate that the extremely low- and extremely high-involvement groups were significantly different from each other for daytime sleepiness scores. For self-reported accident involvement, the two extreme groups were actually not significantly different from each other rather the moderate-involvement group actually reported significantly more accidents than did the high-involvement or the low-involvement groups. It could be hypothesized that this was an artifact of age in that the high-involvement drivers were, on average, 25 years old whereas the low- and moderate-involvement driver groups had an average age of 39 and 38, respectively.

Separating the drivers into three groups failed to find significant differences for the two personality inventory scales of extraversion and openness to experience. This result may be explained statistically in that by separating the drivers into three groups reduces the statistical power of the sample due to the decreased numbers of drivers in each group.

Most of the statistical tests that were significant with only two groups were also significant with three groups. All univariate analysis results are presented in Table 4.22. Given the exploratory nature of these analyses, conducting two analyses (a two-group and a three-group) was an important step in understanding these data. Both analyses have benefits. The two-group analysis, with a larger number of drivers per group, has better statistical power whereas the three-group analysis provides more separation between the extreme drivers. The significant results demonstrated that very few differences existed between the two- and three-group analyses; therefore, the results that were observed are stable and reliable for the driving population.

Table 4.22. Results from the univariate analyses of driver involvement in inattention-related crashes and near-crashes.

Two-Group Analysis of Mean Demographic Data/Test Score	t-Value	Probability Value	Three-Group Analysis of Mean Demographic Data /Test Score	F-Value	Probability Value
Driver Age	7.07	0.009	Driver Age	6.77	0.002
Years of Driving Experience	7.6	0.007	Years of Driving Experience	7.69	0.0008
N/A			Daytime Sleepiness Score	3.80	0.03
Self-reported traffic violations	4.9	0.03	Self-reported traffic violations	5.54	0.005
N/A			Self-reported accident involvement	4.88	0.009
Extroversion (Five-Factor Personality Inventory)	7.03	0.01	N/A		
Openness to Experience (Five-Factor Personality Inventory)	4.03	0.05	N/A		
Agreeableness (Five-Factor Personality Inventory)	8.26	0.005	Agreeableness (Five-Factor Personality Inventory)	3.77	0.03
Conscientiousness (Five-Factor Personality Inventory)	6.62	0.01	Conscientiousness (Five-Factor Personality Inventory)	3.05	0.05

ANALYSIS TWO: CORRELATION ANALYSIS FOR THOSE DRIVERS WITH LOW, MODERATE, AND HIGH INVOLVMENT IN INATTENTION-RELATED CRASHES AND NEAR-CRASHES.

Correlations were also conducted for each group of involvement. Correlations were performed using the frequency of involvement in inattention-related crashes and near-crashes versus driver survey responses or test battery scores. The significant results are shown in Table 4.23. Several more tests obtained or approached significant results with three groups. The Dula Dangerous Driving: Aggressive Driving Index, the Dula Dangerous Driving Overall Index, Neuroticism, Agreeableness, and Conscientiousness all demonstrated significant correlations for the high-involvement group only. The neuroticism scale also obtained significance for the moderate-involvement group. The Driving Stress Inventory: Thrill-Seeking Scale reached significance for the low-involvement group but no other group.

These results demonstrate that separating the mean values for the high- and low-involvement drivers are more easily differentiable with three groups then with only two groups as seven of the test scores/survey responses demonstrated significant correlation coefficients whereas only four test scores demonstrated significant correlation coefficients with two groups. Many of these correlation coefficients are over 0.4 or above, which are considered to be moderate correlations (Keppel and Wickens, 2004).

Table 4.23. Correlation coefficients for all test battery questionnaires.

	Low Involvement		**Moderate Involvement**		**High Involvement**	
Test Score/Survey Response	**Corr Coef**	**Prob Value**	**Corr Coef**	**Prob Value**	**Corr Coef**	**Prob Value**
Aggressive Driving – Dula Dangerous Driving	0.04	0.75	-0.13	0.52	**0.48**	**0.02**
Dula Dangerous Driving Index	0.13	0.34	-0.21	0.29	**0.46**	**0.03**
Thrill-Seeking	**0.26**	**0.5**	-0.03	0.89	-0.23	0.32
Neuroticism	0.01	0.94	**-0.40**	**0.04**	**0.62**	**0.003**
Agreeableness	-0.01	0.92	**-0.25**	**0.20**	**-0.42**	**0.06**
Conscientious-ness	-0.15	0.27	-0.9	0.63	**-0.42**	**0.06**

Note: Numbers in bold font indicate statistical significant using a 0.05 probability value

ANALYSIS THREE. ARE DRIVERS' RESPONSES TO THE DEMOGRAPHIC, TEST BATTERY, AND PERFORMANCE-BASED TESTS PREDICTIVE OF INVOLVEMENT IN INATTENTION-RELATED CRASHES AND NEAR-CRASHES?

A logistic regression was conducted to determine whether multiple data sources, all obtained from demographic data, test battery results, and performance-based tests, could be used to predict whether a driver was either highly involved in inattention-related crashes and near-crashes or not. Only the seven variables that demonstrated significant differences in involvement level for the above tested t-tests or ANOVAs were used in the analysis. These variables were:

1. Driver Age
2. Driving Experience
3. Number of moving violations in the past 5 years
4. Extraversion score from the NEO Five-Factor Inventory

5. Openness to Experience from the NEO Five-Factor Inventory
6. Agreeableness from the NEO Five-Factor Inventory
7. Conscientiousness from the NEO Five-Factor Inventory

None of the correlation coefficients for any of the above variables or test battery results was greater than ±0.4, which is considered to be a small to moderate effect size in the behavioral sciences. Nevertheless, these variables were used in the logistic regression analysis.

A backward selection technique was used to first identify those variables that make significant partial contributions to predicting whether a driver involvement was low or high. This procedure produced a logistic regression equation with two variables: Driver Age and Agreeableness. The resulting significant regression coefficients and relevant statistics are shown in Table 4.24.

Table 4.24. Results from the logistic regression analysis.

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Probability
Intercept	1	2.61	1.10	5.67	0.02
Driver Age	1	-0.04	0.02	4.77	0.03
Agreeableness	1	-0.06	0.03	5.35	0.02

A forward selection technique was then used to ensure that both of these variables were making significant partial contributions to the prediction equation. The results of this test resulted in the same regression equation, indicating that both Driver Age and Agreeableness are both predictive of a driver's level of involvement in inattention-related crashes and near-crashes.

The correlation coefficients for both Driver Age and Agreeableness were both negative, indicating that as Age or Agreeableness increases, involvement in inattention-related crashes and/or near-crashes will decrease. The odds ratio estimates, as calculated as part of the logistic regression, for Driver Age was 0.96 (Lower Confidence Limit = 0.92 and Upper Confidence Limit = 1.0), which was not significantly different from 1.0. The odds ratio estimate for Agreeableness was similar at 0.94 (Lower Confidence Limit = 0.89 and Upper Confidence Limit = 0.99). These results indicate a slight protective effect in that as an Age or Agreeableness score increases, there will be a decrease in involvement in inattention-related crashes and near-crashes.

DISCUSSION. HOW MIGHT THESE RESULTS BE USED TO MITIGATE THE POTENTIAL NEGATIVE CONSEQUENCES OF INATTENTIVE DRIVING BEHAVIORS AND COULD THIS INFORMATION BE USED TO IMPROVE DRIVER EDUCATION COURSES OR TRAFFIC SCHOOLS?

As part of this analysis, the health screening, questionnaires, and driving performance-based tests were all analyzed to determine if the scores obtained on any of these measures correlated or could determine differences in high- or low-involvement in inattention-related crashes and near-crashes. There were seven variables that produced significant t-tests: Driver Age, Driving Experience, number of moving violations in the past 5 years, and four of the personality scales from the NEO Five-Factor Inventory: Extroversion, Openness to Experience, Agreeableness, and Conscientiousness. When three groups were used, Daytime Sleepiness Rating and Accident Involvement also identified significant differences between groups. For the correlation analysis, several test batteries were significant with three groups that were not significant when using two groups of drivers. A logistic regression was conducted to determine if any of these seven variables were predictive of driver inattention. The results of this analysis indicate that Driver Age and Agreeableness both demonstrated some predictive nature to driver involvement in inattention-related crashes and near-crashes.

The results of the logistic regression indicate that none of the demographic data or test scores, except for Driver Age and the Agreeableness score from the NEO Five-Factor Inventory, demonstrate predictive abilities to pre-determine which drivers may be at greater risk of inattention-related crashes and near-crashes. Predictive qualities aside, obtaining significant differences and significant correlations using highly variable human performance data demonstrates that many of these surveys and test batteries do provide useful information about the driving population.

The significant results of Driver Age, for both the logistic regression and the t-tests, indicate that drivers' education of the dangers of distraction and drowsiness while driving is critical. Note that the younger drivers were over-represented in inattention-related crash and near-crash involvement (Figure 4.2). The significant results in Driving Experience are not surprising as this variable is highly correlated with Driver Age.

The significant t-tests and ANOVAs detecting that the high-involvement drivers were significantly younger than the other groups suggests that younger drivers are over-involved in inattention-related crashes and near-crashes. These results lend some support to those states who have already implemented graduated driver's licensure programs to restrict specific types of driver distraction. The results from this analysis also lend support to those studies that have already shown that these actions may in fact reduce younger drivers' involvement in crashes and near-crashes (Hedlund and Compton, 2005). As part of graduated licensure programs, some states have restricted the number of passengers in the vehicle and other states have banned hand-held-device use for teenage drivers. Conducting a naturalistic driving study with teen drivers would be the next research step to determine frequency of engagement in inattention-related tasks and the impact of inattention on driving.

It is very interesting that the self-reported variable, *number of traffic violations received in the past 5 years*, indicated that high-involvement drivers also had a higher frequency of traffic violations than the low-involvement drivers. This result suggests that those drivers who are attending traffic schools due to multiple traffic violations may indeed be those drivers who are more highly involved in inattention-related crashes and near-crashes. This also suggests that driver inattention is a topic that needs to be addressed in traffic school training. Based on results from other chapters in this report, one item of training may be to assist drivers in their decisions of when to engage in a secondary task, for example. Near-crash/crash risks are much higher in intersections, wet, snowy, or icy roadways, and in moderate traffic density that is moving faster than 25 miles per hour, etc. These are not times in which to engage in a secondary task if it is not necessary that a driver do so. Results from other chapters in this report suggest that eyeglances greater than 2 seconds away from the forward roadway increase near-crash/crash risk. Teaching drivers how to scan the roadway environment but returning to the forward roadway at least once every 2 seconds may also be useful information to incorporate into traffic school and driver's education programs. More research is required to determine how to best present this information and how to optimally incorporate this information into a driver training program.

SUMMARY

The results of this analysis indicated that Driver Age, Driving Experience, self-reported traffic violations and crashes, daytime sleepiness ratings, and personality inventory scores indicated significant differences between the high- and low-involvement drivers for both two and three groups of involvement in inattention-related crashes and near-crashes. Given the exploratory nature of these analyses, two separate analyses were conducted using two groups of involvement and three groups of involvement.

The main results from these analyses are as follows:

- The high-involvement drivers were significantly younger than the low-involvement drivers with average ages of 30 and 38, respectively. With three groups of drivers, the average ages for the three groups were still significant and the average ages of the groups were 39 (low involvement), 38 (moderate involvement), and 26 (high involvement) years old.
- The high-involvement drivers had significantly less driving experience than the low-involvement drivers with an average of 13 versus 25 years for the two groups. For the three-group analysis, the high-involvement group's average years of driving experience was 9.6 years while the moderate- and low-involvement group's averages were 22 and 23 years, respectively.
- High-involvement drivers (Mean = 2.2) reported receiving significantly more moving violations in the past 5 years than the low-involvement drivers (Mean = 1.4). For the three-group analysis, the high-involvement drivers had received an average of 2.6 violations, while the moderate-involvement and the low-involvement groups received an average of 1.8 and 1 violation(s), respectively.
- An interesting result occurred with the number of accidents in the past 5 years. When the drivers were separated into three groups, the average number of reported accidents was significantly different between the low-involvement and the moderate-involvement groups. The low-involvement group reported an average of 0.9 accidents in the past 5 years while the moderate-involvement group reported 1.9 crashes in the past 5 years. The high-involvement group only reported being involved in 1.4 accidents in the past 5 years. It may be that the high-involvement drivers were not truthful with their responses or were trying to impress the researchers.
- High-involvement drivers scored significantly lower on the personality factors of extraversion, openness to experience, agreeableness, and conscientiousness. The same was found when the drivers were separated into three groups, except that the extraversion and the openness to experiences scores were no longer significant. These results partially corroborate Arthur and Graziano (1996) results, in that conscientiousness scores were significantly different between the high-involvement and low-involvement groups; however their results did not include agreeableness, which was found in these analyses to be predictive of inattention-related crash and near-crash involvement.
- For the correlation analysis, only one scale maintained a significant correlation between the two analyses: the Neuroticism Scale from the NEO Five-Factor Inventory. Driver Age or Driving Experience yielded significant correlations when the drivers were separated into two groups, but not for three groups. While many of the significant

correlation coefficients were greater than 0.4 with three groups, these linear relationships do not appear to be stable.

- The only questionnaire data or test battery scores that were predictive of driver involvement in inattention-related crashes and near-crashes were driver age and scores on the agreeableness scale from the NEO Five-Factor Personality Inventory. Interestingly, agreeableness scores for the high- and low-involvement drivers (both two and three groups) were also found to be significantly different from one another.
- No differences were found between the high- and low-involvement drivers using the Driver Stress Inventory, Life Stress Inventory, the Dula Dangerous Driving Index, Waypoint, or the Useful Field of View. While none of these tests were written specifically to assess driver's likelihood of being involved in inattention-related crashes and near-crashes, it was hypothesized that these tests may measure some of the same traits that would increase a driver's willingness to engage in inattention-related tasks while driving.

CHAPTER 5: *OBJECTIVE 4,* WHAT IS THE RELATIONSHIP BETWEEN MEASURES OBTAINED FROM PRE-TEST BATTERIES (E.G., A LIFE STRESS TEST) AND THE FREQUENCY OF ENGAGEMENT IN DISTRACTING BEHAVIORS WHILE DRIVING? DOES THERE APPEAR TO BE ANY CORRELATION BETWEEN WILLINGNESS TO ENGAGE IN DISTRACTING BEHAVIORS AND MEASURES OBTAINED FROM PRE-TEST BATTERIES?

For this analysis, correlations were conducted using the frequency of involvement in *inattention-related baseline epochs* and each driver's composite score or relevant response for 9 of the 11 questionnaires and performance-based tests that were administered to the drivers (Table 5.1). A baseline epoch was deemed to be "inattention-related" if the driver engaged in a secondary task or was marked as drowsy at any point during the 6-second segment. The debrief form and the health assessment questionnaires were not included as they were not designed for this type of analysis.

Table 5.1. Description of questionnaire and computer-based tests used for 100-Car Study.

	Name of Testing Procedure	Type of Test	Time test was administered	Brief description
1.	Driver demographic information	Paper/pencil	In-processing	General information on drivers age, gender, etc.
2.	Driving History	Paper/pencil	In-processing	General information on recent traffic violations and recent collisions
3.	Health assessment questionnaire	Paper/pencil	In-processing	List of variety of illnesses/medical conditions/or any prescriptions that may affect driving performance.
4.	Dula Dangerous Driving Index	Paper/pencil	In-processing	One score that describes driver's tendencies toward aggressive driving.
5.	Sleep Hygiene	Paper/pencil	In-processing	List of questions that provide information about driver's general sleep habits/substance use/sleep disorders
6.	Driver Stress Inventory	Paper/Pencil	In-processing	One score that describes the perceived stress levels drivers experience during their daily commutes
7.	Life Stress Inventory	Paper/pencil	In-processing/Out-processing	One score that describes drivers stress levels based upon the occurrence of major life events
8.	Useful Field-of-View	Computer-based test	In-processing	Assessment of driver's central vision and processing speed, divided and selective attention.
9.	WayPoint	Computer-based test	In-processing	Assessment of the speed of information processing and vigilance.
10.	NEO-FFI	Paper/pencil	In-processing	Personality test
11.	General debrief questionnaire	Paper/pencil	Out-processing	List of questions ranging from seatbelt use, driving under the influence, and administration of experiment.

DATA USED IN THIS ANALYSIS

For the analyses in this chapter, crashes and near-crashes only will be used (incidents will be excluded from the analyses). In Chapter 6, *Objective 2* of the 100-Car Study Final Report, the analyses indicated that the kinematic signatures of both crashes and near-crashes were nearly identical; whereas the kinematic signatures of incidents were more variable. Given this result and to increase statistical power, the data from both crashes and near-crashes will be used in the comparison of questionnaire data to the frequency of involvement in inattention-related crashes and near-crashes.

Note that inattention-related crashes and near-crashes or inattention-related baseline epochs are defined as those events that involve the driver engaging in complex, moderate, or simple secondary tasks or driving while drowsy. Please note that in Chapter 2, *driving-related* *inattention to the forward roadway* was determined to possess a protective effect and therefore was removed from the definition of driving inattention. *Non-specific eyeglance away from the forward roadway* was also shown to not be significantly different from normal, baseline driving; therefore, these events were also removed from the analysis.

DESCRIPTION OF DATA

Figure 5.1 shows the distribution of the number of inattention-related baseline epochs that each driver was involved. Note that seven primary drivers were not involved in any inattention-related baseline epochs. The mean frequency of inattention-related baseline involvement is 87.2, the median frequency is 62, and the range of frequency counts is 0 to 322 baseline inattention epochs.

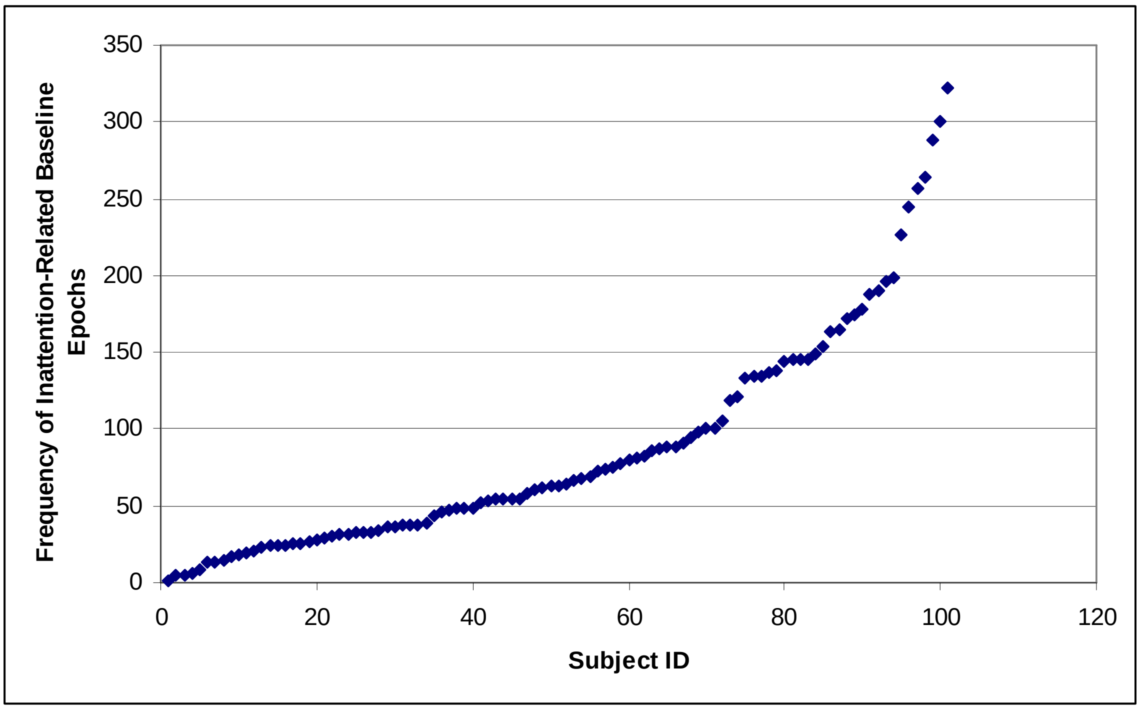

Figure 5.1. The frequency distribution of the number of inattention-related baseline epochs that each driver was involved (N = 101). Note: Subjects were sorted by frequency of involvement to allow the reader to see the range of values.

A Spearman correlation between the frequency of involvement in inattention-related crash and near-crash events and baseline epochs was performed. The results indicated a strong correlation with an R-value of 0.72, $p = 0.0001$. This suggests that drivers who are frequently engaging in inattention-related tasks, as shown by the baseline data, are also those that are more frequently involved in crashes and near-crashes. This also suggests that the better, safer drivers engage in secondary tasks and/or drive drowsy less often than do those drivers who were involved in multiple crashes and near-crashes.

Correlations were conducted using representative survey questions, composite scores from the test batteries, and scores from the computer-based tests and frequency of involvement in *inattention-related baseline epochs.* Table 5.2 presents the corresponding correlation coefficients and probability values for those test scores that were statistically significant. Note that *Driver Age* and *Driving Experience* obtained the highest correlation coefficient at -0.4 while the rest of the coefficients were very weak with R values under 0.3.

Table 5.2. The significant correlations between test battery, survey, and performance-based test scores to the frequency of inattention-related baseline epochs (N = 101).

Name of Testing Procedure	Question/Score	Correlation Coefficient	Probability Value
Driver demographic information	Driver Age	-0.41	<0.0001
	Years of driving experience	-0.44	<0.0001
Dula Dangerous Driving Index	DDDI	0.29	0.004
	Risky Driving	0.26	0.01
Sleep Hygiene	Daytime Sleepiness	0.22	0.03
Driver Stress Inventory	Aggression	0.23	0.02
	Thrill-Seeking	0.26	0.01
NEO-FFI	Extroversion	-0.21	0.03
	Agreeableness	-0.27	0.007
	Conscientiousness	-0.22	0.03
Waypoint	Channel	0.34	0.0014

Correlations were also conducted using the frequency of driver involvement in inattention-related crashes and near-crashes to the relevant responses from the surveys, test batteries, and performance-based tests. This analysis is different from the one conducted in Chapter 4, *Objective 3* in that the drivers are no longer separated into "high involvement" and "low involvement" drivers. Table 5.3 presents only those correlations that were statistically significant. Note that some of the correlations no longer were significant, i.e., Dula Dangerous Driving, Driver Stress Inventory, and Waypoint. Also note that some of the correlations, while still significant, were slightly weaker for the crashes and near-crashes, i.e., Driver Age and Driving Experience.

Table 5.3. The significant correlations between test battery, survey, and performance-based test scores to the frequency of inattention-related crash and near-crash events (N = 101).

Name of Testing Procedure	Question/Score	Correlation Coefficient	Probability Value
Driver Demographic Information	Driver Age	-0.29	<0.004
	Years of driving experience	-0.31	<0.001
Sleep Hygiene	Daytime Sleepiness	0.20	0.05
NEO-FFI	Extroversion	-0.23	0.02
	Agreeableness	-0.26	0.007
	Conscientiousness	-0.20	0.03

CONCLUSIONS

These results suggest a clear relationship between engagement in secondary tasks or driving while drowsy to selected survey responses and test battery scores. According to Keppel and Wickens (2004), correlation coefficients of 0.4 to 0.2 represent small effect sizes as they account for 4 to 16 percent of the variance among these values. While these relationships or associations are small, the fact that these relationships are obtaining statistical significance given the high variability among drivers is a result that should not be overlooked. These results, taken with the results from Chapter 4, *Objective 3* indicate that driver demographic data, driving history data, sleep hygiene data and the NEO Five-Factor Inventory all demonstrate linear relationships to driving performance. Apart from age and driving experience, it is unfortunately unknown how this information could be used to predict which drivers will be high-risk drivers (i.e., those who demonstrate tendencies to drive while they are engaging in secondary tasks or drowsy).

The high correlation of 0.72 between the frequency of driver's involvement in inattention-related crashes and near-crashes and baseline epochs suggests that those drivers who frequently engage in inattention-related activities are also frequently involved in crashes and near-crashes. Those drivers who are not engaging in inattention-related tasks frequently are not frequently involved in inattention-related crashes and near-crashes. Therefore, if an inattention mitigation device was developed, the highly inattentive drivers could possibly benefit from such a device.

CHAPTER 6: *OBJECTIVE 5,* WHAT IS THE RELATIVE NEAR-CRASH/CRASH RISK OF EYES OFF THE FORWARD ROADWAY? DO EYES OFF THE FORWARD ROADWAY SIGNIFICANTLY AFFECT SAFETY AND/OR DRIVING PERFORMANCE?

While eyeglance analyses have been used in transportation research for a variety of purposes and goals, this analysis is the first to establish a direct link between a driver's eyeglance behavior and crash and near-crash causation. Odds ratios were calculated to estimate the relative near-crash/crash risk of *eyes off the forward roadway*. Odds ratios were also calculated to estimate the relative risk for a crash or near-crash of different durations of *eyes off the forward roadway* as well. ANOVAs were conducted to determine if significant differences exist for several measures of eyeglance behavior. These measures include *total time eyes off forward roadway*, *number of glances away from forward roadway*, *glance length*, and *length of longest glance* away from the forward roadway.

Please note that there are some important and significant differences in the method used to conduct the analyses in this chapter and the method used in the previous chapters. First, in Chapters 3, 4, and 5, *driving inattention* was primarily defined as secondary task engagement or the presence of moderate to severe drowsiness. In Chapter 2, inattention also included *driving-related inattention to the forward roadway* and *non-specific eyeglance*. In this chapter, only eyeglance data will be considered. Therefore, any time a driver is not looking forward, regardless of the reason, is considered *eyes off the forward roadway*. Conducting the analysis in this manner completes the analysis of driver inattention in that Chapter 2, *Objective 1* included all four types of inattention. Chapter 3, *Objective 2*, Chapter 4, *Objective 3*, and Chapter 5, *Objective 4* all considered *driver inattention* primarily as *secondary task engagement* and *drowsiness*. Finally, this chapter will include any time the driver's eyes are off the forward roadway, which incorporates part of secondary task and drowsiness but will also encompass *driving-related inattention to the forward roadway* and *non-specific eyeglance.*

To first begin this analysis, an operational definition of "*eyes off forward roadway*" was determined. This metric is time dependent and a relevant time frame surrounding the crash or near-crash was also operationally defined. While some epidemiological studies have used time segments of 5 to 10 minutes prior to a crash (McEvoy et al, 2005; Riedelmeier and Tibshirani, 1997), the 100-Car Study examines within 5 seconds of the onset of the precipitating factor. Recall from the method section that the precipitating factor is the action that initiated the driving event (e.g., lead-vehicle braking) and circumstances that comprise the crash, near-crash, or incident. Therefore, all *eyes off forward roadway* calculations will be based upon a total time of 5 seconds prior and 1 second after the onset of the precipitating factor or *onset of the conflict*. Please note that this is not the instant the crash occurred. The data in which we are primarily interested is the pre-crash data or the seconds leading up to the crash. Therefore the onset of the conflict is used. Table 6.1 presents the metric calculations for the dependent variables that are used in the following analyses.

Table 6.1. Eyes off the forward roadway metrics.

	Eyes Off Forward Roadway Metric	Operational Definition
1.	Total Time Eyes Off Forward Roadway	The number of seconds that the driver's eyes were off the forward roadway during the 5 seconds prior and 1 second after the onset of the precipitating factor.
2.	Number of Glances Away From the Forward Roadway	The number of glances away from the forward roadway during the 5 seconds prior and 1 second after the precipitating factor.
3.	Length of Longest Glance Away from the Forward Roadway	The length of the longest glance that was *initiated* during the 5 seconds prior and 1 second after the onset of the precipitating factor.
4.	Location of Longest Glance Away from the Forward Roadway	The location of the longest glance (as defined by Length of Longest Glance). Location will be based upon distance (in degrees) from center forward and will be in one of three categories: less than 15°, greater than 15° but less than 30°, greater than 30°.

Data Used in These Analyses

Eyeglance analysis was conducted on all crashes, near-crashes, and incidents as well as 5,000 (as opposed to the entire set of 20,000) baseline epochs. Project resources restricted the number of baseline epochs for which eyeglance data reduction could be performed.

To determine the relative near-crash/crash risk of *eyes off forward roadway*, the data was parsed to exclude those events in which the driver of the instrumented vehicle was 1. not at fault and/or 2. was involved in a rear-end-struck crash or near-crash with a following vehicle. For the rear-end-struck crashes, eyeglance data was not available on the following driver, which prevented their inclusion in the analyses.

For the relative risk analyses in this chapter, crashes and near-crashes only will be used (incidents will be excluded from the analyses). In Chapter 6, *Objective 2* of the 100-Car Study Final Report, the analyses indicated that the kinematic signatures of both crashes and near-crashes were nearly identical; whereas the kinematic signatures of incidents were more variable. Given this result and to increase statistical power, the data from both crashes and near-crashes will be used in the calculation of relative near-crash/crash risk and population attributable risk percentage.

QUESTION 1. WHAT IS THE RELATIVE NEAR-CRASH/CRASH RISK OF EYES OFF THE FORWARD ROADWAY?

To answer this question, the odds ratios associated with *eyes off the forward roadway* were calculated since odds ratios are appropriate approximations of relative near-crash/crash risk for rare events (Greenberg et al., 2001). The odds ratios were calculated for all instances of *eyes off the forward roadway* as well as for five ranges of time that the drivers' eyes were off the forward roadway. These five time segments are as follows:

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

The odds ratios were calculated by using the following equation:

Odds Ratio = (A x D)/(B x C) *Equation 6.1*

Where:
A = the number of events where driver's eyes were off the forward roadway <x total time>
B = the number of events where driver's eyes were not off the forward roadway
C = the number of baseline epochs where driver's eyes were off the forward roadway <x total time>
D = the number of baseline epochs where driver's eyes were not off the forward roadway

Table 6.2 presents the odds ratios for the five segments of time as well as an overall odds ratio for *eyes off the forward roadway*. Note that the odds ratios for eyeglances equal to or less than 2 seconds were less than or not significantly different than 1.0. This may indicate that drivers who are scanning their environment are potentially safer drivers. However, eyeglances away from the forward roadway greater than 2 seconds, regardless of location of eyeglance, are clearly not safe glances as the relative near-crash/crash risk sharply increases to over two times the risk of normal, baseline driving. It is important to note that the confidence limits surrounding the point estimate odds ratio values are fairly large, indicating the odds ratio may in fact be somewhat higher or lower. However, the trend does appear to indicate that shorter glances are safer than longer eyeglances away from the forward roadway. The population attributable risk percentage calculations suggest that 23 percent of the crashes and near-crashes that occur in a metropolitan environment are attributable to *eyes off the forward roadway* greater than 2 seconds (Table 6.3).

Table 6.2. Odds ratios and 95 percent confidence intervals for eyes off the forward roadway.

	Total Time of Eyes Off the Forward Roadway	Odds Ratio	Lower CL	Upper CL
1.	Less than or equal to 0.5 seconds	1.31	0.91	1.89
2.	Greater than 0.5 seconds but less than or equal to 1.0 second	0.82	0.60	1.13
3.	Greater than 1.0 second but less than or equal to 1.5 s	0.92	0.65	1.31
4.	Greater than 1.5 seconds but less than or equal to 2.0 seconds	1.26	0.89	1.79
5.	**Greater than 2.0 seconds**	**2.19**	**1.72**	**2.78**
6.	**OR for Eye Glance (all durations)**	**1.32**	**1.09**	**1.60**

Note: only the crashes and near-crashes where the subject driver is at fault are included in these data. Those numbers in bold font are significantly different from normal, baseline driving or 1.0.

Table 6.3. Population attributable risk percentage ratios and 95 percent confidence intervals for eyes off the forward roadway.

	Total Time of Eyes Off the Forward Roadway	Population Attributable Risk Percentage	Lower CL	Upper CL
1.	Less than or equal to 0.5 seconds	4.27	3.66	4.88
2.	Greater than 0.5 seconds but less than or equal to 1.0 second	N/A	N/A	N/A
3.	Greater than 1.0 second but less than or equal to 2.0 s	N/A	N/A	N/A
4.	Greater than 1.5 seconds but less than or equal to 2.0 seconds	3.93	3.29	4.56
5.	**Greater than 2.0 seconds**	**23.26**	**22.50**	**24.01**
	PAR% for Eye Glance (all durations)	**15.47**	**14.45**	**16.49**

Note: only the crashes and near-crashes where the subject driver is at fault are included in these data. Those numbers in bold font are significantly different from normal, baseline driving or 1.0.

While the above results are indicative of any time that a driver's eyes were averted from the forward roadway, regardless of the reason, near-crash/crash risk increases when the eyeglance is over 2 seconds. However eyeglances away from the forward roadway, specifically those to check rear-view mirrors, are important to safe driving. A driver who is glancing at one of the rear-view mirrors, for example, is exhibiting attentive and safe driving. Therefore, odds ratio calculations were also conducted to account for these behaviors. The following odds ratios were calculated for eyes off the forward roadway except when the driver was looking at the center, right, or left rear-view mirrors or checking traffic out the right or left windows. Please note that these glances were shown previously to possess a protective effect on driving safety (Chapter 2, *Objective 1*).

The resulting odds ratios (Table 6.4) demonstrate more effectively that as length of eyeglance from the forward roadway increases, the odds of being in a crash or near-crash also increases. Also note that the eyeglances away from the forward roadway greater than 2 seconds increase an individual's relative near-crash/crash risk by two times that of normal, baseline driving. An overall odds ratio associated with eyeglance away from the forward roadway was also over 1.5 indicating that, eyes off the forward roadway greater than 2 seconds was a strong enough effect to boost the overall odds ratio significantly over 1.0.

The population attributable risk percentages, as shown in Table 6.5, indicated that over 18 percent of all at-fault crashes and near-crashes occurring in an urban environment are attributable to eyes off the forward roadway. Eighteen percent of these crashes and near-crashes were attributable to eyeglances away from the forward roadway greater than 2 seconds. This finding demonstrates that eyes off the forward roadway, especially eyeglances greater than 2 seconds, is a key issue in crash causation. Recall that this estimate does not include those crashes where the driver was not at fault and rear-end struck crashes since eyeglance data were not available. Therefore, it is possible that this estimate could be higher than is currently estimated.

Table 6.4. Odds ratios and 95 percent confidence intervals for eyes off forward roadway excluding eyeglances to center, right, and left rear-view mirrors.

	Total Time of Eyes Off Forward Roadway	**Odds Ratio**	**Lower CL**	**Upper CL**
1.	Less than or equal to 0.5 seconds	1.13	0.67	1.92
2.	Greater than 0.5 seconds but less than or equal to 1.0 second	1.12	0.79	1.59
3.	Greater than 1.0 second but less than or equal to 1.5 seconds	1.14	0.79	1.65
4.	Greater than 1.5 but less than or equal to 2.0	1.41	0.98	2.04
5.	**Greater than 2.0 seconds**	**2.27**	**1.79**	**2.86**
6.	**OR for Eye Glance Away From the Forward Roadway**	**1.56**	**1.29**	**1.88**

Note: only the crashes and near-crashes where the subject driver is at fault and the driver is not looking at a rear-view mirror are included in this table. Those numbers in bold font are significantly different from normal, baseline driving or 1.0.

Table 6.5. Population attributable risk percentage ratios and 95 percent confidence intervals for eyes off the forward roadway excluding eyeglances to center, right, and left rear-view mirrors.

	Total Time of Eyes Off Forward Roadway	Population Attributable Risk Percentage	Lower CL	Upper CL
1.	Less than or equal to 0.5 seconds	0.74	0.41	1.06
2.	Greater than 0.5 seconds but less than or equal to 1.0 second	1.53	1.04	2.02
3.	Greater than 1.0 second but less than or equal to 2.0 seconds	1.56	1.10	2.03
4.	Greater than 1.5 seconds but less than or equal to 2.0 seconds	3.81	3.35	4.26
5.	**Greater than 2.0 seconds**	**18.88**	**18.27**	**19.49**
6.	**PAR% for Eye Glance**	**18.25**	**17.49**	**19.01**

Note: only the crashes and near-crashes where the subject driver is at fault and the driver is not looking at a rear-view mirror are included in this table. Those numbers in bold font are significantly different from normal, baseline driving or 1.0.

QUESTION 2. DO EYES OFF THE FORWARD ROADWAY SIGNIFICANTLY AFFECT SAFETY AND/OR DRIVING PERFORMANCE?

To answer this research question, four metrics of *eyes off the forward roadway* were calculated and ANOVAs were conducted to determine if significant differences exist between the crashes, near-crashes, and incidents plus baseline driving epochs. The first ANOVA was conducted using *total time eyes off forward roadway*. The ANOVA indicated significant differences among the four levels of severity as shown in Figure 6.1 ($F(3, 11{,}174) = 33.36$, $p < 0.0001$). Tukey post-hoc t-tests indicate that significant differences were present between all pairs as shown in Table 6.6. These results indicate that drivers involved in crashes had their eyes off the forward roadway a significantly longer portion of the 6 seconds prior to the conflict than did those drivers involved in near-crashes or incidents. Interestingly, drivers' eyes were off the roadway a significantly smaller portion of the 6-second segment than those drivers involved in safety-relevant conflicts.

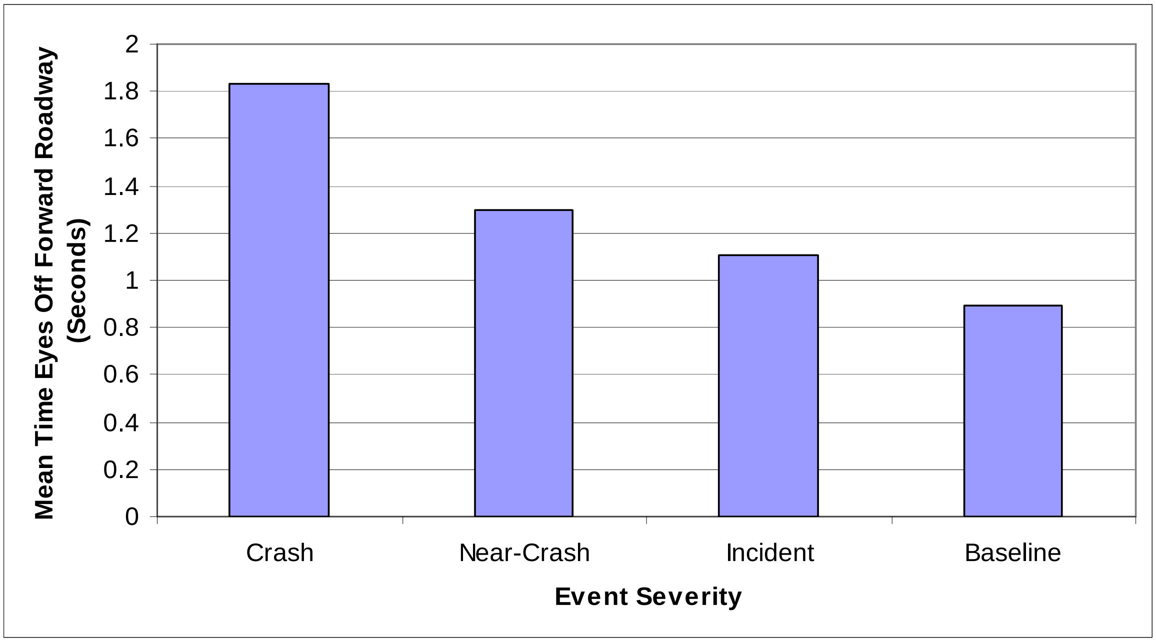

Figure 6.1. The total mean time drivers' eyes were off the forward roadway during the 6-second segment of time prior to the onset of the conflict.

Table 6.6. T-test results for total time eyes off the forward roadway.

	Severity	**dF**	**t-value**	**p-value**
1.	Crash and Near-crash	11,174	2.74	0.03
2.	Crash and Incident	11,174	3.79	0.009
3.	Crash and Baseline	11,174	4.87	< 0.0001
4.	Near-crash and Incident	11,174	2.57	0.05
5.	Near-crash and Baseline	11,174	5.60	<0.0001
6.	Baseline and Incident	11,174	8.10	<0.0001

The second metric involved the number of glances away from the forward roadway that occurred during the 5 seconds prior and 1 second after the onset of the conflict. Figure 6.2 shows the mean number of glances made by drivers just prior to involvement in crashes, near-crashes, incidents, and baseline events. An ANOVA indicated statistical significance among these four levels of event severity, $F(3, 11{,}174) = 22.02$, $p < 0.0001$. Post hoc Tukey t-tests were conducted on all pair combinations which indicated that near-crashes were significantly different from the baseline epochs, ($t(11{,}174) = 2.83$ $p < 0.05$) and incidents were significantly different from baseline epochs ($t(11{,}174) = 7.93$, $p < 0.0001$).

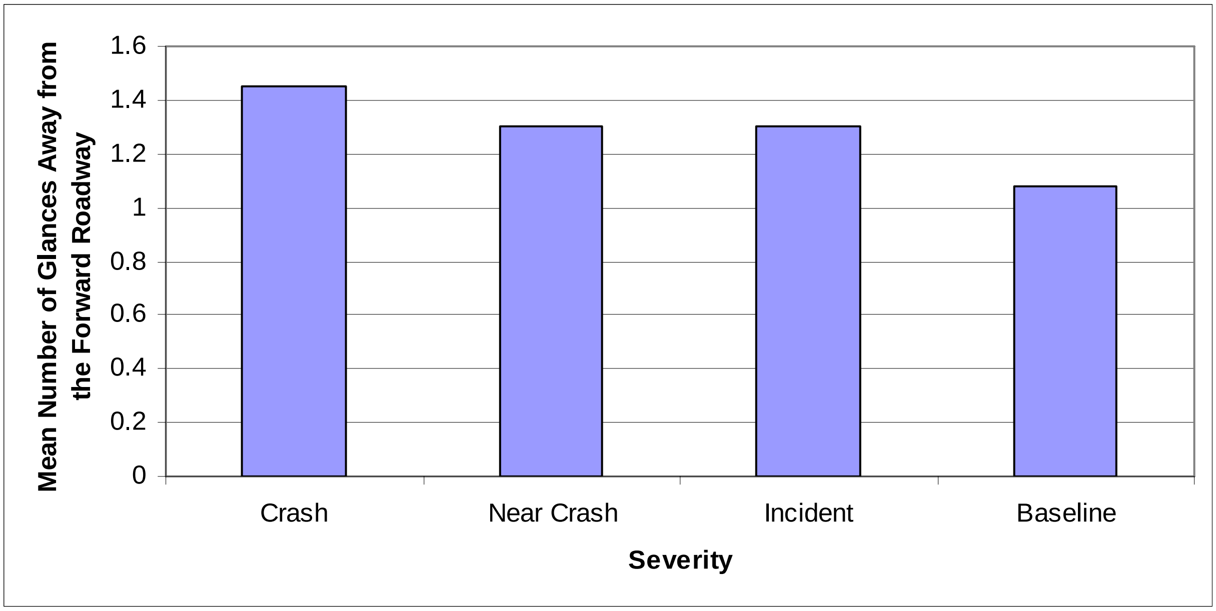

Figure 6.2. Mean number of glances away from the forward roadway occurring during 5 seconds prior and 1 second after the onset of the conflict or during a 6-second baseline driving epoch.

The mean length of longest glance away from the forward roadway is the only metric not confined to the 5 seconds prior and 1 second after the onset of the conflict. Rather, the longest glance away simply has to be initiated within the 5 seconds prior and 1 second after but may extend into the actual conflict. This metric was calculated since there were many crashes that occurred in which the driver was looking away from the forward roadway up to the moment of the crash. This eyeglance behavior would be missed if restricted to the 6-second period of time surrounding the *onset of the conflict*.

Figure 6.3 shows the results of the ANOVA which indicates that drivers' mean length of longest glance was over 0.5 seconds longer for crashes than for near-crashes ($F(3, 11{,}177) = 34.94$, $p < 0.0001$). Post hoc Tukey t-tests indicated that all four groups were significantly different from each other. The results from the post hoc Tukey t-tests are shown in Table 6.7. Note that these results are similar to those found by Dingus, Antin, Hulse and Wierwille, (1989) that stated that drivers do not tend to look away from the forward roadway greater than 1 or 1.5 seconds for any given glance. Figure 6.3 supports this earlier result in that the mean length of any one glance was between 1.6 and 0.7 seconds.

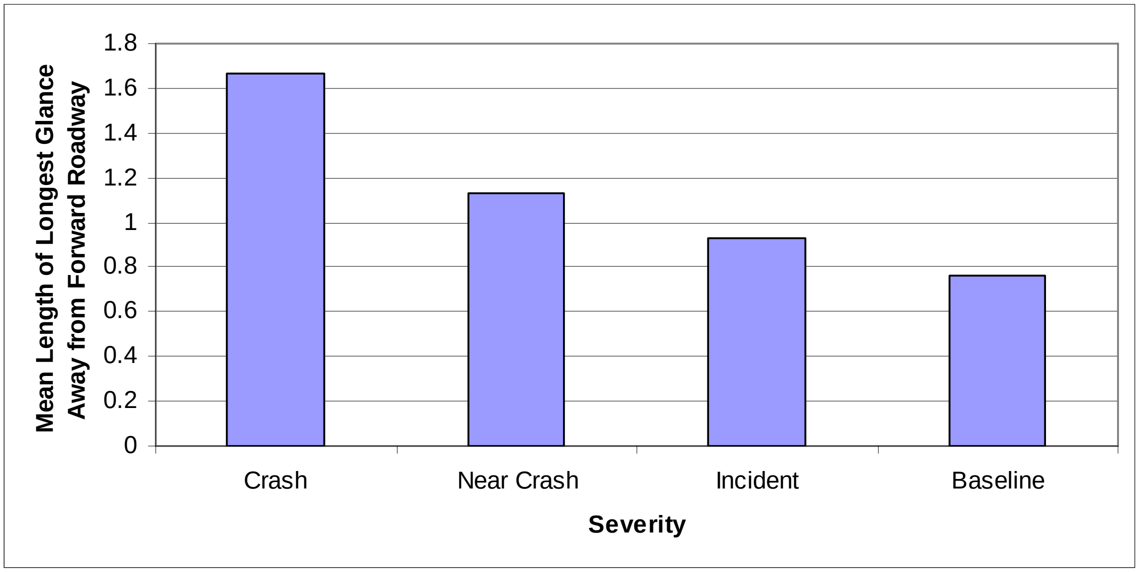

Figure 6.3. Mean length of longest glance initiated during the 5 seconds prior and 1 second after the onset of the conflict.

Table 6.7. Results from the Tukey post hoc T-Tests.

	Severity	**dF**	**t-value**	**p-value**
1.	Crash and Near-crash	11,177	3.16	0.0087
2.	Crash and Incident	11,177	4.52	<0.0001
3.	Crash and Baseline	11,177	5.53	< 0.0001
4.	Near-crash and Incident	11,177	3.38	0.0040
5.	Near-crash and Baseline	11,177	6.22	<0.0001
6.	Baseline and Incident	11,177	7.60	<0.0001

Eye-Glance Location Analysis

The eyeglance location analysis was an analysis of the location of the longest glance away from the forward roadway that was initiated during the 5 seconds prior and 1 second after the onset of the conflict. Eyeglance data reduction was conducted using the following locations of eyeglance:

- Left window
- Left mirror
- Left Forward
- Center Forward
- Center Mirror
- Right Forward
- Right mirror
- Right Window
- Instrument Panel
- Radio/HVAC
- Passenger in right-hand seat

- Hand-held device
- Object/Other
- Eyes closed

These locations were split into three general locations based upon degrees of visual angle away from center forward (illustrated in Figure 6.4). The first group, called Ellipse 1, included all locations that were 20° or less away from center forward. Ellipse 2 included all locations that were up to 40° but greater than 20°. The last Ellipse includes all locations greater than 40° as well as hand-held device, object, and eyes closed. The eyeglance categories that were assigned to each ellipse are as follows:

Ellipse 1: Left Forward, Right Forward, and Instrument Panel
Ellipse 2: Center Mirror, Radio/HVAC, and Left Mirror
Ellipse 3: Left Window, Right Mirror, Right Window, Passenger in Right-Hand Seat, Hand-Held Device, Object/Other, and Eyes Closed.

While there is some overlap in these ellipse selections, the eyeglance location was placed in the ellipse closer to the central field of view than further away.

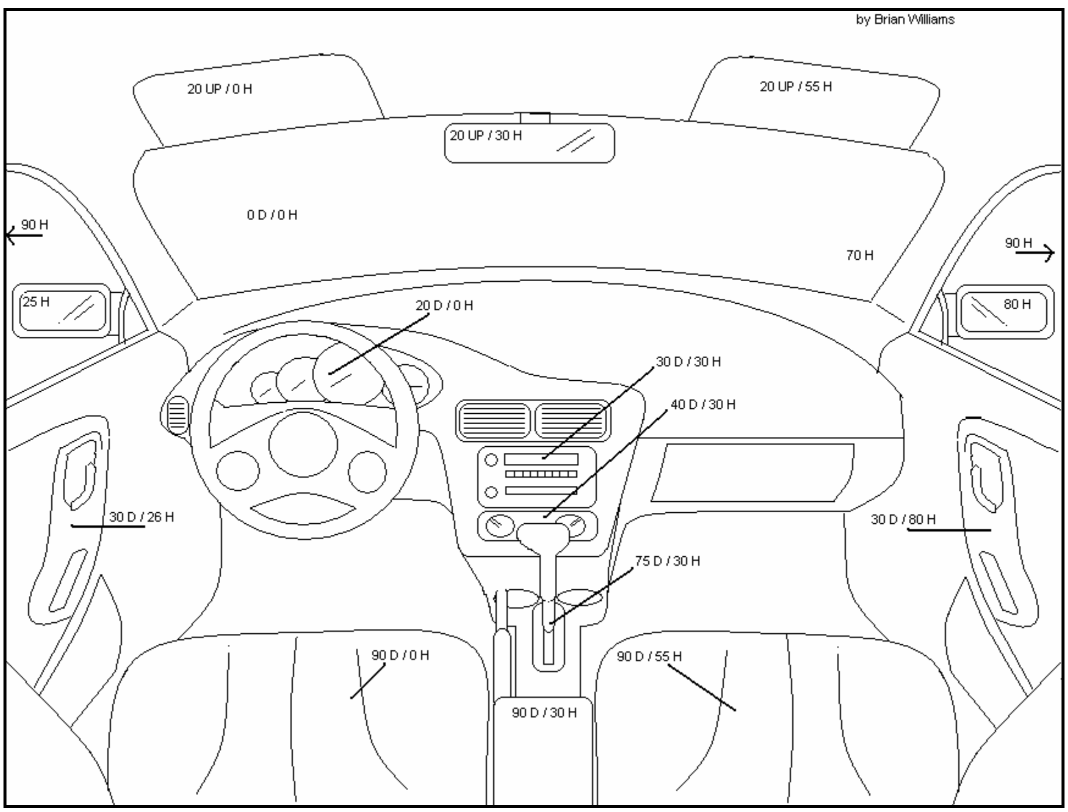

Figure 6.4. Depiction of degrees of visual angle from center forward that objects in the cockpit of an automobile are generally located.

Figure 6.5 presents the percent of crashes, near-crashes, incidents, and baseline epochs in which the longest glance away from the forward roadway was within each ellipse. A chi-square analysis was conducted to determine if there were significant differences in the frequency of events or epochs at these locations, and the results indicated that there are significant differences (χ (9) = 208.42, p > 0.0001). Note that for incidents, the driver's longest glances away from the forward roadway are spread fairly evenly across all three ellipse locations, however for crashes and near-crashes, drivers' longest glances were most frequently between 20° and 40° away from center forward. Baseline epochs had the most glances in Ellipse 3; however it is unknown whether the differences among the three ellipse locations for baseline epochs are significantly different. These results may indicate that many crashes and near-crashes could potentially be avoided if the driver's gaze could be re-directed when gaze direction resides between 20 and 40° away from center forward.

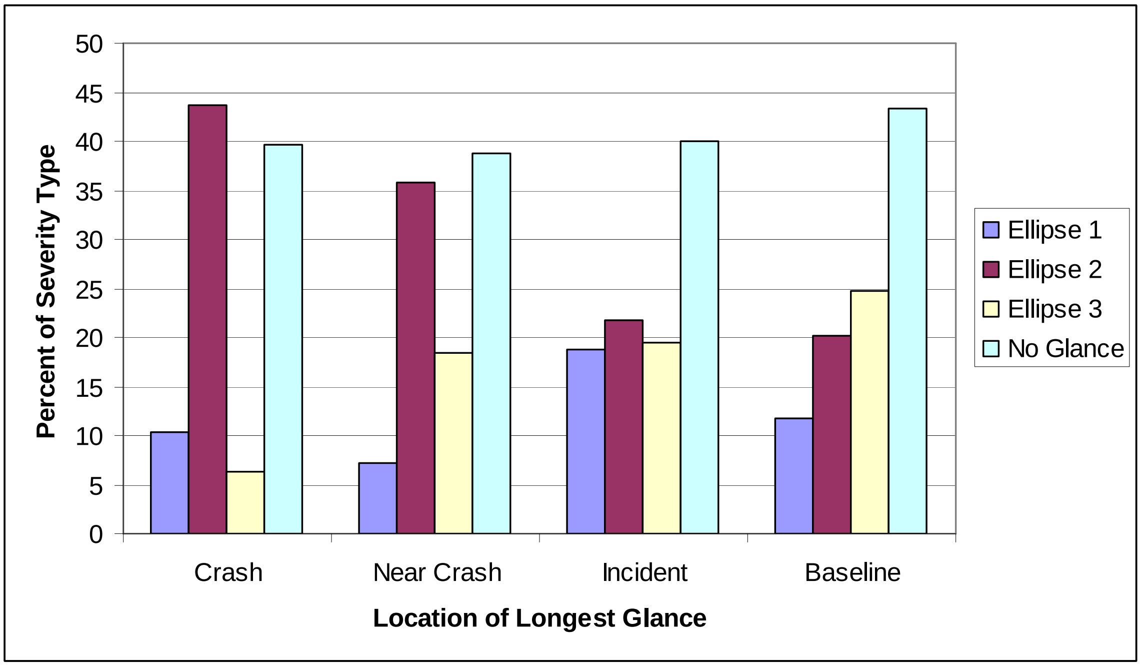

Figure 6.5. The percentage of the location of the longest glance away from the forward roadway by severity.

CONCLUSIONS

The use of eyeglance behavior in driving research is a complicated construct. W*hy* the driver was looking away from the forward roadway can not be ignored from the analysis if one is interested in driving inattention. In driving research it is commonly written that a driver looking away from the forward roadway is an *inattentive driver*. It is also commonly written that a driver who is systematically scanning his/her environment (i.e., looking away from the forward roadway) is an *attentive driver*.

The total time eyes are away from the forward roadway may or may not be a source of potential inattention, depending upon the *purpose* for looking away. The results, using the metric *total time eyes are away from the forward roadway*, indicate that viewing the rear-view mirror or windows to check traffic were safe actions that resulted in a relative near-crash/crash risk of less than 1.0. When the *total time eyes were off the forward roadway* was greater than 2seconds, regardless of where the driver was looking, an increased risk of crash or near-crash involvement (OR = 2.3) was observed.

Statistically significant differences were identified using the four eyeglance behavior metrics for crashes, near-crashes, incidents, and baseline epochs. These results indicated that the longer eyeglances and longer periods of time that the drivers' eyes were away from the forward roadway significantly impacted driving performance. Drivers who were involved in crashes had an average total time eyes away from the forward roadway of nearly 2 seconds with 1.5 seconds mean length of longest glances. Drivers involved in near-crashes had an average total time away from the forward roadway closer to 1 second and the same for mean longest glance length. While statistically significant differences were observed for number of glances, caution may be required as the practical differences between 1.4 glances and 1.2 glances away from the forward roadway.

Interesting results were also obtained when analyzing the location of the longest glance away from the forward roadway. Note that for crashes and near-crashes, drivers were more far more frequently looking in Ellipse 2 than other locations. The frequency of longest-glance location for incidents and baseline epochs appeared to be somewhat more evenly spread across the three ellipses. One issue with this analysis was that if the driver was looking at a hand-held device or at another object, the distance away from center forward is unknown and may not be located within Ellipse 3. It was decided to put these two categories in Ellipse 3 as it appeared that drivers usually were looking at objects in their lap or the seat next to them, and dialed their hand-held device near their lap. It is doubtful that this discrepancy in the operational definition had a very large impact as the frequencies for the category was fairly low for the crashes and near-crashes, especially.

These results demonstrate that eyeglances away from the forward roadway, especially those that do not involve checking rear-view mirrors, may be contributing factors to a high percentage of crashes. Please note that for 40 percent of the crashes, near-crashes, and incidents, the driver did not look away from the forward roadway for the 5 seconds prior and 1 second after the onset of the conflict. This result leaves 60 percent, a majority of the crashes, near-crashes, and incidents, where glances away from the forward roadway were a contributing factor. This result has implications for collision-avoidance-warning designers in that if they could incorporate where the driver is looking in their warning algorithms, their systems could be vastly improved by reducing false alarms and also reducing crash involvement and/or injuries.

CHAPTER 7: *OBJECTIVE 6*, ARE THERE DIFFERENCES IN DRIVING PERFORMANCE FOR DRIVERS WHO ARE ENGAGING IN A DISTRACTION TASK VERSUS THOSE DRIVERS WHO ARE ATTENDING TO DRIVING? ARE SOME OF THE SAFETY SURROGATE MEASURES MORE SENSITIVE TO DRIVING PERFORMANCE DIFFERENCES WHEN DRIVING DISTRACTED VERSUS OTHER SAFETY SURROGATE MEASURES?

To determine whether there were any differences in driving performance between inattentive and attentive drivers, the baseline database was evaluated. A discriminant analysis was conducted to determine if any statistically significant differences were present between the baseline epochs that involved drivers engaging in secondary tasks and/or driving while drowsy and those baseline epochs where the driver was attentive. Prior to conducting the discriminant analysis, a stepwise selection procedure was conducted to determine which driving performance measures were accounting for the highest percentage of variance. This provided insight into which driving performance measures (surrogate safety measures) are most sensitive to inattentive driving.

DATA USED IN THIS ANALYSIS

Table 7.1 presents all the driving performance data that were used in the discriminant analysis. Please recall from Chapter 1: Introduction and Method that the vehicle speed could not be 0 mph for the duration of the epoch. The vehicle was in motion for at least a portion of the 6-second segment for all 20,000 epochs.

Table 7.1. Driving Performance Data Used in the Discrimnant Analysis.

	Driving Performance Measure	Description
1.	Average percent throttle	Percent that throttle pedal was depressed by driver over the duration of 6-second epoch.
2.	Maximum percent throttle	Maximum percent that throttle pedal was depressed by driver over the duration of the 6-second epoch.
3.	Minimum lateral acceleration	Minimum absolute value of lateral acceleration over the 6-second epoch.
4.	Average lateral acceleration	Average absolute value of lateral acceleration over the 6-second epoch.
5.	Maximum lateral acceleration	Maximum absolute value of lateral acceleration over the 6-second epoch.
6.	Maximum longitudinal acceleration	Maximum longitudinal positive acceleration across the 6-second epoch.
7.	Average longitudinal acceleration/deceleration	Average longitudinal acceleration/deceleration value across 6-second epoch.
8.	Maximum longitudinal deceleration	Maximum longitudinal negative deceleration across the 6-second epoch.
9.	Yaw time differential	Duration of the maximum peak-to-peak across the 6-second epoch (i.e., jerk).
10.	Average speed	Average vehicle speed across the 6-second epoch.
11.	Maximum speed	Maximum vehicle speed across the 6-second epoch.

There were some driving-performance measures that were not included in the analyses. Some of these measures include forward range, range-rate, and TTC. These dependent measures, while useful in identifying crashes, near-crashes, and incidents when used in conjunction with longitudinal deceleration, were too variable to use with the baseline data. There were many epochs with no lead vehicle present as well as difficulties in filtering spurious radar data when using only 6-second segments. Radar data is notoriously noisy and effectively filtering for this task proved to be too time consuming given the resources available. Even with effective filtering, we hypothesize that this data would not have yielded different results than the results that will be presented with the data that were used.

STEPWISE SELECTION PROCEDURE AND CANONICAL DISCRIMINANT ANALYSIS

A stepwise selection procedure was conducted to determine if all of the above variables are necessary to distinguish between a driver who is engaging in a secondary task or is driving while drowsy to a driver who is attentive to the forward roadway. The stepwise selection procedure initially uses a forward selection procedure but after each selection, the procedure checks to ensure that all the variables previously selected remain significant (Johnson, 1998). In this manner, the stepwise selection procedure will select those driving performance variables or surrogate safety measures that can best discriminate between an attentive and an inattentive driver.

Table 7.2 presents those surrogate safety measures that the stepwise selection procedure selected. The standardized canonical coefficient can be used to interpret the relative contribution that each variable is making to the model. The magnitude and the sign of the value are both used in this interpretation; therefore, the average percent throttle is contributing the most to the model whereas yaw time differential is contributing the least.

Table 7.2 The safety surrogate measures that best discriminate between attentive and inattentive drivers.

Variable	Standardized Canonical Coefficient
Average Percent Throttle	0.81
Yaw time differential	0.29
Average Lateral Acceleration	-0.51
Maximum Longitudinal Deceleration	-0.44

The stepwise selection procedure also indicated that these four safety surrogate measures together achieved a multivariate measure analogous to an R-squared value of 0.004 indicating that these four variables account for less than 1 percent of the variance associated with inattentive and attentive driving. While differences are present between attentive and inattentive drivers, these surrogate safety measures are not adequately explaining these differences.

DISCRIMINANT ANALYSIS

The discriminant analysis was conducted to determine whether these surrogate safety measures were predictive of inattentive driving. Table 7.3 shows that 51.4 percent of the attentive epochs were correctly classified and 54.5 percent of the inattentive epochs were correctly classified. These results suggest that the predictive linear model using these surrogate safety measures is not able to accurately predict whether the driver is attentive or inattentive as these percentage values are too close to 50 percent accuracy or chance.

Table 7.3. The percent of baseline epochs that the linear discriminant analysis model was successfully able to distinguish.

	Attentive Baseline Epochs (percent)	Inattentive Baseline Epochs (percent)	Total (percent)
Attentive Baseline Epochs	51.4	48.6	100
Inattentive Baseline Epochs	45.8	54.2	100
Total	48.5	51.5	100

DISCUSSION

The stepwise selection procedure indicated that the average percent throttle, yaw time differential, average lateral acceleration, and maximum longitudinal deceleration were the safety surrogate measures most sensitive to inattentive driving. While these safety surrogate measures were most sensitive to inattentive driving, they were only able to account for less than 1 percent of the variance. The subsequent discriminant analysis indicated that the predictive abilities of these four safety surrogate measures to distinguish between attentive and inattentive driving was not better than chance or 50 percent accuracy.

Other discriminant analyses using the variance of the above safety surrogate measures were also attempted. These results were similar to the above results in that the surrogate safety measures selected in the stepwise selection procedure accounted for less than 1 percent of the variance. The discriminant analysis also indicated poor predictability that was not significantly different from chance (i.e., 50 percent were correctly identified and 50 percent were incorrectly identified).

There are several hypotheses as to why the surrogate safety measures did not adequately explain the differences in attentive versus inattentive driving. One hypothesis is that the results from these analyses are accurate and that inattentive driving does not in fact differ significantly from attentive driving. Rather it is only in the presence of multiple other contributing factors and extreme circumstances that differences exist in the inattentive driver's ability to effectively respond versus an attentive driver's ability to effectively respond to an emergency situation. Testing this hypothesis is possible with the 100-Car Study data but would require specific baseline events to be identified and reduced that match on a variety of environmental and situational variables per individual driver. This reduction and analysis effort is beyond the scope of this project but could be conducted in the future.

A second hypothesis is that there are differences that exist for these safety surrogate measures but these differences are not being captured adequately by using point estimates. A point estimate may not be accurately capturing the differences between inattentive and attentive drivers. A different statistical analysis or what is known as functional data analysis may produce different results. Functional data analysis would use overall rates of change for each baseline epoch rather than a point estimate to summarize the data for that epoch. While this technique could be used, it would require additional data reduction and time spent researching these relatively new data analysis methods. These techniques are generally not attempted unless the point estimate analysis produced some promising results; therefore, this hypothesis should only be tested as a last resort.

A third explanation for these findings is that the 6-second duration for the baseline epochs is too short to accurately assess driving performance. Recall that the baseline epochs were 6 seconds in duration to compare to the time frame used by trained data reductionists to assess whether a particular behavior or action by the driver contributed to the occurrence of the crash, near-crash, or incident. It is unknown whether a point estimate for a longer duration of time would be any better than the analysis already conducted. Also note that lengthening the time duration would require additional data reduction.

After conducting multiple discriminant analyses using a variety of surrogate safety measures, it is clear that the databases that currently exist are not adequate to test the above hypotheses that are listed here. More data reduction that is specifically designed to adequately assess driving performance for individual drivers during specific environmental conditions is required to further assess this research objective.

CHAPTER 8: CONCLUSIONS

GENERAL CONCLUSIONS

The analyses reported in this document are the first to evaluate driver inattention immediately prior to a crash and near-crash. These analyses used data collected as part of a large-scale naturalistic driving study. The analytical methods used were applied from epidemiology, empirical research, and qualitative research. The application of these analytical methods demonstrates the power of naturalistic driving data and its importance in relating driving behavior to crash and near-crash involvement.

Driver inattention was operationally defined at the beginning of this report as one of the following:

- Driver engagement in secondary task(s)
- Driver drowsiness
- Driving-related inattention to the forward roadway
- Non-specific eyeglance away from the forward roadway

These four types of inattention, either in isolation or in combination, were used to answer the research questions addressed in this letter report. Some of the important findings addressed as part of these questions are presented below:

- Due to the detailed pre-crash/near-crash data reduction, this study allowed for the calculation of relative near-crash/crash risk of engaging in various types of inattention-related activities. Some of the primary results were that driving while drowsy increases an individual's near-crash/crash risk by between four and six times that of normal, baseline driving, engaging in complex secondary tasks increases risk by three times and engaging in moderate secondary tasks increases risk by two times. *Driving-related inattention to the forward roadway* was actually shown to be safer than normal, baseline driving (odds ratio of 0.45). This was not surprising as drivers who are checking their rear-view mirrors are generally alert and engaging in environmental scanning behavior.

- This study also allowed for the calculation of population attributable risk percentages. This calculation produces an estimate of the percentage of crashes and near-crashes occurring in the population at-large that are attributable to the inattention-related activity. The results of this analysis indicated that driving while drowsy was a contributing factor for between 22 and 24 percent of the crashes and near-crashes, and secondary-task distraction contributed to over 22 percent of all crashes and near-crashes. This is a useful metric since odds ratios estimate risk on a per-task (or drowsiness episode) basis while the population attributable risk percentage accounts for the frequency of occurrence. Thus, some inattention-related activities that indicated high relative near-crash/crash risk had corresponding population attributable risk percentages indicating low total percentages. This was due to lower frequency of occurrence. Conversely, other more frequently performed inattention tasks, while obtaining lower relative near-crash/crash risks, obtained higher population attributable risk percentages.

- The prevalence of driving inattention was analyzed by using "normal baseline driving" (i.e., no crashes, near-crashes, or incidents present) as established by the baseline database. The four types of inattention were recorded alone and in combination with the other types of inattention. The percent of the total baseline epochs in which drivers were engaged in each type of inattention is as follows:

  secondary tasks – 54 percent of baseline epochs
  driving-related inattention – 44 percent of baseline epochs
  drowsiness – 4 percent of baseline epochs
  non-specific eyeglance – 2 percent of baseline epochs

  Note that the total is higher than 100 percent since drivers engaged in multiple types of inattention at one time. Also note that non-specific eyeglance was most frequently recorded as associated with the other types of inattention, but accounts for only 2 percent of the baseline epochs, singularly. Given that the baseline epochs most closely represent "normal baseline driving," these results suggest that drivers are engaging in inattention-related tasks a majority of the time.

- The analysis of eyeglance behavior indicates that total eyes-off-road durations of greater than 2 seconds significantly increased individual near-crash/crash risk; whereas eyeglance durations less than 2 seconds did not significantly increase risk relative to normal baseline driving. The purpose behind an eyeglance away from the roadway is important to consider, an eyeglance directed at a rear-view mirror is a safety-enhancing activity in the larger context of driving, while eyeglances at objects inside the vehicle are not safety-enhancing. It is important to remember that scanning the driving environment is an activity that enhances safety as long as it is systematic and the drivers' eyes return to the forward view in under 2 seconds.

- The results for the analysis investigating the impact of driver drowsiness on environmental conditions yielded many interesting findings. First, the relative near-crash/crash risks of driver drowsiness may vary depending on time of day or ambient lighting conditions. When compared to total baseline epochs, far fewer drowsiness-related baseline epochs were observed during the daylight hours while a greater number were identified during darkness. Drowsiness was also seen to slightly increase in the absence of high roadway or traffic demand. A higher percentage of drowsiness-related baseline epochs were found during free-flow traffic densities, on divided roadways, and areas free of roadway junctions.

- The results of the analysis investigating the impact of complex- or moderate-secondary-task engagement on various environmental conditions were more varied. Each of the eight environmental conditions resulted in odds ratios greater than 1.0 for engaging in complex secondary tasks. Engaging in moderate secondary tasks rarely resulted in odds ratios significantly greater than 1.0, indicating that these behaviors may not be as risky as driving drowsy or engaging in complex secondary tasks.

- The most frequent type of secondary task engagement, hand-held device use, also obtained odds ratios greater than 1.0 for both *dialing hand-held device* (CL = 1.6 – 4.9) and *talking/listening to a hand-held device* (CL = 0.9 – 1.8). *Talking/listening to a hand-held device* was not significantly different than 1.0, indicating that this task was not as risky as *dialing a hand-held device*. Regardless of the slightly different odds ratios, these two secondary tasks had nearly the identical population attributable risk percentages (each attributing to 3.6 percent of crashes and near-crashes). One hypothesis for this is that drivers were talking/listening to hand-held devices a much larger percentage of time than they were dialing hand-held devices. Thus, the percent of crashes and near-crashes that were attributable to these two actions was similar due to the fact that dialing was more dangerous but was performed less frequently whereas talking/listening was less dangerous but performed more frequently.

- The results from the survey and test battery response analyses indicate that driver age, driving experience, self-reported traffic violations, self-reported accidents, daytime sleepiness ratings, and personality inventory scores indicate significant differences between the drivers with high and low involvement in inattention-related crashes and near-crashes.

- A clear relationship between involvement in inattention-related crashes and near-crashes and engaging in inattention-related activities during baseline driving was observed. A correlation of 0.72 was obtained between the frequency of driver's involvement in inattention-related crashes and near-crashes and the frequency of involvement in inattention-related baseline epochs. This result, according to Keppel and Wickens (2004), is a large effect in the behavioral sciences. This suggests that those drivers who frequently engage in inattention-related activities are also more likely to be involved in inattention-related crashes and near-crashes. Those drivers who are not frequently engaging in inattention-related tasks frequently are less likely to be involved in inattention-related crashes and near-crashes.

RELATIVE RISK OF A CRASH OR NEAR-CRASH: CONCLUSIONS

Odds ratio calculations, or relative-risk calculations for a crash or near-crash, were conducted in three separate chapters. First, Chapter 2, *Objective 1,* odds ratios were calculated for three levels of secondary task complexity, two durations of time that eyes were off the forward roadway for *driving-related inattention to the forward roadway*, two durations of time for *non-specific eyeglance away from the forward view*, and *driver drowsiness* (moderate to severe). Odds ratio calculations were calculated in Chapter 3, *Objective 2* to determine whether driving while engaging in secondary tasks or drowsy through various types of driving environments produced higher near-crash/crash risks. Finally, odds ratios were also calculated for total length of time eyes were off the forward roadway by increments of 0.5 seconds in Chapter 6, *Objective 3*.

Data used to calculate the odds ratios included a subset of the 69 crashes and 761 near-crashes where the driver was at-fault that were collected as part of the 100-Car Study and 20,000 baseline epochs (5,000 baseline epochs for any odds ratios requiring eyeglance data only). Please note that the 20,000 baseline driving epochs were first selected based upon the number of crashes, near-crashes, and incidents that each vehicle (not driver) was involved and then randomly selected across the entire 12 months of data collection. Each baseline epoch was a 6-second segment when the vehicle was in motion. This stratification technique created a case-control data set as those vehicles who were more involved in crashes, near-crashes, and incidents also had more baseline events to compare. Case-control designs are optimal for calculating odds ratios due to the increased power that a case-control data set possesses. Greenberg et al. (2001) argue that using a case-control design allows for an efficient means to study rare events, such as automobile crashes. Thus, the causal relationships that exist for these events can be evaluated by using relatively smaller sample sizes than are used in typical crash database analyses where thousands of crashes may be used.

Table 8.1 presents the odds ratios for the different types of inattention that increase individual near-crash/crash risk. Please note that *driving-related inattention to the forward roadway* is not in this table as this type of inattention was found to be safer than normal, baseline driving. Tables 8.2 and 8.3 present the odds ratios for the interaction of drowsiness with various environment and road-type conditions and the interaction of complex secondary tasks with environmental conditions, respectively. The odds ratios for the interaction of moderate-secondary-task engagement and environmental variables will not be presented as a majority of these odds ratios were not significantly different from 1.0. Table 8.4 presents the odds ratios for the lengths of total time eyes were off the forward roadway. All tables present only those odds ratios that were greater than 1.0. In all tables, those that were significantly different from 1.0 are in bold font.

Table 8.1. Odds ratios and 95 percent confidence intervals for all types of driving inattention where odds ratios were greater than 1.0.

Type of Inattention	Odds Ratio	Lower CL	Upper CL
Complex Secondary Task	**3.10**	**1.72**	**5.47**
Moderate Secondary Task	**2.10**	**1.62**	**2.72**
Simple Secondary Task	1.18	0.88	1.57
Moderate to Severe Drowsiness (in isolation from other types of inattention)	**6.23**	**4.59**	**8.46**
Moderate to Severe Drowsiness (all occurrences)	**4.24**	**3.27**	**5.50**
Reaching for a Moving Object	**8.25**	**2.50**	**31.16**
Insect in Vehicle	6.37	0.76	53.13
Looking at External Object	**3.70**	**1.13**	**12.18**
Reading	**3.38**	**1.74**	**6.54**
Applying Makeup	**3.13**	**1.25**	**7.87**
Dialing Hand-Held Device	**2.79**	**1.60**	**4.87**
Handling CD	2.25	0.30	16.97
Eating	1.57	0.92	2.67
Reaching for Object (not moving)	1.38	0.75	2.56
Talking/Listening to a Hand-Held Device	1.29	0.93	1.80
Drinking from Open Container	1.03	0.33	3.28

Table 8.2. Odds ratios and 95 percent confidence intervals for the interaction of drowsiness by environmental conditions where odds ratios were greater than 1.0.

Type of Roadway/ Environment	Odds Ratio	Lower CL	Upper CL
Lighting Levels			
Dawn	**2.43**	**0.96**	**6.17**
Daylight	**5.27**	**3.55**	**7.82**
Dusk	**6.99**	**3.82**	**12.80**
Darkness-Lighted	**3.24**	**1.92**	**5.47**
Darkness-Not Lighted	**3.26**	**1.82**	**5.86**
Weather			
Clear	**4.34**	**3.22**	**5.86**

Rain	**4.41**	**2.41**	**8.08**
Road Type			
Divided	**3.73**	**2.61**	**5.34**
Undivided	**5.54**	**3.47**	**8.84**
One-Way	**3.40**	**1.76**	**6.59**
Roadway Alignment			
Straight Level	**3.96**	**2.93**	**5.34**
Curve Level	**5.81**	**3.66**	**9.21**
Straight Grade	**6.29**	**2.20**	**17.96**
Traffic Density			
LOS A: Free Flow	**4.67**	**3.02**	**7.21**
LOS B: Flow with Some Restrictions	**4.81**	**2.70**	**8.58**
LOS C: Stable Flow – Maneuverability and speed are more restricted	**3.63**	**2.01**	**6.54**
LOS D: Flow is Unstable – Vehicles are unable to pass with temporary stoppages	**4.29**	**1.88**	**9.80**
LOS F: Unstable Flow- Temporary restrictions, substantially slow drivers	**3.71**	**1.93**	**7.13**
Roadway Surface Conditions			
Dry	**4.52**	**3.39**	**6.03**
Wet	**3.17**	**2.03**	**4.95**
Traffic Control Device			
Traffic Signal	**2.71**	**1.90**	**3.85**
Stop Sign	**5.55**	**2.71**	**11.36**
Traffic Lanes Marked	**5.57**	**2.43**	**12.78**
No Traffic Control	**4.83**	**3.60**	**6.48**
Relation to Junction			
Intersection	**3.48**	**2.17**	**5.59**
Intersection-Related	**6.82**	**4.10**	**11.35**
Entrance/Exit Ramp	**3.21**	**1.81**	**5.71**
Interchange	**5.86**	**2.39**	**14.35**
Non-Junction	**5.02**	**3.65**	**6.90**

Table 8.3. Odds ratios and 95 percent confidence intervals for the interaction of complex secondary task engagement and environmental variables where odds ratios were greater than 1.0.

Type of Roadway/ Environment	Odds Ratio	Lower CL	Upper CL
Lighting Levels			
Daylight	**3.06**	**1.84**	**5.06**
Dusk	**8.91**	**4.41**	**18.03**
Darkness-Lighted	**4.58**	**2.46**	**8.52**
Darkness-Not Lighted	**24.43**	**12.40**	**48.10**
Weather			
Clear	**3.68**	**2.29**	**5.92**
Rain	**5.11**	**1.86**	**14.07**
Road Type			
Divided	**4.20**	**2.40**	**7.33**
Undivided	**3.60**	**1.89**	**6.79**
One-Way	**3.66**	**1.63**	**8.18**
Roadway Alignment			
Straight Level	**3.59**	**2.20**	**5.84**
Curve Level	**3.58**	**1.95**	**6.60**
Straight Grade	**26.00**	**7.31**	**92.53**
Curve Grade	**6.75**	**2.08**	**21.89**
Traffic Density			
LOS A: Free Flow	**4.67**	**2.32**	**9.38**
LOS B: Flow with Some Restrictions	**3.67**	**1.65**	**8.19**
LOS C: Stable Flow – Maneuverability and speed are more restricted	**3.80**	**1.68**	**8.58**
LOS D: Flow is Unstable – Vehicles are unable to pass with temporary stoppages	1.75	0.61	5.01
LOS F: Unstable Flow- Temporary restrictions, substantially slow drivers	**2.45**	**1.01**	**5.93**
Roadway Surface Conditions			
Dry	**4.44**	**2.88**	**6.84**
Wet	1.03	0.58	1.80

Traffic Control Device			
Traffic Signal	**3.14**	**2.15**	**4.58**
Stop Sign	**3.27**	**1.38**	**7.75**
Traffic Lanes Marked	**4.02**	**2.47**	**6.54**
No Traffic Control	**4.83**	**3.60**	**6.48**
Relation to Junction			
Intersection	1.59	0.86	2.97
Intersection-Related	**3.32**	**1.73**	**6.38**
Parking Lot	**9.11**	**3.76**	**22.07**

The odds ratios presented for the time eyes were off the forward roadway suggests that any time driver's eyes were off the forward roadway greater than 2 seconds increases near-crash/crash risk by two times (Table 8.4). None of the eyeglances away from the forward roadway that were less than 1.5 seconds were significantly different from 1.0.

Table 8.4. Odds Ratios and 95 percent confidence intervals for Eyes Off Forward Roadway Excluding Eye Glances to Center, Right, and Left Rear-View Mirrors.

Total Time of Eyes Off the Forward Roadway	Odds Ratio	Lower CL	Upper CL
Less than or equal to 0.5 s	1.13	0.67	1.92
Greater than 0.5 seconds but less than or equal to 1.0 s	1.12	0.79	1.59
Greater than 1.0 seconds but less than 1.5 seconds.	1.14	0.79	1.65
Greater than 1.5 seconds but less than or equal to 2.0 s	1.41	0.98	2.04
Greater than 2.0 s	**2.27**	**1.79**	**2.86**
OR for Eye Glance Away From the Forward Roadway	**1.56**	**1.29**	**1.88**

POPULATION ATTRIBUTABLE RISK PERCENTAGE CONCLUSIONS

A population attributable risk percentage calculation is a measure of the percentage of crashes and near-crashes that could be attributed to the variable being measured. Population attributable risk percentages are useful when interpreting odds ratios, or relative risk calculations for a crash or near-crash. Some odds ratios may have a very high individual risk; however that behavior/situation does not occur frequently in nature and therefore attributes to very few crashes in the population. An example of high odds ratios leading to low population attributable risk percentage includes the secondary tasks of *reaching for a moving object, external distraction, reading, applying makeup,* and *eating.* Even though each of these tasks obtained very high individual near-crash/crash risk, these factors did not account for a large percentage of actual crashes and near-crashes as shown by the population attributable risk percentage calculations in Table 8.5. Drowsiness, in contrast, resulted in a high relative near-crash/crash risk value and attributed to between 22 and 24 percent of the crashes and near-crashes in the population. This finding is important since these values are much higher than most crash database research has shown (Campbell, Smith, and Najm, 2003).

Also note that while the odds ratio for t*alking/listening to a hand-held device* was only slightly above 1.0 and much lower than *dialing a hand-held device*, the population attributable risk percentage was similar for both actions. This result may be due primarily to the relative frequency of occurrence of both actions. *Dialing a hand-held device* may be more dangerous but it requires less time whereas *talking/listening to a hand-held device* occurred frequently and perhaps, for long periods of time. *Talking/listening to a hand-held device* was the most frequent type of secondary task distraction observed.

Table 8.5. The population attributable risk percentage ratios and 95 percent confidence intervals for the types of driver inattention.

Type of Inattention	Population Attributable Risk Percentage	Lower CL	Upper CL
Complex Secondary Task	4.26	3.95	4.57
Moderate Secondary Task	15.23	14.63	15.83
Simple Secondary Task	3.32	2.72	3.92
Moderate to Severe Drowsiness (in isolation from other types of inattention)	22.16	21.65	22.68
Moderate to Severe Drowsiness (all occurrences)	24.67	21.12	26.23
Complex Secondary Tasks			
Dialing Hand-Held Device	3.58	3.29	3.87
Reading	2.85	2.60	3.10
Applying Makeup	1.41	1.23	1.59
Reaching for a Moving Object	1.11	0.97	1.25
Insect in Vehicle	0.35	0.27	0.44
Moderate Secondary Tasks			
Talking/Listening to a Hand-Held Device	3.56	3.10	4.10
Eating	2.15	1.85	2.46
Reaching for Object (not moving)	1.23	0.96	1.50
Looking at External Object	0.91	0.77	1.05
Handling CD	0.23	0.15	0.32

An important result from these analyses is that eyeglances greater than 2 seconds contributed to 18 percent of all crashes and near-crashes and eyeglances in general attributed to 18 percent of all crashes and near-crashes that occur in a metropolitan driving environment (Table 8.6). While the purpose or location of eyeglance does matter, the longer the time away from the forward roadway, the more dangerous the activity becomes. It is apparent that many crashes are attributable to long glances away from the forward roadway.

Table 8.6. Population attributable risk percentage ratios and 95 percent confidence intervals for eyes off forward roadway excluding eyeglances to center, right, and left rear-view mirrors.

Total Time of Eyes Off the Forward Roadway	Population Attributable Risk Percentage	Lower CL	Upper CL
Less than or equal to 0.5 seconds	0.74	0.41	1.06
Greater than 0.5 seconds but less than or equal to 1.0 second	1.53	1.04	2.02
Greater than 1.0 second but less than 1.5 seconds.	1.56	1.10	2.03
Greater than 1.5 seconds but less than or equal to 2.0 seconds	3.81	3.35	4.26
Greater than 2.0 seconds	18.88	18.27	19.49
OR for Eye Glance Away From the Forward Roadway	18.25	17.49	19.01

LIMITATIONS OF THE STUDY

Please note that there are some limitations of the given data set that must be considered when interpreting these results. First, the 100-Car Study was conducted in one geographical area of the country and that location was a metropolitan area; therefore, the odds ratios and the population attributable risk percentages are generalizable to a metropolitan environment and probably less so to the United States driving population at-large.

Further analyses need to be conducted to determine how all of these individual odds ratio and population attributable risk percentage calculations interact with each other. Please note that many of these odds ratios were individually calculated and do not account for any correlations that probably exist between many of these variables, i.e., weather conditions and roadway surface conditions. A logistic regression could be performed to assess the odds ratios and population attributable risk percentages accounting for these naturally occurring correlations. Please note that measures were taken to reduce the amount of correlation by using only those events where one type of inattention was present. For example, the odds ratios that were calculated on *drowsiness* or one of the levels of *secondary task*, *driving-related inattention*, or *non-specific eyeglance* used only those events that contained a single type of inattention. Therefore, the correlations between these odds ratios are somewhat controlled. The odds ratios that were calculated on each secondary task type (i.e., *dialing hand-held device*) are not as controlled and correlations probably do exist among some of these. While this should not detract from the odds ratio calculation itself, these odds ratio calculations and subsequent population attributable risk percentage calculations should not be summed to assess an overall impact of secondary task engagement, for example.

While eyeglance duration was used in two chapters of this report, secondary task duration analysis was not presented. Project resources limited this reduction task primarily because of the difficulties involved in operationally defining "task duration." While others have operationally defined secondary task duration (Stutts, et al., 2003), there were many issues in the data collection and reduction procedures that created obstacles for this type of reduction. For example, there were only cameras pointing at the driver which made a length of *conversation with passenger* difficult to assess. Also no continuous audio channel was present which also hindered a calculation of *duration of conversation with passenger, radio usage,* and *hands-free devices*. The use of 90-second segments of crash and near-crash events and 6-second baseline epochs also precluded the determination of length of hand-held device conversations, and sometimes eating, drinking, or more lengthy secondary-task types. While some of these issues could be alleviated with more time (i.e., reducing the entire trip file rather than a 90-second segment), the issues of no audio or view of the passenger seating in the vehicle will be difficult to overcome. Future research may attempt to overcome these issues with either a snapshot of the passenger compartment to determine number of passengers in the vehicle or brief but frequent bursts of an audio channel to help determine conversation length, whether the stereo is in use, etc.

APPLICATION OF RESULTS

As was repeatedly found throughout these analyses, drivers are inattentive and/or looking away from the forward roadway during a significant portion of the events and baseline epochs. While some of this inattention may be due to systematic scanning of the driving environment or engagement in secondary tasks or drowsiness, any eyeglance away from the forward roadway greater than 2 seconds greatly increases near-crash/crash risk. Developers of collision avoidance warning systems should incorporate these findings into newer generations of warning systems. If the system can incorporate driver eyeglance location prior to a crash, the false alarm rate of these warning systems could be greatly reduced thus increasing their effectiveness.

It is apparent from the results of the analyses in Chapter 3, *Objective 2,* that there are roadway and traffic environments that are better suited to engage in secondary tasks (Tables 8.3 and 8.5). Generally, it appears that engaging in secondary tasks during more visually cluttered, lower sight-distance, or demanding traffic environments (intersections, entrance/exit ramps, curved roadways), poor weather or roadway conditions (rainy weather, icy or wet road surfaces) are not the optimal locations and/or moments to engage in secondary tasks. This information could be used to better educate young drivers or those drivers who are attending traffic schools about the dangers of distracted driving and how to avoid crashes and near-crashes due to distraction. It was also found that near-crash/crash risk due to drowsiness increased when drivers were on straight/level roadways and less visually demanding environments (i.e., low traffic densities). Drivers should be aware that it may be harder to fight the effects of drowsiness and that near-crash/crash risk does increase despite the less-demanding driving environment.

The strong correlation obtained between involvement in inattention-related crashes and near-crashes and involvement in inattention-related baseline epochs has several implications on driving behavior. First, this strong correlation implies that those drivers who are getting caught, per se, by involvement in inattention-related crashes and near-crashes, are also those who frequently engage in secondary tasks or drive drowsy on a regular basis. This may also indicate that there are not very many drivers who do engage in secondary tasks and/or drive drowsy frequently while driving that are *never or rarely* involved in inattention-related crashes and near-crashes. This relationship will be further explored in Task 5 of this research contract.

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APPENDIX A: SECONDARY TASKS

Table A-1. Secondary tasks recorded during data reduction.

	Passenger-Related Secondary Task	
	Passenger in adjacent seat	***Driver is talking to a passenger sitting in adjacent seat that can be identified by the person encroaching into the camera view or the driver is clearly looking and talking to the passenger.***
	Passenger in rear seat	***Driver is talking to a passenger sitting in rear seat that can be identified by the person encroaching into the camera view or the driver is clearly looking and talking to the passenger seated in the rear.***
	Child in adjacent seat	***Driver is talking to a child sitting in the adjacent seat who can be identified by the child encroaching into the camera view or the driver is clearly looking and talking to the child.***
	Child in rear seat	***Driver is talking to a child sitting in the rear seat who can be identified by the child or child related paraphernalia encroaching into the camera view or the driver is clearly looking and talking to the passenger seated in the rear.***
	Talking/Singing: No Passenger Apparent	
	Talking/singing/dancing	***Driver appears to be vocalizing either to an unknown passenger, to self, or singing to the radio. Also, in this category are instances where the driver exhibits dancing behavior.***
	Internal Distraction: Not vehicle or passenger related.	
	Reading	***Driver is reading papers, a magazine, a book, or a map***
	Moving object in vehicle	***Driver is distracted by stationary objects suddenly in motion due to hard braking, accelerating, or turning corner.***
	Object dropped by driver	***Driver dropped an object and is now looking for it or reaching for it.***
	Reaching for object in vehicle (not cell phone)	***Driver is attempting to locate an object while driving.***
	Insect in vehicle	***Driver is distracted by a flying insect that is in the cabin of the vehicle.***

	Pet in vehicle	***Driver is distracted by a pet that is in the cabin of the vehicle.***
	Wireless Device	
	Talking/listening	***Driver is clearly conversing on the cell phone.***
	Head-set on/conversation unknown	***Driver has a hands-free head-set on but the conversation is unknown***
	Dialing hand-held cell phone	***Driver is attempting to dial a hand-held cell phone while the vehicle is in gear.***
	Dialing hand-held cell phone using quick keys	***Driver is attempting to use quick keys to dial a hand-held cell phone while the vehicle is in gear.***
	Dialing hands-free cell phone using voice activated software	***Driver is attempting to dial a hands-free cell phone using voice activation while the vehicle is in gear.***
	Locating/reaching/answering cell phone	***Driver is attempting to locate the cell phone by reaching for it in order to use it or answer it while the vehicle is in gear.***
	Cell phone: other	***Any other activity associated with a cell phone i.e., looking at a cell phone for time, or screening calls but not dialing, or talking while the vehicle is in gear.***
	Locating/reaching for PDA	***Driver is attempting to locate a PDA by reaching for it in order to use it or to answer it while the vehicle is in gear.***
	Operating PDA	***Driver is using (looking at, using stylus, or pressing buttons) while the vehicle is in gear.***
	Viewing PDA	***Driver is only looking at a PDA, no stylus or button presses, while the vehicle is in gear.***
	Vehicle-Related Secondary Task	
	Adjusting climate control	***Driver is looking at and/or reaching to adjust the HVAC system while the vehicle is in gear.***
	Adjusting the radio	***Driver is looking at and/or reaching to adjust the radio/stereo system while the vehicle is in gear.***
	Inserting/retrieving cassette	***Driver is inserting or retrieving a cassette while the vehicle is in gear.***
	Inserting/retrieving CD	***Driver is inserting or retrieving a compact disc while the***

		vehicle is in gear.
	Adjusting other devices integral to vehicle	***Driver is looking at and/or reaching to adjust another in-dash system while the vehicle is in gear.***
	Adjusting other known in-vehicle devices	***Driver is looking at and/or reaching to adjust another in-vehicle system (i.e., XM Radio) while the vehicle is in gear.***
	Dining	
	Eating with a utensil	***Driver is eating food with a utensil while the vehicle is in gear.***
	Eating without a utensil	***Driver is eating food without utensil while the vehicle is in gear.***
	Drinking with a covered/ straw	***Driver is drinking out of a covered container (travel mug) or covered container with a straw while the vehicle is in gear.***
	Drinking out of open cup/ container	***Driver is drinking out of an open cup or container that can be easily spilled while the vehicle is in gear.***
	Smoking	
	Reaching for cigar/cigarette	***Driver is reaching for cigar/cigarette/pipe while the vehicle is in gear.***
	Lighting cigar/cigarette	***Driver is lighting the cigar/cigarette/pipe while the vehicle is in gear.***
	Smoking cigar/cigarette	***Driver is smoking the cigar/cigarette/pipe while the vehicle is in gear.***
	Extinguishing cigar/cigarette	***Driver is putting the cigar/cigarette out in an ashtray while the vehicle is in gear.***
	Daydreaming	
	Lost in thought	***Driver is haphazardly looking around but not at any single distraction.***
	Looked but did not see	***Driver is looking in the direction of a conflict but does not react in a timely manner. Driver may also exhibit a surprised look at the moment of realization.***
	External Distraction	

	Looking at previous crash or highway incident	***Driver is looking out of the vehicle at a collision or a highway incident that has happened recently.***
	Pedestrian located outside the vehicle	***Driver is looking out of the vehicle at a pedestrian who may or may not pose a safety hazard (generally not in the forward roadway).***
	Animal located outside the vehicle	***Driver is looking out of the vehicle at an animal that may or may not pose a safety hazard (generally not in the forward roadway).***
	Object located outside the vehicle	***Driver is looking out of the vehicle at an object of interest that may or may not pose a safety hazard. Objects may or may not be in the forward roadway.***
	Construction zone	***Driver is looking out of the vehicle at construction equipment that may or may not pose a safety hazard.***
	Personal Hygiene	
	Combing/brushing/fixing hair	***Driver is grooming or styling hair while the vehicle is in gear. Driver may or may not be looking in a mirror.***
	Applying make-up	***Driver is applying makeup while the vehicle is in gear. Driver may or may not be looking in a mirror.***
	Shaving	***Driver is shaving facial hair while the vehicle is in gear. Driver may or may not be looking in a mirror.***
	Brushing/flossing teeth	***Driver is brushing or flossing teeth while the vehicle is in gear. Driver may or may not be looking in a mirror.***
	Biting nails/cuticles	***Driver is biting nails and/or cuticles. Driver may or may not be looking at nails and/or cuticles.***
	Removing/adjusting jewelry	***Driver is removing/adjusting/putting on jewelry while the vehicle is in gear.***
	Removing/inserting contact lenses	***Driver is attempting to remove or insert contact lenses while the vehicle is in gear.***
	Other	***Driver is cleaning/adjusting/altering something on their person while the vehicle is in gear.***
	Driving-related Inattention to Forward Roadway	
	Checking center rear-view mirror	***Driver is observing traffic in rear-view mirror while moving forward or stopped, but the vehicle is in gear (i.e.,***

		stopped at an intersection).
	Looking out left side of windshield (not in direction in motion)	***Driver is looking out the left side of the windshield while the vehicle is either moving forward or stopped, but is in gear. This is not marked if the driver is making a left turn.***
	Looking out right side of windshield (not in direction in motion)	***Driver is looking out the right side of the windshield while the vehicle is either moving forward or stopped, but is in gear. This is not marked if the driver is making a right turn.***
	Checking left rear-view mirror	***Driver is observing traffic in left rear-view mirror while moving forward or stopped, but the vehicle is in gear (i.e., stopped at an intersection).***
	Looking out left window	***Driver is observing traffic in left window while moving forward or stopped, but the vehicle is in gear (i.e., stopped at an intersection).***
	Checking right rear-view mirror	***Driver is observing traffic in right rear-view mirror while moving forward or stopped, but the vehicle is in gear (i.e., stopped at an intersection).***
	Looking out right window	***Driver is observing traffic in right window while moving forward or stopped, but the vehicle is in gear (i.e., stopped at an intersection).***
	Looking at instrument panel	***Driver is checking vehicle speed/temperature/RPMs while vehicle is moving or stopped, but is in gear.***

APPENDIX B: COPY OF QUESTIONNAIRES

DEMOGRAPHIC QUESTIONNAIRE

Subject ID # ___________

Please answer each of the following items.

1. What is your age in years: _________

2. Gender: _____ Male _____ Female

3. What is your highest level of education?
   a. Didn't complete high school
   b. High school graduate
   c. Some college
   d. 2-year college degree/trade school
   e. 4-year college degree
   f. Masters degree
   g. Professional degree
   h. Doctorate degree

4. What is your occupation: ____________________

5. What group do you identify yourself with
   a. Latino/Latina
   b. African-American
   c. Caucasian
   d. Middle Eastern
   e. Pacific Islander
   f. Asian
   g. Other ________________

6. How many years have you been driving? ______________

7. What type of driving do you usually do? (please indicate all that apply)
   a. Around town driving
   b. Commuting on freeways
   c. Commuting on other main roads
   d. Short distance travel (50-200-mile round trip)
   e. Middle distance travel (201-500-mile round trip)
   f. Long distance travel (>500-mile round trip)

DRIVING HISTORY – SUBJECT INTERVIEW

In the past year, how many moving or traffic violations have you had? ___________

What type of violation was it?

(1). ____________________
(2). ____________________
(3). ____________________
(4). ____________________
(5). ____________________

In the past year how many accidents have you been in? ________________

For each accident indicate the severity of the crash (select highest)

a. Injury
b. Tow-away (any vehicle)
c. Police-reported
d. Damage (any), but no police report

Using the diagram indicate each of the following: Category, Configuration, Accident type

	Accident 1	**Accident 2**	**Accident 3**	**Accident 4**	**Accident 5**
Accident Severity					
Accident Category					
Accident Configuration					
Accident Type					

Comments: ____
____
____
____

HEALTH ASSESSMENT

To the Participant: Please note that your responses to the following questions will in no way affect your ability to participate in the study. Your honest answers are appreciated

1. Do you have a history of any of the following?

a.	Stroke	Y	N
b.	Brain tumor	Y	N
c.	Head injury	Y	N
d.	Epileptic seizures	Y	N
e.	Respiratory disorders	Y	N
f.	Motion sickness	Y	N
g.	Inner ear problems	Y	N
h.	Dizziness, vertigo, or other balance problems	Y	N
i.	Diabetes	Y	N
j.	Migraine, tension headaches	Y	N
k.	Depression	Y	N
l.	Anxiety	Y	N
m.	Other psychiatric disorders	Y	N
n.	Arthritis	Y	N
o.	Auto-immune disorders	Y	N
p.	High blood pressure	Y	N
q.	Heart arrhythmias	Y	N
r.	Chronic fatigue syndrome	Y	N
s.	Chronic stress	Y	N

If yes to any of the above, please explain?

____

____

____

____

2. Are you currently taking any medications on a regular basis? Y N

If yes, please list them.

____

____

____

3. (Females only) Are you currently pregnant? Y N

4. Height __________

5. Weight __________lbs.

DULA DANGEROUS DRIVING INDEX

Please answer each of the following items as honestly as possible. Please read each item carefully and then circle the answer you choose on the form. If none of the choices seem to be your ideal answer, then select the answer that comes closest. THERE ARE NO RIGHT OR WRONG ANSWERS. Select your answers quickly and do not spend too much time analyzing your answers. If you change an answer, erase the first one well.

1. I drive when I am angry or upset.

   A. Never B. Rarely C. Sometimes D. Often E. Always

2. I lose my temper when driving.

   A. Never B. Rarely C. Sometimes D. Often E. Always

3. I consider the actions of other drivers to be inappropriate or "stupid."

   A. Never B. Rarely C. Sometimes D. Often E. Always

4. I flash my headlights when I am annoyed by another driver.

   A. Never B. Rarely C. Sometimes D. Often E. Always

5. I make rude gestures (e.g., giving "the finger," yelling curse words) toward drivers who annoy me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

6. I verbally insult drivers who annoy me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

7. I deliberately use my car/truck to block drivers who tailgate me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

8. I would tailgate a driver who annoys me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

9. I "drag race" other drivers at stop lights to get out front.

   A. Never B. Rarely C. Sometimes D. Often E. Always

10. I will illegally pass a car/truck that is going too slowly.

   A. Never B. Rarely C. Sometimes D. Often E. Always

11. I feel it is my right to strike back in some way, if I feel another driver has been aggressive toward me.

   A. Never B. Rarely C. Sometimes D. Often E. Always

12. When I get stuck in a traffic jam I get very irritated.

   A. Never B. Rarely C. Sometimes D. Often E. Always

13. I will race a slow moving train to a railroad crossing.

   A. Never B. Rarely C. Sometimes D. Often E. Always

14. I will weave in and out of slower traffic.

A. Never B. Rarely C. Sometimes D. Often E. Always

15. I will drive if I am only mildly intoxicated or buzzed.

A. Never B. Rarely C. Sometimes D. Often E. Always

16. When someone cuts me off, I feel I should punish him/her.

A. Never B. Rarely C. Sometimes D. Often E. Always

17. I get impatient and/or upset when I fall behind schedule when I am driving.

A. Never B. Rarely C. Sometimes D. Often E. Always

18. Passengers in my car/truck tell me to calm down.

A. Never B. Rarely C. Sometimes D. Often E. Always

19. I get irritated when a car/truck in front of me slows down for no reason.

A. Never B. Rarely C. Sometimes D. Often E. Always

20. I will cross double yellow lines to see if I can pass a slow moving car/truck.

A. Never B. Rarely C. Sometimes D. Often E. Always

21. I feel it is my right to get where I need to go as quickly as possible.

A. Never B. Rarely C. Sometimes D. Often E. Always

22. I feel that passive drivers should learn how to drive or stay home.

A. Never B. Rarely C. Sometimes D. Often E. Always

23. I will drive in the shoulder lane or median to get around a traffic jam.

A. Never B. Rarely C. Sometimes D. Often E. Always

24. When passing a car/truck on a 2-lane road, I will barely miss on-coming cars.

A. Never B. Rarely C. Sometimes D. Often E. Always

25. I will drive when I am drunk.

A. Never B. Rarely C. Sometimes D. Often E. Always

26. I feel that I may lose my temper if I have to confront another driver.

A. Never B. Rarely C. Sometimes D. Often E. Always

27. I consider myself to be a risk-taker.

A. Never B. Rarely C. Sometimes D. Often E. Always

28. I feel that most traffic "laws" could be considered as suggestions.

A. Never B. Rarely C. Sometimes D. Often E. Always

SLEEP HYGIENE QUESTIONNAIRE

Using the following rating scale, to what extent do you currently experience the following?

	None				Moderate					Severe
Daytime sleepiness	1	2	3	4	5	6	7	8	9	10
Snoring	1	2	3	4	5	6	7	8	9	10
Difficulty Falling Asleep	1	2	3	4	5	6	7	8	9	10
Difficulty Staying Asleep	1	2	3	4	5	6	7	8	9	10
Difficulty Waking Up	1	2	3	4	5	6	7	8	9	10
Daytime Sleepiness	1	2	3	4	5	6	7	8	9	10
Obtain Too Little Sleep	1	2	3	4	5	6	7	8	9	10

Read through the following questions carefully and answer each as accurately as possible:

1. When you are working:
what time do you go to bed ____:____ a.m./p.m. and wake up ____:____ a.m./p.m.

2. When you are not working:
what time do you go to bed ____:____ a.m./p.m. and wake up ____:____ a.m./p.m.

3. Do you keep a fairly regular sleep schedule? Yes_____ No_____

4. How many hours of actual sleep do you usually get? ________

5. Do you consider yourself a light, normal, or heavy sleeper? ________________

6. Do you feel uncomfortably sleepy during the day? never_____ every day_____
more than once per week_____ once per week _____ a few times a month _____
once a month or less_____

7. Do you ever have an irresistible urge to sleep or find that you fall asleep in unusual/ inappropriate situations? never_____ every day_____ more than once per week_____
once per week _____ a few times a month _____ once a month or less_____

8. Do you usually nap during the day (or between major sleep periods)?
Yes_____ No_____

9. Do you drink caffeinated beverages (coffee, tea, Coca-Cola, Mountain Dew, Jolt Cola)?
Yes_____ No_____

10. If yes, how many cups/glasses per day? __________________

11. How often do you drink alcohol? never_____ every day_____
more than once per week_____ once per week _____ once a month or less_____

12. Do you smoke cigarettes, cigars, pipe or chew or snuff tobacco? Yes_____ No_____

13. If yes, how often? __________________________

PRIMARY SLEEP DISORDERS

14. Have you ever been diagnosed with or suffer from any of the following sleep disorders?

Narcolepsy	Yes	No
Sleep Apnea	Yes	No
Periodic Limb Movement	Yes	No
Restless Leg Syndrome	Yes	No
Insomnia	Yes	No

DRIVER STRESS INVENTORY

Please answer the following questions on the basis of your usual or typical feelings about driving. Each question asks you to answer according to how strongly you agree with one of two alternative answers. Please read each of the two alternatives carefully before answering. To answer, circle the number which expresses your answer most accurately.

Example: Are you a confident driver?

1 2 3 4 5 6 7 8 9 10

Not at all — Very Much

1. Does it worry you to drive in bad weather?

   1 2 3 4 5 6 7 8 9 10

   Very Much — Not at all

2. I am disturbed by thoughts of having an accident or the car breaking down.

   1 2 3 4 5 6 7 8 9 10

   Very Rarely — Very Often

3. Do you lose your temper when another driver does something silly?

   1 2 3 4 5 6 7 8 9 10

   Not at all — Very much

4. Do you think you have enough experience and training to deal with risky situations on the road safely?

   1 2 3 4 5 6 7 8 9 10

   Not at all — Very much

5. I find myself worrying about my mistakes and the things I do badly when driving.

   1 2 3 4 5 6 7 8 9 10

   Very rarely — Very often

6. I would like to risk my life as a racing driver.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

7. My driving would be worse than usual in an unfamiliar rental car.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

8. I sometimes like to frighten myself a little while driving.

1 2 3 4 5 6 7 8 9 10

Very much Not at all

9. I get a real thrill out of driving fast.

1 2 3 4 5 6 7 8 9 10

Very much Not at all

10. I make a point of carefully checking every side road I pass for emerging vehicles.

1 2 3 4 5 6 7 8 9 10

Very Much Not at all

11. Driving brings out the worst in people.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

12. Do you think it is worthwhile taking risks on the road?

1 2 3 4 5 6 7 8 9 10

Very much Not at all

13. At times, I feel like I really dislike other drivers who cause problems for me.

1 2 3 4 5 6 7 8 9 10

Very much Not at all

14. Advice on driving from a passenger is generally:

1 2 3 4 5 6 7 8 9 10

Useful Unnecessary

15. I like to raise my adrenaline levels while driving.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

16. It's important to show other drivers that they can't take advantage of you.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

17. Do you feel confident in your ability to avoid an accident?

1 2 3 4 5 6 7 8 9 10

Not at all Very much

18. Do you usually make an effort to look for potential hazards when driving?

1 2 3 4 5 6 7 8 9 10

Not at all Very much

19. Other drivers are generally to blame for any difficulties I have on the road.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

20. I would enjoy driving a sports car on a road with no speed-limit.

1 2 3 4 5 6 7 8 9 10

Very much Not at all

21. Do you find it difficult to control your temper when driving?

1 2 3 4 5 6 7 8 9 10

Very much Not at all

22. When driving on an unfamiliar road do you become more tense than usual?

1 2 3 4 5 6 7 8 9 10

Very much Not at all

23. I make a special effort to be alert even on roads I know well.

1 2 3 4 5 6 7 8 9 10

Very much Not at all

24. I enjoy the sensation of accelerating rapidly.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

25. If I make a minor mistake when driving, I feel it's something I should be concerned about

1 2 3 4 5 6 7 8 9 10

Very much Not at all

26. I always keep an eye on parked cars in case somebody gets out of them, or there are pedestrians behind them.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

27. I feel more anxious than usual when I have a passenger in the car.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

28. I become annoyed if another car follows very close behind mine for some distance

1 2 3 4 5 6 7 8 9 10

Very much Not at all

29. I make an effort to see what's happening on the road a long way ahead of me.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

30. I try very hard to look out for hazards even when it's not strictly necessary.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

31. Are you usually patient during the rush hour?

1 2 3 4 5 6 7 8 9 10

Very much Not at all

32. When you pass another vehicle do you feel in command of the situation?

1 2 3 4 5 6 7 8 9 10

Not at all Very much

33. When you pass another vehicle do you feel tense or nervous?

1 2 3 4 5 6 7 8 9 10

Not at all Very much

34. Does it annoy you to drive behind a slow moving vehicle?

1 2 3 4 5 6 7 8 9 10

Very much Not at all

35. When you're in a hurry, other drivers usually get in your way.

1 2 3 4 5 6 7 8 9 10

Not at all Very much

36. When I come to negotiate a difficult stretch of road, I am on the alert.

1 2 3 4 5 6 7 8 9 10

Very much Not at all

37. Do you feel more anxious than usual when driving in heavy traffic?

1	2	3	4	5	6	7	8	9	10
Not at all									Very much

38. I enjoy cornering at high speeds.

1	2	3	4	5	6	7	8	9	10
Not at all									Very much

39. Are you annoyed when the traffic lights change to red when you approach them?

1	2	3	4	5	6	7	8	9	10
Very much									Not at all

40. Does driving, usually make you feel aggressive?

1	2	3	4	5	6	7	8	9	10
Very much									Not at all

41. Think about how you feel when you have to drive for several hours, with few or no breaks from driving. How do your feelings change during the course of the drive?

a)	More uncomfortable physically (e.g., headache or muscle pains)	1	2	3	4	5	6	7	8	9	10 No change
b)	More drowsy or sleepy	1	2	3	4	5	6	7	8	9	10 No change
c)	Maintain speed of reaction	1	2	3	4	5	6	7	8	9	10 Reactions to other traffic becomes increasingly slower
d)	Maintain attention to road-signs	1	2	3	4	5	6	7	8	9	10 Become inattentive to road-signs

e)	Normal vision	1	2	3	4	5	6	7	8	9	10 Vision becomes less clear
f)	Increasingly difficult to judge your speed	1	2	3	4	5	6	7	8	9	10 Normal judgment of speed
g)	Interest in driving does not change	1	2	3	4	5	6	7	8	9	10 Increasingly bored and fed up
h)	Passing becomes increasingly risky and dangerous	1	2	3	4	5	6	7	8	9	10 No change

LIFE STRESS INVENTORY

Please read through the following events carefully. Mark each event which occurred within the past year.

____ Death of spouse or parent

____ Divorce

____ Marital separation or separation from living partner

____ Jail term

____ Death of close family member

____ Personal injury or illness

____ Fired from job

____ Marital or relationship reconciliation

____ Retirement

____ Change in health of family member

____ Pregnancy

____ Sex difficulties

____ Gain of new family member

____ Business readjustment

____ Change in financial state

____ Death of close friend

____ Change to different line of work or study

____ Change in number of arguments with spouse or partner

____ Mortgage or loan for major purchase (home, etc.)

____ Foreclosure of mortgage or loan

____ Change in responsibilities at work

____ Son or daughter leaves

____ Trouble with in-laws/partner's family

____ Outstanding personal achievement

____ Mate begins or stops work

____ Change in living conditions

____ Marriage/establishing life partner

____ Change in personal habit

____ Trouble with boss

____ Change in work hours or conditions

____ Change in residence

____ Change in schools

____ Change in church activities

____ Change in recreation

____ Change in social activities

____ Minor loan (car, TV, etc)

____ Change in sleeping habits

____ Change in number of family get-togethers

____ Change in eating habits

____ Vacation

____ Christmas (if approaching)

____ Minor violation of the law

APPENDIX C: DATA REDUCTION VARIABLES

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 seconds 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 one minute prior to the onset of the initial trigger and 30 seconds 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-subject 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 subject vehicle to any other vehicle, pedestrian, cyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, cyclists 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 subject vehicle. Any other vehicle, pedestrian, cyclist, 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 subject vehicle is defined as a control input that falls inside of the 99 percent confidence limit for control input as measured for the same subject.

Near-crash - Any circumstance that requires a rapid, evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash. 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. As a guide: subject 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, cyclists or animals.

Comment: Initial coding step. Invalid events result in no further coding. Non-subject 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 percent of the data were collected. The specific data signatures that were used to identify valid events are as follows:

Lateral acceleration - Lateral motion equal or greater than 0.7 g.
Longitudinal acceleration - Acceleration or deceleration equal 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 seconds or less.
All longitudinal decelerations between 0.4 g and 0.5 g coupled with a forward TTC value of $\leq$ 4 seconds and that the corresponding forward range value at the minimum TTC is not greater than 100 feet.
Rear Time To Collision (RTTC) - Any rear TTC trigger value of 2 seconds or less that also has a corresponding rear range distance of $\leq$ 50 feet 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 subject 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-degree change in heading (i.e., vehicle must return to the same general direction of travel) within a 3-second window of time.

5. Driver Subject Number (C-N-I-B)
All primary drivers' subject 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 an oncoming traffic
4=Conflict with a vehicle in adjacent lane
5=Conflict with a merging vehicle
6=Conflict with a vehicle turning across subject vehicle path (same direction)
7=Conflict with a vehicle turning across subject vehicle path (opposite direction)
8=Conflict with a vehicle turning into subject vehicle path (same direction)
9=Conflict with a vehicle turning into subject vehicle path (opposite direction)
10 =Conflict with a vehicle moving across subject vehicle path (through intersection)
11=Conflict with a parked vehicle
12=Conflict with a pedestrian
13=Conflict with a pedal cyclist
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 subject 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, drowsiness, 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 seconds
018b = Ahead, decelerated and stopped on roadway 2 seconds 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 seconds
050b = Ahead, decelerated and stopped on roadway 2 seconds 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

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 nonmotorist in roadway
084 = Pedalcyclist/other nonmotorist approaching roadway
085 = Pedalcyclist/or other nonmotorist unknown location
086 = Pedestrian/pedalcyclist/other nonmotorist—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 subject 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
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, and 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 seconds 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

= 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

= Dining
13a = Eating with a utensil
13b = Eating without a utensil
13c = Drinking from a covered container (i.e., straw)
13d = Drinking from an uncovered container

= 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 make-up
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 rear-view mirror
19c = Center rear-view mirror
19d = Right rear-view 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 3 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 4 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 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 seconds prior to the event based on review of driver videos. For drowsiness levels above a criterion level of and 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-and-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 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 whether there 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
9 = Other
99 = Unknown

DRIVER STATE VARIABLES

1. Driver 1 Hands on Wheel (C-N-I-B)
Reductionists will 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 (subject 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. Observer Rating of Drowsiness (ORD)

For crashes and near-crashes, reductionists rated the driver's drowsiness on a scale of 0-100. The procedure for measuring ORD was developed and first used by Wierwille and Ellsworth (1994).   This scale is broken down as is shown in Figure C-1.

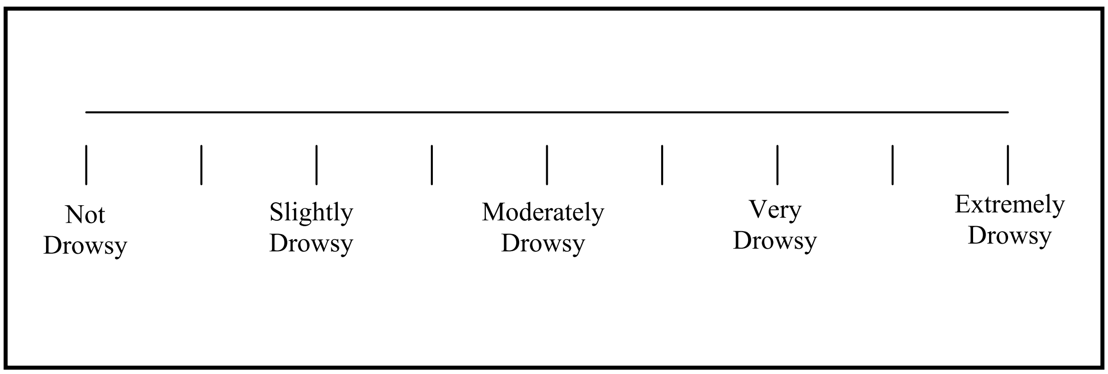

Figure C-1. The observer rating of drowsiness scale where not drowsy is equal to 0 and extremely drowsy is equal to 100.

Reductionists were instructed to watch the driver's face and body language for a period of time prior to the trigger. As described by Wierwille and Ellsworth (1994), signs indicative of drowsiness include rubbing face or eyes, facial contortions, moving restlessly in the seat, and slow eyelid closures. Reductionists were trained to look for these signs of drowsiness and make a subjective but specific assessment of the level of drowsiness. After watching the video data, reductionists employed a rating scale to record an ORD level. Please note that for a driver to be considered '"drowsy" in all of the analyses in this report, the ORD rating needed to be 60 or higher. The specific drowsy behaviors that reductionists used to rate a driver's drowsiness level were as follows:

- **Not Drowsy:** A driver who is <u>not drowsy</u> while driving will exhibit behaviors such that the appearance of alertness will be present. For example, normal facial tone, normal fast eye blinks, and short ordinary glances may be observed. Occasional body movements and gestures may occur.

- **Slightly Drowsy:** A driver who is slightly drowsy while driving may not look as sharp or alert as a driver who is not drowsy. Glances may be a little longer and eye blinks may not be as fast. Nevertheless, the driver is still sufficiently alert to be able to drive.

- **Moderately Drowsy:** As a driver becomes moderately drowsy, various behaviors may be exhibited. These behaviors, called mannerisms, may include rubbing the face or eyes, scratching, facial contortions, and moving restlessly in the seat, among others. These actions can be thought of as countermeasures to drowsiness. They occur during the intermediate stages of drowsiness. Not all individuals exhibit mannerisms during intermediate stages. Some individuals appear more subdued, they may have slower closures, their facial tone may decrease, they may have a glassy-eyed appearance, and they may stare at a fixed position.

- **Very Drowsy:** As a driver becomes very drowsy eyelid closures of 2 to 3 seconds or longer usually occur. This is often accompanied by a rolling upward or sideways movement of the eyes themselves. The individual may also appear not to be focusing the eyes properly, or may exhibit a cross-eyed (lack of proper vergence) look. Facial tone will probably have decreased. Very drowsy drivers may also exhibit a lack of apparent activity and there may be large isolated (or punctuating) movements, such as providing a large correction to steering or reorienting the head from a leaning or tilted position.

- **Extremely Drowsy:** Drivers who are extremely drowsy are falling asleep and usually exhibit prolonged eyelid closures (4 seconds or more) and similar prolonged periods of lack of activity. There may be large punctuated movements as they transition in and out of intervals of dozing.

6. 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 seconds pre-event period will be obtained through video reduction.

7. Driver 1 Eyeglance Reconstruction (C-N)
Eyeglances for the previous 30 seconds 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, eyeglances 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 eyeglance 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/Person (s)
Reductionists will identify the number of vehicles in the immediate environment and then record the following variables.

2. Location of other Vehicle/Persons
Reductionists will identify the location of vehicles in the immediate environment with respect to the subject vehicle and then record the following variables.

A = In front of subject vehicle
B = In front and to the immediate right of the subject vehicle
C = On the right side of the subject vehicle, closer to front seat of the vehicle.
D = On the right side of the subject vehicle, closer to rear seat of the vehicle.
E = Behind and to the immediate right of the subject vehicle.
F = Behind the subject vehicle
G = Behind and to the immediate left of the subject vehicle.
H = On the left side of the subject vehicle, closer to the rear seat of the vehicle.
I = On the left side of the subject vehicle, closer to the front seat of the vehicle.
J = In front and to the immediate left of the subject vehicle.

3. Vehicle/Person 2 Type (Modified version of GES Variable V5, Body Type)
Data reductionists will record what type of vehicles that are in the subject 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: Multistop/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 = Cyclist
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 subject 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 that a police accident report form is collected from the subject.

0 = None apparent
1 = Drowsy, sleepy, asleep
2 = Ill, blackout
3a = Angry
3b = Other emotional state
4 = Drugs and 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 subject 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 D: ANOVA TABLES

Table D-1. T-test summary table for Driver Attentiveness (Driver Age).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Age					
Attention Category	1	1371.7638	1371.764	7.07	0.0091

Table D-2. T-test summary table for Driver Attentiveness (Male Driver's Age).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Age/Male					
Attention Category	1	294.02362	294.0236	1.63	0.2066

Table D-3. T-test summary table for Driver Attentiveness (Female Driver's Age).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Age/Female					
Attention Category	1	1031.7459	1031.746	4.9	0.0328

Table D-4. T-test summary table for Driver Attentiveness (Years of Driving Experience).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Experience					
Attention Category	1	1482.5217	1482.522	7.6	0.0069

Table D-5. T-test summary table for Driver Attentiveness (Number of Traffic Violations).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Violations					
Attention Category	1	18.324647	18.32465	4.9	0.029

Table D-6. T-test summary table for Driver Attentiveness (Number of Accidents).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Accidents					
Attention Category	1	0.1762382	0.176238	0.08	0.7764

Table D-7. T-test summary table for Driver Attentiveness (Number of Illnesses).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Illness					
Attention Category	1	0.2442525	0.244252	0.12	0.7337

Table D-8. T-test summary table for Driver Attentiveness (Daytime Sleepiness Rating).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Daytime Sleepiness Rating					
Attention Category	1	16.615563	16.61556	3.61	0.0602

Table D-9. T-test summary table for Driver Attentiveness (Number of Hours of Sleep).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Number of Hours of Sleep					
Attention Category	1	0.0491863	0.049186	0.05	0.8157

Table D-10. T-test summary table for Driver Attentiveness (Life Stress Score).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Life Stress Score					
Attention Category	1	9824.6815	9824.682	0.8	0.3754

Table D-11. T-test summary table for driver attentiveness for Driver Behavior Questionnaire.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Aggression					
Attention Category	1	123.64634	123.6463	0.57	0.4526

Table D-12. T-test summary table for driver attentiveness Driver Behavior Questionnaire.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Dislike of Driving					
Attention Category	1	32.855265	32.85527	0.31	0.5785

Table D-13. T-test summary table for driver attentiveness Driver Behavior Questionnaire.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Hazard Monitoring					
Attention Category	1	362.16148	362.1615	2.66	0.1057

Table D-14. T-test summary table for driver attentiveness for Driver Behavior Questionnaire.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Thrill-seeking					
Attention Category	1	262.34811	262.3481	0.98	0.325

Table D-15. T-test summary table for driver attentiveness for Driver Behavior Questionnaire.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Drowsiness Proneness					
Attention Category	1	202.42993	202.4299	1.15	0.2868

Table D-16. T-test summary table for driver attentiveness and the Dula Dangerous Driving Questionnaire.

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: DDDI					
Attention Category	1	117.71573	117.7157	0.94	0.3344

Table D-17. T-test summary table for driver attentiveness the Dula Dangerous Driving Questionnaire.

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Negative Emotion					
Attention Category	1	15.387279	15.38728	0.66	0.4181

Table D-18. T-test summary table for driver attentiveness the Dula Dangerous Driving Questionnaire.

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Aggressive Driving					
Attention Category	1	2.8125107	2.812511	0.19	0.6652

Table D-19. T-test summary table for driver attentiveness the Dula Dangerous Driving Questionnaire.

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Risky Driving					
Attention Category	1	24.275174	24.27517	1.29	0.2587

Table D-20. T-test summary table for driver attentiveness for the NEO Five-Factor Personality Inventory.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Neuroticism					
Attention Category	1	734.107	734.107	2.75	0.1004

Table D-21. T-test summary table for driver attentiveness for the NEO Five-Factor Personality Inventory.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Extroversion					
Attention Category	1	976.01176	976.0118	7.03	0.0093

Table D-22. T-test summary table for driver attentiveness for the NEO Five-Factor Personality Inventory.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Openness					
Attention Category	1	537.18718	537.1872	4.03	0.0473

Table D-23. T-test summary table for driver attentiveness for the NEO Five-Factor Personality Inventory.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Agreeableness					
Attention Category	1	941.01129	941.0113	8.26	0.0049

Table D-24. T-test summary table for driver attentiveness for the NEO Five-Factor Personality Inventory.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Conscientiousness					
Attention Category	1	554.77672	554.7767	6.62	0.0115

Table D-25. T-test summary table for Driver Attentiveness.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Channel Capacity					
Attention Category	1	0.4384058	0.438406	0.1	0.7526

Table D-26. T-test summary table for driver attentiveness for the Waypoint Performance-Based Test.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Preventable Near-Crash/Crash Risk					
Attention Category	1	1.0471015	1.047101	2.05	0.1555

Table D-27. T-test summary table for driver attentiveness for the Waypoint Performance-Based Test.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Expected # of Moving Violations in the Next 5 Years					
Attention Category	1	0.0036232	0.003623	0.01	0.9299

Table D-28. T-test summary table for driver attentiveness for the Waypoint Performance-Based Test.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Expected Seat Belt Use					
Attention Category	1	0.0664504	0.06645	0.57	0.4539

Table D-29. T-test summary table for driver attentiveness for the Useful Field of View Performance-Based Test.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: UFOV					
Attention Category	1	5.9753086	5.975309	1.39	0.2404

Analysis of Variance Tables for Driver Attentiveness

Table D-30. ANOVA summary table for Driver Attentiveness (Driver Age).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Age					
Attention Category	2	2538.22963	1269.11481	6.77	0.0017

Table D-31. ANOVA summary table for Driver Attentiveness (Years of Driving Experience).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Experience					
Attention Category	2	2858.6439	1429.322	7.69	0.0008

Table D-32. ANOVA summary table for Driver Attentiveness (Number of Traffic Violations).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Violations					
Attention Category	2	38.949862	19.47493	5.54	0.0052

Table D-33. ANOVA summary table for Driver Attentiveness (Number of Accidents).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Accidents					
Attention Category	2	19.292393	9.646197	4.88	0.0094

Table D-34. ANOVA summary table for Driver Attentiveness (Daytime Sleepiness Rating).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Daytime Sleepiness Rating					
Attention Category	2	35.005781	17.50289	3.8	0.0255

Table D-35. ANOVA summary table for Driver Attentiveness (Hours of Sleep).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Hours of Sleep					
Attention Category	2	1.1631296	0.581565	0.65	0.5258

Table D-36. ANOVA summary table for driver attentiveness for Driver Behavior Questionnaire (Aggression).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Aggression					
Attention Category	2	123.14055	61.57028	0.29	0.7522

Table D-37. ANOVA summary table for driver attentiveness for Driver Behavior Questionnaire (Dislike).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Dislike of Driving					
Attention Category	2	37.498264	18.74913	0.17	0.8405

Table D-38. ANOVA summary table for driver attentiveness for Driver Behavior Questionnaire (Hazard).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Hazard Monitoring					
Attention Category	2	791.19383	395.5969	2.9	0.0594

Table D-39. ANOVA summary table for driver attentiveness for Driver Behavior Questionnaire (Thrill-seeking).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Thrill-seeking					
Attention Category	2	224.13074	112.0654	0.41	0.6661

Table D-40. ANOVA summary table for Driver Attentiveness Driver Behavior Questionnaire (Drowsiness).

Source of Variation	**df**	**SS**	**MS**	**F value**	***p* value***
Dependant Variable: Drowsiness Proneness					
Attention Category	2	63.21934	31.60967	0.18	0.8377

Table D-41. ANOVA summary table for driver attentiveness for the Dula Dangerous Driving Inventory (DDDI).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: DDDI					
Attention Category	2	368.34603	184.173	1.52	0.2238

Table D-42. ANOVA summary table for driver attentiveness for the Dula Dangerous Driving Inventory (NE).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Negative Emotional					
Attention Category	2	116.1119	58.05595	2.64	0.0762

Table D-43. ANOVA summary table for driver attentiveness for the Dula Dangerous Driving Inventory (AD).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Aggressive Driving					
Attention Category	2	4.8314514	2.415726	0.16	0.8501

Table D-44. ANOVA summary table for driver attentiveness for the Dula Dangerous Driving Inventory (RD).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Risky Driving					
Attention Category	2	46.012434	23.00622	1.21	0.3033

Table D-45. ANOVA summary table for driver attentiveness for the Useful Field of View.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: UFOV					
Attention Category	1	23.945798	11.9729	2.47	0.0887

Table D-46. ANOVA summary table for driver attentiveness for the NEO Five-Factor Personality Inventory (N).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Neuroticism					
Attention Category	2	544.88275	272.4414	1.05	0.3549

Table D-47. ANOVA summary table for driver attentiveness for the NEO Five-Factor Personality Inventory (E).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Extroversion					
Attention Category	2	531.03909	265.5195	1.96	0.1461

Table D-48. ANOVA summary table for driver attentiveness for the NEO Five-Factor Personality Inventory (O).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Openness					
Attention Category	2	258.81916	129.4096	0.96	0.3853

Table D-49. ANOVA summary table for driver attentiveness for the NEO Five-Factor Personality Inventory (A).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Agreeableness					
Attention Category	2	819.18283	409.5914	3.77	0.0261

Table D-50. ANOVA summary table for driver attentiveness for the NEO Five-Factor Personality Inventory (C).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Consciousness					
Attention Category	2	486.96632	243.4832	3.05	0.0512

Table D-51. ANOVA summary table for driver attentiveness for the waypoint performance-based test (channel 1).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Channel Capacity					
Attention Category	2	6.0800916	3.040046	0.7	0.4968

Table D-52. ANOVA summary table for driver attentiveness for the waypoint performance-based test (pcr).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Preventable Near-Crash/Crash Risk					
Attention Category	2	0.7911188	0.395559	0.79	0.4588

Table D-53. ANOVA summary table for driver attentiveness for the waypoint performance-based test (mvr).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Expected # of Moving Violations in the Next 5 Years					
Attention Category	2	0.0735243	0.036762	0.08	0.9262

Table D-54. ANOVA summary table for driver attentiveness for the waypoint performance-based test (seatbelt).

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Expected Seat Belt Use					
Attention Category	2	0.1220738	0.061037	0.54	0.5835

Analysis of Variance Tables for Chapter 6

Table D-55. ANOVA summary table for eyeglance for total time eyes off the forward roadway.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Total Time					
Severity	3	175.797	58.599	33.36	<.0001

Table D-56. ANOVA summary table for eyeglance for number of eyeglances.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Number of Glances					
Severity	3	127.34777	42.44926	22.02	<.0001

Table D-57. ANOVA summary table for eyeglance for length of longest glance.

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Length of Longest Glance					
Severity	3	134.75325	44.91775	34.94	<.0001

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