ASSESSING THE EFFECTS OF DRIVING INATTENTION ON RELATIVE CRASH RISK

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ABSTRACT

While driver distraction has been extensively studied in laboratory and empirical field studies, the prevalence of driver distraction on our nation's highways and the relative crash risk is unknown. It has recently become technologically feasible to conduct unobtrusive large-scale naturalistic driving studies as the costs and size of computer equipment and sensor technology have both dramatically decreased.

A large-scale naturalistic driving study was conducted using 100 instrumented vehicles (80 privately-owned and 20 leased vehicles). This data collection effort was conducted in the Washington DC metropolitan area on a variety of urban, suburban, and rural roadways over a span of 12-13 months. Five channels of video and kinematic data were collected on 69 crashes and 761 near-crashes during the course of this data collection effort.

The analyses conducted here are the first to establish direct relationships between driving inattention and crash and near-crash involvement. Relative crash risk was calculated using both crash and near-crash data as well as normal, baseline driving data, for various sources of inattention. Additional analyses investigated the environmental conditions drivers choose to engage in secondary tasks or drive fatigued, assessed whether questionnaire data were indicative of an individual's propensity to engage in inattentive driving, and examined the impact of driver's eyes off the forward roadway.

The results indicated that driving inattention was a contributing factor in 78% of all crashes and 65% of all near-crashes. Odds ratio calculations indicated that fatigued drivers have a 4 times higher crash risk than alert drivers. Drivers engaging in visually and/or manually complex tasks are at 7 times higher crash risk than alert drivers. There are specific environmental conditions in which engaging in secondary tasks or driving fatigued is deemed to be more dangerous, including intersections, wet roadways, undivided highways, curved roadways, and driving at dusk. Short, brief glances away from the forward roadway for the purpose of scanning the roadway environment (e.g., mirrors and blind spots) are safe and decrease crash risk, whereas such glances that total more than 2 seconds away from the forward roadway are dangerous and increase crash risk by 2 times over that of more typical driving.

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DEDICATION

To Ken, for all of your encouragement and confidence throughout this academic journey. It would not have been possible without you. It would not have even started…

To my parents, for your unconditional love and support.

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1. LITERATURE REVIEW

Introduction

Crashes on US roadways kill over 40,000 people, injure over 2,000,000 people, and cost the US economy over $1 billion every year. While driver distraction has widely been considered a contributing factor in at least 25% of all crashes (Wang, Knipling, and Goodman, 1996; Treat, 1980), many researchers argue that this estimate is low. This low estimation is based on the fact that the data rely on epidemiological data collected primarily from police accident reports. These reports are highly dependent upon either the driver admitting to being inattentive or an eyewitness reporting that the driver was inattentive. Few accidents have an eyewitness, and most drivers will not volunteer that information to the investigating officer in fear of a traffic citation and/or increased insurance costs.

Empirical research has used dependent variables (also known as *safety surrogate measures*) such as lateral deviation, longitudinal acceleration/deceleration, time to collision, eyeglance frequency, and glance location to gain insight and understanding into the impacts of driver distraction on driving performance. Researchers have devised experimental protocols on test tracks and simulators and have collected driving performance data for these safety surrogate measures. While this research is important and useful to understanding whether these behaviors cause decrements in driving performance, it is largely unknown how these decrements in driving performance transfer to relative crash risk on roadways (Hancock, Lesch, and Simmons, 2003; Dingus, 1995).

Questionnaire, survey, and observational data have also been used extensively to assess the correlations and associations between involvement in crashes and driving inattention. Many studies have been conducted using phone or personal interviews to assess driver's involvement in crashes and to determine whether drivers were engaging in inattention-related tasks, such as using a cell phone or talking to passengers, near the time of the crash (McEvoy, Stevenson, McCartt, Woodward, Haworth, Palamara, & Cercarelli, 2005; Reidelmeier & Tibshirani, 1997a). Other researchers have used observational techniques of recording license plates and cell phone use at busy intersections and either matching DMV records or assessing frequency of use (Eby & Vivoda, 2003; Glassbrenner, 2005). While these studies have demonstrated strong associations between driving inattention and crash involvement, surveys and observational techniques cannot assess causation. The correlations that this type of research show may have more to do with the type of individuals who are willing to respond to such testing techniques than to the construct being measured.

The impact of environmental situations on drivers willingness to engage in secondary distraction tasks and/or drive while fatigued is an area of research that has not been explored extensively. While much driving research cites higher crash rates at intersections, during adverse weather conditions, during nighttime driving, and with high traffic densities, very little research has explored the impact of driving inattention during these environmental conditions (Traffic Safety Facts, 2004; Hancock, Lesch, & Simmons, 2003). This lack is primarily due to difficulties in assessing these situations in real-world conditions without placing research participants in dangerous situations.

Research in the area of driver distraction has been on-going, primarily because cell phone and other telemetric industries are continuing to sell products, which people then use in their vehicles. While organizations such as the Society of Automobile Engineers (SAE) and the Alliance of Automobile Manufacturers have developed design guidelines to assist human factors engineers in the design of such systems, many of these guidelines have been deemed inadequate. Researchers argue that the guidelines are generally too broad and do not take into account actual driving data. Unfortunately, how drivers actually use these cell phones and other telematic devices in the real world driving environment is unknown. Without this information, researchers are unable to assess the adequacy of these design guidelines.

The field of transportation research currently lacks a full understanding of distracted driving behavior in the natural roadway environment. Current technology has made unobtrusive in-vehicle data collection systems an economically feasible option in collecting large-scale naturalistic driving data. Several federal regulating agencies are currently funding studies to obtain a better, holistic understanding of safe driving behavior. These large-scale naturalistic driving studies are the ideal mechanism to bridge the gap of understanding between epidemiological research (such as studies using crash databases) and empirical research (such as studies using instrumented vehicles with an experimenter present).

With large scale studies (those performed over a long duration with a large number of vehicles), enough crash data can be collected to determine the prevalence of driving distraction as well as the relative crash risk associated with driving distraction. Also, the data collection systems can capture the corresponding driving performance data both prior to and during the crashes, providing much needed pre-crash and crash driving data to compare to near-crash and normal driving. Such comparisons would allow a greater understanding of how driving behavior and driving performance directly contribute to the occurrence of crashes. This knowledge can then be applied to assess the usefulness and importance of current design guidelines for in-vehicle communication, navigation, and travel advisory systems.

This chapter will present a summary of the state-of-the art in epidemiological, empirical, and qualitative inattention-related driving research, discuss the data reduction method of hazard analysis or critical incident analysis, and describe how research methods can be integrated using large-scale naturalistic driving data to:

1) Assess the prevalence of driver inattention and the impact of relative crash risk
2) Determine under what environmental conditions drivers choose to engage in inattention-related tasks
3) Assess whether psychological test batteries or computer-based tests are correlated or can predict a driver's willingness to engage in inattention-related tasks
4) Apply this information to assess the usefulness of current in-vehicle system guidelines, specifically those related to eyeglance behavior.

Review of Driving Inattention Research

Epidemiological Research

Epidemiological research has the advantage of external validity, large amounts of data spanning decades, and data taken directly from automobile crashes. Unfortunately, these data are generally reactive to a problem in that analyses are conducted once a problem is identified. It can be used to show trends, but it takes years to fully understand any trend in epidemiological research. There are two primary types of epidemiological research in transportation safety: data collected from crash databases and case-control studies.

The epidemiological data on driver distraction has been recently focused on cell phone use, with some notable exceptions. Treat (1980) conducted what has become the seminal work in epidemiological transportation research, the Indiana Tri-Level study. This study investigated crashes in Monroe County, Indiana from 1972 through 1977 using three graded levels of detail.

Treat investigated 13,568 crashes at a crash database level of detail, followed by on-scene crash investigations for 2,258 crashes. Finally, in-depth investigations were performed by a multidisciplinary team for 420 of the collisions. This study found that 15% of crashes were caused by driver inattention and that 9% of all collisions were caused by internal distraction, or diversion by an activity or event inside the vehicle (Treat, 1980).

Wang, Knipling, and Goodman (1996) also found similar results from a study using the National Accident Sampling System Crashworthiness Data System This study showed that 13.3% of all crashes were caused by driver distraction, 9.7% of crashes were caused by the driver 'looking but not seeing,' and 2.6% of crashes were caused by fatigue. A similar study conducted in England and Wales, using only fatal crashes over a ten year period, found that only 2% of fatal crashes were caused by distraction (Stevens & Minton, 2001). Some of this discrepancy could due to differences in police reporting techniques or to the fact that only fatal crashes were examined.

Some of the most widely cited epidemiological studies come from the medical community. Redelmeier & Tibshirani (1997a) conducted one of the more highly publicized studies of cell phone use and motor vehicle collisions. They conducted a case-control study using 699 drivers who both (1) owned cell phones and (2) were involved in motor vehicle collisions with substantial property damage but no injuries. Each person's cell phone calls on the day of the collision and during the week prior to the collision were analyzed through the use of billing records. Results showed that the relative crash risk of using a cell phone while in the vehicle was 4.3 times that of normal driving. The same authors then published another article comparing these results to driving under the influence of alcohol. They stated that driving at the legal limit is similar to driving with a cell phone; however, with a blood alcohol level of 0.05%, a driver would be 10 times as likely to be involved in a collision (Redelmeier & Tibshirani, 1997b).

Violanti (1998) conducted a case-control study investigating fatal crashes and cell phone involvement. His results suggest that driving with a cell phone increases crash risk by a factor of 2 over the risk of normal driving. He also argues that combined factors such as phone use, driving on the left side of the lane, and driver inattention all increased fatality risk more than phone use by itself.

A third study that used similar methods to Redelmeier and Tibshirani (1997) was recently completed in Australia (McEvoy, Stevenson, McCartt, Woodward, Haworth, Palamara, & Cercarelli, 2005). In this case-crossover study, experimenters interviewed crash victims in emergency rooms in three major hospitals in a metropolitan area. Participants were interviewed about their usual habits regarding cell phone use, description of the crash, cell phone use prior to crash, and type of cell phone. Medical records as well as cell phone records were then obtained, and cell phone use prior to the crash was obtained. Records for three other time periods (24 hours, 72 hours, and 7 days prior) were also obtained for control data. The results of this study indicated that mobile phone use while driving increases crash risk by 4 times that of normal driving.

The crash database studies discussed first are very informative and useful for estimating the overall safety of US highways as well as directing empirical research in areas where definite safety problems exist. The case-control studies are widely cited and publicized as they were published in the prestigious New England Journal of Medicine and the British Medical Journal; however, safety research experts have urged caution in the interpretation of these results. The studies operationally linked ‘cell phone use’ and ‘collision’ within a fairly large time period suggesting that a cell phone call 5 or even 10 minutes prior to a collision somehow caused or contributed to that collision. The driving conditions and traffic situations within a time period of 5 or 10 minutes can change dramatically, and thus caution is urged in the interpretation of these results.

Generally the epidemiological literature is the most divergent in its findings in that studies based on federally funded crash databases finds that driver distraction is a contributory cause in approximately 15-25% of all crashes. This is a significant portion of crashes; however, cell phones or in-vehicle displays contribute to only 2% of these crashes. Most safety researchers believe that cell phones may contribute to a greater percentage of crashes, based on the fact that most police accident reports do not record whether a cell phone or other in-vehicle device was present or in use during a collision (Stutts, 2005).

Empirical Research

While there are many types of driver distraction or sources of driving inattention, the act of conversation, whether on a cell phone or with a passenger, has recently become a highly publicized issue. There are two schools of thought on the problem of distracted driving in the field of empirical research: those researchers who argue that various forms of driver distraction may cause a general withdrawal of *visual attention* from the forward roadway (e.g. Ranney, 2005) and those researchers who argue that various types of driver distraction cause a selective withdrawal of *cognitive attention* (e.g. Strayer, Drews, & Couch, 2004, Strayer & Johnston, 2001). The empirical research conducted using driving simulators, test-tracks, and instrumented vehicles is discussed below highlighting those results relating to cognitive versus visual attention.

Simulator Studies. Most simulator studies that investigate driving inattention operationalize and control levels of driving inattention by incorporating secondary tasks of varying difficulty while measuring driving performance in a roadway environment. Participants navigate a simulated roadway while performing some type of secondary task such as conversing with an experimenter, monitoring displays/devices, or using a new in-vehicle technology, such as cell phone (hands held or hand-free), satellite radio system, entertainment system, navigational device, internet, email, and text messaging. Simulators provide a safe method in which to obtain highly accurate driving performance and eyeglance measures while controlling the participants' exposure to a range of driving scenario difficulties and secondary task difficulties.

There are some discrepant results among researchers about whether various types of driving inattention degrade driving performance to unsafe levels. Some highly publicized simulator studies compared driving while talking on a cell phone to driving while intoxicated (Strayer, Drews, & Crouch, 2004) and have compared younger driver's responses while talking an a cell phone to those of an attentive, older driver (Strayer & Drews, 2004). The first study demonstrated slower braking profiles, slower speed recoveries, and greater following distances for drivers using cell phones versus drivers intoxicated at a 0.08% BAC level. Also, three of the participants were involved in collisions while talking on a cell phone, whereas none of the intoxicated drivers were in collisions. The authors argue that this is due to the phenomenon known as 'perceptual blindness,' in that the cell phone conversation required all of the driver's cognitive resources and that the drivers were essentially unable to process the forward roadway environment. The second study indicated that when younger drivers are talking on a cell phone, their response times to lead vehicle brake lights were similar to the reaction times of 60 year-old drivers. These authors argue that drivers are unable to cognitively process the forward roadway environment properly because the cell phone conversation consumes too many of the driver's cognitive resources.

Research investigating hand-held versus hands-free devices suggest that the use of hands-free devices results in fewer lane deviations due to the driver's eyes remaining on the forward roadway for a greater percentage of time (e.g., Jenness, Lattanzio, O'Toole, Carter & Graham, 2000). Other research investigating speech-based operation of an in-vehicle email system indicated that there is cognitive distraction or cognitive load present while using speech recognition systems (Lee, Caven, Haake, & Brown, 2001). Jenness et al. (2002) found similar results, in that driving performance was best with no dialing, degraded during voice-activated dialing, and worst during manual dialing. Both studies concluded that good design of the cell phones and speech recognition software is critical to minimizing the impact of distraction on driving performance by allowing drivers to keep their eyes on the forward roadway.

Highly emotional or cognitively complex conversation on cell phones has been shown to result in slower speeds (Haigney, Taylor, & Westerman, 2000), greater speed deviations (Briem, & Hedman, 1995), and failure to respond to highway traffic situations (McKnight & McKnight, 1993). Other studies comparing driving without conversation to driving while conversing with passengers, on a hand-held cell phone, or on a hands-free cell phone have indicated slower reaction times for all three types of conversation (e.g., Consiglio, Driscoll, Witte, & Berg, 2003). Shinar, Tractinsky, & Compton (2005) argued that driving performance while engaging in emotional conversations or performing mathematical operations; however these effects disappear with practice.

Test-track Studies. Test tracks provide a fairly controlled, safe driving environment; however, there are still real-world impacts from poor driving performance. Test-track studies that investigate the impacts of driving inattention on driving performance use many similar methods to simulator research. Test-track studies often present participants with a variety of unanticipated traffic scenarios to assess how well drivers can react while engaging in a secondary task of varying visual, manual, or cognitive complexity (Dingus, Antin, Hulse, and Wierwille, 1989).

Hancock, Lesch, & Simmons (2003) conducted a study investigating drivers' compliance to stop at a red light. In some of the trials, the participants were prompted to press a button on a simulated cell phone display, while there was no distraction task during other trials. The results indicated that drivers whose eyes were not diverted from the forward roadway stopped at the red light in 95% of the trials, whereas compliance dropped to 85% in the presence of the distraction task.

Fumero (2004) conducted a test track study using an in-vehicle information system that was operated by either auditory commands or visual/manual commands. The results of this study indicated that driving performance measures decreased significantly during the visual/manual demanding tasks and were superior during the auditory only tasks. This suggests that auditory modes are preferable to visual/manual modes, in that drivers are better able to maintain lane position and obtain the information from the in-vehicle device more accurately when their eyes can remain on the roadway ahead. Subsequent analyses from this study, conducted by Tijerina, Fumero, Garcia, & Kochar (personal communication), demonstrated that total eyes off roadway time, mean glance time, and number of glances away from the forward roadway were significantly worse during visually demanding tasks. Results also suggest that these measures were *predictive* of lane departures, suggesting that if drivers are engaging in visually demanding tasks, their abilities to maintain the lateral position of the vehicle will degrade.

Zwahlen, Adams, and DeBald (1988) examined eyeglance behavior while using a touch-screen in the vehicle. Drivers were instructed to traverse a closed driving course while operating a touch-screen radio and HVAC system. Lane deviations and eyeglance frequency and duration were measured. Zwahlen found that driving performance was significantly degraded the longer the driver's eyes were diverted away from the forward roadway. Based on the results of this study, Zwahlen proposed a tentative design guideline of acceptable eyeglance behavior (one to two eyeglances with an average duration of 1.0 second). Up to four eyeglances with slightly longer duration was considered a 'gray area.' More than four eyeglances or glances longer than 2 seconds would require a design change, as these conditions would create unsafe driving behavior. These results will be later be compared to an on-road study by Wierwille (1993).

Goodman, Tijerina, Bents, & Wierwille (1999) argue that test-tracks provide a more naturalistic driving task than do simulators; however, it is dependent upon the research methods used as to the degree of realism. Some test-track research is conducted with drivers only moving at 25 mph, which the authors argue is not closer to real-world driving than simulators. Test track research in which subjects drive at highway speeds would provide the most realistic scenario.

On-Road Studies. While on-road studies present the most realistic environment in which to measure driving performance, it also presents the most risky driving environment in that the experimenters cannot control the driving demands. If the researchers create a task that is too demanding (or distracting) or becomes too distracting because of an unforeseen or unanticipated traffic conflict, the subjects could potentially injure themselves or others.

One of the most widely publicized on-road studies investigating driver distraction in passenger vehicles was the AAA Driver Distraction Study (Stutts, Feaganes, Rodgman, Hamlett, Meadows, Reinfurt, Gish, Mercadente, & Staplin (2003). In this study, 70 drivers' vehicles were instrumented with a data collection system for one week. Three hours of driving data were reviewed and reduced to determine 1) the types of distraction tasks, 2) frequency of engagement, and 3) duration of typical distraction tasks. Analyses were also conducted to assess how engagement in secondary tasks impacted driving performance (lane crossings, eyes off forward roadway, and time that both hands were off the steering wheel).

The results from this study indicated that drivers engaged in inattention-related tasks during more than 30% of their driving time. Conversing with passengers accounted for 15% of the total time, followed by eating/drinking, internal distractions (manipulating the radio controls), external distractions, and smoking. The types of secondary driving distractions that increased the driver's percent eyes off road time and the number of lane crossings are presented in Table 1.1. Of twenty-eight possible secondary task types, eight of the top ten secondary tasks that increased percent time eyes off road were also in the top ten most frequent tasks with the largest number of lane crossing occurrences. This provides more evidence to a link between eyes off road time and degraded driving performance. While these results provide the first attempt to identify the distractions drivers engage in while driving, no data were collected on crashes. Therefore, direct associations between distraction behaviors and crashes could not be assessed.

Table 1.1. The ten secondary tasks leading to the highest percentage of eyes off road time and number of lane crossings per hour for the AAA Driver Distraction Study (adapted from Stutts, et al. 2003).

	Secondary Tasks Increasing Percent Eyes Off Road Time	Percent Eyes Off Road	Secondary Tasks Increasing Lane Crossings.	# of Lane Crossing per Hour
1.	Reading/Writing	91.5	Lighting/Extinguishing Cigarette/Cigar	30.2
2.	Dialing/Answering Cell phone	67.6	Distracted by baby	24.2
3.	Grooming	34.6	Distracted by adult	22.9
4.	Manipulating Audio Controls (Radio)	22.6	Reading/Writing	20.9
5.	Distracted by Baby	21.9	Grooming	20.8
6.	Reach/lean/look for Internal object	20.1	Reach/lean/look for Internal object	18.4
7.	Lighting/Extinguishing Cigarette/Cigar	19.3	Preparing to eat/drink	18.2
8.	Distracted by adult	19.0	External Distraction	15.4
9.	Manipulating vehicle controls	15.4	Dialing/Answering Cell phone	14.2
10.	Distracted by child	14.6	Distracted by child	11.6

Other on-road researchers found corroborating evidence to the test track results of Fumero et al. (2004), in that the frequency of lane deviations decreased when using a hands-free cell phone versus a hand-held cell phone (Brookhuis, DeVries, & DeWaard, 1991). Gellatly and Kliess (2000) investigated eyeglance measures while using an in-vehicle entertainment system. They found that using the system for tasks such as email, navigation, and communications/internet required lengthy task times, too many eyeglances, and long eyeglances. Tasks using the cell phone, CD player, or climate control did not cause drivers to look away from the driving task for either too long or too frequently. The authors argued that these results could be summarized by using a simple measure of total task time, which is similar to findings from a simulator study conducted by Farber, Blanco, Curry, Greenberg, Foley, & Serafin (1999).

Wierwille (1993) proposed a model of task difficulty using eyeglance duration as a direct measure. Using data from on-road studies (Wierwille, Hulse, Fischer & Dingus, 1990; Dingus, Antin, Hulse, & Wierwille, 1989), Wierwille proposed that when doing an in-vehicle task, the driver will look away from the external visual scene towards the appropriate location. If the driver can perform the task in 1 s or less, then the driver will do so, followed by a return of the gaze to the forward scene. If the driver cannot perform the task in 1 s or less, then the driver will direct the gaze away from the visual scene for up to 1.5 seconds, return the gaze to the external scene, and continue to go back and forth until the task is complete. Drivers will not tend to look away from the visual scene for more than 1.5 seconds. This on-road finding is very similar to the test track reuslts of Zwahlen et al. (1988) and other research by Green (1999).

Other researchers studying more cognitive-related activities found that the effects of complex conversations (i.e., spatial imagery tasks or memory tasks) while driving reduced the frequency of eyeglances to the periphery and increased the frequency of hard braking (Harbluk & Noy, 2002). Lamble, Kauranen, Laakso, & Summala, (1999) found drivers' reaction time to a decelerating lead vehicle was 0.5 seconds later and time-to-collision was 1.0 second later during complex conversation or dialing than when not performing these operations. All of these researchers argued for extreme caution in the use or operation of cell phones in the vehicle.

Recarte & Nunes (2000) conducted a study looking at eyeglance location of drivers while performing either verbal or spatial-imagery tasks. The results suggested that glance frequency to mirrors or speedometer decreased significantly during the spatial-imagery tasks. The average eyeglance duration fixation was also longer during spatial-imagery tasks than for verbal or no secondary tasks. These results suggest that drivers reduce their visual sampling of the environment while performing cognitively complex tasks, thus reducing their ability to scan the environment for potential hazards.

Summary of Empirical Research

Research investigating the effects of cognitive inattention and visual inattention stem from separate theoretical philosophies. Those who argue that cognitive inattention impacts driving performance ascribe to the Multiple Resource Theory (Wickens, 1992), which states that all humans have a limited pool of attention resources from which they can draw. When interacting with the environment, humans perceive, process, and respond. Humans can perceive using all five sensory organs, interpret this information, and then respond to this information. If multiple sources of information are presented via the same sensory organ (e.g., visual), humans have greater limitations on the amount of information they can process than if the information is presented via multiple sensory organs (e.g., visual and auditory). The driving task is primarily visual with manual responses to the steering wheel and accelerator/brake. Conversation is primarily presented through the auditory channel, which allows the driver to process both the visual driving scene and listen to the conversation. The research presented suggests that even though these types of distractions are not directly competing, the driver's overall ability to process information is degraded and key visual information is getting lost, leading to missed obstacles and slower reaction times.

Those researchers who argue that visual inattention is a greater decrement to driving performance subscribe to an ecological psychology theory which argues that a driver's perception, attention, and workload cannot be subdivided nor studied outside of the context of driving (Hancock & Scallen, 1999). Instead, the driver-vehicle-environment must be studied as one functional entity. The driver's control responses must be analyzed as a function of the driving environment or what Gibson & Crooks (1938) described as the 'field of safe travel.' Humans learn the principles of motion or locomotion during early stages of development. These same principles apply to the task of driving an automobile, although the vehicle is a more efficient tool for locomotion. The driving task is primarily perceptual with the control responses being very simple and easily over-learned. Obtaining information from the forward visual scene requires very little effort as this task is also over-learned (Gibson & Crooks, 1938).

Gibson and Crooks described a concept called the *field of safe travel* as the roadway environment consisting of areas of safe and unsafe areas of the roadway where the safe location is typically the middle of the roadway and the unsafe locations are generally obstacles such as curbs, ditches, or other vehicles. When an emergency situation occurs, the safe and unsafe areas may shift so that the stopped vehicle in the middle of the roadway becomes an unsafe area to drive and a sloping ditch or a curb instantly becomes the safer pathway through the environment.

Driver inattention usually means that drivers avert their visual attention to an object or event that is not pertinent to the driving task. During these moments, the driver's field of safe travel may develop incorrect boundaries without the driver realizing that the boundaries have suddenly changed. To counteract the impact of inattention, drivers generally adopt semi-automatic habits such as increasing their safety margins so that they may safely divert their attention for moments at a time.

While researchers may champion either the multiple resource theory or the ecological theory, results from the empirical research are mixed. Strayer et al. (2004) and Lamble et al. (1999) argue that cognitive distractions lead to degraded driving performance; however, degraded driving performance was defined in these studies as increased following distances and slower reaction times. Other researchers have argued that increased following distances are *protective* and demonstrate a driver's willingness to compensate for their inattention (e.g., Ranney, 2005). Slower reactions may be an artifact of increased following distances as the drivers have allowed themselves more time *to* react. Other researchers argue that visual distractions degrade driving performance to a greater degree than cognitive distractions such as conversation (e.g., Jenness et al. (2002), Carter et al. (2000), Lee et al. (2001), and Fumero et al. (2004)).

Due to the artificiality of both simulators and test-tracks and the limitations of the instrumented vehicle studies presented here, the question of whether visual inattention or cognitive inattention is more detrimental to driving performance remains unresolved. These driving performance measures must be observed in the natural environment to determine whether drivers more often collide with objects while looking straight ahead while conversing or instead whether collisions are primarily caused by the driver not scanning the forward environment at the correct points in time.

Review of Roadway Environment Research

There has been limited research on the impact of inattentive drivers traversing various types of roadway environments. Stutts, Reinfurt, Staplin, and Rodgman (2001) conducted a study using five years of National Accident Sampling System Crashworthiness Data System crash investigation data and narratives from the North Carolina Crashworthiness Data System. The results of this analysis indicated the importance of context in the analysis of inattention-related crashes. While the analysis did not produce many conclusive results, primarily due to lack of power, there appeared to be a higher rate of crashes during the following situations:

- Driver was adjusting the radio at night
- Driver was moving objects in the vehicle on non-level roadways

- Drivers with passengers in the vehicle were involved in intersection crashes

Other empirical research, cited in the previous section, indicated poor decision making and increased red light-running while conversing on phones near intersections (Hancock, Lesch, and Simmons (2003); Harbluk, Noy(2002) & Neale, ??). More research is needed to assess the impacts of driving inattention on driving performance during conditions such as at night, on rainy roadways, and during light versus heavy traffic conditions. Many of studies investigating driving inattention during risky driving environments (e.g., rainy roadways, nighttime driving) cannot be conducted in the real-world environment without placing the participants at greater risk of accident or injury. Regardless, the context in which drivers choose to engage in secondary tasks is important for understanding the impacts of driving inattention on real-world driving.

Review of Survey/Questionnaire Data

Transportation researchers have attempted to assess driver's crash risk using personality inventories and life stress indices, as well as health status and/or demographic data. While extensive data exists on crash risk related to driver age, reliable data correlating personality inventory or other psychological test scores to crash risk are not as prevalent. One possible reason for this is that most research in this area requires self-reported data. For example, research has been conducted asking participants to report the number of traffic violations and/or the number of crashes experienced over a period of time (Matthews, Desmond, Joyner, Carcary, & Gilliland, 1996). An attempt was then made to correlate this information with a participant's score on a personality inventory or other test. Other researchers have correlated empirical driving data with psychological test scores to screen drivers prior to collecting empirical data (e.g., Dula & Ballard, 2003; Liu & Lee, 2005). Recall that in empirical studies only surrogate measures of driving safety can be evaluated, and thus these data cannot be associated directly with crash risk. Self-reported data have been criticized in that participants may not remember all the violations and/or crashes they have experienced. Drivers also may not report minor crashes, and they may have underlying motivations for not being honest in their reports (e.g., fear of being dismissed as a study participant if they report too many crashes).

Some of the more common test batteries that have been used in transportation research are described below, along with results of research using these tests. No known psychological test or assessment of driving inattention or direct assessment of driving distraction was available at the time of this writing.

Walter Reed Army Institute of Research's Preliminary Sleep Questionnaire. This questionnaire assesses a driver's sleep habits and/or sleep disorders that may cause fatigue during normal, waking hours. Fatigue has long been considered an important factor in accidents and general driving behavior. The National Highway Traffic Safety Administration and the Federal Motor Carrier Safety Administration have conducted numerous multi-million dollar research studies to gain understanding of the impact of fatigue on commercial drivers and private vehicle drivers (Dingus, Neale, Garness, Hanowski, Keisler, Lee, et al. 2001; Hanowski, Wierwille, Garness, & Dingus, 2000). This questionnaire provides an assessment of general sleep habits and frequencies of daytime sleepiness. This test also contains a thorough section on medical and sleep history.

Dula Dangerous Driving Index. The Dula Dangerous Driving Index (Dula & Ballard, 2003) is a test battery that measures and classifies a driver's level of aggressive driving behavior. This is a 28-item pencil/paper questionnaire that provides measures of a driver's level of aggression, negative emotional level (hostility), propensity for risky driving (impatience), and an overall measure of dangerous driving. This test was validated using simulator driving tests and by by correlating the test results with the NEO Five Factor Personality Inventory. It is hypothesized that general impatience, hostility, and aggression levels would increase a driver's willingness to engage in secondary tasks while driving.

Driver Stress Inventory. The Driver Stress Inventory was developed by Matthews, Desmond, Joyner, Carcary, & Gilliland (1996) and is a follow-up to the earlier Driver Coping Questionnaire. This test provides scores on five driver stress factors: aggression, dislike of driving, hazard monitoring, thrill-seeking, and fatigue proneness. These five scales were validated against drivers' self-reported accident involvement, reckless driving citations, and Goldberg's Big Five personality dimensions of neuroticism, extraversion, conscientiousness, agreeableness, and openness.

This inventory was used by Liu & Lee (2005) to classify drivers *a priori* into groups of aggressive and non-aggressive drivers for a study conducted on a test-track. The results indicated that there were significant differences between the two groups of drivers in their willingness to speed, brake hard to a stop at an intersection, or go through an amber traffic light while engaged in a cell phone conversation.

Life Stress Inventory. The Life Stress Inventory measures the types of stress and life changes that drivers may have experienced during the past 12 months. Generally, this inventory has been used in association with risk level for health problems or illness. However, high levels of stress have also been linked to involvement in crashes. Elander, West, and French (1993) cite a study conducted by Brown & Bohnert (1968) in which 80% of the drivers involved in fatal crashes were under serious life stress (e.g., marital, financial, or professional stress). It is hypothesized that drivers encountering stressful life situations would be more willing to engage in secondary tasks while driving or would be more prone to fatigue while driving. It is also possible that drivers could be more cognitively distracted (e.g. daydreaming, worrying) while driving.

NEO Five Factor Personality Inventory. The NEO Five Factor Personality Inventory, (Costa & McCrae, 1992) provides a measure for the five major dimensions of normal personality: neuroticism, extraversion, openness, agreeableness, and conscientiousness. Dewar (2004) cited research that attempted to link scores on the five factor personality inventories to crash risk. The research findings are mixed in that some researchers cite significant relationships between one or more of the five factor personality scales and accident involvement; however there does not appear to be a substantial body of research in support of any one personality scale. Arthur & Graziano (1996) conducted a study in which self-reported crash involvement or traffic violations were correlated with scores on the five personality factors. Their results suggested that the scores on the conscientiousness scale were significantly different between those drivers involved in crashes and those not involved in crashes.

Other research, as cited by Arthur and Graziano, has found some correlation between neuroticism and extraversion and crash risk. Eysenck & Eysenck (1975) and Shaw & Sichel (1971) both found links between neuroticism and crash involvement. Fine (1963) found significant correlations between extraversion and reported numbers of crashes and violations with younger males. Based on these studies, there appears to be support for the hypothesis that some of the five factors of the personality inventory do have an association with crash risk.

Waypoint. The Waypoint test is a computer-based performance test that measures an individual's vigilance and speed of information processing (Cantor, 2005). The test uses a 'connect the dots' paradigm where the participant, using a touch screen, proceeds through the screen of dots by pressing first 'A,' then '1,' then 'B,' then '2, and so on. The test gets increasingly difficult. The Waypoint test provides a measure of crash risk in terms of the individual's reaction times, channel capacity, and situational awareness.

The National Highway Traffic Safety Administration has sponsored research examining Waypoint's predictive values for older drivers. Scores on Waypoint correctly identified high risk drivers 62% of the time and mistakenly identified low risk drivers as high risk 9% of the time.

Useful Field of View (UFOV). The UFOV is another computer-based performance test used to measure an individual driver's crash risk (Visual Awareness,Inc., 2002). This test measures an individual's central visual processing speed, divided attention, and selective attention. This test has also been used successfully at predicting crash risk of older drivers. The National Institutes of Health suggested that a driver's risk rises 16% for every 10 points of visual reduction in the driver's useful field of view for drivers 55 years and older. While this test has not been used for younger drivers, it may have predictive capabilities for driver crash risk, regardless of age.

Review of Hazard Analysis Technique

Many industrial safety researchers face the same challenges as transportation researchers when attempting to directly measure safety or to predict the probability that an accident will occur given certain circumstances. In most settings, accidents that lead to injury or death are fairly rare events; therefore, any corrective action is reactive and not proactive. Safety engineers would benefit if they were able to be more proactive in identifying unsafe acts that may eventually lead to injury or death.

Heinrich, Petersen, and Roos (1980) developed a hazard analysis technique based on the underlying premise that for every injury accident, there were many similar accidents where no injury occurred. For example, for a unit group of 550 accidents of similar type and involving the same person, approximately 500 would result in no injury, 49 would result in minor injuries, and only 1 would result in a major injury. Therefore, if the safety engineer can identify the no injury accidents and reduce their numbers, minor and major injuries might be prevented.

Following this premise, transportation researchers from GM developed a method using cameras to observe traffic conflicts at intersections (Parker & Zegeer, 1989). Their general definition of a traffic conflict was: "An event involving two or more road users, in which the action of one user causes the other user to make an evasive maneuver to avoid a collision." This hazard analysis method has become known as the traffic conflict technique. This method has been used to estimate crash risk at intersections using a count of traffic conflicts rather than crashes. Wierwille, Hankey, Kieliszewski, Hanowski, Medina, et al. (2001) employed the traffic conflict technique by unobtrusively videotaping traffic at intersections to identify causes of driver errors (critical incidents), near-crashes, and crashes. They chose rural, suburban, and urban intersections with a high number of collisions. This study was conducted to develop a taxonomy classification of driver errors, part of which was used in the current study and which is discussed further in the Method section of this report.

Variations of the traffic conflict technique have been developed for use in an instrumented vehicle. This modification involves cameras being strategically placed on one vehicle to determine the number of traffic conflict involvements for a particular driver (e.g., Mollenhauer, 1997; Hanowski, Wierwille, Garness, & Dingus, 2000; Dingus, Neale, Garness, Hanowski, Kiesler, Lee, et al., 2001; Wierwille, Hankey, Kieliszewski, Hanowski, Medina, et al., 2001). Hanowski et al. (2000) and Dingus et al. (2001) used this modified version of the traffic conflict technique by videotaping a single commercial vehicle driver and the environment surrounding this vehicle to identify driver errors (critical incidents), near-crashes, and crashes that impacted the instrumented vehicle. This technique proved useful in identifying the impacts of fatigue in truck driving and determining the prevalence of fatigue among the drivers who participated in the study.

Both versions of traffic conflict techniques have proven to be useful; however, in the studies using the modified traffic conflict technique, fewer than 50 subjects were used and each driver was only recorded for approximately two weeks of driving. While data on thousands of critical incidents were collected, there were fewer than 30 near-crashes and only two crashes were recorded (Dingus, Neale, Garness, et al., 2001). It is noteworthy that these two crashes were not reported to the police as they were minor property damage collisions. Therefore, very little crash data have been collected using instrumented vehicles, even when an experimenter is not present in the vehicle during data collection.

Just as the modified version of the traffic conflict technique proved useful in observing the impact of *fatigue* in commercial truck driving, it could also prove useful in observing the impact of *driving inattention* in the general driving public. While these previous studies had limitations on the number of subjects and the length of data collection, relative crash risk of driving inattention cannot be assessed without collecting data on crashes. A large-scale naturalistic field study where the number of subjects and length of data collection is increased substantially is the only way to increase the probability that data would be collected on one or more police-reported crashes.

Summary of Dissertation Research

This dissertation research used data collected from the 100-Car Naturalistic Driving Study. The 100-Car study was a large-scale naturalistic driving study in which 100 instrumented vehicles (80 privately-owned and 20 leased vehicles) were used for data collection. This data collection effort was conducted in the Washington DC metropolitan area on a variety of urban, suburban, and rural roadways over a span of 12-13 months. During the course of data collection, over 42,000 hours of driving data were collected. Data were also collected on 69 crashes, 761 near-crashes, and 8,125 incidents.

This naturalistic driving data set is the first data set to collect pre-crash and crash data on crashes of varying levels of severity ranging from police-reported airbag-deployed injury crashes to high speed curb strikes. This powerful dataset and the subsequent analyses demonstrate how large-scale naturalistic driving studies can bridge the gaps between epidemiological data analyses, empirical data analysis techniques, and qualitative questionnaire data to provide a deeper and holistic understanding of the impact of driving inattention on crash risk.

The following research questions are addressed in this dissertation research:

1) What is the prevalence of driver inattention and its impact on driver's relative crash risk?
2) Under what environmental conditions do drivers choose to engage in secondary tasks while driving and what are the corresponding relative crash risks in secondary task engagement?
3) Are there any differences or relationships present between inattentive and attentive drivers scores on relevant psychological questionnaire/demographic data?

4) What is the relative crash risk of eyes off the forward roadway?

2. METHOD

The following section describes the methods used in the 100 Car Naturalistic Driving Study to collect continuous driving data, to reduce the video data, and the methods used to create the databases used for the data analysis as described in Chapters 3 through 6.

Drivers

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 receive a leased vehicle for this study. Drivers were recruited by placing flyers on vehicles as well as by placing newspaper announcements in the classified section. Drivers who had their private vehicles instrumented received $125.00 per month and a bonus at the end of the study for completing necessary paperwork. Drivers who received a leased vehicle 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 148 additional drivers. Chapter 3 presents an exhaustive review of driver demographics.

The 100-Car Data Acquisition System

The 100-Car instrumentation package was designed and developed in-house by the VTTI Center for Technology Development. This system operated continuously after the system initialization period (the computer boot-up period which took approximately 90 seconds after the ignition was turned on) until the driver turned the ignition off. Any commercial off-the-shelf components that were integrated into the instrumentation package are specifically noted in the following system description.

The core of the data acquisition system was a Pentium-based PC104 computer. The computer ran custom data acquisition software and communicated with a distributed data acquisition network. Each node on the network contained an independently programmable micro-controller capable of controlling or measuring a moderate number of signals. This system configuration maximized flexibility while minimizing the physical size of the system. Although capable of being expanded to 120 nodes, the vehicles were configured with 10 nodes. A schematic representation of the system appears in Figure 2.1.

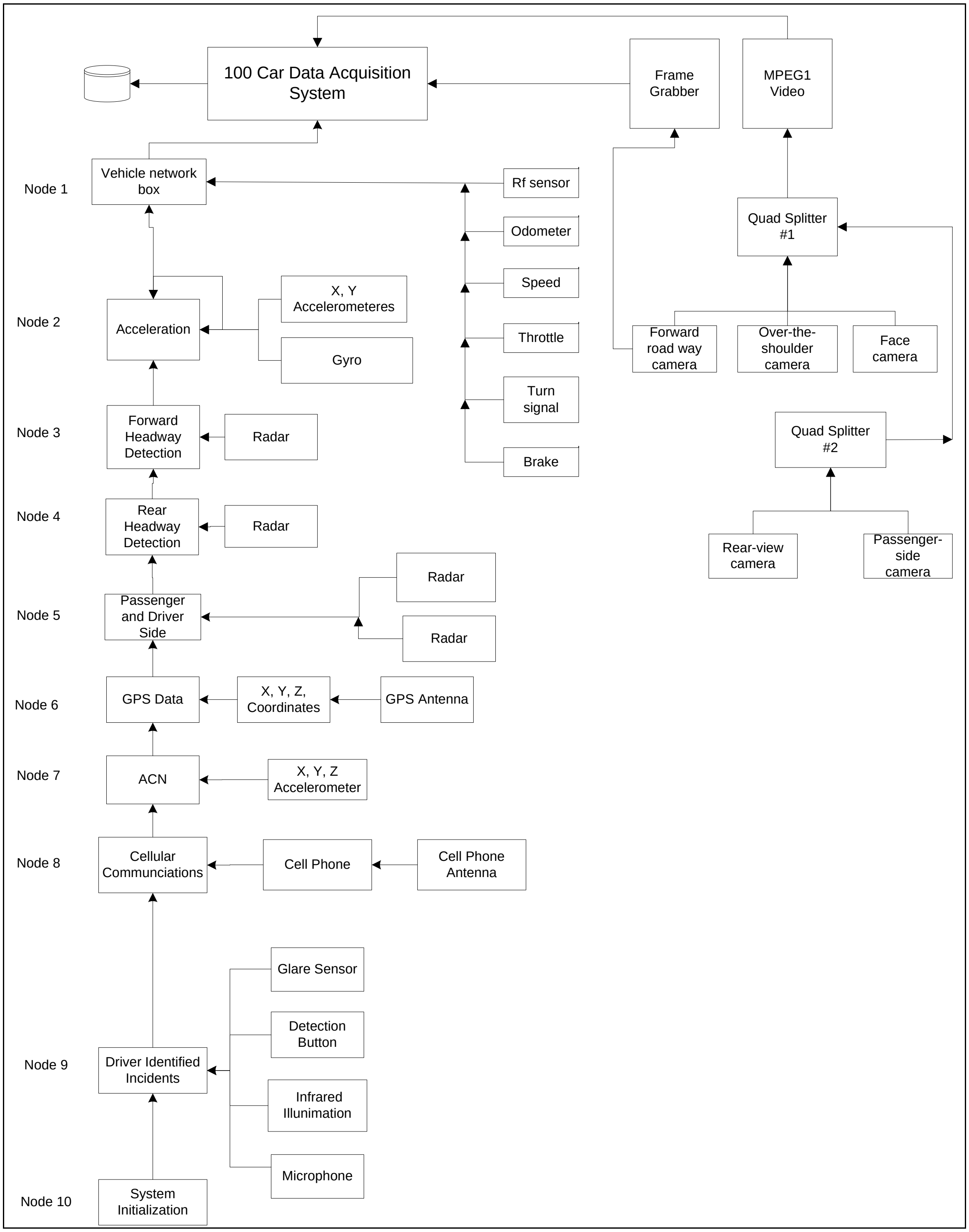

Figure 2.1. 100-Car data hardware collection system schematic.

This system of distributed data acquisition provided a very flexible and maintainable hardware data collection system. The main unit was mounted in the trunk under the "package shelf" (Figures 2.2 and 2.3). The vehicle network box was located under the front dashboard. The incident box was mounted above the rearview mirror. Wiring was run though the normal wire chases on a vehicle to all the various network nodes, as well as to the cameras. All of the microprocessor boards, including the firmware and data collection software, were developed at VTTI.

Figure 2.2. The main DAS unit mounted under the "package shelf" of the trunk.

Figure 2.3. The 100-Car DAS.

Node 1: Vehicle Network Box

This node was responsible for interfacing with the on-board diagnostics (OBDII) network in the vehicle. Various data elements were pulled off the network if they were available. Several sensors were hardwired such as the radio frequency sensor, the left turn signal, the right turn signal, and the brake light.

Node 2: Accelerometer Box

This node was responsible for collecting the lateral and longitudinal acceleration of the vehicle, along with the turning rate. MEMs based sensors were used.

Nodes 3-4: Headway Detection

These nodes were responsible for interfacing with an EATON VORAD EVT300 Doppler radar. Figure 2.4 shows the computer board for the node. The radars were mounted on the front and rear of the vehicles and were concealed behind plastic license plates (Figure 2.5).

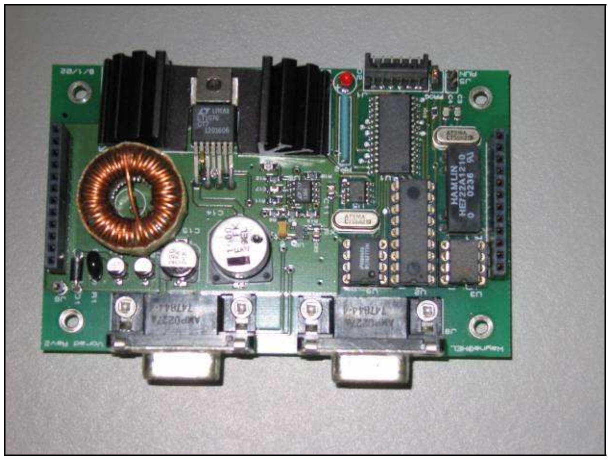

Figure 2.4. Computer board for the Vorad unit.

Figure 2.5. Radar unit mounted on the front of a vehicle, covered by a plastic license plate.

Node 5: Side Obstacle Detection

These nodes were responsible for interfacing with a proprietary Doppler radar. These radars were capable of detecting targets at 30 ft and 180 degrees of span. These radar units were only available on the 20 leased vehicles.

Node 6: GPS Data Node

This node was responsible for interfacing with a standard automotive GPS unit.

Node 7: Automatic Collision Notification

This node detected the possibility of a collision by sensing three accelerations. It would trigger a call to a dispatcher if it detected a crash.

Node 8: Cellular Communications

This node served as an interface between the computer and a standard cell phone. It was capable of receiving a call and connecting that call with the on-board computer; likewise, the computer had the capability of calling to researchers to inform of on-board malfunctions.

Node 9: Incident Box

This node concentrated several data variables. It contained an incident push button (shown mounted above the rear-view mirror in Figure 2.6) that the driver could press that would open an audio channel for the driver to verbally record an incident. It also housed the face camera, IR LEDs, and the glare sensor (shown mounted behind the rear-view mirror in Figure 2.7).

Figure 2.6. The incident push button box mounted above the rearview mirror.

Figure 2.7. The mounting for the glare sensor behind the rearview mirror. Note the forward view camera as part of the same mounting assembly.

Node 10: System Initialization

This node was responsible for qualifying the operating conditions, turning the computer on and off, and charging the cellular telephone backup battery. It also contained a watchdog functionality to maintain correct system operation and a real-time clock for periodic system checkups.

Lane Tracking System

The lane tracking system incorporated a high resolution frame grabber and a full resolution image of the forward roadway. The data collection software ran an embedded version of a custom in-house machine-vision lane tracking system.

Procedures for Data Collection, Retrieval, and Storage

Video Data

There were five cameras located in the vehicle (Figure 2.8). One camera monitored the driver's face and the left side of the vehicle. A second camera monitored a 68° field of view (FOV) out the forward windshield. A third camera monitored a 68° FOV of the rear-view. The fourth camera monitored the passenger's side of the vehicle. Finally, the fifth camera monitored the driver's hands, instrument panel, and center console of the vehicle.

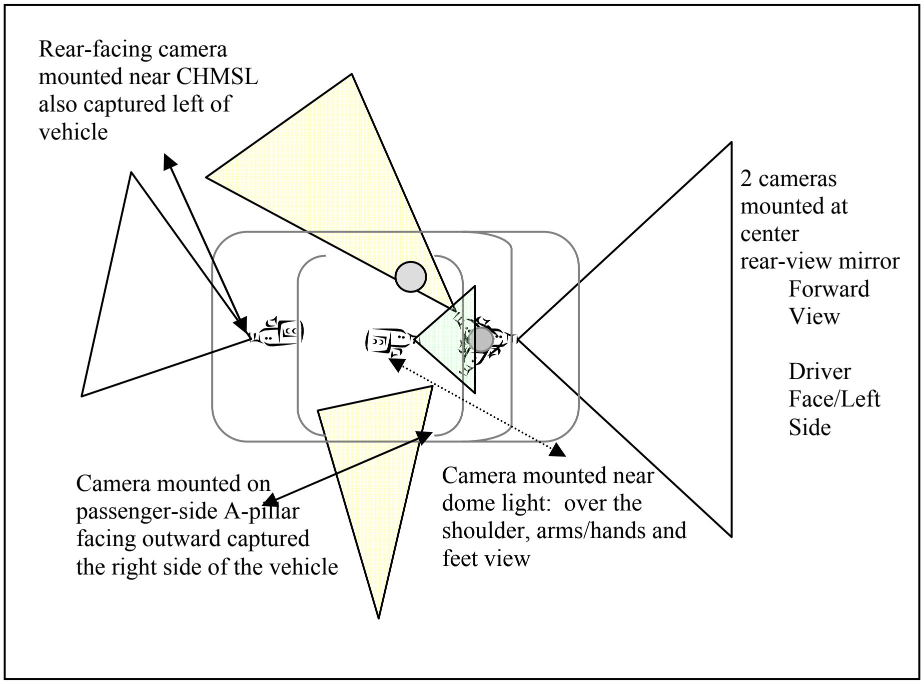

Figure 2.8. The five camera views recorded in the instrumented vehicle: 1) forward, 2) driver's face/left side of vehicle, 3) rear-view, 4) over the driver's shoulder capturing the driver's hands and feet, the steering wheel, and the instrument panel, and 5) right side of vehicle.

Infrared lighting was used to illuminate the vehicle cab so that the driver's face and hands could be viewed on camera during nighttime driving. Figure 2.9 shows the placement and viewing angles of all five cameras in the quad-split image presented to allow data reductionists to monitor all five channels of video simultaneously.

<table>
<tr><td>Driver Face and Left Side View
(60° Horizontal)</td><td>Forward View
(68° Horizontal)</td></tr>
<tr><td rowspan="2">Over-the-Shoulder View
(Pinhole, 70° Diagonal)</td><td>Right Side View
(Pinhole, 70° Diagonal)</td></tr>
<tr><td>Rearview
(68° Horizontal)</td></tr>
</table>

Figure 2.9. The double quad, split video image.

All video on-board the 100-Car data collection system was compressed using MPEG 1 compression. This allowed greater storage of video on-board the vehicle hard drives and required less server space to store the raw video data. While the initial data stream was recording at 30 Hz, the compression algorithm reduced the actual number of unique frames to approximately 7.5 frames per second (Figure 2.10).

Figure 2.10. A video image from the 100-Car data. The driver's face has been distorted to protect the driver's identity.

Driving Performance Data

Driving performance data were collected continuously and events were identified using specific values of driving performance dependent variables. Eleven main hardware sensor components were incorporated into the data collection system, as shown and described in Table 2.1 and depicted in Figure 2.1. In addition, relative lane position was derived using a combination of hardware on the instrumented vehicle and software written by VTTI computer programmers. This lane tracking system used machine vision based on input to the forward camera (prior to video compression). All data were stored in the data collection system in real-time.

Table 2.1. Description of Sensor Components.

Sensor Component	Description
Vehicle Network box	Collection of data directly from the in-vehicle network box. Some data includes vehicle speed, brake application, % throttle, turn signal, etc.
Acceleration	Collection of lateral, longitudinal, and gyro.
Forward headway detection	Collection of radar data (range, range-rate, azimuth, etc.) to indicate the presence of up to 7 targets in front of the vehicle.
Rear headway detection	Collection of radar data (range, range-rate, azimuth, etc.) to indicate the presence of up to 7 targets behind the vehicle.
Side vehicle detection	Collection of radar data indicating the presence of a vehicle on the sides of the vehicle.
Global Positioning System	Collection of latitude, longitude, and horizontal velocity as well as other GPS related variables.
Automatic Collision Notification System	High bandwidth collection of acceleration to detect a severe crash.
Cellular communications	Communication system designed for vehicle tracking and system diagnostics.
Driver Identified Events/Glare sensor	Collection of lux value (for night-time conditions only) as well as event button.
System Initialization	Overall system operation.

Demographic and Questionnaire Data

Prior to the installation of the data collection system in the participant's vehicle or acquisition of a leased vehicle, each participant met with a VTTI researcher at the UVA/VT Northern Virginia Center in Falls Church, VA. During this meeting, a VTTI researcher:

- Obtained informed consent from the private-vehicle or leased-vehicle participant, and explained that a Certificate of Confidentiality had been obtained from the National Institute of Mental Health for the participant's protection.
- Explained that the study was investigating traffic in northern Virginia.
- Explained the logistics of data collection system installation and maintenance.
- Asked the participant to agree to a vision and hearing exam.
- Ask the participant to complete questionnaires and take two computer-based tests.

The tests and questionnaires, as well as whether these were completed prior to or after data collection, are listed in Table 2.2. Full text versions of the informed consent form, tests, and questionnaires are located in Appendix A. A copy of the approved IRB permission is in Appendix E.

Table 2.2. Description of all tests and questionnaires administered to study participants.

Test/Questionnaire	Test Type	When Administered	Brief Description
1. Visual Acuity Test	Performance test using verbal report	Before data collection	Used the Snellen Eye Chart to test driver's visual acuity.
2. Audiogram Air Conduction Test	Examination using an audiometer	Before data collection	Assessed hearing levels at a frequency range of 125-8000 Hz.
3. Medical Health Assessment	Questionnaire	Before data collection	Obtained any information on prior health problems that may relate to driving performance.
4. Walter Reed Army Institute of Research Preliminary Sleep Questionnaire	Questionnaire	Before data collection	Measured and recorded subject's sleep habits and problems that may cause fatigue.
5. Dula Dangerous Driving Index	Questionnaire	Before data collection	Classified driver's level of aggressive driving behavior.
6. Driver Stress Inventory	Questionnaire	Before data collection	Used a 10-point Likert Scale to obtain information about driver's general attitudes toward driving on a variety of roadways and in traffic congestion.
7. Life Stress Inventory	Questionnaire	Before and after data collection	Obtained information about the types of stress and changes that the subject may have experienced in the past year to determine the risk level for illness.
8. NEO FFI (Neuroticism Extraversion Openness Five Factor Model)	Questionnaire	Before data collection	Measured the five dimensions of normal personality: neuroticism; extraversion; openness; agreeableness; and conscientiousness.
9. Way Point	PC-Based performance test	Before data collection	Used to identify drivers who may be at high risk for crashes by measuring their information processing speed and aptitude for vigilance.
10. Useful Field of View (UFOV)	PC-Based performance test	Before data collection	Used to measure a driver's risk for crash involvement by using the driver's central vision and processing speed, divided attention, and selective attention.
11. Debriefing Questionnaire	Questionnaire	After data collection	List of questions collecting information on driver's recollections about events that occurred during the last year, seat belt use, alcohol use, etc.
12. Driver Demographic Information	Questionnaire	Before data collection	List of questions collecting information on driver's age, gender, level of education, occupation, etc.
13. Driving History	Questionnaire	Before data collection	List of questions collecting information on driver's traffic violations and accident history, type, etc.
14. Post-Crash Interview Form	Interview questionnaire	In the event of a crash	Used to collect driver's description of crash
15. Seatbelt	Questionnaire	Before data collection	Assessed seatbelt use and attitudes toward seatbelt use.

Data Retrieval and Storage

To collect the data from the experimental vehicles, "chase vehicles" were used to track the vehicle, go to the location, and download data. The chase vehicle drivers "called" the vehicle using a cellular telephone and laptop configuration. In-house software displayed a map showing icons for the chase vehicle and experimental vehicle locations. The chase vehicle driver then drove to the location of the instrumented vehicle and downloaded the data from the experimental vehicle (downloading required a data transfer cable connected to an outlet near the rear license plate of the instrumented vehicle, which was connected to a data storage device). After each download, data integrity was verified. Data were again duplicated in Northern Virginia onto DVDs; one copy was then sent to VTTI and the other copy was kept in Northern Virginia.

As the data arrived at VTTI, the triggering software was run on each DVD (see 'Data Reduction') and the resulting relevant event epochs were saved. Event epochs were copied and saved on the networked attached storage server (NAS) at VTTI. The remainder of the video and raw data contained on the DVD remained on the DVD.

Once the triggered data were copied to the NAS at VTTI, the data were deleted from the experimental vehicle hard drive using in-house software. Once the data arrived at VTTI a fourth copy was created on the NAS before the on-board data were deleted. The purpose of this detailed duplication and storage scheme was to maintain a minimum of two data copies at all times.

Procedure For Data Reduction

Sensitivity Analysis

As stated previously, data were collected continuously to optimize the trigger criteria values after driving performance data were collected. If the triggers had been set prior to data collection, valuable events may have been lost without any method of recovery. One method of efficiently establishing trigger criteria is to perform a sensitivity analysis.

Figure 2.11 shows the data reduction plan in a flow chart format. Raw data from the vehicles were saved on the NAS at VTTI until approximately 10% of the data expected to be collected for the entire study was stored on the NAS. At that time, a sensitivity analysis was performed to establish post-hoc trigger criteria.

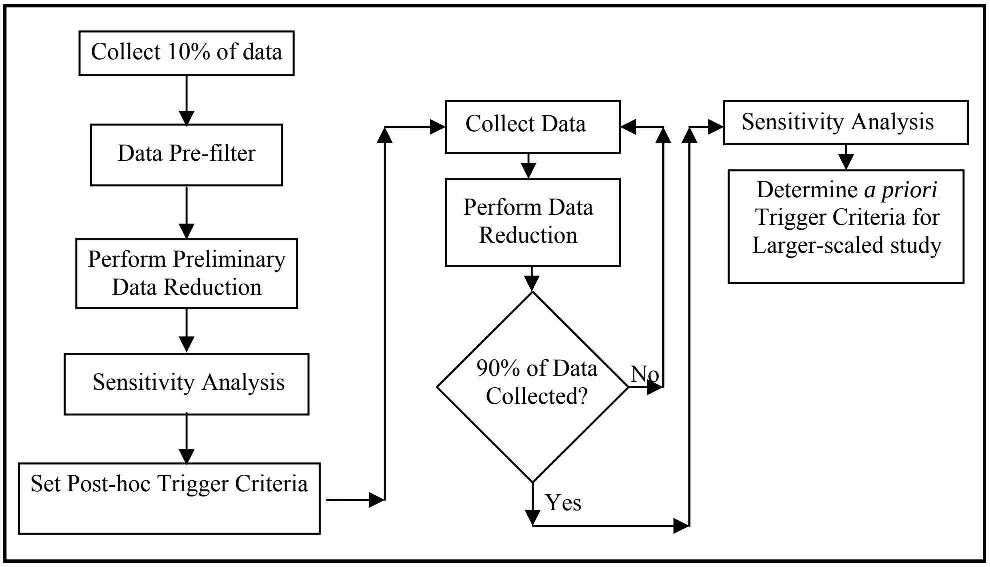

Figure 2.11. Flow chart of the data reduction process.

The sensitivity analysis was conducted by making iterative adjustments to the trigger values to ensure that most of the valid events were identified with only a few invalid events also being identified. The list of dependent variables ultimately used as event triggers is presented in Table 2.3.

Table 2.3. 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 coupled with a forward TTC of 4 s or less. • All longitudinal decelerations between 0.4g and 0.5g coupled with a forward TTC value of ≤ 4 s and that the corresponding forward range value at the minimum TTC is not greater than 100 ft.
3. Event Button	• Activated by the driver by pressing a button located on the dashboard when an event occurred that he/she deemed critical.
4. Forward Time-to-Collision	• Acceleration or deceleration equal to or greater than 0.5 coupled with a forward TTC of 4 s or less. • All longitudinal decelerations between 0.4g and 0.5g coupled with a forward TTC value of ≤ 4 s and that the corresponding forward range value at the minimum TTC is not greater than 100 ft.
5. Rear Time-to-Collision	• Any rear TTC trigger value of 2 s or less that also has a corresponding rear range distance of ≤ 50feet 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.

A sensitivity analysis was performed by setting the trigger criteria to a very liberal level, reducing the chance of a missed valid event to a minimal level while allowing a high number of invalid events (false alarms) to be identified (see Figure 2.12). Data reductionists then viewed all of the events produced from the liberal trigger criteria and classified each event as valid or invalid. The number of valid events and invalid events that resulted from this baseline setting was recorded.

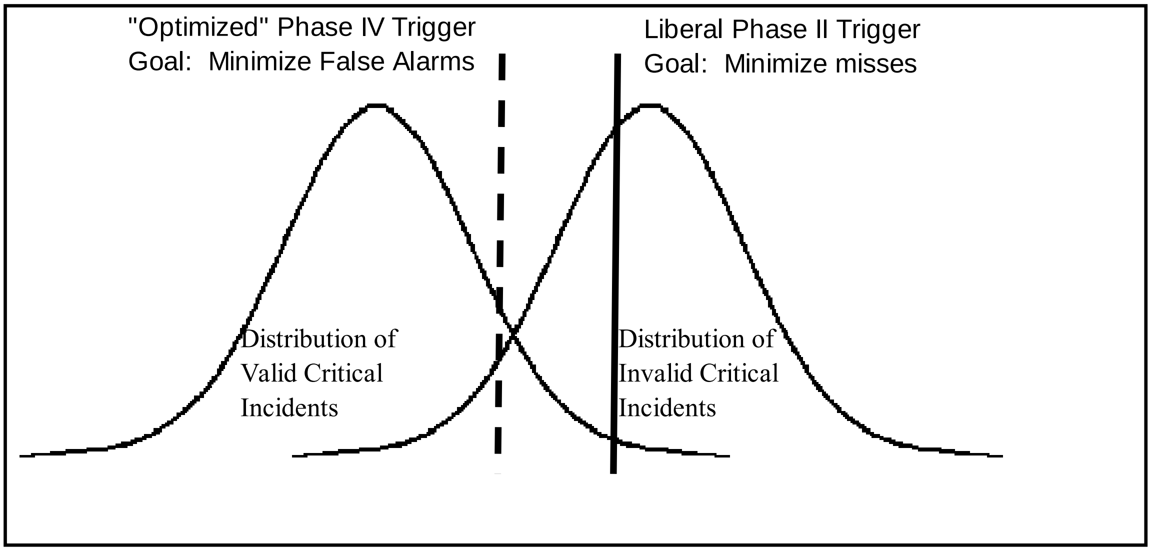

Figure 2.12. Graphical depiction of trigger criteria settings using the distribution of valid events. Note that this distribution and criterion placement is unique for each trigger type.

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% and a false alarm rate of less than 30%.

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 discovered soon after the sensitivity analysis process had begun, that the variability in light vehicle drivers' braking, acceleration, and steering behavior is much larger than with truck drivers. It is likely that this is due to differences in vehicle dynamics and the more uniform driving skill of commercial truck drivers.

Given the large 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 events in order to validate 10,548 events. The distribution of the total number of reduced events by severity is shown in Table 2.4.

Table 2.4. 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
Non-Conflict Events	1,423

Once the trigger criteria were set, data reductionists watched 90 s epochs for each event (one minute prior to and 30 s 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 reduce an average of 4 events per hour. Eleven data reductionists were recruited by posting flyers and notices to various graduate student listserves 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, and provided training on all relevant operational and administrative procedures (approximately 4 hours of training). The manager gave each data reductionist a data reduction manual to guide them 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 in data reduction.

The data reductionists performed two general tasks for this project. On the first 10-15% of the data, they performed a preliminary data reduction task in which they viewed events to determine whether the event was valid or invalid and determined the severity of the event. After the trigger criteria was set using the results from the sensitivity analysis, the data reductionists then validated the data, determined severity, and performed a full data reduction. For the full data reduction, they recorded all of the required variables (discussed below) for the event type. To ascertain severity of the event, reductionists used the decision tree, as shown in Figure 2.13.

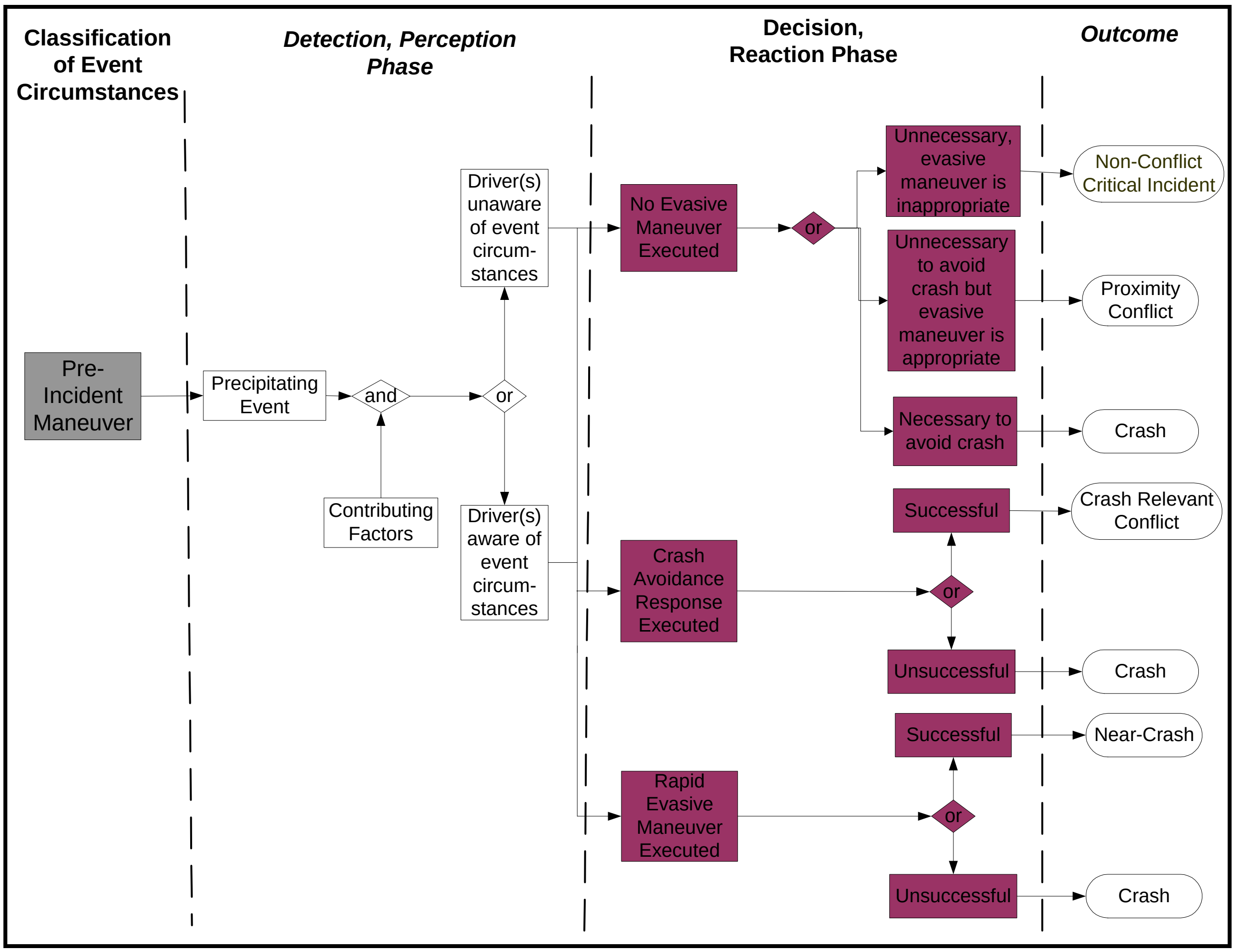

Figure 2.13. Decision tree used to classify event severity.

Data Reduction Software Framework

There were two separate data reduction efforts that created two separate data bases that are used in the following analyses. The first data reduction effort was conducted using the critical incident technique (as described above) to identify the crashes, near-crashes, and incidents that drivers were involved. This data base is referred to as the *event database*. The second data reduction effort was conducted to obtain data on driving where no safety-relevant situation occurred or baseline driving. This database will be referred to as the *baseline database*.

Event Database. The event data reduction framework 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 variables recorded were selected based upon past instrumented vehicle studies (Hanowski et al., 2000; Dingus, et al., 2002), national crash databases (General Estimates System and Fatality Accident Reporting System), and questions on Virginia State Police Accident Reports.

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 event severity. Crash-relevant conflicts and proximity conflicts had the least amount of information recorded and near-crashes and crashes had 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 2.5 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 B.

Table 2.5. 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 (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(s) 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. The *baseline database* was comprised of approximately 20,000 6 s 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. Rather, these epochs were selected at random throughout the 12-13 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 five seconds prior or one second after the onset of the conflict to be considered a contributing factor to the crash, near-crash, or incident.

Each *baseline epoch* was randomly selected from the 12 months of data collected on each vehicle. However, the number of baseline epochs selected per vehicle was stratified as a proportional sample based upon the 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 crash risk) due to the increased power that a case-control data set possesses. Greenberg, Daniels, Flanders, Eley, & Boring, (2001) argue that using a case-control design allows for an efficient means to study rare events, such as automobile crashes, and to evaluate the causal relationships that exist for these events by using relatively smaller sample sizes than are used in typical crash database analyses where thousands of crashes may be used. Given that relative crash risk calculations were an objective of the following analyses, the creation of a case control data set was deemed important.

Given that the number of baseline epochs was dependent upon the number of crashes, near-crashes, and incidents that each vehicle was involved, please note that four vehicles did not have any crashes, near-crashes, or incidents and were therefore eliminated from the inattention baseline data base. Some possible reasons that these vehicles did not contain a single crash, near-crash, or incident were that these vehicles had very low mileage or that the drivers exhibited safe driving behavior.

Figure 2.14 shows the number of events for each vehicle (y-axis) and the corresponding number of baseline epochs identified for that vehicle (x-axis). Note that the vehicles involved in multiple crashes, near crashes, and incidents also had a larger number of baseline inattention epochs.

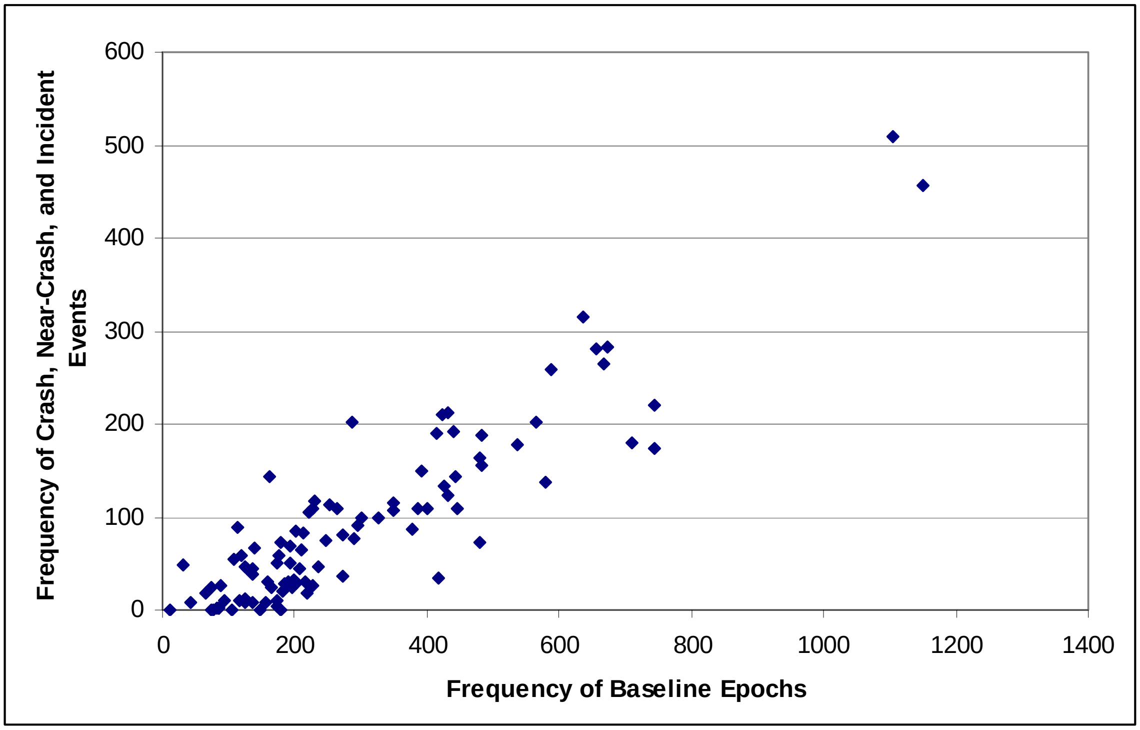

Figure 2.14. The frequency of each vehicle's involvement in crash, near-crash, and incident events versus the number of inattention baseline epochs selected for each vehicle.

The *baseline database* was used in the assessment of the prevalence of various types of inattentive driving, to determine the relative crash risk for each of these types of inattention, and 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 108 primary drivers are represented in the baseline epochs

3.) Multiple drivers drove each vehicle

4.) No environmental or driver behavior data was used in the stratification

The variables that were recorded for the 20,000 *baseline epochs* included the vehicle, environmental, and most driver state variables. In addition, eyeglance analyses were performed for 5000 randomly selected baseline inattention epochs from the 20,000 baseline epochs. These 5000 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 inattention 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 Event Database and the Baseline Inattention Database.

Table 2.6. Description of the Databases Created for the Inattention Analysis

	100-Car Event Database	**Baseline Inattention 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
	Eye-glance data (Crashes, near crashes, and incidents)	Eye-glance data on 5000 randomly selected baseline inattention events.
	Observer Rating of Drowsiness (ORD) for Crashes and Near crashes	Fatigue was marked yes/no with 'yes' = ORD of 60 or above.
5.	Driver/Vehicle 2	N/A
6.	Narrative	N/A

By The Numbers – Top Level Project Statistics

The final top-level statistics for the 100-Car Study are provided in Table 2.7. Note that 109 primary drivers drove 100 vehicles, of which 78 were personal vehicles and 22 were leased vehicles. More than 100 primary drivers were used because some drivers dropped out of the study and others were replaced for various reasons. Altogether, there were 241 total drivers (primary drivers plus secondary drivers). Over 6 terabytes of data were collected and stored on over 1,300 DVDs. Altogether, there were 82 crashes. Of those, complete data were available for 69. Also, of the 82 crashes, 49 were low g events, such as struck or ran over curb, median, parking blocks, or small animal). There were 761 near-crashes and over 8,000 incidents.

Table 2.7. Top-level 100-Car study statistics.

Parameter	Statistic
Participants:	109 primary drivers 241 total drivers
Vehicles:	78 personal, 22 leased
Miles driven:	2,025,000
Hours of driving data collected:	47,382.65
Average speed:	29 mph
Overall duration of data collection in months:	18.5
Amount of data in terabytes:	6.4 TB
Amount of data in DVDs:	1,361 DVDs
Crashes:	82 (69 with complete data)
Near-Crashes:	761
Incidents:	8,295

3. ASSESSMENT OF THE PREVALENCE OF DRIVER INATTENTION AND THE IMPACT OF RELATIVE CRASH RISK

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. It was the author's intention to define and run analyses on these events; therefore, 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 severe fatigue, 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 B.
- *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 such items as checking the speedometer, checking blind-spots, observing adjacent traffic prior to or during a lane change, looking for a parking spot, and checking mirrors.
- *Fatigue* – driver behavior that included 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* - moments when the driver glances, usually momentarily, away from the roadway, but at no discernable object, person, or unknown location. Eye-glance reduction and analysis of these events was done for crashes, near crashes, incidents, and 5000 of the baseline events.

The terms driver inattention and driver distraction have been used throughout the transportation literature at times interchangeably and 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 risk, and population attributable risk for each of these associated types of inattention will be determined in this chapter.

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, Klauer, Neale, Petersen, Lee, Sudweeks,et al. (2005), analyses indicated that the kinematic signatures of 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 calculation of relative crash risks.

Please note that secondary task, driving-related inattention to the forward roadway, and fatigue were all recorded for crash and near-crash events as well as baseline inattention epochs. Eyeglance data, on the other hand, was recorded for all events and 5000 of the baseline epochs (25 percent of the baseline epochs). Therefore all analyses that are conducted requiring eyeglance data will use only the 5000 baseline epochs. All other analyses utilize the entire baseline inattention database. Please note that the 5000 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 20,000 baseline epochs.

Recall from the Method section that the baseline database consisted of a stratified random sample of epochs. This stratification was performed to produce a case-control data set which possesses greater statistical power for the calculation of relative crash risk.

Prevalence of Inattention in Driving

To determine the relative frequency of inattention, the baseline epochs were analyzed to determine the frequency with which drivers were engaging in inattention-related tasks during normal driving. These analyses indicated that driving inattention was identified in 73 percent of all baseline epochs. 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 fatigued, or looking away from the forward roadway very frequently.

Prevalence of Each Type of Inattention in Driving

To assess the prevalence of driver inattention, two comparisons were performed on slightly different subsets of data. First, a comparison was conducted of the four types of inattention for the crashes and near crashes versus the <u>5000</u> baseline epochs (Figure 3.1).

Second, a separate comparison of three types of inattention, secondary task, fatigue, and driving-related inattention to the forward roadway, for all 20,000 baseline epochs and crashes and near crashes is described in Figure 3.2 in order to present the frequency analysis for the entire dataset.

Figure 3.1 shows the percentage of the total number of crashes, near crashes, and baseline epochs that were inattention-related. Please note that 78% of all crashes, 65% of all near-crashes, and 73% of all 20,000 baseline epochs contained at least one of the four types of inattention. Therefore, if one sums across each bar representing crashes, it will equal 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. S*econdary task, driving-related inattention*, and *driver fatigue* 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. Fatigue occurred far less frequently for the baseline inattention 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.

An interesting result demonstrated in Figure 3.1 was that for the baseline epochs, non-specific eyeglance most commonly occurred in conjunction with other sources of driver inattention. However, a higher percentage of crashes and near-crashes was observed with only non specific eyeglance as a contributing factor. This result will be more fully analyzed later in this chapter and in Chapter 6 when eyeglance duration metrics are used.

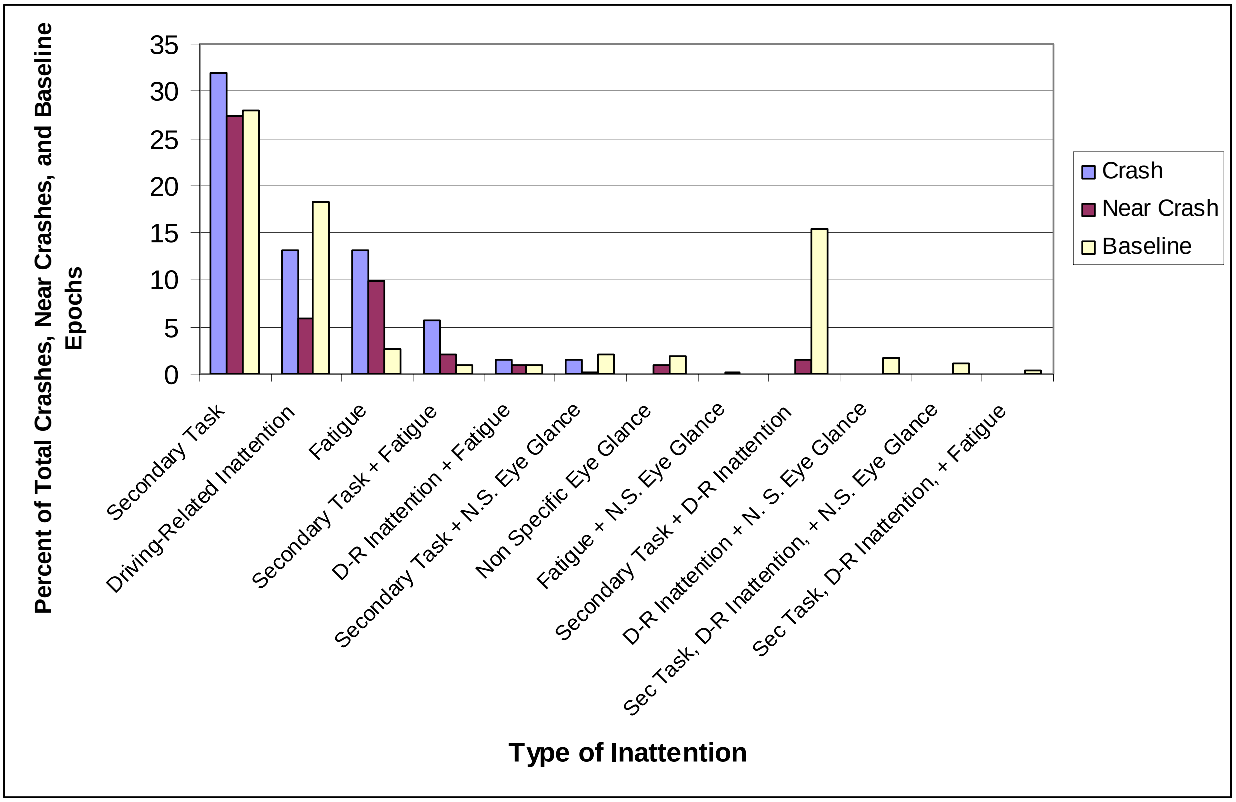

Figure 3.1. The percentage of the total number of crashes and near crashes identified in the 100 Car Naturalistic Study and the percentage of 5000 baseline epochs in which these four types of inattention were identified as a contributing factor.

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 using all 20,000 baseline epochs. Without non-specific eyeglance, the combinations of inattention-type are fewer as the '*secondary task plus non-specific eyeglance* category in Figure 3.1 is now combined with *secondary task* category in Figure 3.2. *Secondary tasks* are still the most frequent type of inattention, followed by *driving-related inattention to the forward roadway* and *fatigue*.

Note that for the baseline epochs, secondary tasks are again the most frequent, followed by *driving-related inattention to the forward roadway* and combinations of these two types of inattention. Fatigue, however, was observed in less than 2.2 percent of all baseline epochs. This is an interesting finding when comparing fatigue's low percentage for baseline events to the much higher percentage involvement in crashes and near crashes. This may indicate that driver fatigue may significantly increase 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 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 of this chapter.

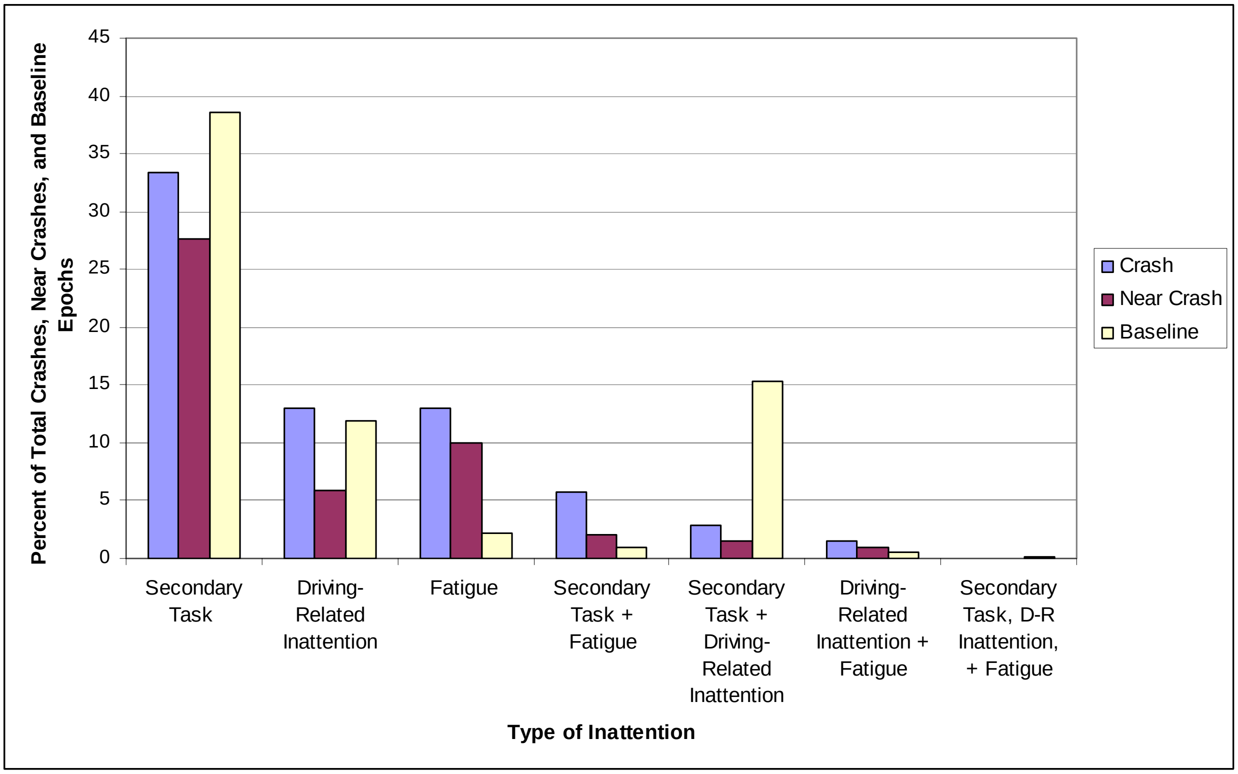

Figure 3.2. The percentage of crashes and near crashes in which three types of inattention were identified as a contributing factor.

Relative Crash Risk for Types of Inattention

Using the baseline data as a measure of exposure, odds ratios were calculated to obtain an estimate of relative crash risk for each of the four types of inattention. In addition, population attributable risks 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 each provides. While the odds ratio (relative risk) calculation provides information regarding individual crash risk when engaging in a particular behavior, the population attributable risk calculation provides an estimate of the percentage of crashes that each type of behavior causes in the population.

Therefore, while an individual's crash risk may increase while performing a particular task, drivers may not engage in this behavior very often or the behavior may require a brief duration; therefore, very few crashes are in fact caused by this behavior. On the other hand, if a specific type of behavior does not increase individual crash risk greatly in isolation, this behavior may in fact occur frequently and/or for long durations while driving, and therefore would account for many crashes in the population.

The following odds ratios were calculated for three levels of secondary task, two levels of driving-related inattention, two levels of non-specific eyeglance, and one level of fatigue. The three levels of secondary tasks are complex secondary tasks, moderate secondary tasks, and simple secondary tasks. The complexity levels are based upon whether the task requires either multi-step, multiple eyeglances away from the forward roadway, and/or multiple button presses (Dingus, Antin, Hulse, & Wierwille, 1989). Moderate complexity tasks are those that require at most two glances away from the roadway and/or at most two button presses, while simple tasks are those that require none or one button press and/or one glance away from the forward roadway. Table 3.1 presents the task types that were assigned to each level of complexity. For operational definitions for each of these tasks, please refer to Appendix B.

Table 3.1. 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 for more than 1.0 to 1.5 s 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: 1) Total time eyes are off the roadway - greater than 2 s or 2) Total time eyes are off the forward roadway - less than 2 s. 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 the environment compared to those drivers who are looking away from the forward roadway for a longer duration.

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 to those interested readers.

The baseline data was categorized in the same manner using three levels of secondary tasks, two levels of driving-related inattention, and two levels of non-specific eyeglance data. Due to the importance of glance length, eyeglance data were required for the separation of driving-related inattention to the forward roadway and non-specific eyeglance. Therefore, *only the 5000 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 complexity secondary task) while checking their left rear-view mirror for 0.5 s (driving-related inattention less than 2 s), for example. Very few combinations emerged for the crash and near-crash events. Odds ratios were not calculated for all combinations of inattention types since the frequency counts were very low in most instances (resulting in wide confidence intervals). Odds ratios will be calculated for *fatigue* and fatigue combined with other types of inattention as these odds ratios were statistically meaningful.

Definition of an Odds Ratio Calculation. A commonly used measure of the likelihood of event occurrence is termed as the *odds*. The odds measures the frequency of event occurrence (i.e., presence of inattention type) to the frequency of event non-occurrence (i.e., absence of inattention type). That is, the odds of event occurrence is defined as the probability of event occurrence divided by the probability of non-occurrence. The 2x2 contingency table in Table 3.2 is used to illustrate this, and related measures.

Table 3.2. 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 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, Daniels, Flanders, Eley, & Boring, 2001). Referring to Table 3.2. the odds ratio would be defined as

$$\theta = \frac{\pi_1 / (1-\pi_1)}{\pi_2 / (1-\pi_2)} = \frac{\frac{n_{11}}{n_{12}}}{\frac{n_{21}}{n_{22}}} = \frac{n_{11} n_{22}}{n_{12} n_{21}} \qquad \textit{Equation 3.1}$$

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 re-written as shown below. Basic odds ratios are calculated as shown in Equation 3.2.

Odds Ratio = (A x D)/(B x C) *Equation 3.2*

Where:

A = the number of events where <inattention type> was present without any other type of inattention

B = the number of baseline epochs where <inattention type> was present without any other type of inattention

C = the number of events where < inattention type> was *not* present or was present but in combination with other types of inattention

D = the number of baseline epochs where <inattention type> was *not* present or was present but in combination with other types of inattention

To interpret odds ratios, a value of 1.0 indicates no significant danger above normal driving. An odds ratio less than 1.0 indicates that this activity is safer than normal driving or creates a protective effect. An odds ratio greater than 1.0 indicates that this activity increases one's relative risk 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 just driving the vehicle.

Table 3.3 shows the odds ratio calculations as well as the upper and lower 95 percent confidence intervals for all four types of inattention. *Fatigue*, *Fatigue (all combinations)*, *Moderate Secondary Tasks,* and *Complex Secondary Tasks* obtained odds ratios of 4.3, 6.5, 2.4, and 7.1, respectively. This result suggests that drivers who drive while severely fatigued are between four and six times as likely to be involved in a crash or near crash. Drivers who are engaging in *moderate secondary task*s are two times as likely to be involved in a crash or near crash, and drivers engaging in *complex secondary tasks* are over seven times as likely. On the other hand, drivers who are looking in their mirrors and checking for blind spots with eyeglances less than 2 s are actually safer than those drivers who do not check their mirrors as is indicated by the very low odds ratio of 0.48. This finding was not surprising since drivers who are checking their blind spots and rear-view mirrors are generally attentive and aware of their surroundings. The odds ratio for *driving-related inattention to the forward roadway- greater than 2 s* obtained an odds ratio slightly greater than 1 (OR = 1.02) but not significantly different than 1.0 (as indicated by the upper and lower confidence interval containing 1.0). This result indicates that this is probably just as safe as normal driving but does not create a protective effect on the driver. The odds ratio for *simple secondary task*s was also greater than 1.0, however, the lower confidence interval was less than 1.0, indicating that these tasks are not significantly more dangerous than normal driving.

Table 3.3. Odds ratios for each type and level of inattention. Those values in bold font are significantly different than 1.0 (normal driving).

Type of Inattention	Odds Ratio	Lower CI	Upper CI
Complex Secondary Task	**7.10**	**4.46**	**11.19**
Moderate Secondary Task	**2.38**	**1.85**	**3.06**
Simple Secondary Task	1.20	0.93	1.55
Moderate to Severe Fatigue	**4.31**	**3.13**	**5.94**
Moderate to Severe Fatigue (all occurrences)	**6.47**	**4.84**	**8.64**
Driving-Related Inattention to the Forward Roadway – Greater than 2 Seconds	1.02	0.63	1.65
Driving-Related Inattention to the Forward Roadway – Less than 2 Seconds	0.48	0.35	0.65
Non-specific Eyeglance Away from the Forward Roadway- Greater than 2 s	1.17	0.35	3.89
Non-specific Eyeglance Away from the Forward Roadway- Less than 2 s	0.65	0.33	1.29

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 fatigue (combination) took into account all events in which fatigue was a contributing factor regardless of whether another type of inattention was present. Five thousand baseline epochs were used and all crashes and near-crashes where the driver was at fault.

Table 3.4 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 the calculations in Table 3.4. 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 power associated with breaking data into smaller subsets. While there were over 40 secondary tasks identified by the data reductionists, only those secondary tasks that were observed for crashes and near crashes as well as baselines epochs are presented in the table.

In other words, some secondary tasks were not observed for either the events or baseline epochs, and it was therefore 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 seen in table 3.4, 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, dialing a hand-held device*, and *eating*. *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 one but with lower confidence intervals below 1.0, indicating that these secondary tasks may not actually be more dangerous than driving alone.

The tasks that had odds ratios less than 1.0 or were safer than driving alone also were interesting findings. Driving with a passenger had the smallest odds ratio and thus, the largest protective effect. This is not a surprising finding, in that, having another person in the vehicle who can also be watching for potential hazards can be helpful to the driver. Also, having a passenger in the vehicle may cause the driver to drive more safely to reduce the likelihood of injuring their passenger. While either of these explanations are likely in the case of adults, it is important to note that extensive research has been done with teenaged drivers that reports opposite results with passengers present (Williams, A F., 2003; Rice, Peek-Asa, & Krause; 2003). Several studies have found that for novice drivers or teenaged drivers, the presence of passengers increased crash risk.

All drivers in the present study were over the age of 18 years old 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 3.5. The results suggest that the odds ratios for the 18 to 20 years olds is nearly the same as it is for the drivers who are 20 years of age and older. This result corroborates research findings by Williams (2003) where 16-17 year old drivers' crash risk increased with the number of passengers in the vehicle up to 6 times that of normal driving, drivers 18-19 year old drivers' showed a very slight increase in crash risk, and older drivers demonstrated a protective effect for the presence of passengers.

Table 3.4. Odds ratios for the secondary tasks.

Type of Secondary Task	Odds Ratio	Lower CI	Upper CI
Complex Secondary Tasks			
Reaching for a Moving Object	**8.25**	**2.34**	**29.0**
Insect in Vehicle	5.94	0.71	49.4
Reading	**3.18**	**1.66**	**6.12**
Dialing Hand-Held Device	**2.58**	**1.49**	**4.47**
Applying Makeup	**2.90**	**1.17**	**7.33**
Moderate Secondary Tasks			
Looking at External Object	**3.46**	**1.05**	**11.34**
Inserting/Retrieving CD	2.10	0.27	15.77
Eating	**1.47**	**0.87**	**2.48**
Reaching for non-moving object	1.29	0.70	2.37
Talking/Listening to a Hand-Held Device	1.23	0.89	1.67
Combing Hair	0.34	0.04	2.44
Simple Secondary Task			
Adjusting Radio	0.71	0.41	1.22
Drinking from open container	0.96	0.30	3.04
Passenger in Adjacent Seat	0.42	0.30	0.58
Child in Rear Seat	0.30	0.04	2.20
Passenger in Rear Seat	0.18	0.02	1.30
Other personal hygiene	0.64	0.31	1.37
Drinking from open container	0.96	0.30	3.04

*Calculation included frequency of events/epochs that included the type of inattention by itself or in combination with other types of inattention. 20,000 baseline epochs were used and all crashes and near-crashes where the driver was at fault.

Table 3.5. Odds ratio calculations for 'Passenger Present' for drivers who are younger and older than 20 years of age.

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

Calculation of Population Attributable Risks

For all types of inattention, population attributable risk calculations were also performed. The population attributable risk was not calculated for driving-related inattention to the forward roadway since it was shown to have a protective effect. A population attributable risk calculation is a measure of the percentage of crashes and near crashes in a metropolitan area that could be attributed to the driver inattention of interest. Please note that these data have some significant limitations with regard to trying to generalize to the driving population of the entire US. Specifically, the sample was limited to only one area and the sample size was small relative to the more standard applications of this statistic. An example of this limitation is that since the data were collected in only a metropolitan area, some degree of caution should be exercised in the interpretation of these results to the population at large that includes a substantial rural driving component.

The population attributable risk calculation uses a population exposure estimate as well as the point estimate for the relative risk calculation. The population exposure estimate is determined by dividing the number of inattention-related baseline epochs by the total number of baseline epochs.

Population attributable risk is calculated as follows:

$$PAR\% = [(P_e (RR - 1))/(1 + P_e (RR - 1))] * 100 \qquad \textit{Equation 3.3}$$

Where P_e = population exposure estimate

RR = relative risk or odds ratio

For example, to assess a population attributable risk for complex secondary task, 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 present:

e.g. P_e = 44 epochs with complex secondary task/4977 total baseline epochs = 0.009

Thus, e.g. PAR% = [(0.009) (7.10 – 1)/7.10 + (0.009) (7.10 – 1))]*100 = 5.10

For a more complete discussion of the population attributable risk calculations see Sahai & Khurshid (1996).

The population attributable risk calculations are presented in Table 3.4 for all of those types of inattention and secondary tasks with an odds ratio greater than 1.0. A population attributable risk 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 fatigue* accounts for between 8 and 13 percent of all crashes and near crashes, c*omplex, moderate, and simple secondary tasks* account for 16 percent of all crashes and near crashes. *Dialing hand-held device, talking on a hand-held device*, and *reading* all contributed to 1.5 percent, 1.4 percent, and 1.2 percent individually to all crashes and near crashes, respectively. The rest of the secondary tasks each accounted for less than 1 percent of all crashes and near crashes. In total, the three types of secondary task distraction and fatigue are contributing factors in over 25 percent of all crashes and near crashes.

Table 3.6. Population attributable risks for types of inattention and the specific secondary tasks.

Type of Inattention	**Population Attributable Risk**	**Lower CI**	**Upper CI**
Complex Secondary Task	5.10	4.87	5.28
Moderate Secondary Task	9.26	8.93	9.61
Simple Secondary Task	2.33	1.98	2.67
Moderate to Severe Fatigue	8.14	7.87	8.4
Moderate to Severe Fatigue (all occurrences)	12.75	12.44	13.10
Driving-Related Inattention to the Forward Roadway – Greater than 2 s	0.06	-0.11	0.22
Non-specific Eyeglance Away from the Forward Roadway-Greater than 2 s	0.08	0.01	0.14
Dialing Hand-Held Device	1.54	1.41	1.67
Reading	1.23	1.12	1.34
Applying Makeup	0.59	0.51	0.67
Reaching for moving object in vehicle	0.47	0.41	0.53
Insect in vehicle	0.14	0.11	0.18
Talking/Listening to Hand-Held Device	1.44	1.2	1.69
Eating	0.86	0.72	1.00
Reaching for non-moving object	0.45	0.32	0.44
Looking at external object	0.38	0.32	0.44
Inserting/Retrieving CD	0.09	-2.67	2.8

Summary

The results from these analyses demonstrate the power of large-scale naturalistic driving studies in that the prevalence of driving inattention, frequency of occurrence, and relative crash risk for various types of driver inattention can finally be calculated using pre-crash driving behavior data. While relative risk calculations have been obtained using survey data and/or police accident reports, this study is the first to directly observe drivers 6 seconds prior to crashes and near-crashes and compare their behavior to their driving behaviors during normal, routine driving.

To calculate the prevalence and frequency of driver inattention, the baseline database was used. This analysis indicated that drivers are engaging in one of four types of inattention in over 70 percent of the 20,000 baseline epochs. Interestingly, when frequency of occurrence is summed across the number of baseline epochs that included each type of inattention, *secondary task engagement* accounted for 54 percent, *driving-related inattention to the forward roadway* accounted for 27 percent, and *fatigue* only accounted for 4 percent of the inattention baseline epochs.

The results of the relative crash risk calculations indicated that drivers are between four times to 6 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 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 seven times as likely when engaging in a complex secondary task.

The 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 of greater than one indicating a higher individual crash risk when a driver engages in these activities. Interestingly, *driving-related inattention to the forward roadway – less than 2 seconds, non specific eyeglance – less than 2 seconds*, *driving with a passenger*, *singing to the radio*, and even some engagement with radio and the heating/air conditioner unit all had odds ratios of less than one. These results suggest that these activities are indicative of a relatively alert driver.

For drivers over the age of 18, having a passenger in the vehicle may result in a safer driving situation since that 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* crash risk. An analysis was conducted to determine whether younger drivers' (18-20 year old drivers) crash risk increased in the presence of passengers. The results of this analysis corroborated previous research suggesting that any increased crash risk associated with the presence of passengers is greatly reduced or virtually extinguished with drivers 18 years of age and older.

Even though the odds ratios for *reaching for a moving object, external distraction, reading, applying makeup, dialing a hand-held device,* and *eating* presented greater individual 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 calculations since they were relatively rare. Fatigue attributed for between 8 and 13 percent of the crashes and near crashes in the population which is much higher than most crash database research has shown (e.g., Campbell, Smith, and Najm, 2003). All complexity levels of secondary tasks attributed to 16 percent of the crashes and near crashes in an urban environment. In total, inattention contributed to a minimum of 25 percent of all crashes and near crashes that occur in this population. This calculation is a conservative estimate since it does not take into account those crashes and near crashes with multiple types of inattention present.

4. ASSESSMENT OF THE ENVIRONMENTAL CONDITIONS IN WHICH DRIVERS CHOOSE TO ENGAGE IN SECONDARY TASKS AND/OR DRIVE WHILE FATIGUED AS WELL AS AN ASSESSMENT OF THE RELATIVE RISKS OF ENGAGING IN DRIVING INATTENTION WHILE ENCOUNTERING THESE ENVIRONMENTAL CONDITIONS.

This research objective is the first attempt at using large-scale naturalistic driving data to determine the environmental conditions in which drivers choose to engage in secondary tasks or to drive while fatigued. The associated relative crash risks of either engaging in complex or moderate secondary tasks or driving fatigued during poor environmental conditions was also assessed. Several types of environmental variables were recorded during the data reduction process for both the 100-Car 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 4.1. 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, for example.

Table 4.1. 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 3). Recall that this data is referred to as *event* data for this dissertation. 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 inattention database, please refer to Chapter 2, Methods.

For the following analyses, the term *inattention-related events* 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 driving or provided a protective effect. Also, *no- 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).

The odds ratios in this chapter are maximum likelihood estimates obtained using logistic regression analysis because two variables were being assessed simultaneously (as compared to a single variable, as was true for the previous chapter). 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 analysis both models and provides 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 crash risk in various weather, roadway, and traffic environments. These three odds ratio calculations assess the following:

1) Is driving fatigued 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 moderately complex secondary tasks during < *environmental variable level*> riskier than driving alert in < *environment* level>?

Only fatigue, complex, and moderately complex secondary tasks were used in the following odds ratio calculations. Recall from the previous chapter that complex and moderately complex secondary task engagement 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 moderately complex secondary tasks required two or three eyeglances or button presses. It was also demonstrated in the previous chapter that these two types of secondary tasks as well as fatigue had higher relative crash risks than normal driving, whereas simple secondary tasks were found to not be significantly riskier than normal driving. Therefore, only fatigue, complex, and moderately complex 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. 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 fatigued 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. Table 4.2

presents the number of crashes, near-crashes, and baseline epochs observed for each of these lighting levels.

Table 4.2 The frequency of fatigue and secondary task-related events and epochs that were recorded for each type of lighting levels.

Lighting Level	Frequency of Fatigue and Secondary Task-Related Crashes and Near-Crash Events	Frequency of Fatigue and Secondary Task - Related Baseline Epochs
Darkness-Lighted	48	1767
Darkness- Not Lighted	29	1010
Dawn	11	24
Daylight	98	13281
Dusk	49	492
Total	308	9818

Figure 4.1 presents the baseline data percentages for inattention-related epochs, fatigue-related epochs, and total number of epochs for each level of lighting. The majority of inattention-related events and total baseline epochs occurred during daylight hours; this replicates findings from many previous instrumented-vehicle studies (e.g., Lee, Olsen, & Wierwille, 2003; Dingus, Neale, Garness, Hanowski, Kiesler, Lee, et al., 2001). The fatigue-related events, however, were more evenly split between the daylight and the darkness conditions. The percentages are very similar for the inattention-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 fatigue at different rates 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 fatigue was observed during the day, whereas higher percentages of fatigue were observed at night compared to the baseline epochs.

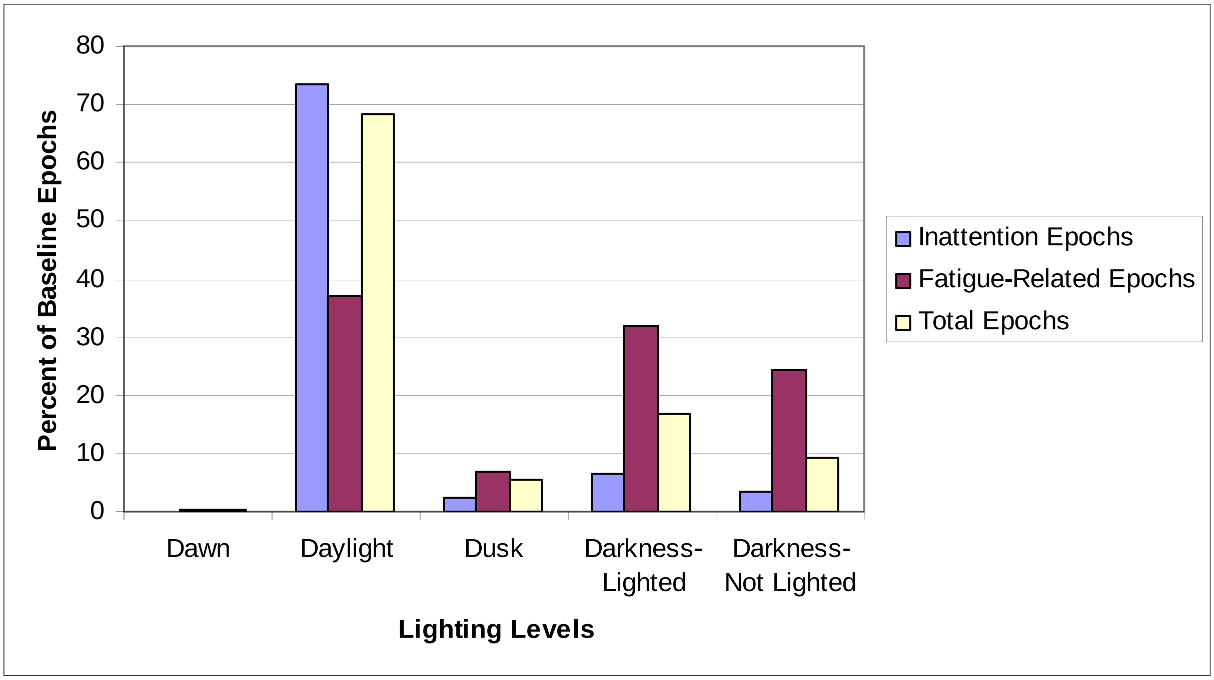

Figure 4.1. Percentage of inattention-related baseline and percentage of total baseline epochs for the different lighting levels observed.

As shown in Table 4.3, driving fatigued in any of the ambient lighting levels is riskier than driving while alert. However, it appears that driving fatigued during the daylight may be slightly riskier than driving fatigued in the dark. While it is perhaps commonly thought that most fatigue-related crashes occur at night, a majority of the fatigue-related crashes in this study occurred during the daytime in heavy traffic (during morning and evening commutes). Thus, the risks of driving fatigued during the day may be slightly higher than at night due to higher traffic density.

Table 4.3. Odds Ratios for the interaction of fatigue by type of lighting.

Type of Lighting	Odds Ratio	Lower CI	Upper CI
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

Relative 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 4.4 and 4.5). This was especially true for engaging in complex tasks at night, as these relative crash risks were higher than during dawn, dusk, or daylight. The relative crash risk for engaging in moderate secondary tasks all were 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 the complex tasks or driving while fatigued.

Table 4.4. Odds ratios for the interaction of complex secondary task by type of lighting.

Type of Lighting	Odds Ratio	Lower CI	Upper CI
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**

Table 4.5. Odds ratios for the interaction of moderate secondary task by type of lighting.

Type of Lighting	Odds Ratio	Lower CI	Upper CI
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

Weather

Reductionists used the video to assess the weather conditions outside the vehicle. An analysis of whether drivers engaged in inattention-related activities during poor weather conditions was then conducted. Table 4.6 presents the frequency counts of the number of fatigue 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 4.6. The frequency of fatigue and secondary tasks events and epochs that were recorded for each type of weather.

	Type of Weather	Frequency of Secondary Task and Fatigue-Related Crashes and Near-Crash Events	Frequency of Secondary Task and Fatigue-Related Baseline Epochs
1.	**Clear**	246	8698
3.	**Rain**	61	1050
4.	**Sleet**	0	6
5.	**Snow**	0	23
6.	**Fog**	0	15
7.	**Mist**	0	18
8.	**Other**	0	8
	Total	307	9818

Figure 4.2 presents the percent of fatigue, inattention-related, and total baseline epochs for each weather type. Nearly all of the epochs occurred during clear weather, with 11% occurring during rainy weather. The percentages are nearly identical for inattention-related, fatigue-related, and total baseline epochs for all weather conditions, indicating that drivers were not engaging in secondary tasks or driving fatigued substantially differently during any particular type of weather. The total number that occurred during sleet, snow, fog, mist, and other weather condirions were very small (the sample size was perhaps not large enough to adequately address the issue of secondary task engagement during these types of weather).

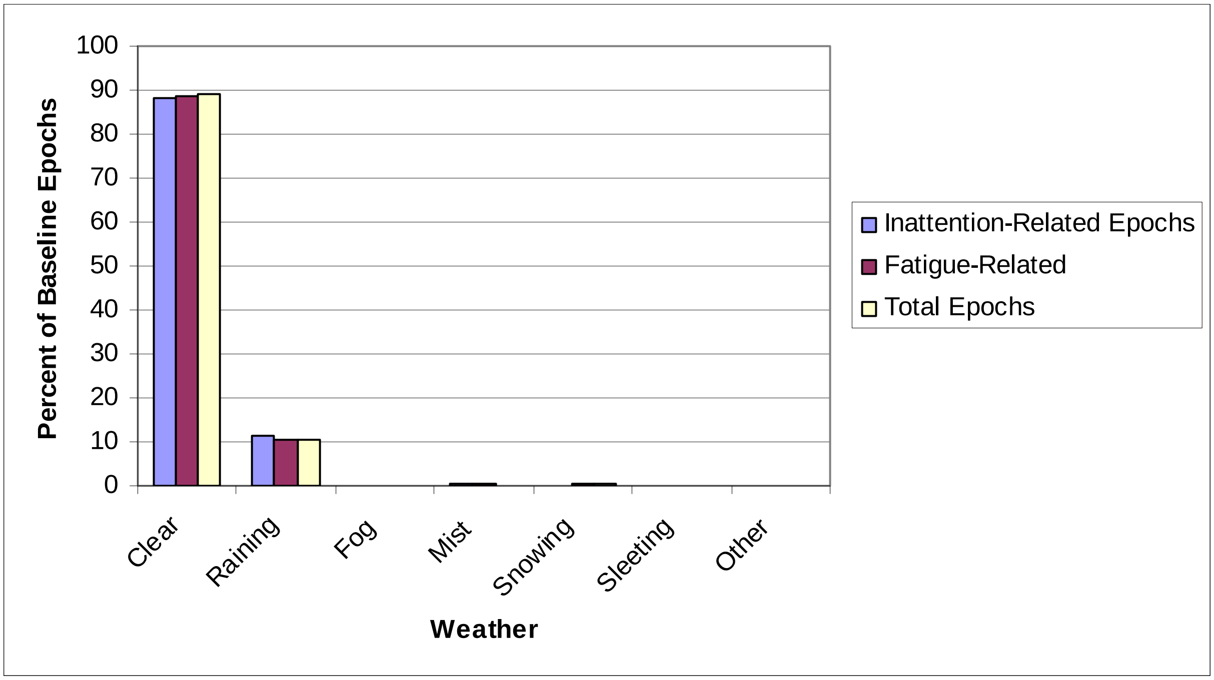

Figure 4.2. Percentage of inattention-related baseline inattention epochs and crash and near-crash events for each type of weather.

Table 4.7 presents the odds ratio calculations for the different types of weather. Driving while fatigued during both rainy and clear weather is significantly more risky than driving alert during the same conditions. Interestingly, the elevated crash risk is the same for both suggesting that driving fatigued is very dangerous, regardless of roadway conditions. Unfortunately, the other weather conditions could not be assessed due to low statistical power.

Table 4.7. Odds ratios for the interaction of fatigue by type of weather.

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

* No calculation due to no observations in either baseline inattention epochs or crash/near-crash events.

The relative risk calculations for complex secondary tasks also suggest that engaging in complex secondary tasks is significantly more risky than driving alert in similar conditions (Table 4.8). The relative risk estimate is higher for rain, suggesting that it may be riskier to engage in complex tasks during the rain than in clear weather. Some caution is urged in this interpretation because the confidence interval surrounding the odds ratio for engaging in a complex task during the rain is also larger than it was for clear weather.

Table 4.8. Odds ratios for the interaction of complex secondary task by type of weather.

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

The odds ratio for engaging in moderate secondary tasks indicate that it may be safer to engage in moderate secondary tasks than complex secondary tasks (Table 4.9). 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 fatigued or engaging in complex secondary tasks.

Table 4.9. Odds ratios for the interaction of moderate secondary task by type of weather.

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

Roadway and Surface Conditions

Road Type

Road Type (called “Traffic Flow” in the General Estimates System 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 4.10 shows the distribution of inattention-related events and epochs that occurred on each type of traffic flow roadway. Most inattention-related events and epochs occurred on divided roadways.

Table 4.10. The frequency of inattention-related events and epochs that were recorded for each road type.

Road Type	Frequency of Fatigue and Secondary Task-Related Crashes and Near-Crash Events	Frequency of Fatigue and Secondary Task-Related Baseline Epochs
Divided	164	6281
Undivided	128	2973
One-way	12	280
No Lanes	3	284
Total	307	9818

Figure 4.3 presents the percent of total fatigue-related epochs, secondary task-related epochs, and total baseline epochs for the various road types. While divided roadways were most frequent for all categories, undivided roadways were also a significant percentage of the epochs. 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 fatigue 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 fatigue-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 more fatigue.

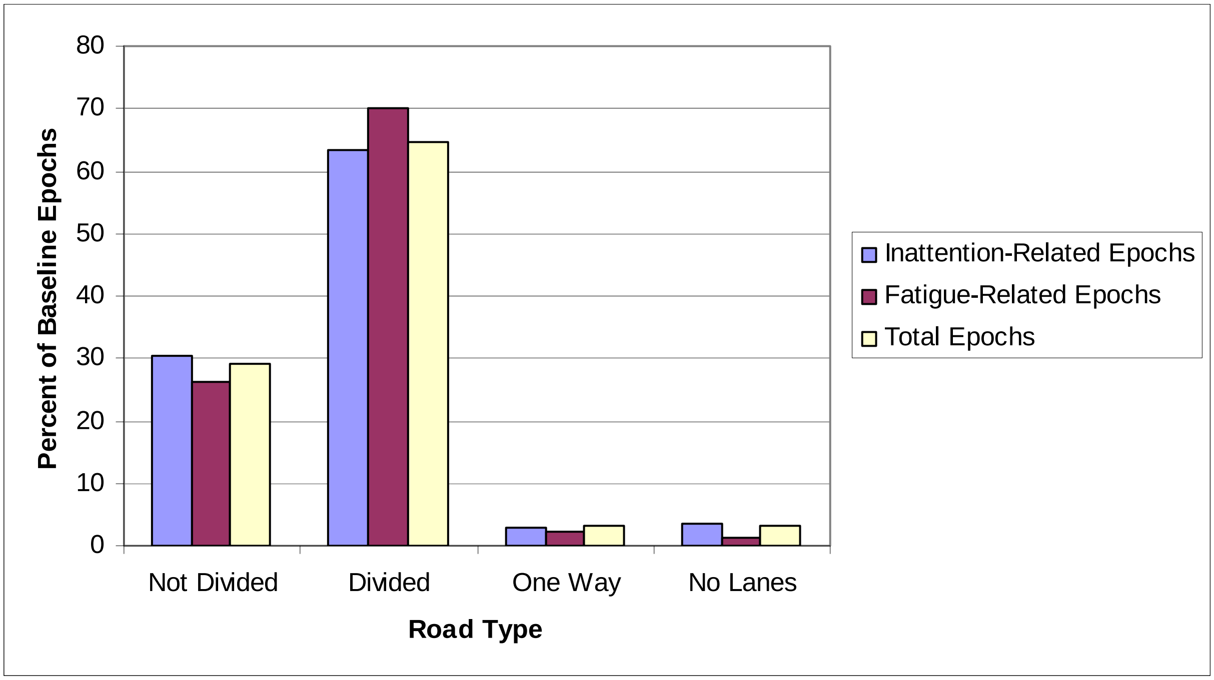

Figure 4.3. Percentage of inattention-related baseline epochs and total number of baseline epochs by type of roadway.

Even though drivers appear to be engaging in secondary tasks or driving fatigued on these types of roadways equally, that does not necessarily mean that it is equally safe to do so. Odds ratios for fatigue, complex secondary task and moderate secondary task engagement were calculated for each road type and are presented in Tables 4.11 - 4.13. All of the odds ratios for the interaction of fatigue and road type were greater than 3.0 suggesting that driving while fatigued on any of these road types increases crash risk by at least 3 times that of driving alert on the same types of roadways.

Engaging in complex tasks while driving on undivided roadways was slightly less dangerous than engaging in complex 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 moderately complex tasks were not significantly different from 1.0 indicating that engaging in moderate secondary tasks is less risky than engaging in complex or driving fatigued.

Table 4.11. Odds ratio calculations for the interaction of fatigue by road type.

Road Type	Odds Ratio	Lower CI	Upper CI
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

Table 4.12. Odds ratio calculations for the interaction of complex secondary task by road type.

Road Type	Odds Ratio	Lower CI	Upper CI
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

Table 4.13. Odds ratio calculations for the interaction of moderate secondary task by road type.

Road Type	Odds Ratio	Lower CI	Upper CI
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

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 fatigue, specific types of roadway alignment may increase 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 4.14 presents the frequency of inattention-related events and 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 4.14. The frequency of fatigue and secondary task-related events and epochs that were recorded for each type of roadway alignment.

Type of Roadway Alignment	Frequency of Fatigue and Secondary Task-Related Crashes and Near-Crash Events	Frequency of Fatigue and Secondary Task - Related Baseline Epochs
Curve Grade	5	77
Curve Level	46	917
Straight Grade	5	210
Straight Level	250	8611
Straight Hill Crest	1	0
Curve Hill Crest	0	0
Other	0	1
Total	307	9816

Figure 4.4 compares the percentage of fatigue-related, inattention-related, and total baseline epochs for different levels of roadway alignment. While 90% of fatigue, inattention-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 inattention-related activities based upon the alignment of the roadway, nor are there differences in drivers fatigue on these different roadway alignments.

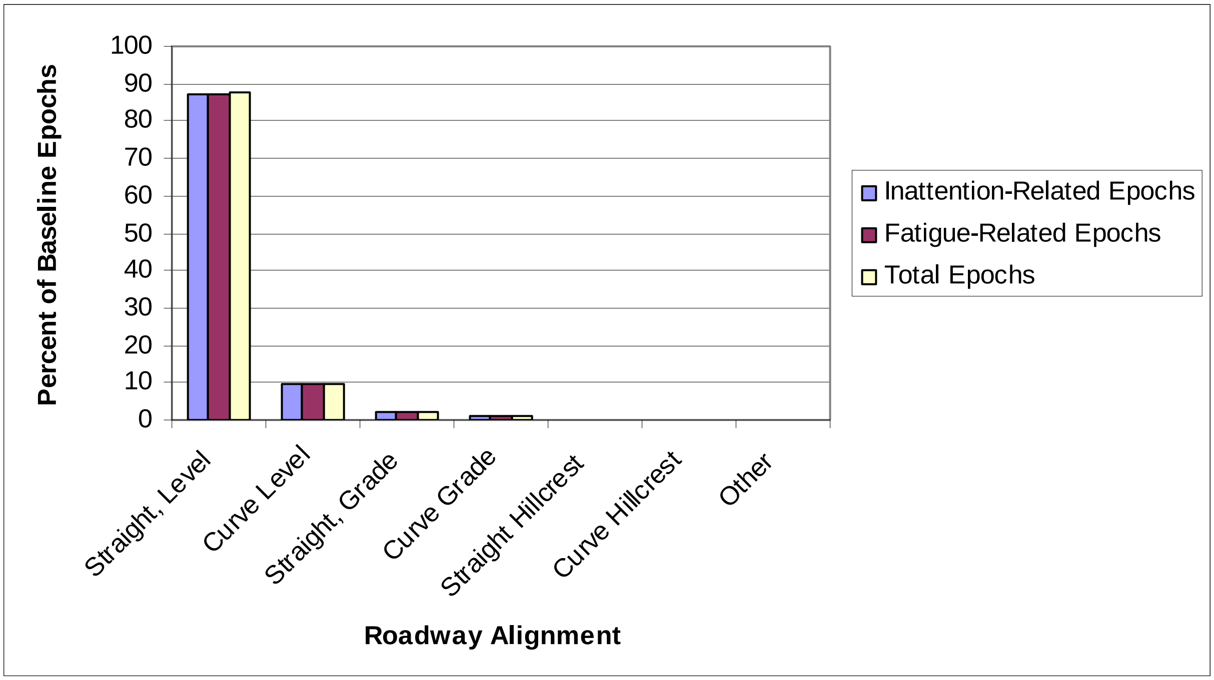

Figure 4.4. Percentage of inattention-related baseline epochs and total number of baseline epochs for each type of roadway alignment.

To determine whether there is increased individual crash risk for driving fatigued or engaging in inattention-related activities for particular types of roadway alignment, odds ratios were calculated and are presented in Tables 4.15-4.17. The odds ratio calculation for straight, grade had the highest crash risk, suggesting that fatigued 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 4.15). The odds ratio for the straight, grade was not significantly higher than either curve, level or straight, level (since the confidence intervals 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 4.16). 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 that of 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 fatigued on these road alignments.

Table 4.15. Odds ratio calculations for fatigue and roadway alignment.

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

Table 4.16. Odds ratio calculations for complex secondary task and roadway alignment.

Type of Roadway Alignment	Odds Ratio	Lower CI	Upper CI
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**

Table 4.17. Odds ratio calculations for moderate econdary task and roadway alignment.

Type of Roadway Alignment	Odds Ratio	Lower CI	Upper CI
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

Traffic Density

Traffic density was recorded by the data reductionists using the Transportation Research Board's Level of Service Definitions (*Highway Capacity Manual*, 2000). The Level of Service 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 4.18 along with the frequency of inattention-related events and epochs that were recorded at each level of traffic density.

Table 4.18. The frequency of inattention-related events and epochs that were recorded at each level of traffic density.

Traffic Density	Frequency of Inattention-Related Crashes and Near-Crash Events	Frequency of Inattention-Related Baseline Epochs
LOS A: Free Flow	131	6930
LOS B: Flow with Some Restrictions	118	5306
LOS C: Stable Flow – Maneuverability and Speed are more Restricted	84	1192
LOS D: Flow is Unstable – Vehicles are unable to pass with temporary stoppages.	37	285
LOS E: Unstable Flow- Temporary restrictions, substantially slow drivers	15	133
LOS F: Forced Traffic Flow Conditions with Low Speeds and Traffic Volumes Below Capacity	2	87
Total	307	13,933

*Note that Inattention is defined as only those events where drivers were involved in secondary tasks or were severely fatigued.

Figure 4.5 presents the percentage of fatigue, inattention-related, and total baseline epochs that occurred at each level of traffic density. As traffic density increased, the frequency of fatigue and inattention-related epochs decreased. The percentage for inattention-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 fatigue-related epochs were slightly different, with more fatigue 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 fatigue because the driver is under-stimulated.

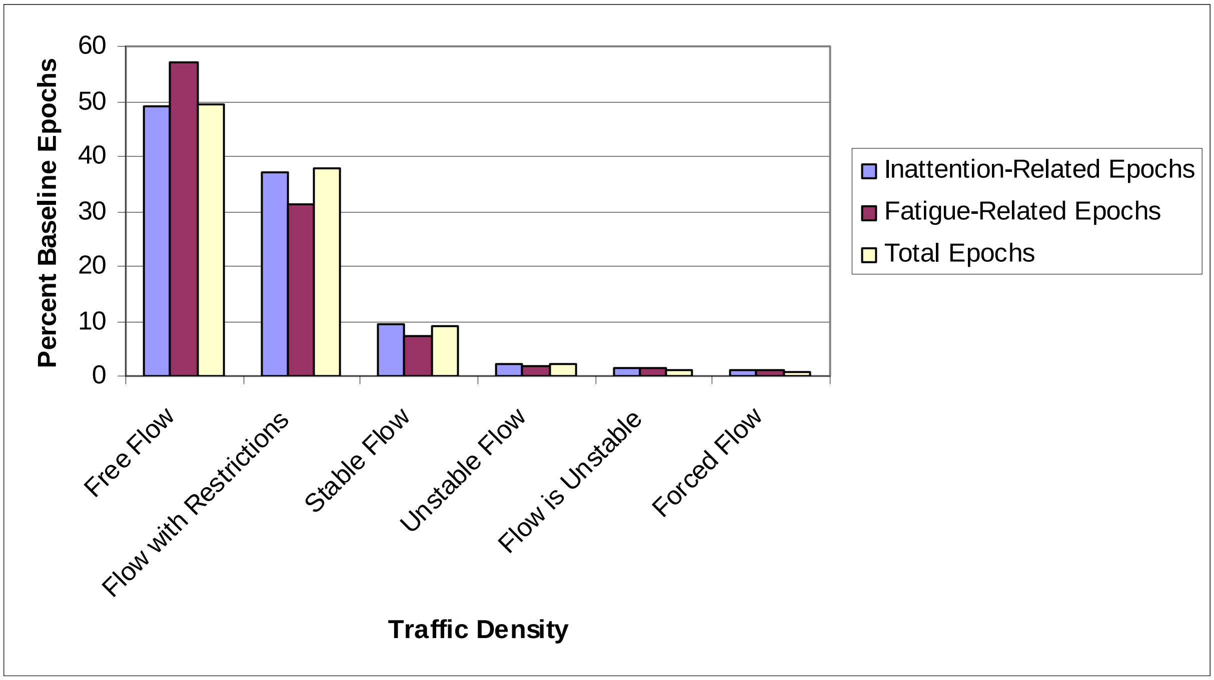

Figure 4.5. Percentage of inattention-related baseline inattention epochs and crash and near-crash events for all traffic densities.

Odds ratios were calculated to determine if any of these traffic densities present greater individual crash risk. Tables 4.19-4.21 present the odds ratio calculations for each level of density for fatigue. The odds ratio calculations for driving fatigued at each level of traffic density suggest that driving fatigued is at least 3 times riskier than driving in while alert. 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 crash risk by at least 3 times that of alert driving. 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 or elevates crash risk to the extent as driving fatigued or engaging in complex secondary tasks. This result was found to be true across all levels of traffic density for moderate task engagement.

Table 4.19. Odds ratio calculations for fatigue and traffic density.

Type of Traffic Density	Odds Ratio	Lower CI	Upper CI
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**

Table 4.20. Odds ratio calculations for complex secondary task and traffic density.

Type of Traffic Density	Odds Ratio	Lower CI	Upper CI
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**

Table 4.21. Odds ratio calculations for moderate secondary task and traffic density.

Type of Traffic Density	Odds Ratio	Lower CI	Upper CI
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

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 4.22 shows the frequency of inattention-related events and baseline epochs for all six surface condition types. Nearly all of the inattention-related events and epochs occurred on dry pavement.

Table 4.22. The frequency of fatigue and secondary task-related epochs that occurred at each roadway surface condition level.

Surface Condition	Frequency of Fatigue and Secondary Task-Related Crashes and Near-Crash Events	Frequency of Fatigue and Secondary Task - Related Baseline Epochs
Dry	266	8765
Wet	40	949
Icy	1	4
Snowy	0	97
Muddy	0	1
Other	0	2
Total	307	9818

Figure 4.6 shows the percentages of fatigue-related, inattention-related, and total baseline epochs that occurred for each type of surface condition. Nearly 90% of all fatigue, inattention-

related epochs, 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 fatigue and total number of baseline epochs, as well as for inattention-related and total number of baseline epochs. This indicates that drivers did not choose to engage in secondary tasks or drive fatigued as a function of the surface condition of the roadway.

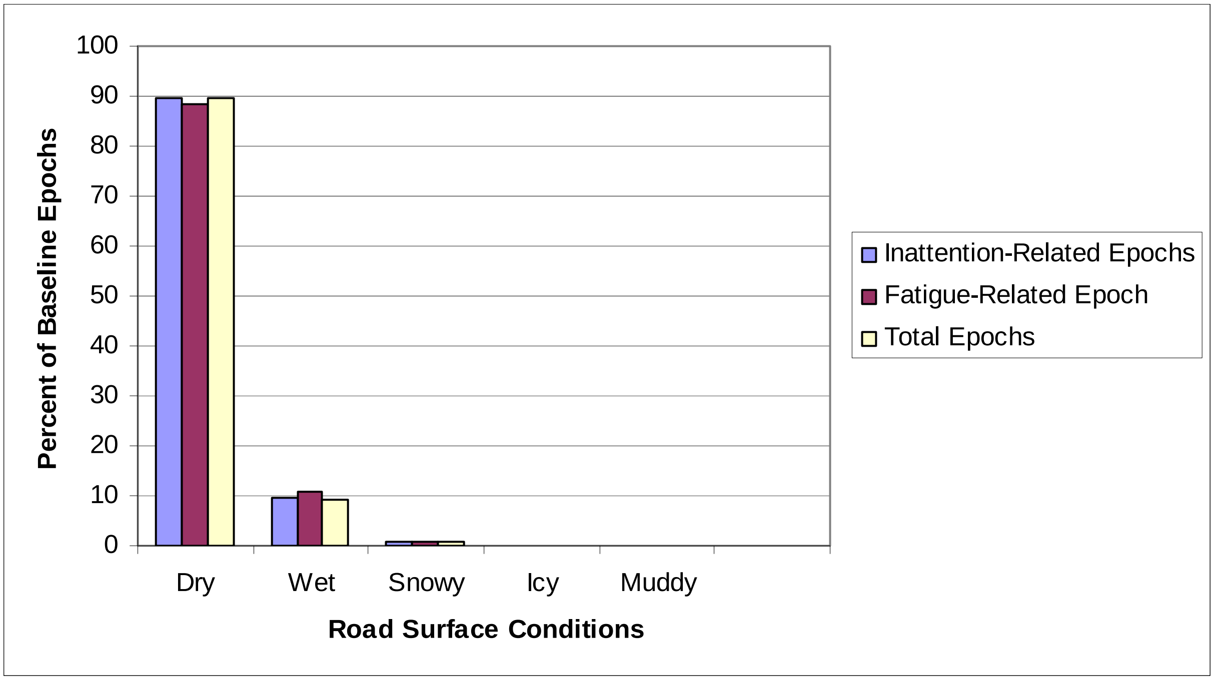

Figure 4.6. Percentage of inattention-related baseline epochs and percentage of total baseline epochs for all surface conditions.

Odds ratio calculations were conducted to determine whether the crash risks associated with driving fatigued or while engaging in complex or moderately complex secondary tasks were different as a function of poor surface conditions. Table 4.23 presents the odds ratios calculated for driving fatigued 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 fatigued on either dry or wet roadways increased 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 crash risk by four times over that of driving alert on dry roadways. The relative 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 puzzling, 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 moderately complex secondary tasks, which was found to not be as risky as driving fatigued or while engaging in complex secondary tasks. 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 4.23. Odds ratio calculations for fatigue and surface condition.

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

Table 4.24. Odds ratio calculations for complex secondary task and surface condition.

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

Table 4.25. Odds ratio calculations for moderate secondary task and surface condition.

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

Roadway Infrastructure

Traffic Control

The type of traffic control device that a driver needed to heed either 5 s 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 inattention segment, the reductionist also marked it accordingly. Otherwise, the reductionists recorded *No Traffic Control*.

Table 4.26 presents the frequency of inattention-related crash and near-crash events and baseline inattention epochs where the driver was heeding a particular traffic control device during the course of the event or epoch. Most of the events and epochs were marked as *No Traffic Control.*

Table 4.26. The frequency of fatigue and inattention-related epochs that were recorded for each type of traffic control device.

Type of Traffic Control Device	Frequency of Inattention-Related Crashes and Near-Crash Events	Frequency of Inattention-Related Baseline Epochs
Traffic Signal	52	660
Stop Sign	7	74
Traffic Lanes Marked	5	302
Yield Sign	1	19
Slow or Warning Sign	1	9
No Passing Sign	0	1
One-way road	0	8
Officer or Watchman	2	3
No Traffic Control	234	8711
Other	5	30
Total	307	9817

*Note that Inattention is defined as only those events where drivers were involved in secondary tasks or were severely fatigued.

The comparisons between the percent of fatigue-related, inattention-related, and total number of baseline epochs for each type of traffic control device are shown in Figure 4.7. The percentages are very similar across the board, which indicates that drivers are not choosing to engage in secondary tasks or drive while fatigued 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 2, Method).

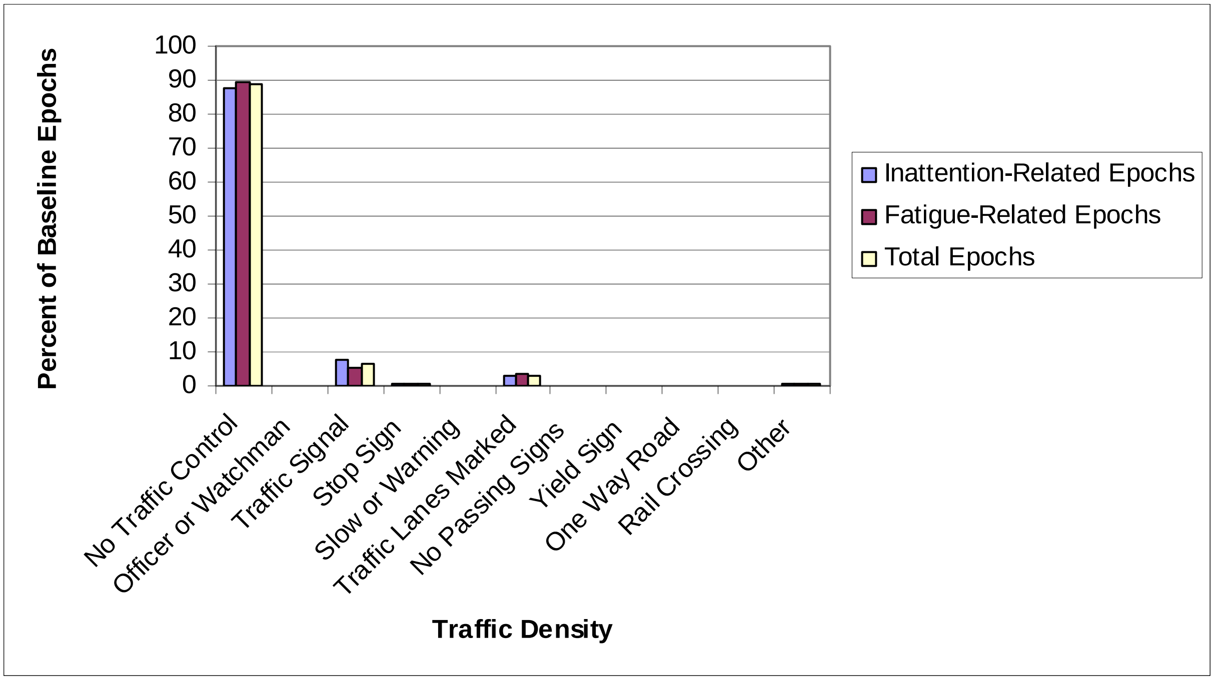

Figure 4.7. Percentage of inattention-related baseline inattention epochs and percentage of total number of baseline epochs for each type of traffic control device.

Odds ratios were calculated to determine whether engaging in complex or moderately complex secondary tasks or driving while fatigued while encountering any of these traffic control devices increased an individual's crash risk (Tables 4.27 through 4.29). The odds ratio calculations for fatigue suggest that fatigue, 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 (Table 4.27). None of the traffic control devices was significantly more risky in the presence of fatigue 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 at all increased crash risk by at least three times over that of an alert driver (Table 4.28). Stop signs or traffic signals were not significantly riskier than no traffic control device. Odds ratios for other traffic control devices were not available because of low power.

The odds ratios for moderately complex secondary task engagement were not significantly different from 1.0 except for traffic signal (Table 4.29). The odds ratio for traffic signal actually showed a protective effect, suggesting either that the traffic signal was able to redirect the drivers' attention to the forward roadway or that the presence of a traffic signal was highly correlated with increased traffic, which redirected the drivers' attention to the forward roadway. Overall, engaging in moderate secondary tasks is not as risky as driving fatigued or while engaging in complex secondary tasks in the presence of any of these traffic control devices.

Table 4.27. Odds ratio calculations for fatigue and each type of traffic control device.

Type of Traffic Control Device	Odds Ratio	Lower CI	Upper CI
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**

Table 4.28. Odds ratio calculations for complex secondary task and each type of traffic control device.

Type of Traffic Control Device	Odds Ratio	Lower CI	Upper CI
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**

Table 4.29. Odds ratio calculations for moderate secondary task and each type of traffic control device.

Type of Traffic Control Device	Odds Ratio	Lower CI	Upper CI
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

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 to 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,e 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 inattention 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 4.30 along with the frequency of inattention-related events and baseline epochs. Note that most events and epochs were not near roadway junctions (i.e., they were "non-junction").

Table 4.30. The frequency of inattention-related events and epochs that were recorded for each type of relation to junction.

Type of Relation to Junction	Frequency of Inattention-Related Crashes and Near-Crash Events	Frequency of Inattention-Related Baseline Epochs
Intersection	54	578
Intersection-Related	30	497
Entrance/Exit Ramp	17	179
Parking Lot	5	226
Driveway/Alley Access	3	33
Interchange	2	23
Rail Grade Crossing	0	1
Other	2	27
Non-Junction	194	8254
Total	307	9816

*Note that Inattention is defined as only those events where drivers were involved in secondary tasks or were severely fatigued.

Figure 4.8 presents the percentages of fatigue-related, inattention-related, and total number of baseline epochs occurring at each of the junction types. Note that non-junction accounted for 84% of the inattention-related baseline epochs as well as of the total baseline epochs. There were very small differences between the percentages of inattention-related and total number of baseline epochs, suggesting that there are only small differences between the percentages of time spent engaging in inattention-related epochs during these junctions and how often drivers encounter these types of junctions. There were slight differences in the percentage of fatigue-related epochs and total epochs, suggesting that a higher percentage of fatigue-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 fatigue effects more often while navigating through less demanding environments.

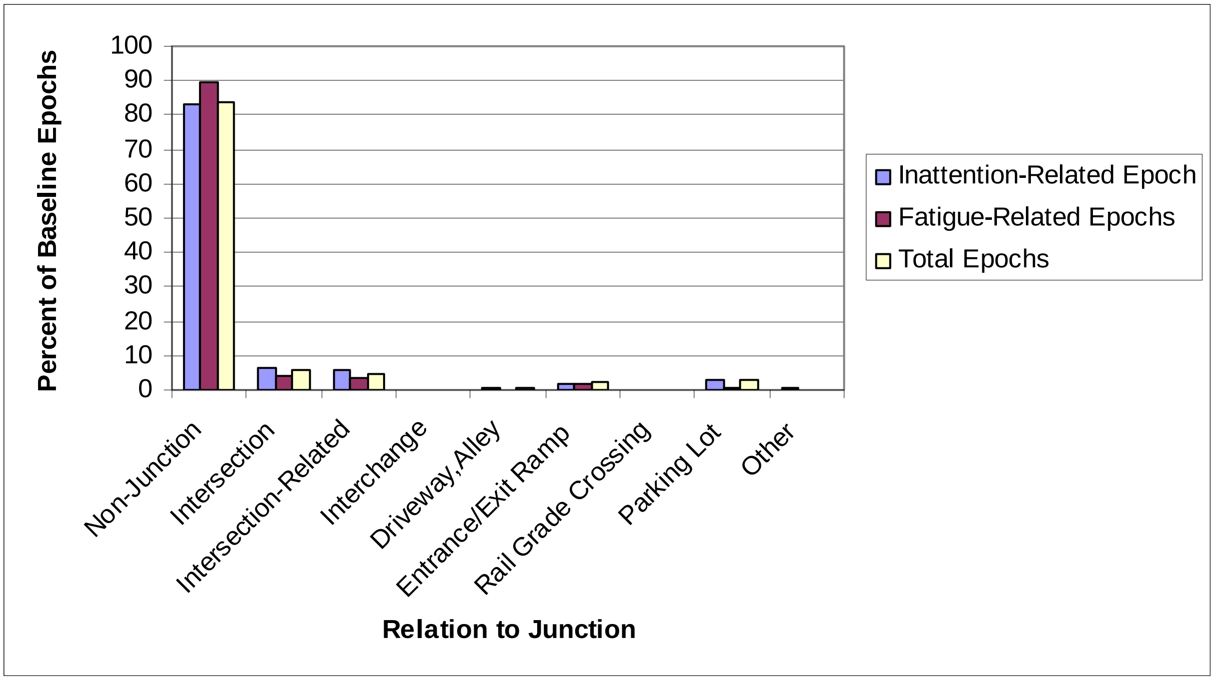

Figure 4.8. Percentage of inattention-related baseline inattention epochs and crash and near-crash events for each type of relation to junction.

To determine whether any of these types of junctions present higher crash risks for inattentive drivers, the odds ratios for each were calculated (Tables 4.31 through 4.33). The results for the fatigue-related odds ratios indicate that 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 4.31). Also, driving while fatigued in general (i.e., non-junction) increases a drivers crash risk by as much as five times over that of an alert driver.

Engaging in complex secondary tasks while in a parking lot or near an intersection increased crash risk over that of an alert driver (Table 4.32). Somewhat surprisingly, the odds ratio for an intersection did not demonstrate an increased crash risk. Drivers may be more careful when in engaging in complex tasks during intersections as these are high visually and cognitively demanding environments.

The odds ratios for engaging in moderately complex 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 4.33). The odds ratio for engaging in moderately complex secondary tasks in a parking lot was very high, with an increased crash risk of nine times over that of an alert driver in a parking lot. This is somewhat frightening, in that many people assume that these are asfer placed in which to engage in these types of tasks. However, there is a wide confidence interval surrounding this point estimate.

Table 4.31. Odds ratio calculations for fatigue and each type of relation to junction.

Type of Relation to Junction	Odds Ratio	Lower CI	Upper CI
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 4.32. Odds ratio calculations for complex secondary task and each type of relation to junction.

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

Table 4.33. Odds ratio calculations for moderate secondary task and each type of relation to junction.

Type of Relation to Junction	Odds Ratio	Lower CI	Upper CI
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

Summary

Two primary research questions were addressed in this chapter:

- Do drivers choose to engage in secondary tasks or drive fatigued 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 and weather conditions, various types of roadways, and proximity to various types of junctions and traffic-control devices. The results for the first question indicate that driver fatigue may vary depending on time of day or ambient light. When compared to total baseline epochs, far fewer fatigue-related baseline epochs were observed during the daylight hours while greater percentage of fatigue-related baseline epochs were identified during darkness. Fatigue was also seen to slightly increase in the absence of high roadway or traffic demand. A higher percentage of fatigue-related baseline epochs were found during free-flow traffic densities, on divided roadways, and areas free of roadway junctions.

T he results for the second question were more varied. Each of the eight environmental conditions resulted in odds ratios greater than 1.0 for both driving while fatigued and while engaging in complex secondary tasks. Engaging in moderately complex secondary tasks rarely resulted in odds ratios significantly greater than 1.0, indicating that these behaviors are not as risky as driving fatigued or while engaging in complex secondary tasks.

In Chapter 3, the odds ratios for risk of driving while fatigued was 4.3-6.5 times, engaging in complex secondary task was 7.1 times, and engaging in moderately complex secondary tasks was 2.4 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 geometry increase individual crash risk, it is important to note that many crashes and near-crashes are also occurring 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 (i.e., Washington, DC). 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 crash risk were not selected based upon any of the above environmental variables. These epochs were selected at random from the 12 months of data collected per vehicle. This baseline then represents a sample of the entire 12 months of data; however, the specific environmental conditions were not used in the sampling procedure. Some degree of caution is therefore suggested in the interpretation of these relative crash risks.

While population attributable risks were calculated in Chapter 3 when assessing the general effects of the four types of driver inattention, population attributable risks 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 calculation would be a very gross estimate and involve an unacceptable potential for error.

Even after collecting data for 12 months on 100 vehicles, there were still many environmental variables with insufficient 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.

Lighting

Results suggest that engaging in a complex secondary task during the dark on unlighted roadways carries significantly greater individual crash risk than does engaging in complex secondary tasks during any other ambient lighting condition. Driving fatigued appeared to have a slightly higher crash risk at dusk; however, this result was not significantly different from the other odds ratios.

Weather

The crash risk of driving fatigued or while engaging in complex secondary tasks was only slightly higher during rainy conditions than during clear conditions. This suggests that the act of driving fatigued and/or engaging in complex secondary tasks is equally dangerous across weather conditions.

Road Type

The odds ratios for driving fatigued or while engaging in complex secondary tasks indicated that drivers are at a three times increased crash risk as compared to an alert driver on similar road types. None of the road types were significantly more risky than any other road type.

Alignment

Drivers who engaged in complex secondary tasks while on a straight, grade roadway are at a significantly higher crash risk than drivers who are engaged in complex secondary tasks on curved or straight, level roadway. Drivers who are fatigued are at a four times greater crash risk than an alert driver, regardless of roadway alignment.

Traffic Density

Drivers who are fatigued increase their crash risk by at least 3.5 times that of an alert driver across all levels of traffic density. Drivers who engage in complex secondary tasks are at least 2.0 times higher crash risk than alert drivers for all levels of traffic density. None of the traffic densities appeared to be riskier than any other traffic density for either fatigue or complex secondary task engagement.

Surface Condition

The odds ratios for surface condition demonstrated that driving fatigued on either wet or dry roads increased crash risk by at least three times over that of driving alert on wet or dry roadways. Engaging in complex secondary task on a dry roadway had a significantly higher crash risk than engaging in complex secondary tasks on a wet roadway. While this result may seem surprising, it could be an artifact of slower speeds and increased headways that frequently occur on rainy roadways. This suggests that it may be more dangerous to engage in complex secondary tasks on dry roadways than on rainy roadways due to traffic density.

Traffic Control

Driving while fatigued or while engaging in complex secondary tasks increased crash risk regardless of whether a traffic control devices was present. This result indicates that the presence of a traffic control device does not impact crash risk as a function of driver fatigue or secondary task engagement.

Relation to Junction

Driving fatigued increased crash risk regardless of whether the driver was near a junction in the roadway. Interestingly, the same result was not found for complex secondary task engagement. Engaging in secondary tasks near an intersection was found to have a lower crash risk than while in a parking lot or traveling near an intersection. This suggests that drivers are more careful while engaging in complex secondary tasks when near an intersection than when they are not near a junction.

5. DETERMINE THE DIFFERENCES IN DEMOGRAPHIC DATA, TEST BATTERY RESULTS, AND PERFORMANCE-BASED MEASURES BETWEEN INATTENTIVE AND ATTENTIVE DRIVERS.

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 5.1). 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 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 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, Klauer, Neale, Petersen, Lee, Sudweeks, 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 involvement in inattention-related crashes and near-crashes.

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 5.1 shows the distribution of all of the primary subjects and the frequency in which they were involved in inattention-related crashes and near crashes. 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.

Two separate analyses of drivers were conducted. The first analysis used the mean frequency value 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".

The second analysis will separate the drivers into three levels of involvement: high, moderate, and low. Drivers who were involved in zero or one inattention-related crash(es) and/or near crash(es) are operationally defined as "low involvement". "Moderate involvement" drivers are those involved in two to four inattention-related events. "High involvement" drivers are those involved in five or more inattention-related events.

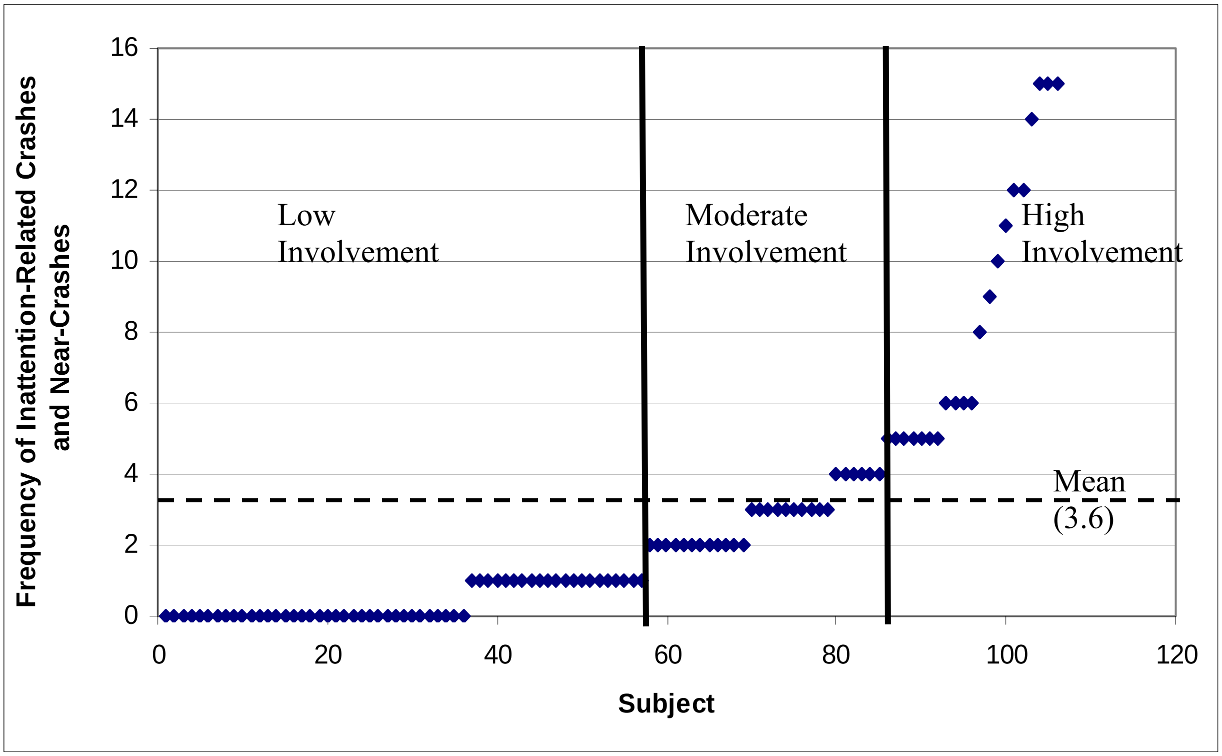

Figure 5.1. The frequency of inattention-related crashes and near crashes by driver in order from low frequency to high frequency.

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 preserve 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. One issue with only two groups is that there is very little separation between the values. Therefore 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 the most attentive and the least attentive drivers will be more easily distinguished. Tables 5.2 and 5.3 provide the descriptive statistics for the drivers' respective group divisions.

Table 5.2. Descriptive statistics on drivers labeled 'low involvement' and 'high involvement' in inattention-related crashes and near-crashes.

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

Table 5.3. 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

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 5.4.

Table 5.4. 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 5.2 shows the average age of the low and highly involved drivers. A t-test was conducted to determine whether there were significant differences in age between groups. The results suggest that the highly involved drivers were significantly younger than the lower involved drivers, $t(102) = 7.07$, $p = 0.009$.

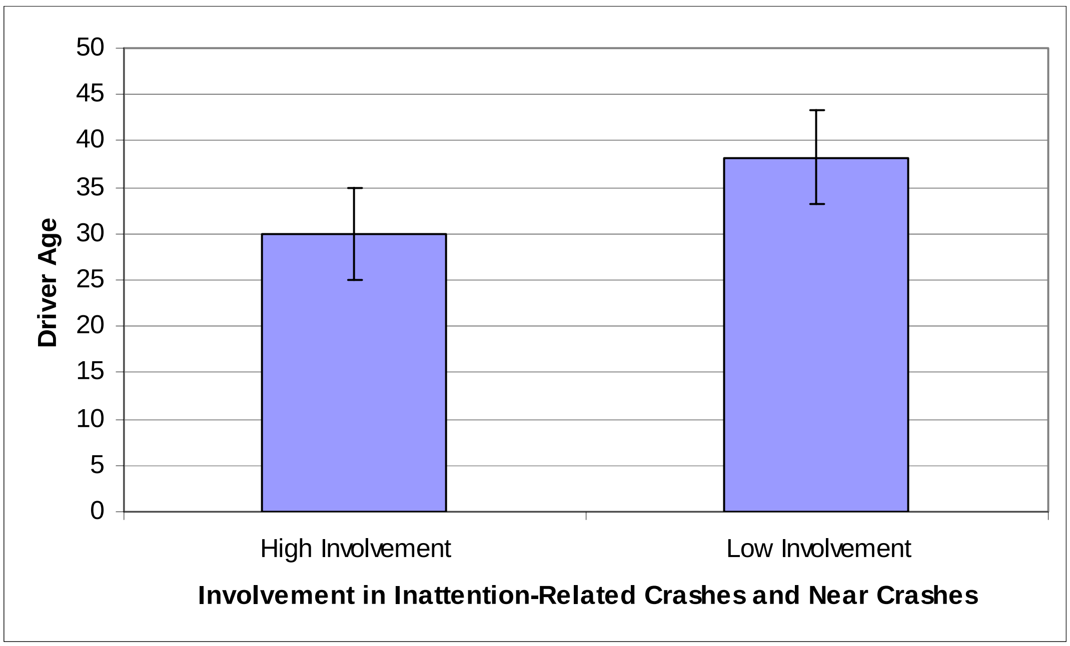

Figure 5.2. Average age of the high and low involvement drivers in inattention-related crashes and near crashes.

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 5.3. Note that the 18- to 20-year-old drivers had significantly more inattentive events than did any of the other age groups, $\chi(5) = 39.93$, $p > 0.01$.

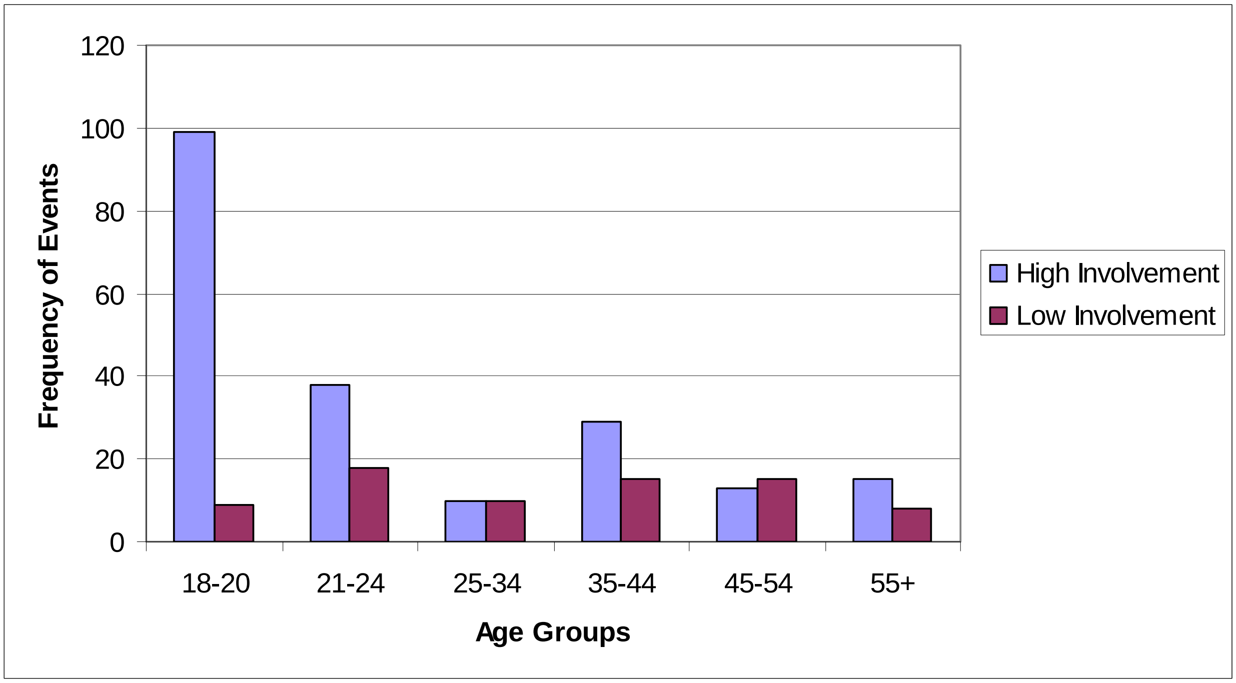

Figure 5.3. The frequency of inattention-related crashes and near crashes for each age group by involvement group.

Gender. An analysis of the gender make-up of both the low and high 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 involvement drivers is shown in Figure 5.4 and low involvement drivers is shown in Figure 5.5. Note that the gender distribution in the inattentive drivers is 49 percent female and 51 percent male, whereas the distribution for attentive drivers is primarily male. Given that the entire subject pool was biased towards males, this result should not be interpreted that males are generally more attentive than females. Rather, these results should be interpreted that both younger males and females (given the results for age) are both equally inattentive drivers.

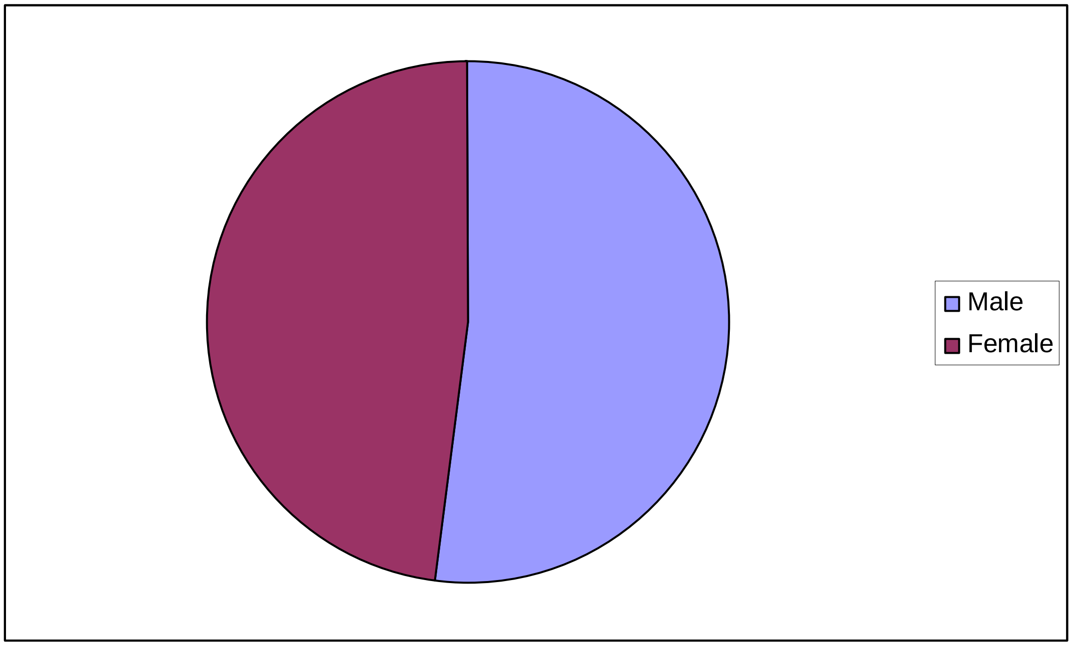

Figure 5.4. Gender breakdown of high involvement drivers.

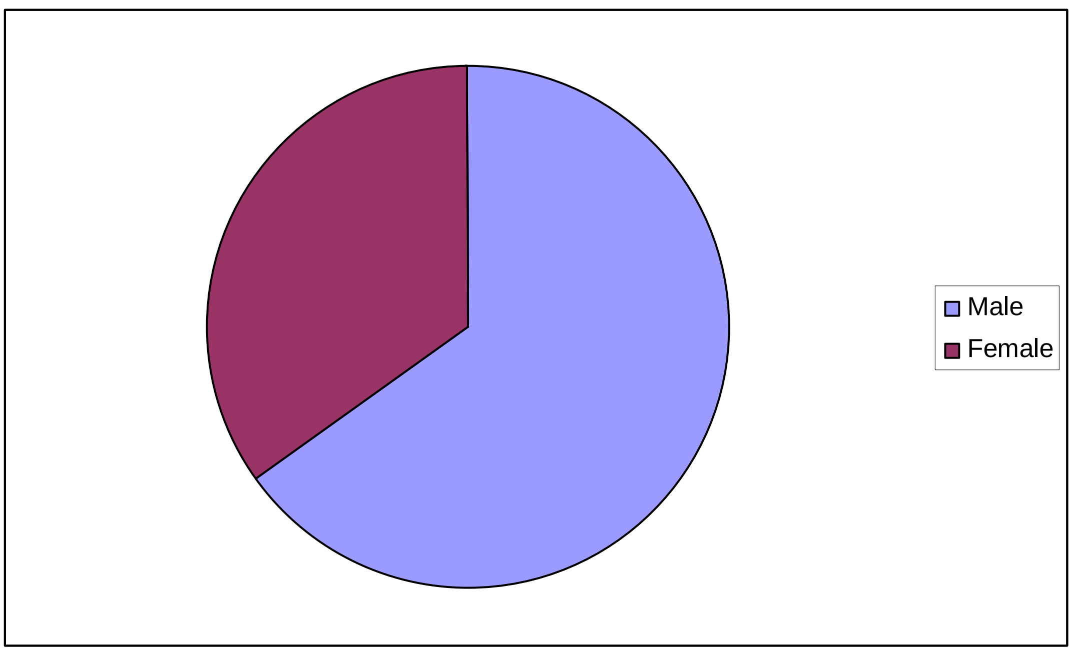

Figure 5.5. Gender breakdown of low involvement drivers.

Years of Driving Experience. An analysis of the number of years of driving experience was also conducted. Figure 5.6 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 16 years of age, this result is most likely correlated with age.

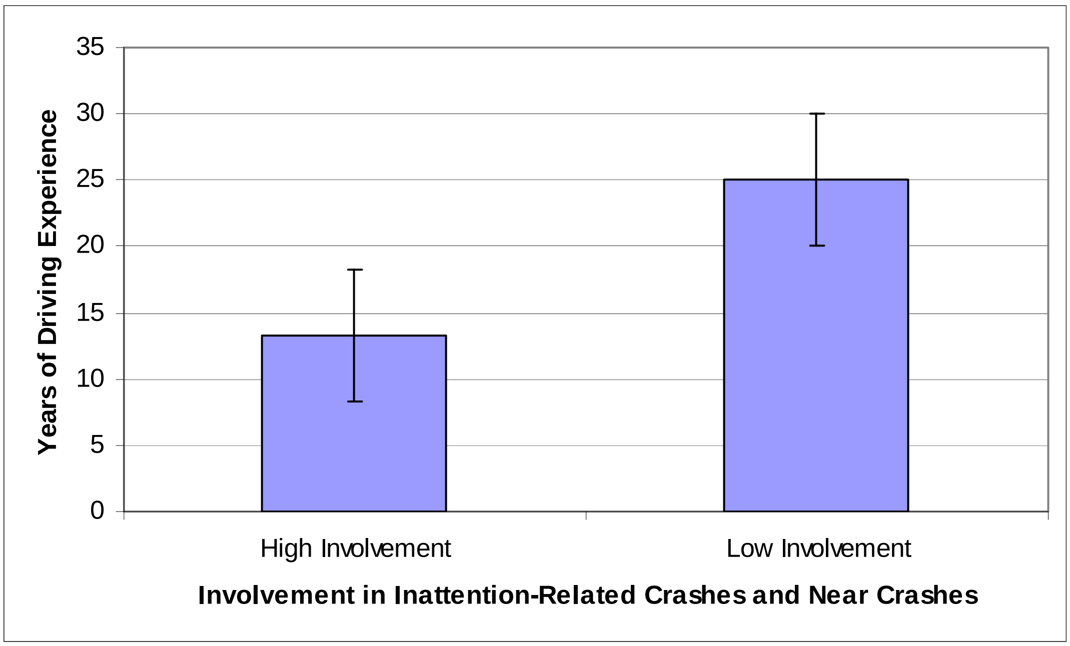

Figure 5.6. Average years of driving experience for drivers with low and high involvement in inattention-related crashes and near crashes.

Fatigue. 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 fatigue 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 involved 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 involvment 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 therefore not significant. Given that no significant results were obtained for these two questions, no further analyses of 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 5.7 shows that high involvement drivers had 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 Accidents. All drivers were also asked to report the number of accidents that they had been involved during the 5 years prior to the start of the study. The average number of accidents that high involvement drivers reported was compared to the low involvement driver reports of accident involvement. Figure 5.7 also shows that high involvement drivers reported involvement in only slightly more accidents than the low involvement drivers. This result was not significant at a 0.05 probability level.

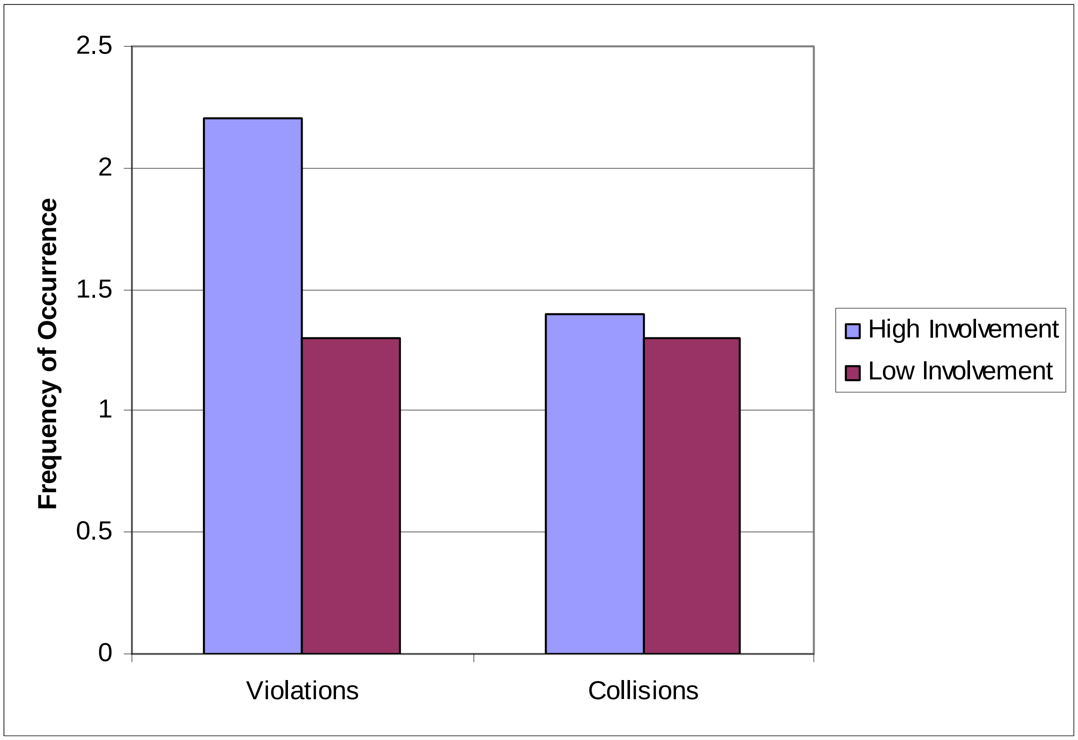

Figure 5.7. Self-reported involvement in traffic violations and collisions for 5 years prior to the onset of the 100-Car Study.

Test Battery Analyses

Table 5.5 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 5.5. 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 Montoring • Thrill-Seeking • Fatigue-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 inattentive and attentive 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 5.6. Note that the highest Life Stress Score was for an low involvement driver.

Table 5.6. 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, & 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 aggression, dislike of driving, hazard monitoring, thrill seeking, and 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 5.7 to 5.11 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 5.7. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near crashes for the driver stress factor scale of *aggression*.

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

Table 5.8. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near crashes for the driver stress factor scale of *dislike of driving*.

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

Table 5.9. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near crashes for the driver stress factor scale of *hazard monitoring*.

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

Table 5.10. Descriptive statistics on the drivers with high and low involvement in inattention-related crashes and near crashes for the driver stress factor scale of *fatigue proneness*.

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

Table 5.11. 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 & 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 Overall Dula Dangerous Driving Index, Negative Emotional Driving Subscale, Aggressive Driving Subscale, and 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 5.12 through 5.15.

Table 5.12. 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 5.13. 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 5.14. 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 5.15. 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, conscientiousness.

Extensive research has been conducted correlating the personality scales of neuroticism, extraversion, agreeableness, and conscientiousness to crash involvement (Arthur & Graziano, 1996; Fine, 1963; Loo, 1979; and Shaw & 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 & McCrae, 1992).

T-tests were conducted comparing the high involvement 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 & 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 5.8 shows the two groups scores with high involvement drivers ranking as "Average" and the low involvement drivers ranking "High."

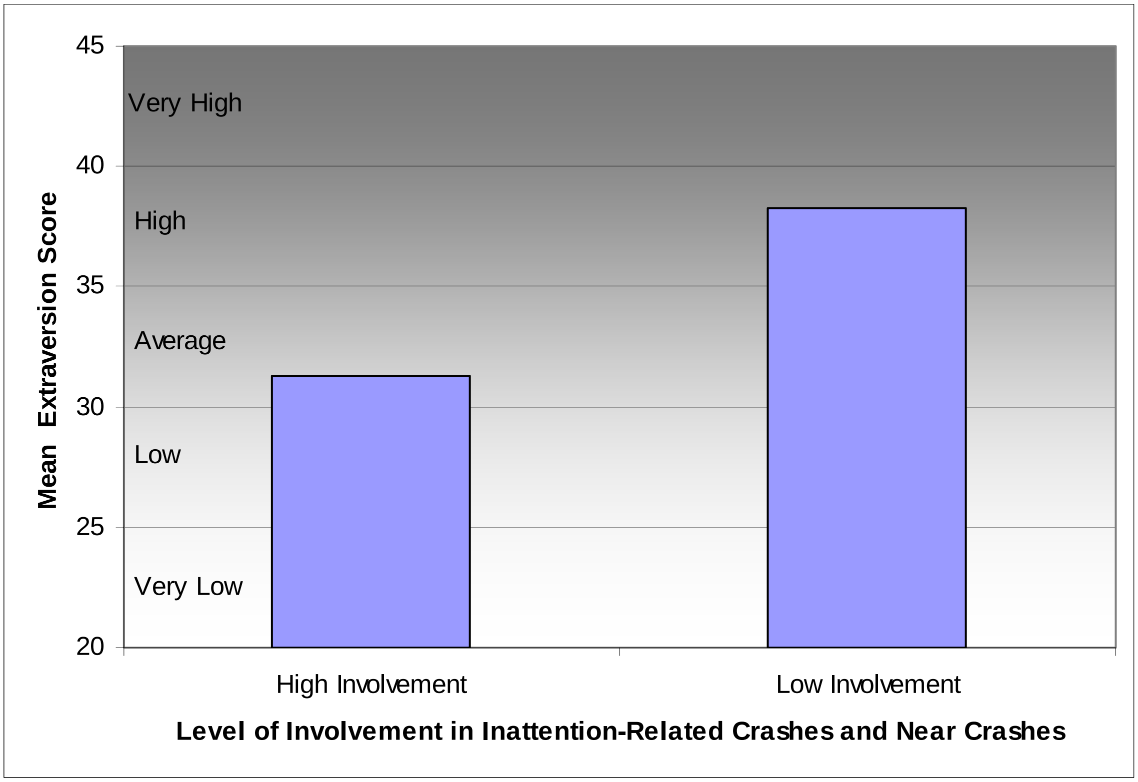

Figure 5.8. Personality scores for the extraversion scale demonstrating significant differences between drivers with high and low involvement in inattention-related crashes and near crashes.

Openness to Experience**.** 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 & 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 5.9 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 high involvement drivers scored in the high range.

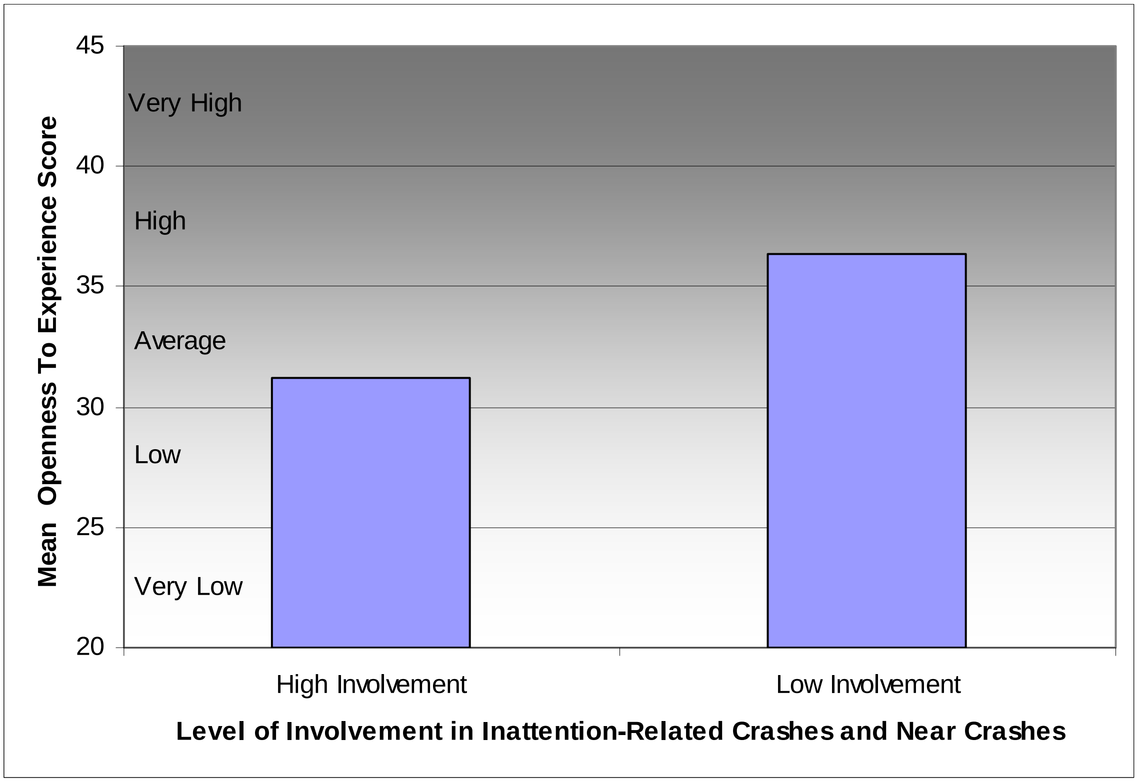

Figure 5.9. Personality scores for the openness to experience scale demonstrating significant differences between drivers with high and low involvement in inattention-related crashes and near crashes.

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 & 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 5.10).

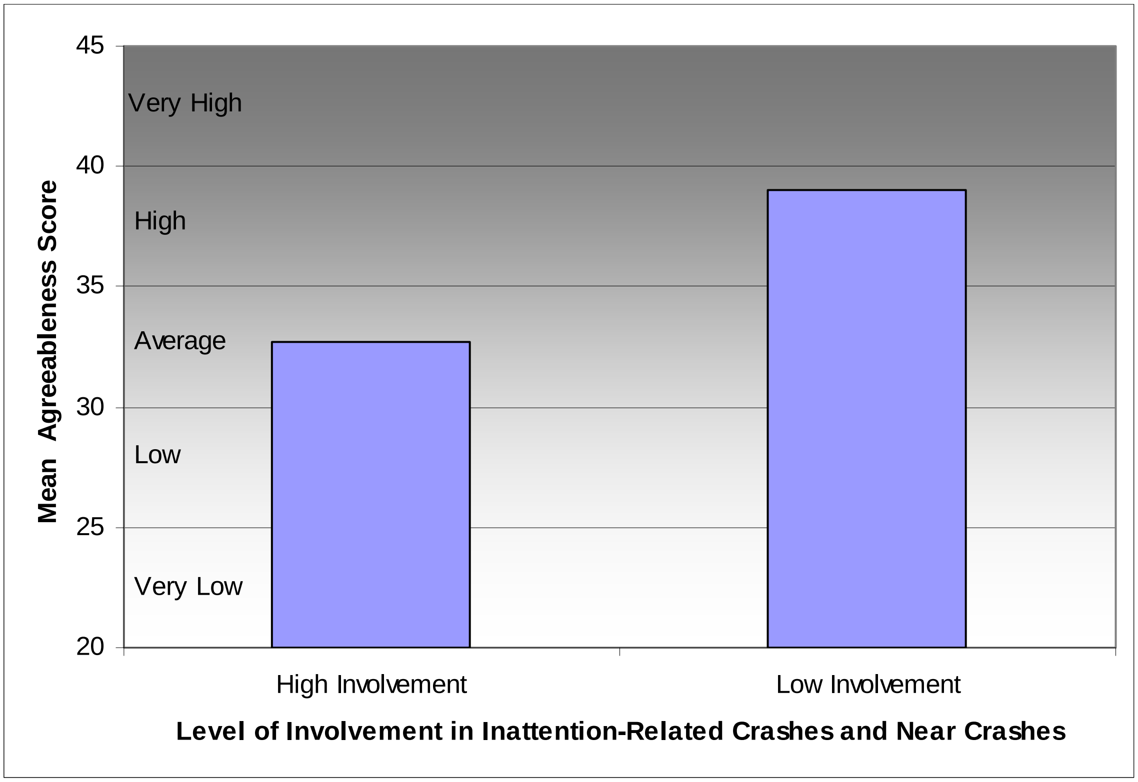

Figure 5.10. Personality scores for the agreeableness scale demonstrating significant differences between drivers with high and low involvement in inattention-related crashes and near crashes.

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 & 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 5.11).

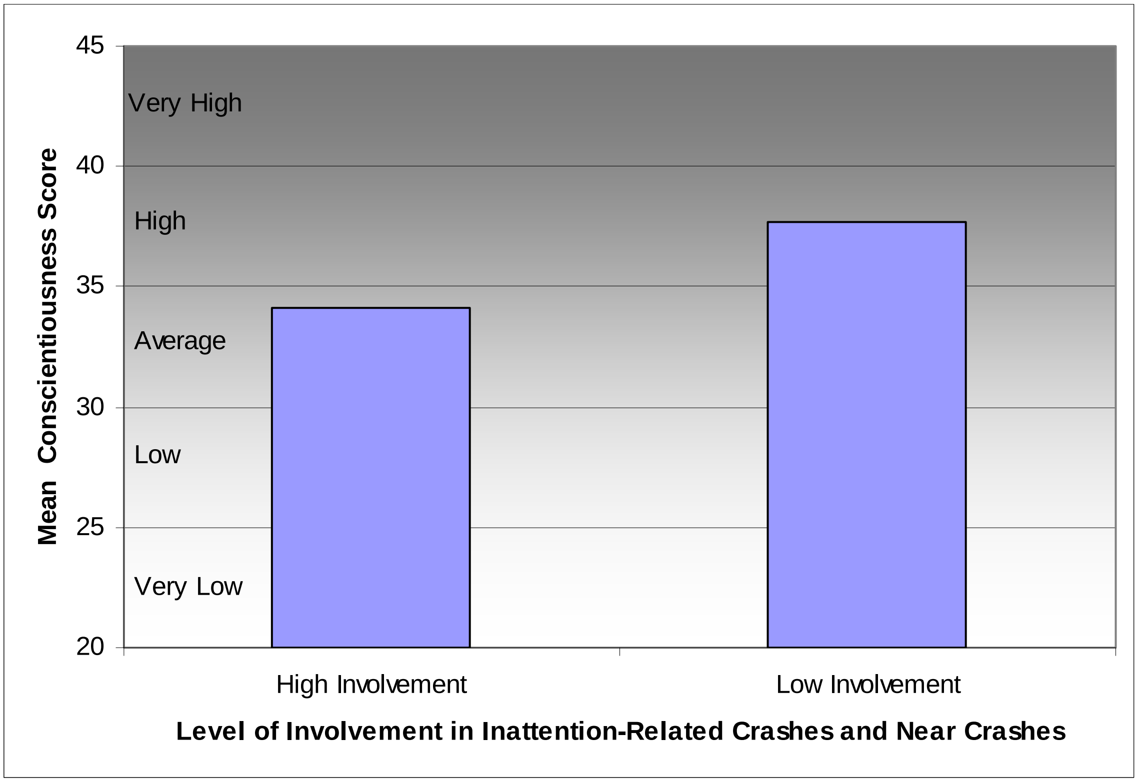

Figure 5.11. Personality scores for the conscientiousness scale demonstrating significant differences between drivers with high and low involvement in inattention-related crashes and near crashes.

The results of the NEO Five Factor Inventory suggest that some differences exist between the low and high involvement drivers. The attentive drivers scored in the "high" or "very high" levels of extroversion, openness to experience, agreeableness, and conscientiousness. The inattentive 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

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

1. Channel capacity: Speed of information processing.
2. Preventable 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 low and high 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 5.16 through 5.19.

Table 5.16. 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 5.17. 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 5.18. 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 5.19. 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 (UFOV) 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, crash risks are assigned to each individual.

T-tests were conducted for the composite UFOV score to determine whether significant differences in the inattentive versus the attentive drivers existed in their central visual processing speed, divided attention, and selective attention abilities. No significant differences between the attentive and inattentive drivers were observed for the UFOV test. Descriptive statistics are presented in Table 5.20.

Table 5.20. 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 Low and High Involvement Groups

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 5.24 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 the 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 responses of crash involvement; this is an interesting finding in that this demonstrates high correlation with actual crash and near crash involvement.

Table 5.21. 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**

Analysis Two: F-Test Analysis for the low, moderate, and high involvement groups

Univariate analyses of variance 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 analyses of variance that were significant will be reported in the following section. Please recall that 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. “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.

Demographic Data and Self-Reported Data Analyses

Driver Age. An analysis of variance and post-hoc Tukey tests were performed to determine if the mean age for each of the three groups were significantly different from each other. The ANOVA indicated significance among the three groups, $F(2,105) = 6.77$, $p < 0.01$. The post-hoc Tukey test results indicated significant differences between the low and high involvement, $t(105) = 3.58$, $p < 0.01$ as well as the high and moderate involvement groups, $t(105) = 2.96$, $p < 0.01$. This suggests that the drivers involved in the most inattention-related crashes and near crashes were significantly younger than those drivers involved in moderate and low numbers of inattention-related crashes and near crashes (Figure 5.12).

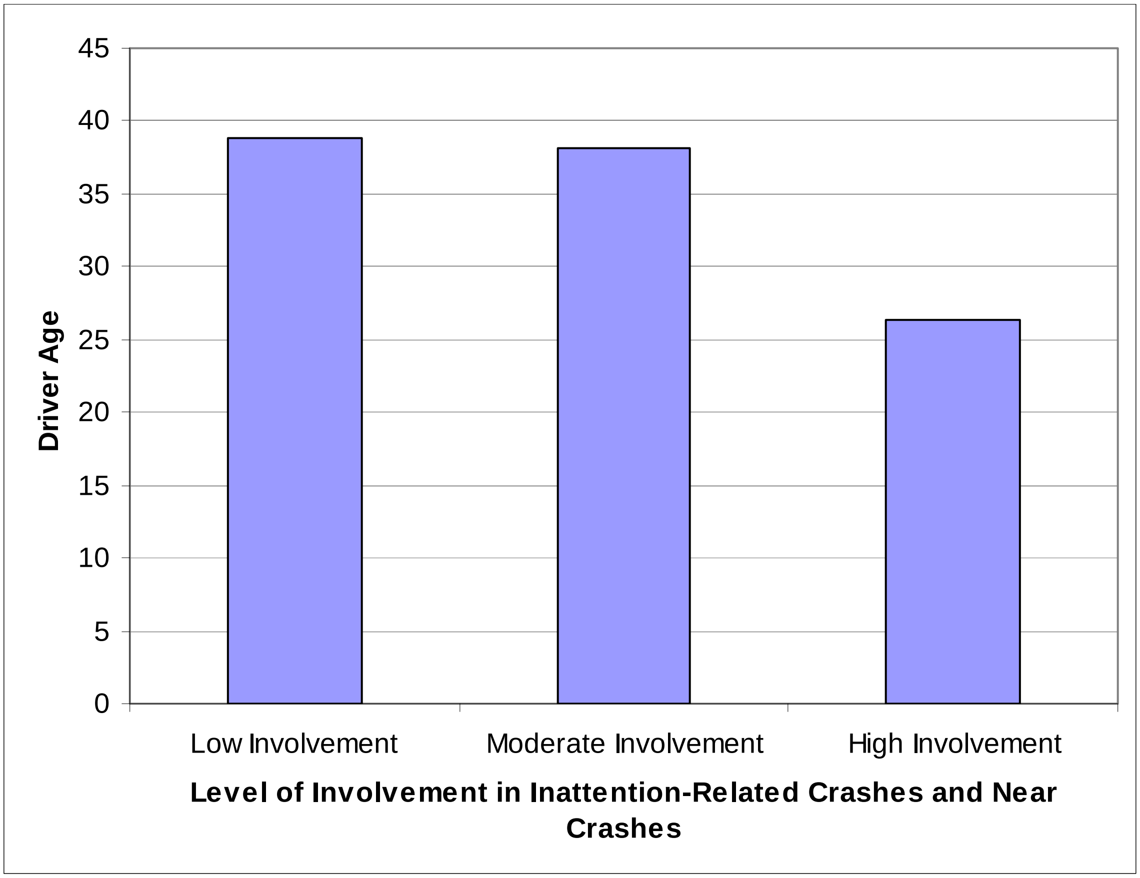

Figure 5.12. Mean age of the drivers for the low, moderate, and high involvement in inattention-related crashes and near crashes.

Years of Driving Experience. The analysis of variance conducted on the number of years of driving experience for the three levels of involvement was conducted and is shown in Figure 5.13. The overall ANOVA indicated significant differences, $F(2,102) = 7.69$, $p < 0.01$. Post-hoc Tukey test results indicated similar results to Driver Age, where the high involvement drivers were significantly different from both the moderate involvement drivers ($t(102) = 3.12$, $p < 0.01$) and the low involvement drivers ($t(102) = 3.81$, $p < 0.01$). This result is not too surprising as the high involvement drivers had less than 10 years of driving experience on average whereas the low and moderate involvement groups had well over 20 years of driving experience.

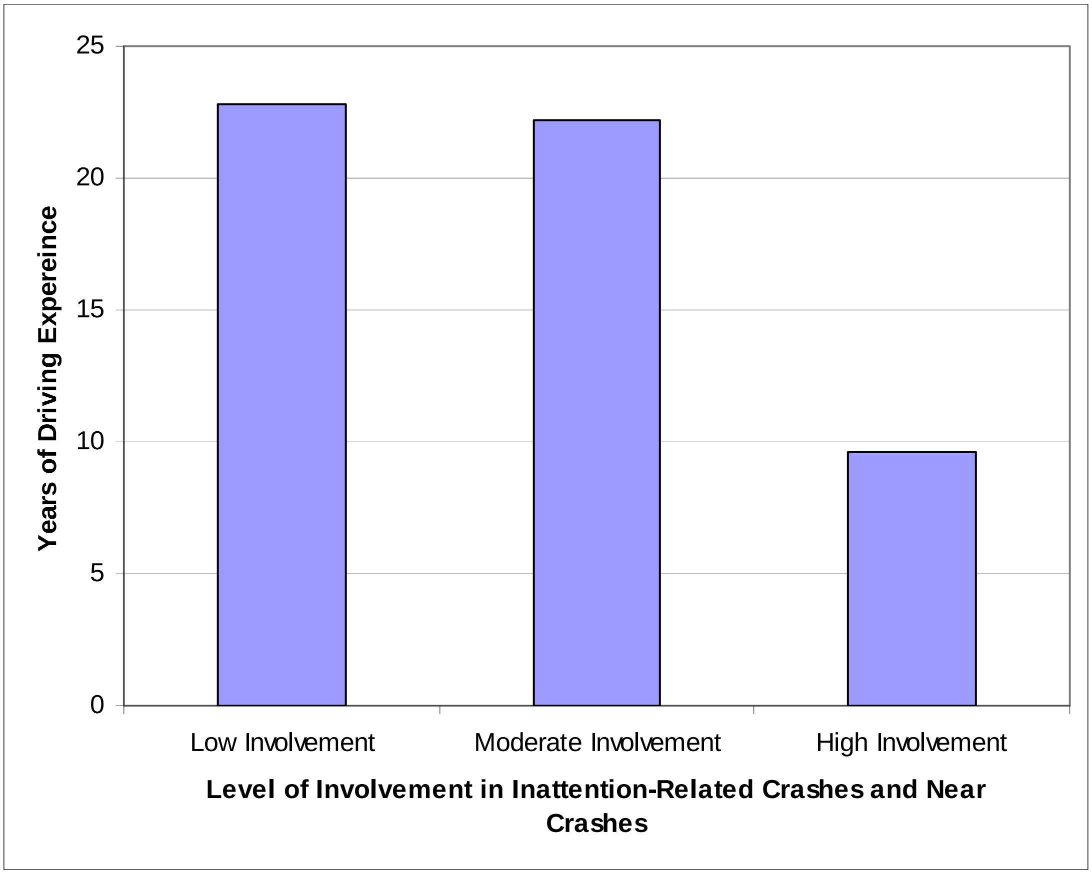

Figure 5.13. The mean years of driving experience for the drivers of the low, moderate, and high involvement in inattention-related crashes and near crashes.

Driving History. At the start of data collection, all drivers were asked to report the number of traffic violations that they had received during the past 5 years as well as the number of accidents that they had been involved over the same period of time. Figure 5.14 shows the mean number of violations and accidents for the three groups of involvement. The ANOVAs for both traffic violations ($F(2, 104) = 5.54$, $p < 0.01$) and accidents were significant ($F(2, 104) = 4.88$, $p < 0.01$). For the number of violations, the high involvement group was significantly different from the low involvement group ($t (104) = 3.22$, $p < 0.01$) but no other differences were found between groups.

The results for accident involvement were much different in that the low involvement and moderate involvement groups were significantly different from each other however, no other pairs were significantly different ($t(104) = 3.10$, $p < 0.01$). These results are somewhat surprising however, the high involvement group was significantly younger and many might not have been driving for a full 5 years.

Figure 5.14. The self-reported frequency of accidents or violations that drivers were involved in over the past 5 years.

Sleep Hygiene. The analysis of variance conducted on the driver's daytime sleepiness scores indicated significant differences among the three groups of drivers ($F(2,103) = 3.80$, $p < 05$). The high involvement drivers rated their daytime sleepiness as significantly more sleepy than the low involvement group ($t\ (103) = 2.49$, $p < 0.05$). No other pairs were significantly different from each other (Figure 5.15). This result from a self-rating is a very interesting finding. Younger drivers have been known to be over-involved in fatigue-related crashes and near crashes and this daytime sleepiness rating score appears to demonstrate a valid relationship to involvement in crashes and near crashes. Please recall that 'inattention-related crashes and near crashes' involve both secondary task involvement and driver fatigue.

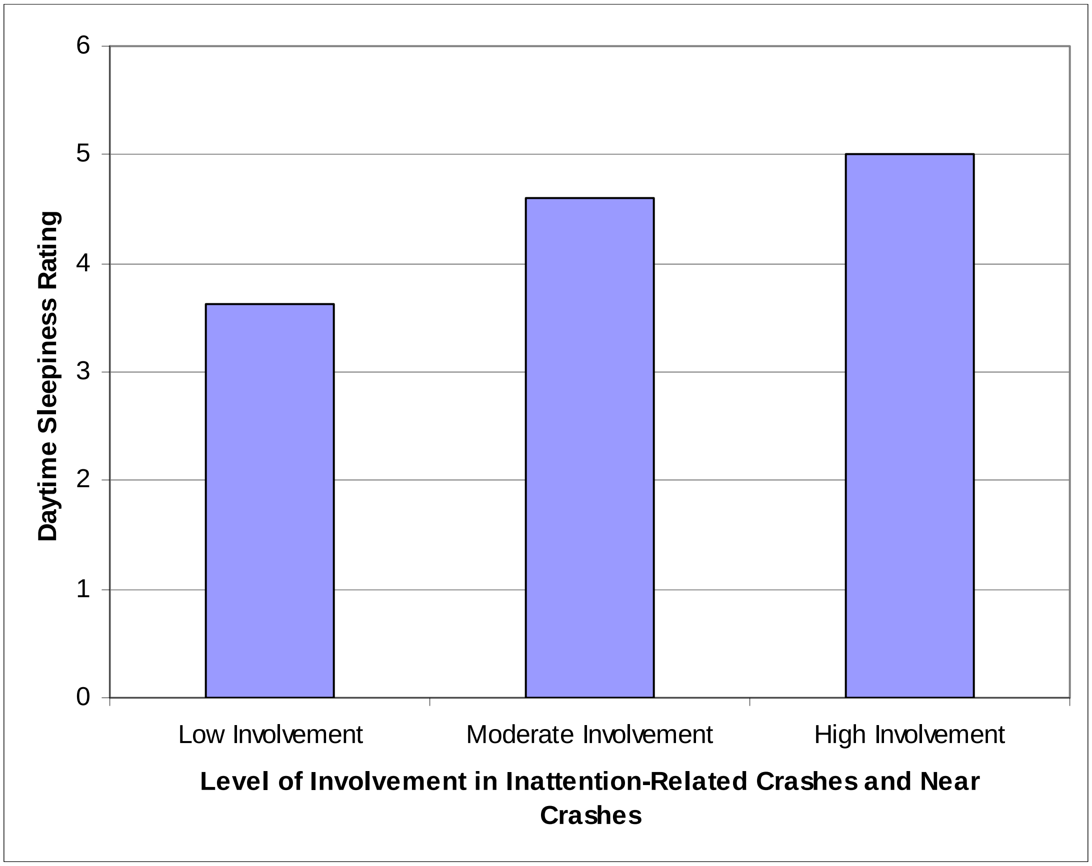

Figure 5.15. Mean daytime sleepiness ratings for the three groups of crash involvement.

Test Battery Analyses

NEO Five Factor Inventory. While all five of the personality scales were analyzed, statistically significant differences were identified between the high and low involvement drivers for the agreeableness and the conscientiousness scales.

Agreeableness**:** An analysis of variance (ANOVA) was conducted on all five of the NEO Five Factor Scales. The results from the agreeableness scores indicated significant differences among the three groups of event involvement ($F(2,110) = 3.77$, $p < 0.05$). A Tukey post-hoc comparison was performed which did not indicate significant differences between any of the pairs however, the high involvement group and the low involvement group approached significance ($t(110) = 2.31$, $p = 0.06$). Thus, drivers in the high involvement group scored on average in the middle of the "average agreeableness" scale whereas the low involvement drivers scored in the "high agreeableness" category (Figure 5.16). Recall from previous discussion that the agreeableness scale measures an individual's altruistic and sympathetic tendencies. Those drivers in the low involvement categories scored high on this scale indicating greater sympathetic tendencies. This group of drivers was probably also involved in fewer "aggressive" driving events than the high involvement group.

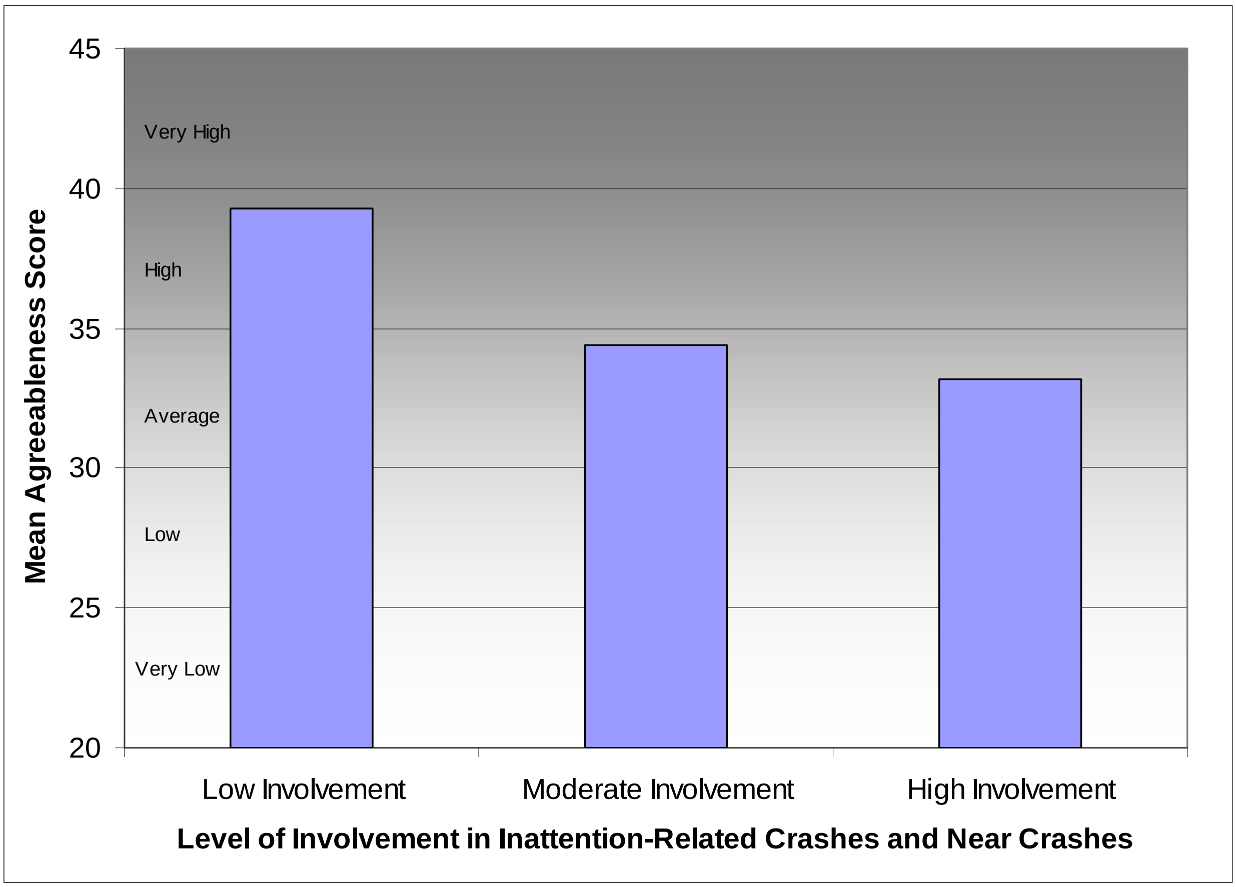

Figure 5.16. Mean Agreeableness Scores (NEO Five Factor Inventory) for the three groups of involvement in inattention-related crashes and near crashes.

Conscientiousness: Driver's scores on the conscientiousness scale from the NEO Five Factor Inventory were also found to be significant as measured by an ANOVA ($F(2, 111) = 3.05$, $p = 0.05$). The Tukey post-hoc analysis indicated similar findings to the Agreeableness scores; however, significant differences were found at the 0.05 probability level between the high and low involvement groups, $t(111) = 2.35$, $p = 0.05$. No other significant differences were observed between any other groups. The high involvement group scored in the 'average' range of conscientiousness whereas, the low involvement group scored in the 'high' range of conscientiousness (Figure 5.17). Recall that conscientiousness measured individual's ability to be disciplined. The low involvement group may also be less apt to break traffic laws. It has already been shown that the high involvement group reported more traffic violations than the low involvement group.

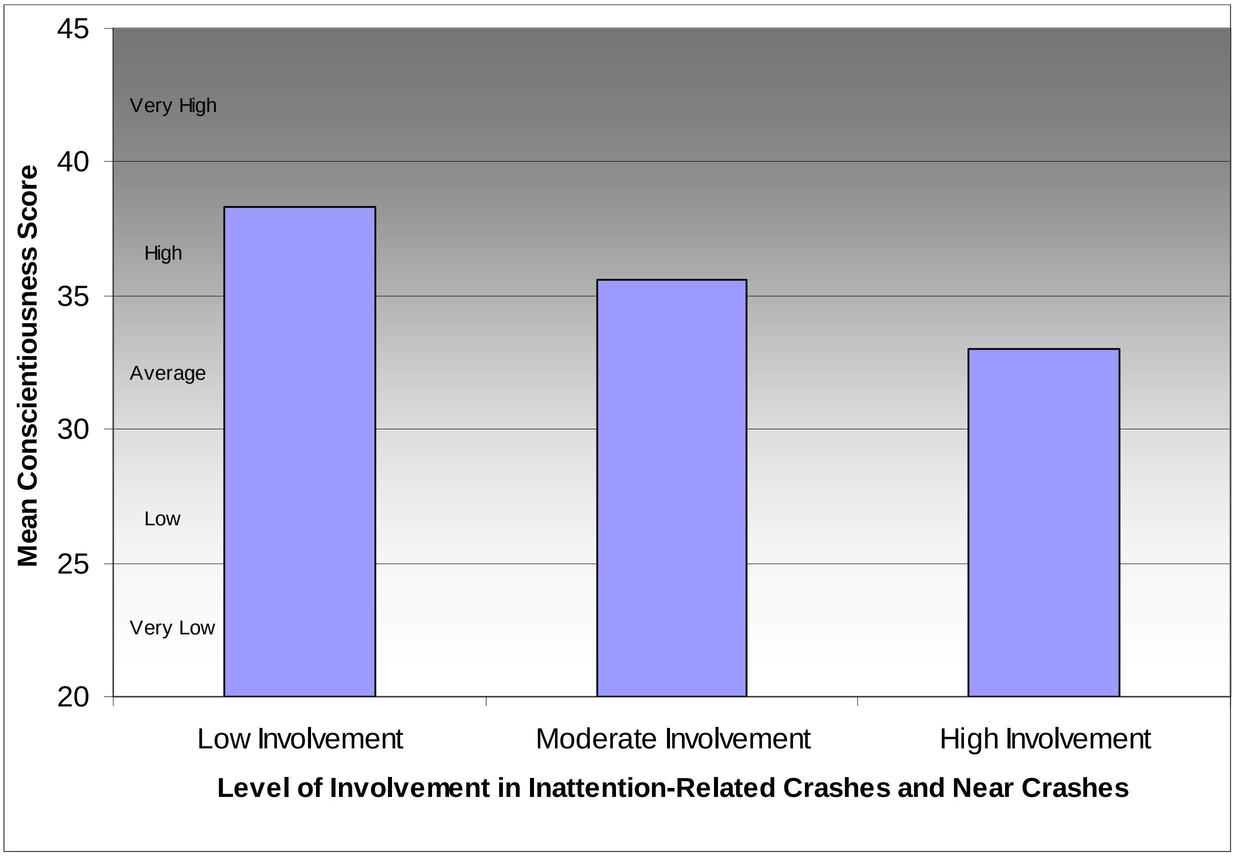

Figure 5.17. Mean Conscientiousness Scores (NEO Five Factor Inventory) for the three groups of involvement in inattention-related crashes and near crashes.

Analysis Two: Correlation analysis for the attentive, moderately inattentive, and highly inattentive groups.

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 5.25. 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 low and high involvement drivers are more easily differentiable with three groups then with only two groups. Many of these correlation coefficients are over 0.4 or above, which are deemed to be moderate correlations (Keppel & Wickens, 2004).

Table 5.22. 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**

Analysis Three. What is the relationship between measures obtained from pre-test batteries 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?

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 fatigued at any point during the 6-second segment. The debrief form and the health assessment questionnaires were not included since they were not designed for this type of analysis.

A 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 who are more frequently involved in crashes and near crashes. This also suggests that the better, safer drivers engage in secondary tasks or drive fatigued less often than do those drivers who were involved in multiple inattention-related 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 5.26 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 moderate with R values under 0.3.

Table 5.23. The significant correlations between test battery, survey, and performance-based test scores to the frequency of inattention-related baseline epochs.

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. Table 5.27 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 5.24. The significant correlations between test battery, survey, and performance-based test scores to the frequency of inattention-related crash and near-crash events.

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

Analysis Four. 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 inattentive or attentive. Only the seven variables that demonstrated significant differences in inattention 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 is inattentive or attentive. 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 5.28.

Table 5.25. 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 inattention.

The correlation coefficients for both Driver Age and Agreeableness were both negative indicating that as age or agreeableness increase, 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 Interval = 0.92 and Upper Confidence Interval = 1.0), which was not significantly different from 1.0. The odds ratio estimate for Agreeableness was similar at 0.94 (Lower Confidence Interval = 0.89 and Upper Confidence Interval = 0.99). These results indicate a slight protective effect in that as age or agreeableness score increases, there will be a decrease in involvement in inattention-related crashes and near crashes.

Summary

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

For the two group analysis, high involvement drivers were operationally defined as those drivers who were involved in four or more inattention-related crashes and/or near crashes while the low involvement drivers were involved in three or less. For the three group analysis, the low involvement group was involved in zero or one inattention-related crash or near crash, the moderate involvement group was involved in two to four, and the high involvement group was involved in five or more inattention-related crashes and/or near crashes during the course of the 100-Car Study. Two analyses were performed to ensure that none of the test scores or survey responses would demonstrate significant differences if the two extreme groups of drivers were separated from the average drivers.

Table 4.27 presents those survey responses and test battery results that showed significant differences for two sets of analyses. Note that separating the drivers into three groups improve the results for several of the test batteries; however, daytime sleepiness scores and self-reported accident involvement were both significantly different with three groups of drivers but not significantly different with two groups of drivers. Two of the NEO Five Factor Inventory Scales were no longer significant when the drivers were separated into three groups.

Table 5.26. Summary of those tests that found significant differences for the two analyses using two levels of attentiveness and three levels of attentiveness.

Two-Group Analysis	Three-Group Analysis
Driver Age	Driver Age
Years of Driving Experience	Years of Driving Experience
N/A	Daytime Sleepiness Score
Self-reported traffic violations	Self-reported traffic violations
N/A	Self-reported accident involvement
Extroversion (Five Factor Personality Inventory)	N/A
Openness to Experience (Five Factor Personality Inventory)	N/A
Agreeableness (Five Factor Personality Inventory)	Agreeableness (Five Factor Personality Inventory)
Conscientiousness (Five Factor Personality Inventory)	Conscientiousness (Five Factor Personality Inventory)

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. The high

involvement group's average years of driving experience was 9.6 years while the moderate and low involvement groups 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). The high involvement drivers had received 2.6 violations, while the moderate involvement and the low involvement groups received 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 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 that many of the drivers had been driving less than 5 years due to their low age and having had less driving experience.
- 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 as correlations with all the drivers in one dataset results in different scales demonstrating significant correlations coefficients.

- The results from the correlation between the frequency of inattention-related baseline epochs and frequency of inattention-related crashes and near-crashes show a high correlation of 0.72. This result suggests that drivers who frequently engage in inattention-related activities are also frequently involved in inattention-related crashes and near crashes. Those drivers who do not frequently engage in inattention-related tasks are not involved in inattention-related crashes and near crashes.
- 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 scores from the NEO Five Factor Personality Inventory. Interestingly, agreeableness scores for the low and high involvement drivers (both two and three groups) were also found to be significantly different from one another.
- Unfortunately, no differences were found between the low and high 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.

6. WHAT IS THE RELATIVE RISK OF EYES OFF THE FORWARD ROADWAY? DO EYES OFF THE FORWARD ROADWAY SIGNIFICANTLY AFFECT SAFETY AND/OR DRIVING PERFORMANCE?

Increased traffic density on US roadways has led to increasingly long commute times for many commuters. In order to make this commute time more productive, US automobile manufacturers and Tier 1 suppliers have been developing telematic devices to assist these drivers in their quest for the *mobile office*. As a result, many transportation safety professionals have become increasingly worried about the impact of these devices on crash risk.

The National Highway Traffic Safety Administration (NHTSA) sponsored a public forum on driver distraction in 2000. As part of this effort, NHTSA requested automobile manufacturers and other organizations who develop standards, (i.e. Society of Automotive Engineers) develop design guidelines and specifications that designers of these telematics devices must adhere to minimize the impacts of driver distraction.

The Alliance of Automobile Manufacturers (AAM) provided an answer to NHTSA by releasing a *Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communcations Systems (*Alliance of Automobile Manufacturers, 2003). Within this document are listed design guidelines, rationale for the guideline, criterion or criteria for design, and justification for these criteria. While many guidelines are listed for items such as display location, legibility, glare, and use of auditory displays, two guidelines specifically referred to reference to length of eyeglance and task completion time. These two guidelines were written as follows:

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

These two guidelines are similar to guidelines for other organizations. The Society of Automotive Engineers has a 15-second rule rather than a 20-second rule. This organization has discussed glance duration and generally accepts that glances should not exceed 2 seconds but have not made a separate ruling to this effect.

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

Other research conducted by Green (1999), Wierwille (1990), Dingus, Antin, Hulse, & Wierwille (1989) all suggest that drivers have self-limiting behavior in that drivers tend not to look away from the forward roadway for greater than 1.5 seconds. Rather, if engaged in a task, they will look back and forth between the task and the roadway, not looking away from the forward roadway for more than 1.5 seconds at any one time, until the task is complete. Therefore, a 2 second design guideline rule may not be a practical guideline for designers, since very few displays would produce a single eyeglance length of 2.0 seconds or more. Total time eyes are off the forward roadway during the completion of the task may be a better limiter and could potentially be used as a design guideline. If total task time cannot exceed 20 seconds, this could potentially mean that drivers eyes are off the forward roadway 15 seconds out of 20 (e.g. drivers eyes on device for 1.5 seconds followed by a 0.5 second glance to roadway and so on for 20 seconds).

While eyeglance analyses have been used in transportation research for a variety of purposes and goals, the analyses presented here are the first to establish a direct link between driver's eyeglance behavior and crash and near-crash involvement. Odds ratios were calculated to estimate the relative risk of eyes off the forward roadway as well as the relative risk of eyes off the forward roadway for varying lengths of time. Analyses of variance were conducted to determine whether there were significant differences among crashes, near crashes, incidents, and baseline epochs for total time eyes off road, number of glances away from the forward roadway, and length of longest glance away from the forward roadway. These analyses were conducted to determine whether the driver's eyes being off the forward roadway does in fact affect safety and/or driving performance.

There are some important and significant differences in the methods used to conduct the analyses in this chapter and methods 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 severe fatigue. In Chapter 2, inattention also included *driving-related inattention to the forward roadway* and *non-specific eyeglance*. In this chapter, only eyeglance data was considered; therefore, any time a driver was 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, which included all four types of inattention. Chapters 3-5 all defined *driver inattention* as *secondary task engagement* and *fatigue* which could also be considered closer to traditional definitions of driver distraction. This final chapter includes any time the driver's eyes were off the forward roadway, which would include some aspects of secondary task and fatigue, but also encompasses *driving-related inattention to the forward roadway* and *non-specific eyeglance.*

To begin this analysis, an operational definition of '*eyes off forward roadway*' is required. This metric is time dependent and a relevant time frame surrounding the crash or near crash must also be operationally defined. While some epidemiological studies have used time segments of 5 or 10 minutes prior to a crash (e.g. McEvoy, Stevenson, McCartt, Woodward, Haworth, Palamara, & Cercarelli, 2005;Riedelmeier & Tibshirani, 1997), the 100-Car Study examines only inattention 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 and circumstances that comprise the crash, near crash, or incident. Therefore, all *eyes off forward roadway* calculations were based upon a total time of 5 s prior and 1 s after the onset of the precipitating factor or *onset of the conflict* (not the moment the crash occurred). The data of interest are the pre-crash data or the moments 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 s prior and one 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 s prior and one 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 s prior and 1 s 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 Included in These Analyses

Eyeglance analysis was conducted on all crashes, near crashes, and incidents as well as 5000 (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 risk of eyes off forward roadway, the data was parsed to exclude those events in which the driver of the instrumented vehicle was not at fault and/or was involved in a rear-end struck crash or near crash with the following vehicle. For the rear-end struck crashes, eyeglance data was not available on the following driver, which prevented their inclusion in the analyses.

Analysis One. What is the Relative Risk of Eyes Off The Forward Roadway?

To answer this question, the odds ratios for eyes off the forward roadway were calculated, as odds ratios are appropriate approximations for a relative risk ratio (Greenberg, Daniels, Flanders, Eley, & Boring, 2001). The odds ratios were calculated for eyes off the forward roadway and for five ranges of total time that the drivers' eyes were off the forward roadway. These five time ranges were:

Less than or equal to 0.5 s

- Greater than 0.5 s but less than or equal to 1.0 s
- Greater than 1.0 s but less than or equal to 1.5 s
- Greater than 1.5 s but less than or equal to 2.0 s
- Greater than 2.0 s

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

Table 6.2 presents the odds ratios for the five segments of time as well as an overall odds ratio for eyeglance away from the forward roadway. Note that the odds ratios for total time eyes off the roadway (EOR) that were equal to or less than 2 s 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, total time EOR greater than 2 s, are clearly not safe as the relative crash risk suddenly increases to over 2 times the crash risk of normal driving. It is important to note that the confidence intervals surrounding these 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 time EOR is safer than when EOR is greater than 2 seconds. The population attributable risk calculations suggest that nearly 15 percent of the crashes and near crashes that occur in a metropolitan environment are attributable to EOR greater than 2 s (Table 6.3).

Table 6.2. Odds ratios for eyes off forward roadway.

	Total Time of Eyes Off Forward Roadway	Odds Ratio	Lower CI	Upper CI
1.	Less than or equal to 0.5 s	1.11	0.79	1.58
2.	Greater than 0.5 s but less than or equal to 1.0 s	0.65	0.49	0.88
3.	Greater than 1.0 s but less than or equal to 1.5 s	0.76	0.54	1.05
4.	Greater than 1.5 s but less than or equal to 2.0 s	1.07	0.77	1.49
5.	**Greater than 2.0 s**	**2.17**	**1.75**	**2.69**
6.	**OR for Eyeglance**	**1.32**	**1.09**	**1.60**

*Only the crashes and near crashes where the subject driver is at fault are included in these data.

Table 6.3. Population attributable risk ratios for eyes off forward roadway.

	Total Time of Eyes Off Forward Roadway	Population Attributable Risk	Lower CI	Upper CI
1.	Less than or equal to 0.5 s	0.85	0.58	1.12
2.	Greater than 0.5 s but less than or equal to 1.0 s	N/A	N/A	N/A
3.	Greater than 1.0 s but less than or equal to 2.0 s	N/A	N/A	N/A
4.	Greater than 1.5 s but less than or equal to 2.0 s	0.57	0.29	0.86
5.	Greater than 2.0 s	14.82	14.35	15.30
	PAR for Eyeglance	**15.45**	**14.45**	**16.49**

*Only the crashes and near crashes where the subject driver is at fault are included in these data.

While the above results indicate that if a driver's eyes are averted from the forward roadway over two seconds, the crash risk will increase, some eyeglances away from the forward roadway are necessary to safe driving. Eyeglances away from the forward roadway, specifically those to check rear-view mirrors or cross traffic, are important to safe driving. A driver who is glancing at one of their rear-view mirrors, for example, is exhibiting attentive and safe driving. Therefore, odds ratio calculations were also conducted to account for these behaviors. The odds ratios were calculated for total time EOR except when the driver was looking at the center, right, or left rear-view mirrors. Recall that these glances were shown previously to possess a protective effect on driving safety (Chapter 2).

The resulting odds ratios (Table 6.4) demonstrate convincingly that as total time EOR increases, the odds ratios get larger. Also note that the EOR greater than 2 s increase an individual's relative crash risk by 2 times. An overall odds ratio of EOR was also over 1.0 indicating that, eyes off the forward roadway greater than 2 s was a strong enough effect to boost the overall odds ratio to over 1.0.

The population attributable risks, as shown in Table 6.5, indicated that nearly 20 percent of all crashes and near crashes occurring in an urban environment are attributable to eyes off the forward roadway. Thirteen percent of these crashes and near crashes were attributable to total time EOR greater than 2 s. This finding demonstrates that eyes off the forward roadway, especially those total times greater than 2 s, is a key issue in crash causation.

Table 6.4. Odds ratios 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 CI	Upper CI
1.	Less than or equal to 0.5 seconds	0.92	0.55	1.55
2.	Greater than 0.5 seconds but less than or equal to 1.0 seconds	0.91	.065	1.27
3.	Greater than 1.0 seconds but less than or equal to 1.5 seconds	0.93	0.65	1.33
4.	Greater than 1.5 but less than or equal to 2.0	1.17	0.81	1.67
5.	**Greater than 2.0 seconds**	**2.14**	**1.71**	**2.66**
6.	**OR for Eyeglance Away From the Forward Roadway**	**1.56**	**1.29**	**1.88**

*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.

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

	Total Time of Eyes Off Forward Roadway	Population Attributable Risk	Lower CI	Upper CI
1.	Less than or equal to 0.5 s	N/A	N/A	N/A
2.	Greater than 0.5 s but less than or equal to 1.0 s	N/A	N/A	N/A
3.	Greater than 1.0 s but less than or equal to 2.0 s	N/A	N/A	N/A
4.	Greater than 1.5 s but less than or equal to 2.0 s	1.05	0.79	1.30
5.	**Greater than 2.0 s**	**13.29**	**12.84**	**13.75**
6.	**PAR for Eyeglance**	**18.25**	**17.49**	**19.01**

*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.

Analysis Two. Does eyes off the forward roadway significantly affect safety and/or driving performance?

To answer this research question, four metrics of eyes off forward roadway were calculated and ANOVAs were conducted to determine whether there were significant differences among crashes, near crashes, incidents and 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 s 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 baseline segment than those drivers involved in safety-relevant conflicts.

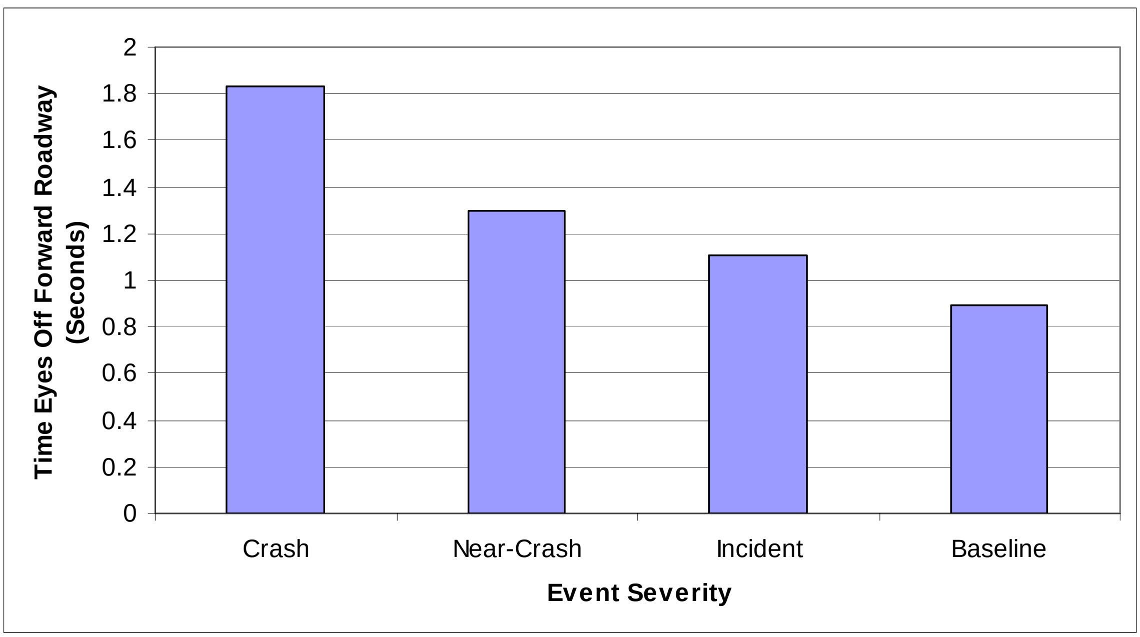

Figure 6.1. The total amount of time drivers' eyes were off the forward roadway during the 6-second segment of time prior to the onset of the conflict.

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

	Severity	dF	t-value	p-value
1.	Crash x 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 s prior and 1 s after the onset of the conflict. Figure 6.2 shows the mean number of glances that drivers exhibited for 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 and incidents were significantly different from the baseline epochs, ($t(11{,}174) = 2.83$ $p < 0.05$; $t(11{,}174) = 7.93$, $p < 0.0001$). Note that these results are similar to those found by Green (1999) and Dingus, Antin, Hulse & Wierwille, (1989) that stated that drivers do not tend to look away from the forward roadway greater than 1 or 1.5 s in a single glance. *Total time eyes off forward roadway* for crashes, as shown in Figure 6.1, was 1.8 s. Figure 6.2 shows that there were, on average, 1.4 eyeglances that occurred during the1.8 second time frame. The same is true for near crashes, incidents, and baseline epochs.

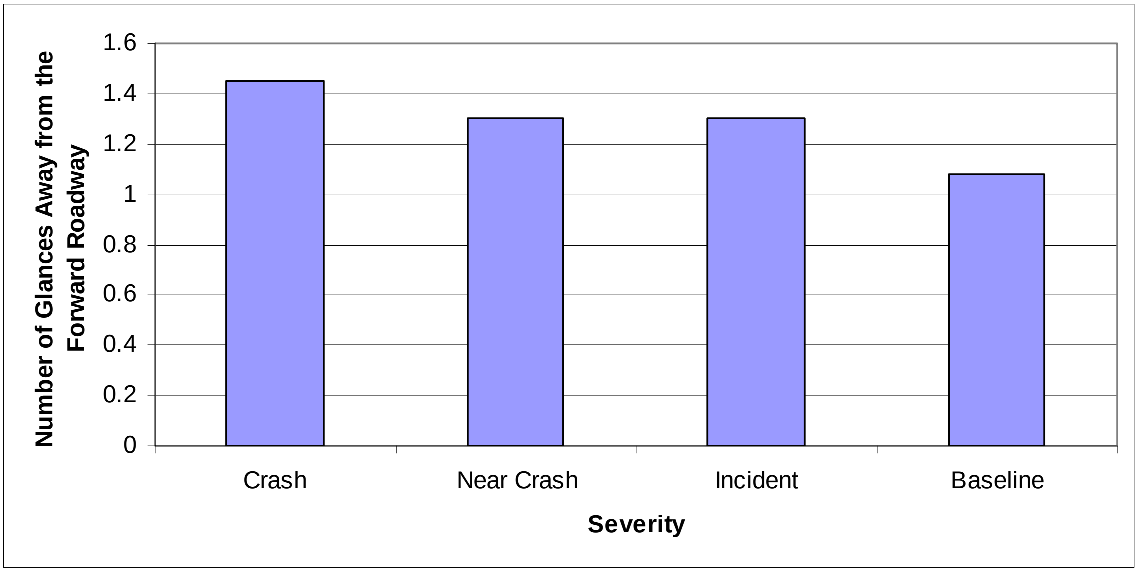

Figure 6.2. Mean number of glances away from the forward roadway occurring during 5 s prior and 1 s after the onset of the conflict or during a 6-second baseline driving epoch.

The mean length of longest glance away from the forward roadway is the only metric not confined to the 5 s prior and 1 s after the onset of the conflict. Rather, the longest glance away simply has to be initiated within the 5 s prior and 1 s 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 have been 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 s longer for crashes than for near crashes ($F(3, 11{,}177) = 34.94$, $p < 0.0001$). Tukey post-hoc t-tests indicated that all four groups were significantly different from one another. The results from the Tukey post-hoc t-tests are shown in Table 6.7.

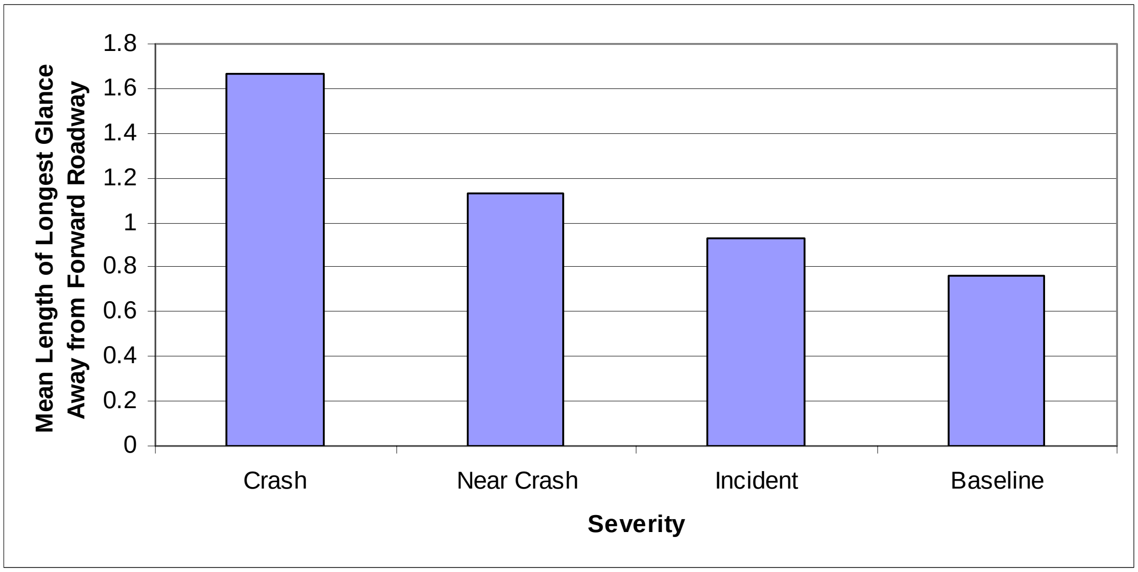

Figure 6.3. Mean length of longest glance initiated during the 5 s prior and 1 safer the onset of the conflict.

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

	Severity	dF	t-value	p-value
1.	Crash x 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

The third analysis, eye-glance location analysis, involved measuring the location of the longest glance away from the forward roadway that was initiated during the 5 s prior and one second after the onset of the conflict. Eye-glance 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, referred to as 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.

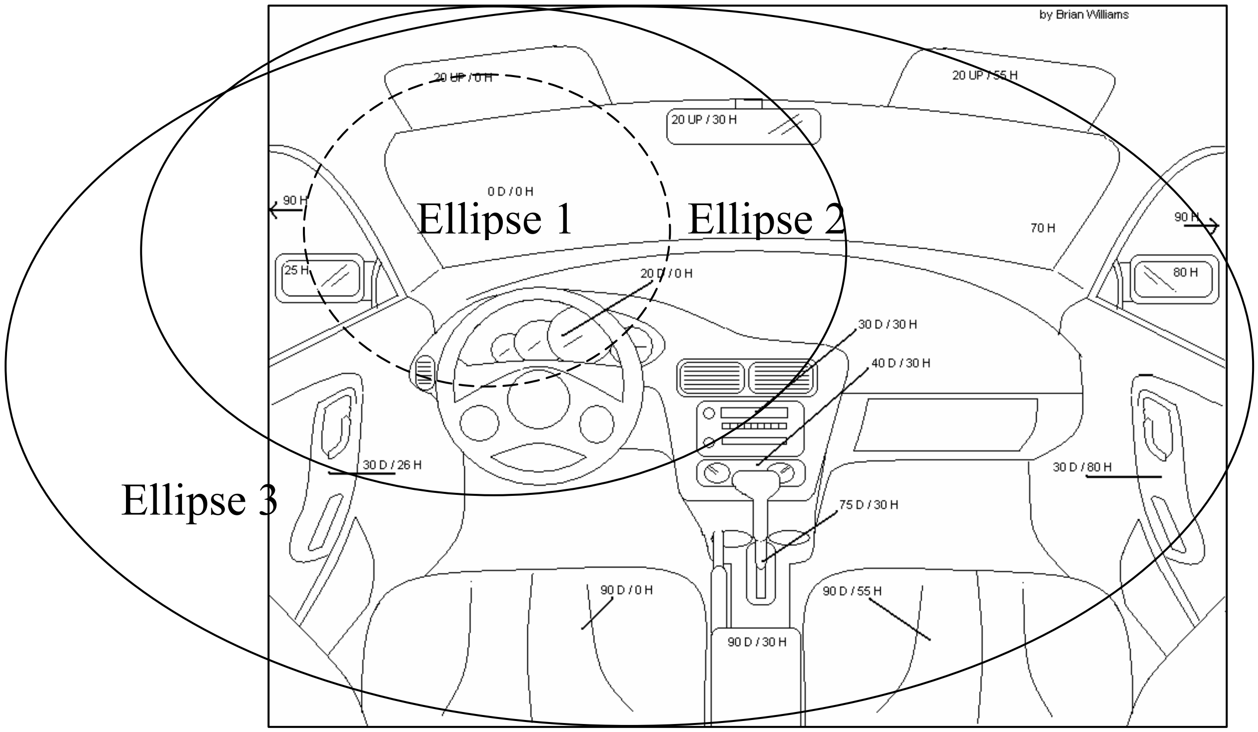

Figure 6.4. Depiction of degrees of visual angle from center forward that objects in the cockpit of an automobile are generally located. (Figure created by VTTI for 100 Car Project).

Figure 6.5 presents the longest glance for percent of crashes, near crashes, incidents, and baseline epochs for each ellipse. A chi-square indicated whether there were significant differences in the frequency of events or epochs at these locations ($X(9) = 208.42$, $p > 0.0001$). For incidents, the drivers' longest glance away from the forward roadway is spread fairly evenly across all three ellipse locations for crashes, and near crashes, where drivers longest glance was more frequently between 20° and 40° away from center forward. Baseline epochs had the highest percentage of long glances in ellipse 3. These results may indicate that many crashes and near-crashes could potentially be avoided if the drivers' attention could be re-directed close to the center forward eye gaze direction.

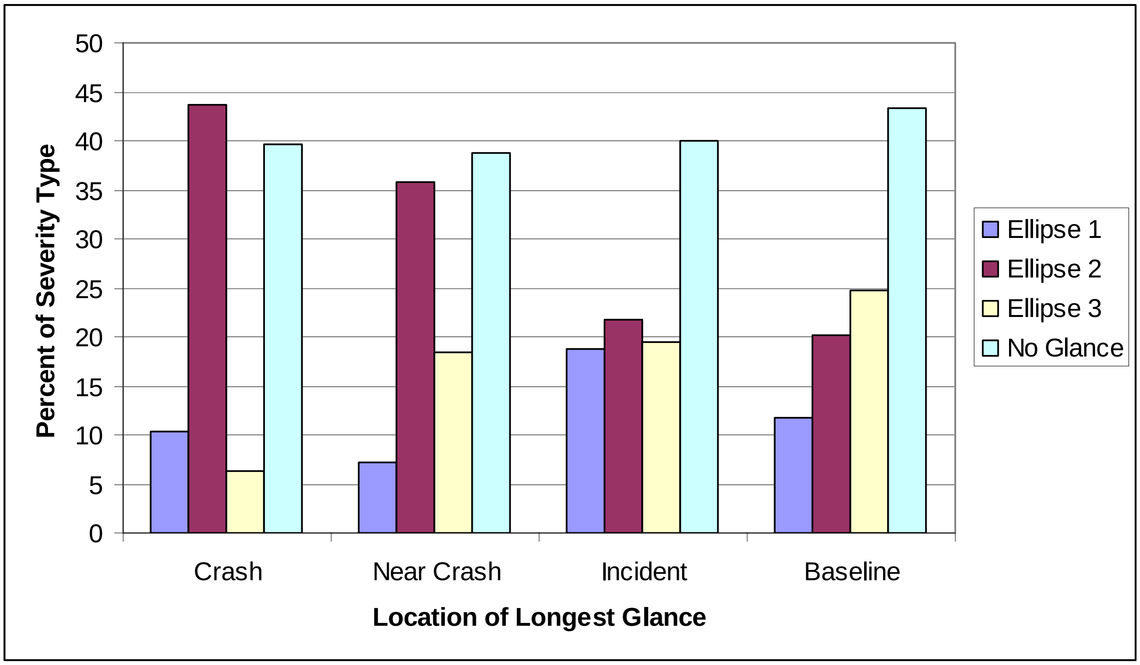

Figure 6.5. The percentage of the location of the longest glance away from the forward roadway by severity.

Summary

The results supported original research that drivers do not tend to look away from the forward roadway greater than 2.0 seconds for any given eyeglance; however, *total time eyes off the forward roadway greater than 2.0 seconds* over a 6 second period was linked to increased crash risk. While telematic design guidelines are currently focused on single eyeglance length and total task time, these results suggest that these guidelines are inadequate and need to focus on total time eyes off the forward roadway for a particular task duration. The total amount of time analyzed was 6 seconds, greater than 2 seconds is 33% of the total time frame. Perhaps designers should focus on keeping driver's eyes on the forward roadway for more than 67% of the total task time.

The use of eyeglance behavior in driving research is a complicated construct. W*hy* the driver was looking away from the forward roadway must be considered if one is interested in driving inattention. In driving research it is commonly stated that a driver looking away from the forward roadway is an *inattentive driver*. It is also commonly stated that a driver who is systematically scanning their environment (i.e. looking away from the forward roadway) is an *attentive driver*. A glance away from the forward roadway may or may not be a source of potential inattention, depending upon the *purpose* for looking away. The results from these analyses indicate that the act of looking away from the forward roadway to view their rear-view mirrors resulted in a relative crash risk of less than 1.0, or safer than normal driving. When glances to rear-view mirrors were removed from the odds ratio calculations for *total time eyes off the forward roadway*, the odds ratio and population attributable risk calculations increased 18 percent indicating that non-purposeful glances away from the forward roadway increase crash risk more so than do purposeful glances.

When addressing the issue of total time eyes off the forward roadway and the respective safety impacts, total time EOR greater than 2 s away increased involvement in crashes and near crashes by 2 times that of normal driving. This was true regardless of the purpose or location of the eyeglance.

Statistically significant differences were identified using four eye-glance behavior metrics for crashes, near crashes, incidents, and baseline epochs. These results indicated that longer eyeglances and longer periods of EOR time had a significant negative impact on driving performance. Drivers who were involved in crashes had total time eyes away from the forward roadway of nearly 2 s with an average length of longest glance of 1.5 s whereas drivers involved in near crashes had total EOR time closer to 1 s with the same for longest glance length. While statistically significant differences were observed for number of glances, caution may be required as there may be little practical difference 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. For crashes and near crashes, drivers were more far more frequently looking in Ellipse 2 than other locations, while 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 their hand-held device or some other object residing inside the vehicle, the distance away from center forward is unknown and may not be located within Ellipse 3. These two categories were placed in Ellipse 3 since it appeared that drivers were usually looking at objects in their lap or the seat next to them, and also dialed their hand-held device near their lap. It is doubtful that this discrepancy in the operational definition had a very large impact, since the frequencies for the category was fairly low, especially for the crashes and near-crashes.

These results demonstrate that eyeglances away from the forward roadway, especially those that do not involve checking rear-view mirrors, may contribute to a high percentage of crashes. For 93 percent of the crashes, near crashes, and incidents, the driver looked away from the forward roadway during the 5 s prior and 1 s after the onset of the conflict. This value was closer to 88 percent for rear-end crashes and near-crashes and incidents with a lead vehicle. If collision avoidance warning designers could incorporate where the driver is looking in their warning algorithms, their systems could be improved with fewer false alarms and greater crash mitigation.

7. CONCLUSIONS

General Conclusions

The analyses reported in this document are the first to assess the relationship between driving-related inattention and crash and near-crash involvement. These assessments were made using data collected as part of a large-scale naturalistic driving database. The analytical methods used were borrowed from epidemiology, empirical research, and qualitative research to obtain answers to four research objectives. 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 at the beginning of this report as one of the following:

1.) Driver engagement in secondary tasks
2.) Driver fatigue
3.) Driving-related inattention to the forward roadway (e.g. checking mirrors)
4.) Non-specific eyeglance away from the forward roadway

These four types of inattention or a reduced set of these four types was used to answer the four research objectives addressed in this dissertation. Some of the important findings addressed as part of these four objectives are presented below:

Objective One. Assessment of the prevalence of driver inattention and the impact of relative crash risk

The prevalence of driving inattention was analyzed by using 'normal driving' as established by the baseline database. The results suggested that drivers are engaging in at least one of the four types of inattention in 73 percent of all baseline epochs. The four types of inattention were recorded alone and in combination with the other types of inattention. The percentage 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
- fatigue – 4 percent of baseline epochs
- non-specific eyeglance – 2 percent of baseline epochs

This study allowed, for the first time, the calculation of relative risk of engaging in various types of inattention-related activities. These calculations were possible for the first time because: 1) detailed driver behavior data were reduced from the video and 2) sufficient data were collected involving crashes and near-crashes. Some of the interesting findings regarding relative crash risks were that driving while fatigued increases an individual's crash risk by between 4.3 and 6. 5 times, engaging in complex secondary tasks increases crash risk by 7.1 times, and engaging in moderately complex tasks increases crash risk by 2.4 times. Driving-related inattention to the forward roadway was actually shown to be safer than normal driving (OR of 0.48) as long as the EOR time was not greater than 2 seconds. This makes intuitive sense because drivers who are checking their rear-view mirrors are generally alert and aware of surrounding traffic.

This study also allowed the calculation of population attributable risks for the first time. This calculation produces an estimate of the percentage of crashes and near-crashes occurring in the population where the specific inattention-related activity was a contributing factor. The results of this analysis indicated that driving fatigued was a contributing factor in 8.1 percent of the crashes and near-crashes, while secondary task types (all three levels of complexity) contributed to more than 16% of all crashes and near-crashes. This is a useful metric, as many inattention-related activities obtained high odds ratios while the corresponding population attributable risks indicated a low total percentage of the crashes and near crashes. This was due to a low frequency of occurrence for these activities whereas other more frequent inattention tasks had lower odds ratios but demonstrated higher population attributable risks.

Objective Two. Assessment of the environmental conditions in which drivers choose to engage in secondary tasks and/or drive while fatigued as well as an assessment of the relative risks of engaging in driving inattention while encountering these environmental conditions.

The results indicate that driver fatigue may vary depending on time of day or ambient light present. Far fewer fatigue-related epochs were observed during the daylight hours and greater percentage of fatigue-related baseline epochs were identified during darkness. Fatigue was also seen to slightly increase in the absence of high roadway or traffic demand. Higher percentages of fatigue-related baseline epochs were found during free-flow traffic densities, on divided roadways, and areas free of roadway junctions suggesting that as drivers' task demand decreases, their fatigue levels may increase.

The relative crash risks calculated for each of the eight environmental conditions suggested that driving fatigued or engaging in complex secondary tasks increased crash risk more so than for engaging in moderate secondary tasks. Some interesting findings were that while driving fatigued on either wet or dry roadways increased crash risk by at least 3 times that of an alert driver on dry pavement, the same was not true for complex secondary task engagement. The crash risk for engaging in complex secondary tasks on wet roadways was not significantly different from that of an alert driver on dry pavement. One hypothesis for this result is that reduced speeds and greater headways on rainy roadways may reduce the crash risk for engaging in complex tasks.

Objective Three. Determine the differences in demographic data, test battery results, and performance-based measures between inattentive and attentive drivers.

The results from the survey and test battery response analyses showed that Driver Age, Driving Experience, self-reported traffic violations, accidents, daytime sleepiness ratings, and personality inventory scores indicate significant differences between the low and high involvement drivers. Given the exploratory nature of these analyses, two separate analyses were conducted. For the two group analysis, *high involvement drivers* were operationally defined as those drivers who were involved in four or more inattention-related crashes and/or near crashes while the *low involvement drivers* were involved in three or less. For the three group analysis, the low involvement group was involved in zero or one inattention-related crash(es) or near crash(es), the moderate involvement group was involved in two to four, and the high involvement group was involved in five or more. Table 7.1 presents the survey responses and test battery results that were significant for these two analyses.

Table 7.1. Summary of those tests that found significant differences for the two analyses using two levels of involvement and three levels of involvement in inattention-related crashes and near crashes.

	Two-Group Analysis	Three-Group Analysis
1.	Driver Age	Driver Age
2.	Years of Driving Experience	Years of Driving Experience
3.	N/A	Daytime Sleepiness Score
4.	Self-reported traffic violations	Self-reported traffic violations
	N/A	Self-reported accident involvement
4.	Extroversion (Five Factor Personality Inventory)	N/A
5.	Openness to Experience (Five Factor Personality Inventory)	N/A
6.	Agreeableness (Five Factor Personality Inventory)	Agreeableness (Five Factor Personality Inventory)
7.	Conscientiousness (Five Factor Personality Inventory)	Conscientiousness (Five Factor Personality Inventory)

The results for the analysis to determine whether any of the survey or test battery responses were associated with driving inattention indicate a clear relationship between engagement in secondary tasks or driving while fatigued.

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, which indicates a large effect in the behavioral sciences. This suggests that drivers who frequently engage in inattention-related activities are also frequently involved in inattention-related crashes and near crashes. Likewise, those drivers who do not frequently engage in inattention-related tasks tend not to be involved in inattention-related crashes and near crashes.

Objective Four. What is the relative risk of eyes off the forward roadway? Do eyes off the forward roadway significantly affect safety and/or driving performance?

The analysis of eyeglance behavior indicates that total time eyes off road durations of greater than 2 seconds significantly increased individual crash risk; whereas total EOR durations less than 2 seconds were not statistically different from normal driving. The purpose of an eyeglance away from the roadway is important to consider since eyeglances directed at rear-view mirrors is a safety enhancing activity while eyeglances at objects in the vehicle are not safety enhancing. 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 s. The length of the total EOR time and the length of the longest glance both indicate that crashes occurred while the driver was looking away for significantly longer periods of time with longer single glance lengths than for near-crashes, incidents, or baseline epochs.

Relative Risk Calculations

Odds ratio calculations, or relative risk calculations, were conducted in three separate chapters. In Chapter 2, odds ratios were calculated for three levels of visual and/or manual complexity of secondary tasks, two durations of time for driving-related inattention to the forward roadway, two durations of time for non-specific eyeglance away from the forward roadway, and two calculations of driver fatigue. Odds ratio calculations were calculated in Chapter 3 to determine whether driving while engaging in secondary tasks or fatigued through various types of driving environments produced higher crash risks. Finally, odds ratios were also calculated in Chapter 6 for total time EOR for five durations.

Data used to calculate the odds ratios included 69 crashes and 761 near crashes collected as part of the 100-Car Study and 20,000 baseline epochs (5000 baseline epochs for any odds ratios requiring eyeglance data). 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 in and then randomly sampled across the entire 12 months of data collection. Each baseline epoch consisted of a 6-second segment of time when the vehicle was in motion. This stratification technique created a case-control dataset, since those vehicles involved in more crashes, near crashes, and incidents also had more baseline events for comparison. Case-control designs are optimal for calculating odds ratios (also referred to as relative crash risk) due to the increased power of a case-control dataset. Greenberg, Daniels, Flanders, Eley, & Boring, (2001) argue that case-control designs allow for an efficient means to study rare events, such as automobile crashes, by evaluating the causal relationships present in the data. This is primarily important when using relatively smaller sample sizes than are used in typical crash data base analyses where thousands of crashes may be used.

Table 7.2 presents the odds ratios for the different types of inattention that increase individual crash risk. Table 7.3 presents the odds ratios for those environments where driving inattentively (engaging in secondary tasks or driving fatigued) is less safe than normal driving.

Table 7.4 presents the odds ratios for the lengths of total EOR time. All tables present only those odds ratios that were greater than 1.0. Those that were significantly different from 1.0 are in bold font. Please note that *driving-related inattention to the forward roadway* is not shown in this table since this type of inattention was found to be safer than normal driving.

The results from the analysis of inattentive driving during various roadway environments indicate that there are times when engaging in inattentive tasks is safer than at other times, as shown by the odds ratio calculations in Table 7.3.

Table 7.2. All Types of Driving Inattention with Odds Ratios Greater than 1.0.

Type of Inattention	Odds Ratio	Lower CI	Upper CI
Complex Secondary Task	**7.10**	**4.46**	**11.19**
Average Secondary Task	**2.38**	**1.85**	**3.06**
Simple Secondary Task	**1.20**	**0.93**	**1.55**
Moderate to Severe Fatigue	**4.31**	**3.13**	**5.94**
Moderate to Severe Fatigue (all occurrences)	**6.47**	**4.84**	**8.64**
Driving-Related Inattention to the Forward Roadway – Greater than 2 Seconds	**1.02**	**0.63**	**1.65**
Non specific Eyeglance Away from the Forward Roadway-Greater than 2 Seconds	**1.17**	**0.35**	**3.89**
Reaching for a Moving Object	**8.25**	**2.34**	**29.0**
Insect in Vehicle	5.94	0.71	49.4
Reading	**3.18**	**1.66**	**6.12**
Applying Makeup	**2.9**	**1.17**	**7.33**
Dialing Hand-Held Device	**2.58**	**1.49**	**4.47**
Looking at External Object	**3.46**	**1.05**	**11.34**
Eating	**1.47**	**0.87**	**2.48**
Handling CD	2.1	0.27	15.77
Reaching for object (not moving)	1.29	0.7	2.37
Talking/Listening to a Hand-Held Device	1.23	0.89	1.67
Combing Hair	0.34	0.04	2.44

Table 7.3. All environmental conditions that obtained odds ratios greater than 1.0.

Type of Roadway Environment	Odds Ratio	Lower CI	Upper CI
Calculations for Fatigue by Environmental Condition			
Lighting			
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			
Free Flow	**4.67**	**3.02**	**7.21**
Flow with Restrictions	**4.81**	**2.70**	**8.58**
Stable flow	**3.63**	**2.01**	**6.54**
Flow is Unstable – Vehicles are unable to pass with temporary stoppages	**4.29**	**1.88**	**9.80**
Unstable Flow- Temporary restrictions, substantially slow drivers	**3.71**	**1.93**	**7.13**
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 Device	**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**

Calculations for Secondary Task by Environmental Condition			
Lighting			
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			
Free Flow	**4.67**	**2.32**	**9.38**
Flow with Restrictions	**3.67**	**1.65**	**8.19**

Stable flow	**3.80**	**1.68**	**8.58**
Flow is Unstable – Vehicles are unable to pass with temporary stoppages	**1.75**	**0.61**	**5.01**
Unstable Flow- Temporary restrictions, substantially slow drivers	**2.45**	**1.01**	**5.93**
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**
No Traffic Control Device	**4.02**	**2.47**	**6.54**
Relation to Junction			
Intersection	1.59	0.86	2.97
Intersection-Related	**3.32**	**1.73**	**22.07**
Parking Lot	**9.11**	**3.76**	**22.07**

The odds ratios presented for the total EOR time suggests that anytime a driver's eyes are off the forward roadway for more than 2 seconds over a 6 second time span, crash risk increases by 2 times (Table 7.4). None of the eyeglances away from the forward roadway that were less than 1.5 seconds were significantly different from 1.0.

Table 7.4. Odds Ratios 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 CI**	**Upper CI**
Greater than 1.5 but less than or equal to 2.0	1.17	0.81	1.67
Greater than 2.0 seconds	**2.14**	**1.71**	**2.66**
OR for Eyeglance Away From the Forward Roadway	**1.56**	**1.29**	**1.88**

Population Attributable Risk Calculations

Population attributable risk is a measure of the percentage of crashes and near crashes in a metropolitan area that can be attributed to the variable being measured. Population attributable risks are useful when interpreting odds ratios, or relative risk calculations, in that 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. In other words, any time a driver engages in that task, risk is increased. However if drivers rarely engage in the task, its overall contribution may be quite low. An example of high odds ratios leading to low population attributable risks include the secondary tasks of *reaching for a moving object, external distraction, reading, applying makeup, dialing a cell phone,* and *eating.* Even though each of these tasks obtained greater individual 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 calculations Table 7.5). Fatigue had the opposite result in that it exhibited a high relative risk value and also contributed to 8 percent of the crashes and near crashes in the population; this is much higher than most crash database research has shown (e.g., Campbell, Smith, and Najm, 2003).

While the odds ratio for t*alking/listening to a cell phone* was barely above 1.0 and less than *dialing a cell phone*, the population attributable risk was the same because talking on a cell phone is more common than dialing a cell phone (conversation has a longer duration).

Table 7.5. The population attributable risks for the types of driver inattention.

Type of Inattention	Population Attributable Risk	Lower CI	Upper CI
Complex Secondary Task	5.10	4.87	5.28
Moderate Secondary Task	9.26	8.93	9.61
Simple Secondary Task	2.33	1.98	2.67
Moderate to Severe Fatigue	8.14	7.87	8.4
Moderate to Severe Fatigue (all occurrences)	12.75	12.44	13.10
Driving-Related Inattention to the Forward Roadway – Greater than 2 Seconds	0.06	-0.11	.022
Non specific Eyeglance Away from the Forward Roadway-Greater than 2 Seconds	0.08	0.01	0.14
Dialing Hand-Held Device	1.54	1.41	1.67
Reading	1.23	1.22	1.34
Applying Makeup	0.59	0.51	0.67
Reaching for a Moving Object	0.47	0.41	0.53
Insect in Vehicle	0.14	0.11	0.18
Talking/Listening to a Hand-Held Device	1.44	1.2	1.69
Eating	0.86	0.72	1.00
Reaching for object (not moving)	0.45	0.32	0.44
Looking at External Object	0.38	0.32	0.44
Handling CD	0.09	-2.67	2.8

The population attributable risks for engaging in inattentive tasks during different types of roadway environments also resulted in some interesting PAR results (Table 7.6). As was stated previously, engaging in inattention-related tasks during various environmental conditions and scenarios contribute to a significant portion of the crashes and near-crashes in a metropolitan area.

Table 7.6. The population attributable risks for the types of roadway environments.

Type of Roadway Environment	Population Attributable Risk	Lower CI	Upper CI
Lighting Levels			
Dawn	0.96	0.95	0.97
Daylight	N/A	N/A	N/A
Dusk	2.79	2.77	2.82
Darkness-Lighted	2.43	2.38	2.49
Darkness-Not Lighted	0.12	0.08	0.16
Weather			
Clear	0.53	0.39	0.67
Rain	5.97	5.93	6.01
Road Type			
Undivided	9.39	9.33	9.46
One-Way	0.75	0.73	0.77
Roadway Alignment			
Curve Level	3.81	3.77	3.85
Curve Grade	0.51	0.50	0.52
Straight Grade	N/A	N/A	N/A
Straight Level	2.57	2.43	2.71
Traffic Density			
Stable Flow – Maneuverability and Speed are more Restricted	6.74	6.70	6.77
Flow is Unstable – Vehicles are unable to pass with temporary stoppages	1.67	1.66	1.69
Unstable Flow- Temporary restrictions, substantially slow drivers	3.57	3.55	3.59
Roadway Surface Conditions			
Dry	6.36	6.23	6.50
Wet	2.52	2.48	2.55
Icy	0.15	0.15	0.16
Traffic Control Device			
Traffic Signal	6.21	6.18	6.25
Stop Sign	0.88	0.87	0.90
Relation to Junction			
Intersection	6.98	6.95	7.02
Intersection-Related	2.95	2.92	2.98
Entrance/Exit Ramp	2.17	2.15	2.19
Driveway/Alley Access	0.37	0.36	0.38
Interchange	0.24	0.23	0.25

Another important finding from these analyses was that eyeglances greater than 2 seconds contributed to 13% of all crashes and near-crashes and eyeglances in general contributed to 18% of all crashes and near crashes that occur in a metropolitan driving environment (Table 7.6). 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 7.7. Population Attributable Risk Ratios for Eyes Off Forward Roadway Excluding Eyeglances to Center, Right, and Left Rear-View Mirrors

Total Time of Eyes Off Forward Roadway	Population Attributable Risk	Lower CI	Upper CI
Greater than 1.5 but less than or equal to 2.0	1.05	0.79	1.30
Greater than 2.0 seconds	13.29	12.84	13.75
PAR for Eyeglance	18.25	17.49	19.01

Theoretical implications of the study

The analyses presented in this dissertation demonstrate that drivers' EOR has an associated increased crash risk whereas cognitive inattention (i.e. talking/listening to cell phone or passenger) does not. These results support the tenets of ecological theory in that drivers are able to directly perceive information regarding their motion through the environment. The attentional resources required to participate and process conversations do not directly interfere with perceiving motion information as long as the drivers' eyes are on the forward roadway. As the task distraction increases time that the drivers eyes are off the forward roadway, crash risk also increases. Thus, the driving performance decrements associated with eyes off the forward roadway, as demonstrated in empirical research, translate into increased crash risk; whereas the driving performance decrements associated with conversations (i.e. cognitive distraction) do not translate into increased crash risk on roadways.

One possible explanation for the lack of crash risk associated with conversations could be because drivers pull over or avoid highly emotional conversations while driving or highly emotional conversations do not occur very frequently and thus the increased crash risk associated with them is being dampened by the more frequent yet, simpler conversations. Given that highly emotionally charged conversations has not directly been analyzed in this data, it is difficult to argue that these types of conversations do not increase crash risk. Rather, these conversations do not appear to impact crash risk to the same degree as do eyes off the forward roadway.

The increased crash risks associated with inattentive drivers and risky driving environments also supports the theories of direct perception. Drivers must keep their eyes on the forward roadway while driving through these environments because they are more visually demanding. Some examples of these risky, visually driving environments include: lower visibility environments where drivers are unable to pick up as much motion information as during daylight, intersections where traffic signals are changing and vehicles may cross paths, or higher traffic densities where multiple vehicles may be altering speed.

Application of Results

These analyses showed repeatedly that drivers are inattentive and/or looking away from the forward roadway during a significant portion of the events and baseline epochs. While a portion of this inattention may be due to systematic scanning of the driving environment or engagement in secondary tasks or fatigue, total eyeglance time away from the forward roadway greater than 2 seconds greatly increases crash risk. Developers of collision avoidance warning systems should incorporate these findings into newer generations of warning systems because false alarm rates could greatly be reduced by incorporating eyeglance information into the collision avoidance algorithms.

The results from these analyses also indicate that current design guidelines and/or suggestions relating to acceptable eyeglance durations for in-vehicle telematic systems are inadequate. Current guidelines suggest that one glance length away from the forward roadway cannot be longer than 2.0 s in duration. Results presented here suggest that drivers tend not to look away from the forward roadway greater than 1.0 second for a single glance length before they will return their eye gaze to the forward roadway. Other design guidelines suggest that a specific task (i.e. changing a radio station on XM Radio) can not take longer than 20 s. Given this requirement, a driver could potentially have their eyes off the forward roadway for easily 10-15 s of this time. The results from these analyses indicate that crash risk increases by 2 times when a drivers eyes are off the forward roadway 30% of 6 s. Design guidelines for new in-vehicle telematic systems needs to take into account total times eyes are off the forward roadway which must be less than 30% of the total task time. Thus, designers of in-vehicle devices must incorporate more voice activation commands and hands-free devices in order for drivers to safely operate them.

It is apparent from the results of the analyses of roadway and traffic environments that there may be safer moments in which to engage in secondary tasks (Tables 7.3 and 7.5). Generally, it appears that engaging in secondary tasks during more visually cluttered or demanding traffic environments (intersections, entrance/exit ramps, curved roadways), poor weather or roadway conditions (rainy weather, icy or wet road surfaces), or roadways with less surface area for safe travel (undivided roadways) are not the optimal locations. This information could be used to better educate young drivers or those drivers who are attending traffic schools. Inattentive drivers reported significantly higher numbers of traffic violations in the past 5 years. This may indicate that those drivers who actually attend traffic schools may in fact be those drivers who would benefit most from this information.

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 engage in secondary tasks or drive fatigued on a regular basis. This may also imply that there are few drivers who frequently engage in secondary tasks and/or drive fatigued frequently that are *never or rarely* involved in inattention-related crashes and near-crashes.

Limitations of the Study

Please note that there are some shortcomings 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 risks are generalizable to a metropolitan environment and not the United States driving population at-large.

Further analyses needs to be conducted to determine how all these individual odds ratio and population attributable risk calculations interact with each other. Please note that all 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 risks 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 initial odds ratios that were calculated on fatigue 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 is somewhat controlled. The odds ratios that were calculated on each secondary task type (i.e. dialing cell phone) 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 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,Feaganes, Rodgman, Hamlett, Meadows, Reinfurt, Gish, Mercadante, & Staplin, 2003), there were many issues in the data collection and reduction procedures that created obstacles for this type of reduction. For example, interior cameras only pointed at the driver, which made a length of 'conversation with passenger' difficult to assess. Also, no continuous audio channel was present, hindering calculations for 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 and whether the stereo is in use.

Future Research

One of the primary goals of the 100 Car Naturalistic Driving study was to serve as a pilot study for a larger, nation-wide naturalistic driving study. The success of this study has proven that technology has advanced to where naturalistic driving data, including cameras and kinematic sensors, can efficiently and accurately capture driver behavior and collect driving performance data. One of the limitations of this study was that data collection occurred in one geographic location. Using an urban environment increased the number of crashes that were captured but these results are not necessarily representative of all drivers in the United States. There is a need to collect naturalistic driving data that is more representative of all drivers in the United States by capturing more rural and suburban driving but also more adverse weather conditions (i.e. snow and icy roadways), data in more adverse topography (i.e. curvy, mountain roadways) as well as capturing the attitude toward driving that varies from the northeastern regions to the southwestern regions of this country. This larger dataset would provide the most accurate relative crash risk assessments for all drivers, in all areas of the country.

The 100 Car Naturalistic Driving dataset is still a very rich dataset that could be mined to answer many existing research questions. More data reduction and analyses can be done to better assess those behaviors which had very high relative crash risks, i.e. fatigue, engagement in complex secondary tasks, etc. More data reduction could also be done to measure secondary task duration for many of the tasks, even though it is not possible to assess duration for some tasks, such as talking to passenger and listening to radio, as discussed above. How often or the percentage of time that drivers are engaging in secondary tasks is still unknown. The impact of these tasks on younger versus older drivers and the percentage of time that drivers of different age groups were engaging would also provide very interesting results for transportation researchers.

There are many key questions that can be answered with naturalistic driving studies. Now that this tool exists, it is hoped that safety researchers will continue to use studies, such as this one, to better understand why crashes occur and eventually, how to prevent crashes.

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APPENDIX A: Secondary Tasks

TableA-1. Secondary Tasks Recorded During Data Reduction.

Secondary Task Distraction Type	Description
Passenger-Related Secondary Task	
Passenger in adjacent seat	Driver is talking to a passenger sitting in adjacent seat that can be identified by their 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 their 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 yr college degree/trade school
    e. 4 yr 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 yearhow 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, answer each as accurately as possible

1. When you are working:
what time do you go to bed ____:____ am/pm and wake up ____:____ am/pm

2. When you are not working:
what time do you go to bed ____:____ am/pm and wake up ____:____ am/pm

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_____

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

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

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

23. If yes, how often? __________________________

PRIMARY SLEEP DISORDERS

24. 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 to other traffic	1	2	3	4	5	6	7	8	9	10	Reactions to

becomes
increasingly slower

d) Maintain attention to road- 1 2 3 4 5 6 7 8 9 10 Become
increasingly
signs 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 1 2 3 4 5 6 7 8 9 10 Normal
judgement of speed
judge your speed

g) Interest in driving does not 1 2 3 4 5 6 7 8 9 10 Increasingly
bored and fed-up
change

h) Passing becomes increasing- 1 2 3 4 5 6 7 8 9 10 No change
ly risky and dangerous

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 s of video after the initial onset of a trigger. If a second trigger occurs within this 1.5 minute segment, the epoch will extend to include a full one minute prior to the onset of the initial trigger and 30 s after the onset of the last trigger.

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

Invalid trigger – Any instance where a trigger appears but no safety-relevant event is present.

Non-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% 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% 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 s or less.
All longitudinal decelerations between 0.4 g and 0.5 g coupled with a forward TTC value of ≤ 4 s and that the corresponding forward range value at the minimum TTC is not greater than 100 ft.
Rear Time To Collision (RTTC) - Any rear TTC trigger value of 2 s or less that also has a corresponding rear range distance of ≤ 50 ft. AND any rear TTC trigger value where the absolute acceleration of the following vehicle is greater than 0.3 g.
Side object detection – Detects presence of other vehicles/objects in the adjacent lane.
Lane change cut-off – Identifies situations in which the 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 deg change in heading (i.e., vehicle must return to the same general direction of travel) within a 3 s window of time.

5. Driver 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, fatigue, or disciplining child while driving.

A. This Vehicle Loss of Control Due to:

001 = Blow-out or flat tire

002 = Stalled engine

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

004 = Minor vehicle failure

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

006 = Excessive speed

007 = Other or unknown reason

008 = Other cause of control loss

009 = Unknown cause of control loss

B. This Vehicle Traveling:

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

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

021 = Ahead, traveling in same direction and decelerating

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

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

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

012 = Over left edge of roadway

013 = Over right edge of roadway

014 = End departure

015 = Turning left at intersection

016 = Turning right at intersection

017 = Crossing over (passing through) intersection

019 = Unknown travel direction

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

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

C. Other Vehicle in Lane:

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

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

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

052 = Ahead, traveling in same direction and decelerating

053 = Ahead, traveling in same direction and accelerating

054 = Traveling in opposite direction

055 = In crossover

056 = Backing

059 = Unknown travel direction of the other motor vehicle

Another Vehicle Encroaching into This Vehicle's Lane:

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

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

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

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

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

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

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

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

062 = From opposite direction over left lane line.

063 = From opposite direction over right lane line

064 = From parallel/diagonal parking lane

065 = Entering intersection—turning in same direction

066 = Entering intersection—straight across path

067 = Entering intersection – turning into opposite direction

068 = Entering intersection—intended path unknown

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

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

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

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

074 = From entrance to limited access highway

078 = Encroaching details unknown

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

080 = Pedestrian in roadway

081 = Pedestrian approaching roadway

082 = Pedestrian in unknown location

083 = Pedalcyclist/other non-motorist in roadway

084 = Pedalcyclist/other non-motorist approaching roadway

085 = Pedalcyclist/or other non-motorist unknown location

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

F. Object or Animal:

087 = Animal in roadway

088 = Animal approaching roadway

089 = Animal unknown location

090 = Object in roadway

091 = Object approaching roadway

092 = Object unknown location

099 = Unknown critical event

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

2 = Ill, blackout

3a = Angry

3b = Other emotional state

4a = Drugs-medication

4b = Drugs-Alcohol

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

6 = Restricted to wheelchair

7 = Impaired due to previous injury

8 = Deaf

50 = Hit and run vehicle

97 = Physical/mental impairment – no details

98 = Other physical/mental impairment

99 = Unknown physical/mental condition

Source: GES D3, Driver Physical/Mental Condition. Element 3 expanded to separate anger from other emotions. Element 50 not applicable.
Coded in General State Variables: Driver's General State, Causal/Contributing Factors, & Precipitating Event.
FORMAT: 16-bit encoded value(s) as listed above.

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

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

00 = Not Distracted

15 = Cognitive distraction

97 = Lost in thought

01 = Looked but did not see

15a = Reading

15b = Talking/singing without obvious passenger

15c = Dancing to the radio

15d = Reading

03 = Passenger in vehicle

3a = Passenger in adjacent seat

3b = Passenger in rear seat

3c = Child in adjacent seat

3d = Child in rear seat

= 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 s 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 & 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 [need definition]
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. Average PERCLOS (Percentage Eyes Closed) (C, N)

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

6. Driver 1 Eyeglance Reconstruction (C-N)

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

1 = Center forward

2 = Left forward

3 = Right forward

4 = Left mirror

5 = Right mirror

6 = Left window

7 = Right window

8 = Instrument panel

9 = Passenger

10 = Object

11 = Cell Phone

12 = Other

Comment: The analysis will include a recording of time the driver's eyes were not "on the road," i.e., straight ahead, forward right, or forward left. When possible, 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: Multiplel 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, fatigued
2 = Ill, blackout
3a = Angry
3b = Other emotional state
4 = Drugs-medication
5 = Other drugs (marijuana, cocaine, etc.)
6 = Restricted to wheelchair
7 = Impaired due to previous injury
8 = Deaf
50 = Hit and run vehicle
97 = Physical/mental impairment – no details
98 = Other physical/mental impairment
99 = Unknown physical/mental condition

7. Driver 2 Actions/Factors Relating to Crash/Incident (VA PAR Variable 17/18) Reductionists will code this for crashes and near-crashes only for each vehicle immediately surrounding the 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 1. T-test Summary Table for Driver Attentiveness (Driver Age)

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

Table 2. T-test Summary Table for Driver Attentiveness (Male Driver's Age)

Source of Variation Dependant Variable: Age/Male	df	SS	MS	F value	*p* value*
Attention Category	1	294.02362	294.0236	1.63	0.2066

Table 3. T-test Summary Table for Driver Attentiveness (Female Driver's Age)

Source of Variation Dependant Variable: Age/Female	df	SS	MS	F value	*p* value*
Attention Category	1	1031.745 9	1031.74 6	4.9	0.0328

Table 4. T-test Summary Table for Driver Attentiveness (Years of Driving Experience)

Source of Variation Dependant Variable: Experience	df	SS	MS	F value	*p* value*

Attention Category	1	1482.5217	1482.522	7.6	0.0069

Table 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 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 7. T-test Summary Table for Driver Attentiveness (Number of Ilnesses)

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 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 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 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 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	123.6463	123.646	0.57	0.4526

		4	3		

Table 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 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 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 15. T-test Summary Table for Driver Attentiveness for Driver Behavior Questionnaire

Source of Variation	df	SS	MS	F value	*p* value*
Dependant Variable: Fatigue Proneness					
Attention Category	1	202.42993	202.42999	1.15	0.2868

Table 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	117.71577	0.94	0.3344

Table 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 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 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 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 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 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 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 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 25. T-test Summary Table for Driver Attentiveness

Source of Variation Dependant Variable: Channel Capacity	df	SS	MS	F value	*p* value*
Attention Category	1	0.4384058	0.438406	0.1	0.7526

Table 26. T-test Summary Table for Driver Attentiveness For the Waypoint Performance-Based Test

Source of Variation Dependant Variable: Preventable Crash Risk	df	SS	MS	F value	*p* value*
Attention Category	1	1.0471015	1.047101	2.05	0.1555

Table 27. T-test Summary Table for Driver Attentiveness For the Waypoint Performance-Based Test

Source of Variation Dependant Variable: Expected # of Moving Violations in the Next 5 Years	df	SS	MS	F value	*p* value*
Attention Category	1	0.0036232	0.003623	0.01	0.9299

Table X. 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 28. 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	5.975308 6	5.97530 9	1.39	0.2404

Chapter 4: Analysis of Variance Tables for Driver Attentiveness

Table 1. 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 2. ANOVA Summary Table for 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 3. 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 4. 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 5. 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 6. 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 7. 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	123.1405 5	61.5702 8	0.29	0.7522

Table 8. 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	37.49826 4	18.7491 3	0.17	0.8405

Table 9. 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 10. 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 11. ANOVA Summary Table for Driver Attentiveness Driver Behavior Questionnaire (Fatigue)

Source of Variation Dependant Variable: Fatigue Proneness	df	SS	MS	F value	*p* value*
Attention Category	2	63.21934	31.60967	0.18	0.8377

Table 12. ANOVA Summary Table for Driver Attentiveness for the Dula Dangerous Driving Inventory (DDDI)

Source of Variation Dependant Variable: DDDI	df	SS	MS	F value	*p* value*
Attention Category	2	368.34603	184.173	1.52	0.2238

Table 13. ANOVA Summary Table for Driver Attentiveness for the Dula Dangerous Driving Inventory (NE)

Source of Variation Dependant Variable: Negative Emotional	df	SS	MS	F value	*p* value*
Attention Category	2	116.1119	58.05595	2.64	0.0762

Table 14. ANOVA Summary Table for Driver Attentiveness for the Dula Dangerous Driving Inventory (AD)

Source of Variation Dependant Variable: Aggressive Driving	df	SS	MS	F value	*p* value*

Attention Category	2	4.8314514	2.415726	0.16	0.8501

Table 15. 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 16. ANOVA Summary Table for Driver Attentiveness for the Useful Field of View

Source of Variation Dependant Variable: UFOV	df	SS	MS	F value	*p* value*
Attention Category	1	23.945798	11.9729	2.47	0.0887

Table 17. ANOVA Summary Table for Driver Attentiveness for the NEO Five Factor Personality Inventory (N)

Source of Variation Dependant Variable: Neuroticism	df	SS	MS	F value	*p* value*
Attention Category	2	544.88275	272.4414	1.05	0.3549

Table 18. ANOVA Summary Table for Driver Attentiveness for the NEO Five Factor Personality Inventory (E)

Source of Variation Dependant Variable: Extroversion	df	SS	MS	F value	*p* value*
Attention Category	2	531.0390 9	265.519 5	1.96	0.1461

Table 19. ANOVA Summary Table for Driver Attentiveness for the NEO Five Factor Personality Inventory (O)

Source of Variation Dependant Variable: Openness	df	SS	MS	F value	*p* value*

Attention Category	2	258.81916	129.4096	0.96	0.3853

Table 20. 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 21. 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 22. 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 23. 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 Crash Risk					
Attention Category	2	0.7911188	0.395559	0.79	0.4588

Table 24. 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 25. 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	0.122073 8	0.06103 7	0.54	0.5835

Analysis of Variance Tables for Chapter 6

Table 1. ANOVA Summary Table for Eyeglance for Total Time Eyes Off Forward Roadway

Source of Variation Dependant Variable: Total Time	df	SS	MS	F value	*p* value*
Severity	3	175.797	58.599	33.36	<.0001

Table 2. ANOVA Summary Table for Eyeglance for Number of Eyeglances

Source of Variation Dependant Variable: Number of Glances	df	SS	MS	F value	*p* value*
Severity	3	127.34777	42.44926	22.02	<.0001

Table 3. ANOVA Summary Table for Eyeglance for Length of Longest Glance

Source of Variation Dependant Variable: Length of Longest Glance	df	SS	MS	F value	*p* value*
Severity	3	134.75325	44.91775	34.94	<.0001

Appendix E: IRB Approval Letters

GINIA POLYTECHNIC INSTITUTE
ND STATE UNIVERSITY

Institutional Review Board

Dr. David M. Moore
IRB (Human Subjects) Chair
Assistant Vice Provost for Research Compliance
CVM Phase II - Duckpond Dr., Blacksburg, VA 24061-0442
Office: 540/231-4991; FAX: 540/231-6033
e-mail: moored@vt.edu

12 March 2002

MEMORANDUM

TO: Thomas Dingus, Vicki Neale, Sheila Garnes
VTTI 0536

FROM: David M. Moore

SUBJECT: IRB APPROVAL – "Naturalistic Driving Study" – IRB # 01-432 ref 01-316

The above referenced protocol was submitted for full review and approval by the IRB at the October 8, 2001 and February 18, 2002 meetings. The board had voted approval of this proposal contingent upon receipt of responses to questions raised during its deliberation. Following receipt and review of your responses, I, as Chair of the Virginia Tech Institutional Review Board, have, at the direction of the IRB, granted approval for this study for a period of 12 months, effective February 18, 2002.

Approval of your research by the IRB provides the appropriate review as required by federal and state laws regarding human subject research. It is your responsibility to report to the IRB any adverse reactions that can be attributed to this study.

To continue the project past the 12 month approval period, a continuing review application must be submitted (30) days prior to the anniversary of the original approval date and a summary of the project to date must be provided. Our office will send you a reminder of this (60) days prior to the anniversary date.

cc:File
D. Richardson

A Land-Grant University—The Commonwealth Is Our Campus
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Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

Institutional Review Board

Dr. David M. Moore
IRB (Human Subjects)Chair
Assistant Vice President for Research Compliance
CVM Phase II- Duckpond Dr., Blacksburg, VA 24061-0442
Office: 540/231-4991; FAX: 540/231-6033
email: moored@vt.edu

DATE: February 28, 2005

MEMORANDUM

TO: Suzanne E. Lee VTTI 0536
Jonathan M. Hankey VTTI 0536
Shane McLaughlin VTTI 0536

FROM: David Moore

SUBJECT: **IRB Exempt Approval:** "Various Data Mining Project of Existing Data int eh 100 Car Naturalistic Database" IRB # 05-147

I have reviewed your request to the IRB for exemption for the above referenced project. I concur that the research falls within the exempt status. Approval is granted effective as of February 25, 2005.

Virginia Tech has an approved Federal Wide Assurance (FWA00000572, exp. 7/20/07) on file with OHRP, and its IRB Registration Number is IRB00000667.

cc: File
OSP 0170