Effects of In-Vehicle Information Systems (IVIS) Tasks on the Information Processing Demands of a Commercial Vehicle Operations (CVO) Driver

Myra Blanco

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Dr. Thomas A. Dingus, Chairman
Dr. Walter W. Wierwille
Dr. Robert J. Beaton

Blacksburg, Virginia

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(ABSTRACT)

This study was performed with two main goals in mind. The first goal was to understand and predict "red-lines" and "yellow-lines" in terms of what the CVO driver can process without hindering the primary task of driving. The second goal was to collect conventional secondary task data for CVO driving performance.

An on-the-road experiment was performed with the help of 12 truck drivers. Type of task, presentation format, information density, and age were the independent variables used in the experiment. The 22 dependent measures collected were grouped into the following categories: eye glance measures, longitudinal driving performance, lateral driving performance, secondary task performance, and subjective assessment.

The findings of this study strongly suggest that paragraphs should not be used under any circumstance to present information to the driver while the vehicle is in motion. On the other hand, the Graphics with Icons represent the most appropriate format in which driving instructions and information should be presented for IVIS/CVO tasks. In order to avoid a high visual attention demand to the driver due to a secondary task, only simple search tasks with the most important information shall be presented. Although the suggested format, type of task, and information density represent a higher visual attention demand than a conventional secondary task, these characteristics seem to bind a task with a moderate attentional demand. Other combinations of format, type of task, and information density will cause an increase in the driver's attentional demand that will consequently deteriorate their driving performance causing unsafe driving situations.

DEDICATION

To the four pillars of my life: God, my husband, and my parents. Without you, my life would fall apart.

I might not know where the life's road will take me, but walking with You, God, through this journey has given me strength.

Miguel, you are everything for me, without your love and understanding I would not be able to make it.

Mom, you have given me so much, thanks for your faith in me, and for teaching me that I should never surrender.

Daddy, you always told me to "reach for the stars." I think I got my first one. Thanks for inspiring my love for transportation.

We made it…

ACKNOWLEDGEMENTS

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Chapter 1. INTRODUCTION

1.1 Motivation

  Commercial vehicle operations (CVO) represent the mass movement of goods and services in the USA and many other countries. The American Trucking Association Statistics Department states that for 1996 (their latest statistic at this point in time), there were 3,019,000 persons with truck driver licenses in the US (A.M. Wakefield, personal communication, August 17, 1998). This figure represents a great number of stakeholders in the matter of Advanced Traveler Information Systems (ATIS). ATIS could help drivers to reduce travel time by presenting real-time information on routes, delays, congestion, and warnings of potential hazards (Dingus and Hulse, 1993). This evolving technology may allow CVO drivers to obtain different types of navigation, planning, and hazard notification assistance in the near future. Thus, CVO drivers could perform their jobs with previous notice of what is happening or will be happening in their traveling routes. All these benefits suggest that research into the possible use of ATIS for CVO applications is merited.

  It is not clear which characteristics of an In-Vehicle Information System (IVIS) may enhance or degrade driver safety. Therefore, empirical research into the use of ATIS is necessary. Research relating the different types of tasks that a CVO driver can perform with this type of technology while maintaining a given performance must be encouraged. Human factors issues such as driver behavior modification resulting from all the in-vehicle tasks that a system of this kind presents for CVO drivers is a research gap that has not yet been filled (Kantowitz, Hanowski, and Kantowitz, 1997). Since a system of this type may contain a combination of different amounts and types of information, leading to a complex set of decisions, the effects of the system on attention resources must be analyzed.

1.2 Background

  1.2.1 Accidents and Driver Error. The Indiana Tri-Level Study (Treat, Tumbas, McDonald, Shinar, Hume, Mayer, Stansifer and Catellan, 1979) is one of the most recognized studies in the area of crash causes. The study states that the cause of an accident falls into one of the following main categories: (1) human, (2) vehicular, and (3) environmental. Treat et al.

determined that driver error accounted for 93% of the crashes. The other two categories of causative factors were cited as 13% for the vehicle factor and 34% for environmental factors. It is important to note that in some cases, more than one factor was assigned as a causal factor.

Human causes are those most closely related to the use of IVIS in the tasks that are going to be studied in this work. The three main categories (human, vehicular, and environmental) are related among each other, and human error can be caused by improper vehicle or highway design characteristics (Dingus, Jahns, Horowitz, and Knipling, 1998). Dingus et al. (1998) recognized three major types of errors within the human error category: (1) recognition, (2) decision, and (3) performance. Decision errors refer to those that occur as a result of a driver's improper course of action or failure to take action. A recognition error may occur if the driver does not properly perceive or comprehend a situation. These two types of errors, recognition and decision, are those that can be minimized by not overloading the driver with information that will hinder his/her information processing abilities. Both of these errors are possible if designers are not careful with their designs. Specifically, an IVIS that does not take into consideration the attention resources that a task will require can be a potential contributor to an accident. The present study will help us understand and predict "red-lines" in terms of what the CVO driver can process without hindering the primary task of driving. In the driver context, it becomes very important to identify the specific information needs and the best way to present the information to minimize driver errors that can lead to accidents.

1.2.2 Information Processing. The amount of information processing required to make a decision depends primarily on the amount of information presented. The frequency with which the task is performed may also be an influential factor, since a task that is commonly performed will need less cognitive resources than one that involves retrieving information from long-term memory. Since the amount of attention resources is finite, an overload of information could cause a loss of attention. Humans are not simply input-output machines, rather, they are goal-oriented creatures who actively select their goals and continue seeking for more relevant information. Rasmussen (1983) presents a model of human information processing which outlines the mental processes that occur during task performance. He points that human behavior is modified during its course by signals of the goal: it may not depend on feedback during its course of action, but rather on experiences from previous actions. The information

processing delineated by his model is divided into the following categories: (1) knowledge-based processing, (2) rule-based processing, and (3) skill-based processing. A diagram of the suggested process is presented in Figure 1.1, and an overview of each level is given below (Rasmussen, 1983).
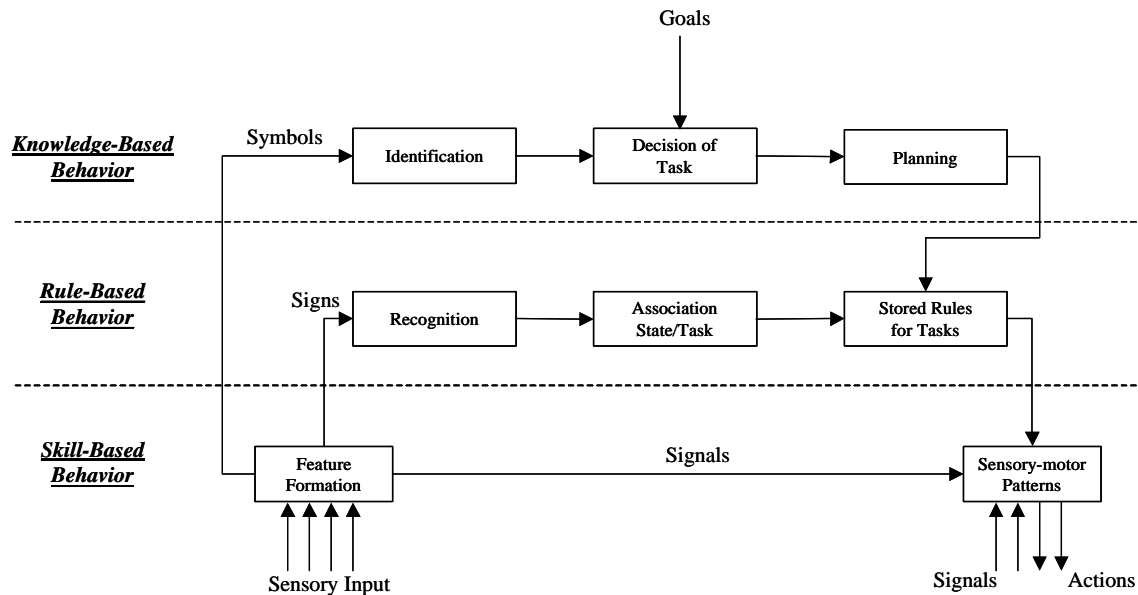
Figure 1.1 Performance levels of the human operator (Rasmussen, 1983)

Knowledge-based processing occurs when actions must be planned at the time, using conscious analytical processes and stored knowledge. Knowledge-based processing is necessary when there is a lack of relevant rules or skills and a person is faced with a relatively unfamiliar task. Sensory input is first transformed into conceptual symbols, which are then used for reasoning about the task in processes such as goal formulation, plan selection, and plan evaluation. Information received is in the form of symbols that are used for causal functional reasoning in predicting or explaining unfamiliar behavior of environmental information. Rule-based processing refers to the composition of subroutines in a familiar work situation that is typically controlled by a stored rule or procedure that has been created through previous experience. Performance is goal-oriented. Information is received in the form of signs that indicate a state in the environment with reference to certain conventions or acts. Signs cannot be processed directly; instead, they serve to activate stored patterns of behavior. Signs refer to situations or proper behavior by convention or prior experience. Skill-based processing

represents sensory-motor performance during activities that take place without conscious control as smooth, automated, and highly integrated patterns of behavior. Information is received in the form of signals, which are sensory data representing time-space variables from a dynamical spatial configuration in the environment. These signals are processed by the operator as continuous variables. The distinction between the perception of information signals/signs/symbols is generally not dependent on the form in which the information is presented, but rather is dependent on the context in which it is perceived.

Lee, Morgan, Wheeler, Hulse, and Dingus (1997) define potential functions for ATIS and CVO. In their work, they relate drivers' capabilities to the capabilities of in-vehicle technology. The development of information flow characteristics and functional descriptions of IVIS is one of their contributions. They characterize the information flow with different decision elements (Table 1.1).

Table 1.1 Decision-making elements that describe the driver interaction with the IVIS (Lee et al., 1997)

Element	Explanation
Detect	Determining if something has changed or exists
Input Select	Selecting information to attend to next
Filter	Eliminating irrelevant information
Search	Looking for a specific item
Identify	Associating a label with an event
Interpret	Determining the meaning of a signal
Code	Translating information from one form to another
Plan	Matching resources to expectations
Test	Calculating the logical or mathematical answer to a problem
Decide/Select	Choosing a response to fit the situation
Control	Selecting a control action or sending a message
Monitor	Observing a process for deviations or events

This line of research is not new at all. The capacity of the working memory, or the amount of information it can hold without detriment to the results of the task studied, has been studied for a long time under several fields. Miller (1956) studied the limits on the capacity for

processing information. He identified the limiting number of items, or memory span, as 7±2 chunks of information. A chunk of information can be a letter, a digit, a word or some other unit. Wickens (1992) expands on this topic, saying that a chunk could even be a string of information where the words are combined in a familiar sequence. This specific sequence will be combined by rules in the long-term memory. Melton (1963) discusses the decay functions of the Brown-Peterson paradigm where faster decay is observed when more items are held in the working memory. This decay is attributed to the rehearsal time of the items held in the working memory. Baddeley (1986, 1990) analyzed the rehearsal in the working memory and the speed of the rehearsal, concluding that the faster the speed, the larger the capacity of the working memory.

The different types of errors a human can perform while driving, the capacity of the working memory, and the decision-making elements must be taken into consideration for the design of IVIS. If human information processing capabilities are not considered as a major design issue, mistakes in the design could be made which in turn could lead to accidents. The cause for these accidents might be incorrectly classified as human error instead of "designer error."

1.2.3 Mental Workload. The decision-making aspect of IVIS will definitely impose an additional amount of cognitive demand on the driver if the tasks that must be performed are not well designed. This can be observed in terms of Norman and Bobrow's (1975) "resource metaphor." That is, if the attention resource demand on the drivers is greater than his/her capability, the workload will be higher than the resource supplies available, which could end in a task failure due to lack of attention. Workload assessment techniques are most appropriately applied to measuring workload on a relative basis, or as an indicator of potential workload that requires further analysis (Wierwille and Eggemeier, 1993). Subjective and performance measures are two possible mental workload assessment techniques. The choice of measurement should be matched with the assessment technique properties and the objective and constraints of the particular evaluation (Wierwille and Eggemeier, 1993). An evaluator is usually interested in both the level of workload and the reason for the workload levels. Measurement techniques can be used to obtain an overall assessment that has global sensitivity (Wierwille and Eggemeier, 1993). Other measurement techniques can be used for diagnostic purposes to determine which

part(s) of the task are the most demanding. Measurement of mental workload can be used for the following purposes: (1) prediction, (2) evaluation, and/or (3) diagnosis. Prediction measures can be used to predict the level of mental workload of a planned system, or when it is desired to know if the mental workload is within a satisfactory range. Evaluation measures can be used for comparing alternative systems to determine the demands across different phases or conditions of the task. Diagnosis measures can be used to determine the drawbacks of a non-optimal system; they can help to determine the overall workload and the specific aspect of the system that is more demanding.

Mental workload measures will be recorded as part of the IVIS/CVO study to assess the task's attention demands. Subjective workload measures will be compared with the primary and secondary task performance measures for the on-road study. This fact is important to ensure that the measured task or design option will result in optimal performance (Salvendy, 1997).

1.2.4 Situation Awareness. The evaluation of situation awareness for a new design that involves multiple task performance is critical, especially if the lack of situation awareness could lead to serious safety implications. Situation awareness is defined as "a person's perception of the elements of the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995a, p. 65). Pew (1994) points out that people can consciously think about only one thing at a time and any type of distraction can degrade their performance. This is one of the areas of interest for human factors analysis since the driving environment, specifically the in-vehicle tasks that drivers perform while using an IVIS, is accompanied by incoming information unrelated to the task in which the driver is engaged. The more time the driver invests in the interpretation of the information presented in the IVIS display, the greater the potential for blocking what is happening in his/her surroundings or causing an improper interpretation of the presented information (Pew, 1994). Situation awareness and mental workload are related to each other. Salvendy (1997) mentions two relationships between situation awareness and mental workload: (1) both are affected by visual display support, and (2) trying to maintain a high level of situation awareness can compete with task demands for limited attention resources, adding to the workload of the task. When workload demands exceed maximum human capacity is situation awareness at risk (Endsley, 1995b). However, problems with situation awareness could also

occur due to low workload (e.g. vigilance problems). For the specific case of this study, measurements of situation awareness are important because a reduction in situation awareness due to increased attention demands could lead to an increase in the probability of accidents.

   1.2.5 In-Vehicle Information Systems and Commercial Vehicle Operations. CVO is one of the main stakeholders in the development of ATIS technologies. If this technology proves to provide clear benefits to CVO, it could end up being a major area for further research and development. What may not be feasible for private automotive research (due to cost and other constraints) could be a reasonable investment for CVO applications. CVO includes a broad range of areas such as fleets of trucks, buses, vans, taxis, and emergency vehicles. Several systems can be classified under ATIS/CVO, including navigational aids, trip planning, and hazard notification systems. Several studies have been conducted involving the CVO driving category. Safety enhancement in the freight industry has been an important element of CVO programs in the nation (Abbasi and Sisiopiku, 1996). Research and development efforts have also been devoted to data collection devices for CVO mileage, fuel tax, and fuel purchase. These devices share the ideal of relieving the driver from the burden of collecting and reporting required truck and trip information. The AMASCOT (Automated Mileage And Stateline Crossing Operational Test) from the Center for Transportation Research and Education Western Highway Institute at the Iowa State University is an example of this effort. Titus (1996) suggested that intelligent transportation systems (ITS) could be the solution to eliminate or at least decrease problems with weight compliance regulations for CVO. Several new technologies have already been identified as ways to improve the work of CVO drivers, with the promise to alleviate the driver's burden. For example, the government is interested in this type of research due to the important step that unifying interaction with the industry in the area of in-vehicle devices for automated record keeping can mean (Hall and Chatterjee, 1996; Hidalgo and McCord, 1996). Automated record keeping can apply to licensing, roadway information, incident clearance, and law enforcement. All these different systems attempt to enhance drivers' abilities, but it is not clear if a system alone or a combination of systems can enhance or hinder drivers' abilities to succeed in this multiple task performance (Lee, 1997). ATIS/CVO systems represent a powerful tool that could influence congestion, safety, mobility, environmental quality, and economic productivity if it is well developed. In order to fulfill this purpose, several

subsystems must be put together to enhance systems capabilities, such as routing and navigation, motorist information, in-vehicle signs, warning and safety information, and commercial vehicle-specific functions (IRANS, IMSIS, ISIS, IVSAWS, and CVO-specific functions, respectively). Table 1.2 presents the 26 functions identified by Lee (1997) for the different subsystems. A broad explanation and more specific details of each function can be found in Lee, Morgan, Wheeler, Hulse, and Dingus (1997). These functions include applications inside or outside the commercial vehicle. For this specific research, the focus will be placed on the in-vehicle information systems. All these IVIS/CVO features and functions should improve productivity and safety, but they can also increase the drivers' mental workload while performing the primary task of driving (Mollenhauer, Dingus, Hankey, Carney, and Neale, 1996).

Table 1.2 Functions of the five different subsystems inside an ATIS/CVO

IRANS	* Trip planning * Multimode travel coordination and planning * Predrive route and destination selection * Dynamic route selection * Route guidance * Route navigation * Automated toll collection * *CVO-specific (route scheduling)*	IVSAWS	* Immediate hazard warning * Road condition information * Automatic aid request * Manual aid request * Vehicle condition monitoring * *CVO-specific (cargo and vehicle monitoring)*
ISIS	* Roadway guidance sign information * Roadway notification sign information * Roadway regulatory sign information * *CVO-specific (road restriction information)*	IMSIS	* Broadcast services/attractions * Services/attractions directory * Destination coordination * Message transfer
CVO-specific		* Fleet resource management * Dispatch * Regulatory administration * Regulatory enforcement	

Chapter 2. RESEARCH OBJECTIVES

2.1 Rationale for the Study

The Center for Transportation Research at Virginia Polytechnic Institute and State University is developing an IVIS Demand Model that will allow designers of in-vehicle information systems (IVIS) to evaluate their proposed designs. The model is based on the attention resource demands that the analyzed IVIS design imposes on the driver while the driver is performing the IVIS task while driving (Wierwille, Gellatly, Dingus, Gallagher, and Benel, 1997). Limited data exist that can be used to model the attention demands placed on commercial vehicle operations (CVO) drivers when interacting with IVIS that have specific design characteristics. Therefore, the collection of data, which can then be integrated into the IVIS evaluation tools, is important. The data can be used to support designers and developers of in-vehicle systems for CVO drivers, as well as to help ensure that future systems developed and marketed by manufacturers do not adversely affect the driving task, thereby creating unsafe circumstances.

The primary objective of this research was to collect on-road data for purposes of evaluating the effects of different types of IVIS tasks on the information processing demands of a commercial vehicle operations driver. This type of data is very important in order to have driver-centered design, which will identify system capabilities needed to make the IVIS useful to the CVO drivers. Empirical studies like this one could help eliminate the incorporation of features that are easy to develop but are not useful to the driver, or the development of technology-centered design (Lee, 1997). The data that was obtained will help to characterize the decision-making process in information processing terms; it will also be analyzed and used in the modeling effort. The IVIS attention demand model is presented below (Figure 2.1).

IVIS Information
Input Demand

IVIS Information
Supplemental
Processing Demand

IVIS Information
Response Demand

Visual
Demand

Auditory
Demand

Supplemental
Information
Processing Demand

Manual
Demand

Speech
Demand

No Response
Required
(decision only)
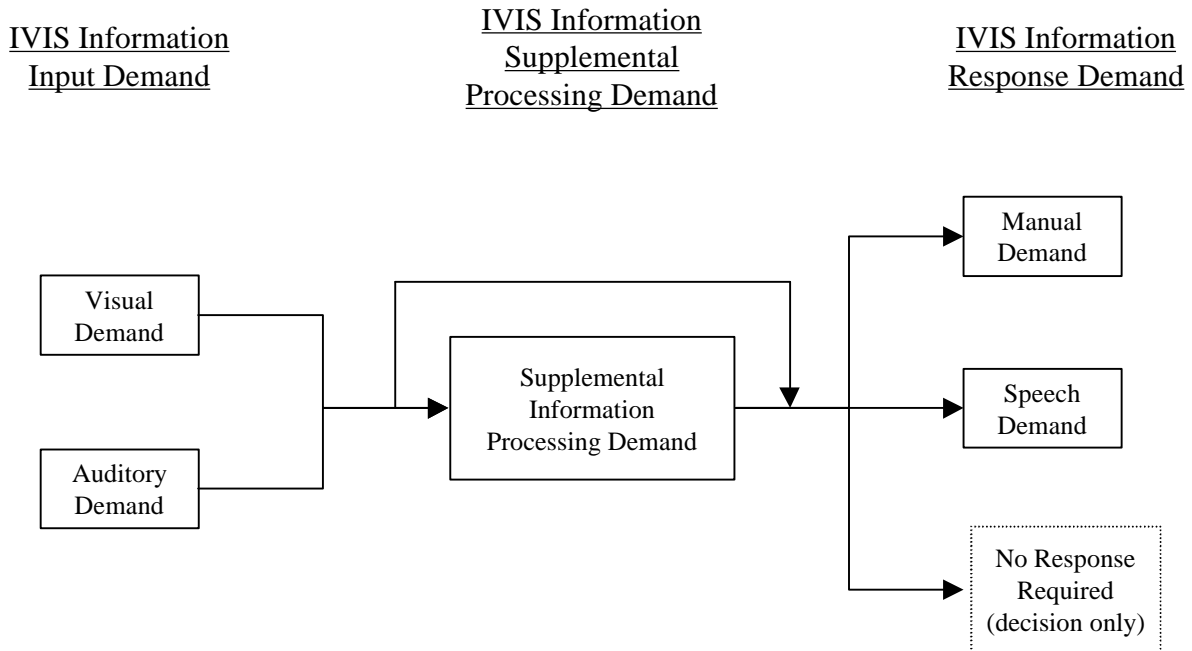
Figure 2.1 In-Vehicle Information System attention demand model (Wierwille, Gellatly, Dingus, Gallagher, and Benel, 1997)

Including IVIS tasks as part of the duties that a driver needs to perform while traveling changes the task of driving itself. This fact can be analyzed by measuring the amount of attention that is needed for the secondary task (IVIS). A portion of the attention resources will be shared with the gathering of relevant external information, while the remaining resources will be used in dealing with the analysis of the information presented in the IVIS display. Obviously, adding this type of task will also add perceptual, cognitive, and motor demands to the driver. Presenting too much information in the IVIS display could result in an excessive number of variables to be analyzed by the driver, thus, according to Miller (1956), reducing the accuracy of judgment. As Wierwille (1993) mentions, there is just one foveal visual resource and it can only be devoted to the gathering of detailed information from just one source. Then, if the information presented is not properly displayed or is too much, it could cause a divergence of the visual attention from the primary task of driving in repeated occasions, which could affect driving performance and safety due to the forward view uncertainty buildup. Figure 2.2 presents a previous model developed by Wierwille (1993) that describes the visual sampling for in-vehicle task performance and illustrates the behavior previously mentioned.
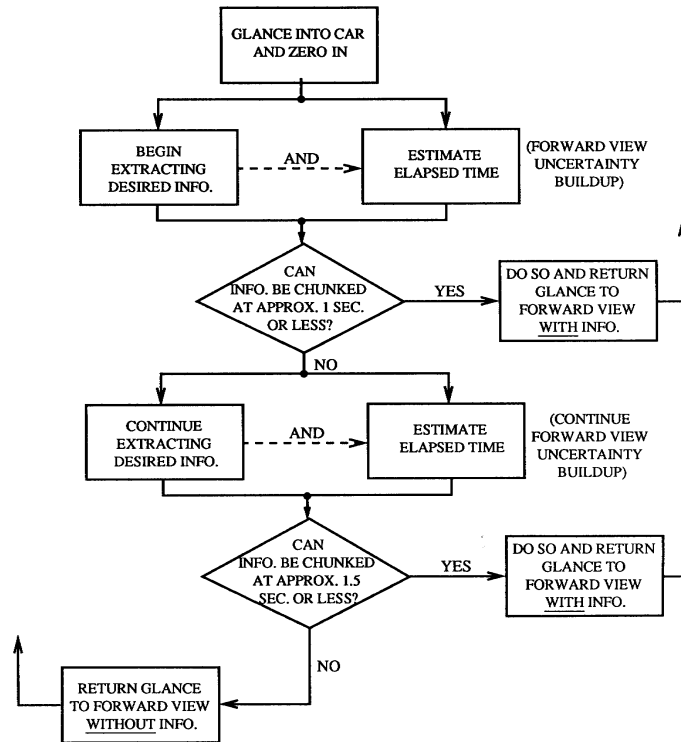
Figure 2.2 A model of visual sampling for in-vehicle task performance (Wierwille, 1993)

The main reason to evaluate the information processing demands of this secondary task is to find the characteristics of the IVIS tasks that will allow CVO drivers to effectively perform the time-sharing required and still be aware of what is happening in their surroundings. The drivers should also receive enough information to make an informed and correct decision.

The study evaluated CVO driver attention demands and performance under several information presentation approaches. These presentation approaches were used specifically to evaluate the drivers under different types of tasks, presentation formats, and information densities presented in each of the IVIS tasks. Thus, a goal of this experiment was also to state "red-lines" and "yellow-lines" for the design of information presentation approaches for the CVO drivers that take into consideration the mental workload and situation awareness for this type of multiple-task performance.

The limited data that existed on attention demands placed on commercial vehicle operations drivers when interacting with IVIS was not the only gap existing in terms of attention demand for CVO drivers. There was also a lack of data related to basic conventional in-vehicle tasks. Thus, part of the effort of this study was to fill this specific gap.

2.2 Experimental Goal

This study was performed with two main goals in mind. The first goal was to understand and predict "red-lines" and "yellow-lines" in terms of what the CVO driver can process without hindering the primary task of driving. A red-line was operationally defined as the point at which driving would be substantially degraded. A red-line is an evaluation method of attentional demand based on a priori criteria. For this study, these criteria were based on expert opinion and previous research. The operational definition of a yellow-line describes it as the point where driving performance is significantly different ($p<0.05$) from the driving performance obtained from a set of baseline driving measures. The measurements used were those most sensitive to the statistical differences between the different IVIS tasks, based on the ANOVA results. These evaluation criteria for red-lines and yellow-lines has been previously used for similar research purposes (Gallagher, 1999).

The second goal was to collect conventional secondary task data for CVO driving performance. The data collected in order to reach both goals was also used for the IVIS Demand Model.

Chapter 3. EXPERIMENTAL METHODOLOGY

To achieve the research objectives, an on-road empirical study was performed. All experimental tasks consisted of driving an instrumented 1997 Volvo/GM Heavy Truck with a 48-foot trailer, and concurrently perform various in-vehicle tasks. The best way to evaluate the information processing demand that secondary tasks, such as IVIS tasks and conventional tasks, were adding to the commercial vehicle driver's primary task of driving was evaluating how the driver's mental workload and situation awareness changed during exposure to the secondary tasks. The following details characterized the experiment.

3.1 Participants

The experiment was performed with the help of 12 male truck drivers divided into two different age groups. CVO drivers were chosen because, as suggested in Mollenhauer, Dingus, Hankey, Carney, and Neale (1996), truck drivers typically operate larger and more complex equipment. Each group consisted of six truck CVO drivers with the following characteristics: (1) active Class A driver's license, (2) more than nine years of experience, and (3) currently working with a tractor-trailer. To recruit the participants, advertisements of the study were sent to 20 freight companies in the New River Valley and Roanoke areas. A classified ad was also printed in the local newspaper for two weeks. Participants received $20/hour for their help.

The two age groups in which the participants were divided are middle age (35 - 45 years) and older drivers (55 years or older). The characteristics of the participants that helped in the experiment in terms of age and years of experience are presented in Table 3.1 and Figure 3.1.

Table 3.1 Age and years of experience data for each age category (units: years)

		Category	
		Middle	**Older**
	Age Range	35 - 45	55 - 70
Age	Mean	40.7	61.5
	Standard Deviation	3.9	5.6
Year of Experience as a CVO driver	Mean	13.3	33.2
	Standard Deviation	4.4	14.5
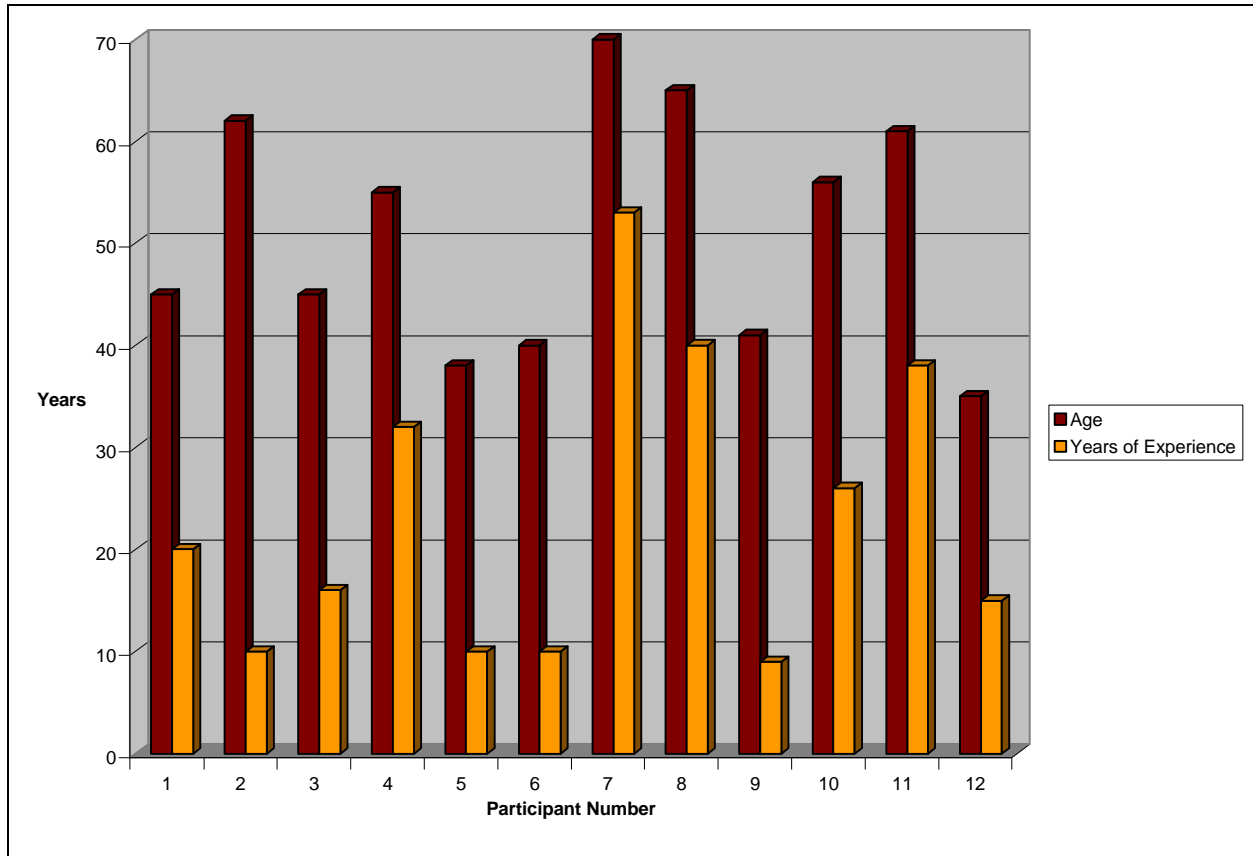
Figure 3.1 Age and years of experience data for each participant

Each participant attended one experimental session that lasted approximately 5 hours. The experimental session consisted of training on the use of the IVIS, practice/familiarization with the experimental vehicle, and the on-road study. Participation was determined by: (1) presentation of a valid Class A commercial driver's license, (2) passing a visual acuity screening test with a score of 20/40 or better (as required by Virginia Law), (3) passing an informal hearing test, and (4) passing a health screening questionnaire to ensure minimal risk. Participants who did not present a valid commercial driver's license, successfully pass the visual acuity or hearing screening test, or who revealed health conditions that made operating the research vehicle a risk were not permitted to participate.

All participants were instructed that they were free to withdraw from the research program at any time without penalty. They were told that no one would try to make them

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participate if they did not want to continue. If they chose at any time not to participate further, they were instructed that they would be paid for the amount of time of actual participation. All data gathered as part of this experiment were treated with anonymity.

3.2 Experimental Design

The study design used for the data collection of the IVIS/CVO tasks and the conventional tasks is shown in Table 3.2. For the IVIS/CVO part of the study, which is an Incomplete Factorial Design, there are four independent variables: (1) type of task, (2) presentation format, (3) information density, and (4) age. The only between-subjects variable of the experiment is age. The other three variables are within-subject variables (type of task, presentation format, and information density). The five in-vehicle conventional tasks are: (1) activate turn signal, (2) adjust vent, (3) adjust power mirror, (4) monitor fuel level, and (5) monitor vehicle speed. Table 3.3 presents a description of what the participant is required to do for each of the conventional tasks.

Table 3.2 Experimental design for IVIS/CVO

		ELEMENT																						
		Search				Search-Compute				Search-Plan				Search-Plan-Compute				Search-Plan-Interpret				Search-Plan-Interpret-Compute			
		Tabular	Paragraph	Graph w/Text	Graph w/Icon	Tabular	Paragraph	Graph w/Text	Graph w/Icon	Tabular	Paragraph	Graph w/Text	Graph w/Icon	Tabular	Paragraph	Graph w/Text	Graph w/Icon	Tabular	Paragraph	Graph w/Text	Graph w/Icon	Tabular	Paragraph	Graph w/Text	Graph w/Icon
AGE	DENSITY	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H	L M H
Middle	1																								
Middle	3																								
Middle	5																								
Middle	6																								
Middle	9																								
Middle	12																								
Older	2																								
Older	4																								
Older	7																								
Older	8																								
Older	10																								
Older	11																								

■ = **UNABLE TO PRESENT**

Table 3.3 Description of the conventional secondary tasks

Conventional Tasks	Participant Requirements
Activate turn signal	* Locate turn signal * Activate turn signal
Adjust vent	* Locate vent * Adjust vent so that air flow is away
Adjust power mirror	* Check mirror adjustment * Locate mirror control * Switch control to proper mirror * Adjust mirror until line-of-sight is correct
Monitoring fuel level	* Locate fuel gauge * Read fuel gauge
Monitoring vehicle speed	* Locate speedometer * Read speedometer

The order in which the different IVIS tasks were presented to the drivers was randomized. The five conventional tasks were also presented randomly. Baseline measures were taken periodically during the study.

3.3 Independent Variables

Type of task, presentation format, information density, and age were the independent variables used in the experiment. The age factor had two levels: middle age participants (35 - 45 years) and older participants (55 year or older). Six different types of tasks were presented to the participants. The decision-making elements from the work of Lee, Morgan, Wheeler, Hulse, and Dingus (1997) were used as the types of tasks. The six types of tasks are: (1) search, (2) search-compute, (3) search-plan, (4) search-plan-compute, (5) search-plan-interpret, and (6) search-plan-interpret-compute. The search element involves the scanning and filtering associated with the extraction of information from the environment that meets pre-defined parameters. Compute involves calculating numerically or logically the answer to a problem. Plan deals with matching

of resources to the current objective when making a decision from definite information, requiring no interpretation of meaning to accomplish an objective. The interpret element involves extracting the meaning from a set of cues and/or the decoding of iconic information in order to make a decision. These decision-making elements were adapted from Lee, et al. (1997).

The information presented during the IVIS tasks followed one of four presentation formats: (1) tabular, (2) paragraph, (3) graphics with text, or (4) graphics with icons. These factors were included based on the following statement from Campbell, Kantowitz, and Hanowski (1995):

> Rapid access and ease in processing in-vehicle information is an important consideration for system effectiveness and, perhaps more importantly, driver safety. Messages, either icons or text, that are difficult to understand may lead to extended glance duration and attention diversion from the primary task of operating the vehicle. Therefore, it is important to consider different formats that in-vehicle messages might take, and investigate their possible effects on driver performance and behavior. (Campbell, Kantowitz, and Hanowski, 1995, p. 1723).

To quantify the information and to identify the points where driving performance starts to deteriorate, the information presented to the driver was presented in three different information densities (categories of information combined with number of alternatives): Low, Medium, and High. The Low level was composed of two different information categories (Table 3.4) and three different alternatives. The Medium level presented three information categories at each of the three alternatives. The High level was formed by four information categories and five different alternatives. The details presented at each information category, or input data, were grouped into familiar units, which can also be seen as chunks of information. Each category of information was composed of the same amount of navigational details for each alternative. Figures 3.2 to 3.5 show examples of what was presented to the participants in the display for the IVIS tasks. Appendix 1 shows all the different screens presented with their classification in terms of format, information density, and type of task in which they were used. For details on the meaning of each of the icons and how the participants were trained to identify the information presented, please refer to Appendix 2.

Table 3.4 Examples of Categories of Information

Category	Examples
Delay	Construction, Weigh Station
Distance	125 miles
Lanes Closed	1 of 2 lanes closed
Rest Area/Truck Stops	Available on Route or Not Available on Route
Restrictions	Weigh Limit, Height Limit, Hazardous Material Hauled
Road Type	Interstate, Highway, US Route
Speed Limit	65 mph
Traffic Density	Low, Medium, or High

Route Planning

Route	Delay
I-90, I-25	Construction
I-80, I-76	None
I-29, US-Rte. 20	Accident

Figure 3.2 Example of a screen of table format with a low level of information density (two categories of information and three alternatives)
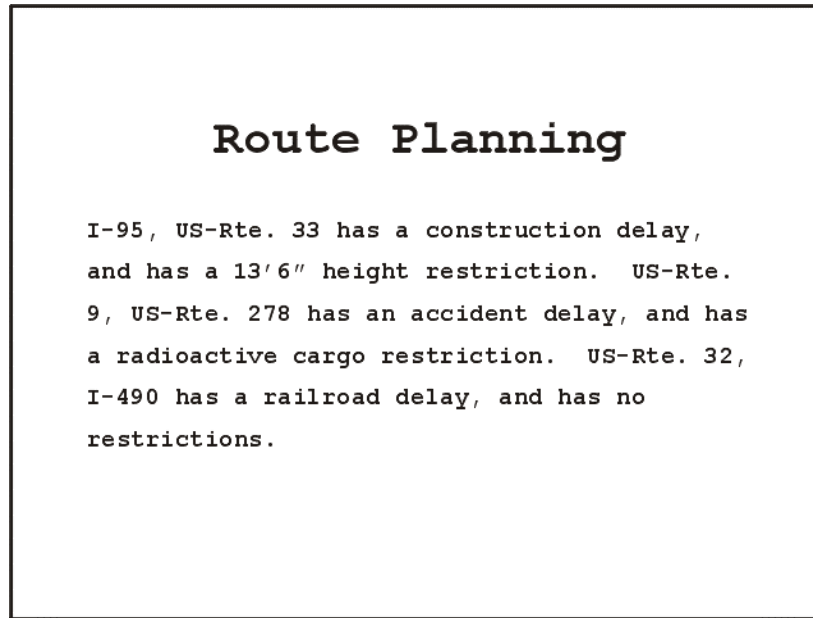
Figure 3.3 Example of a screen of paragraph format with a medium level of information density (three categories of information and three alternatives)
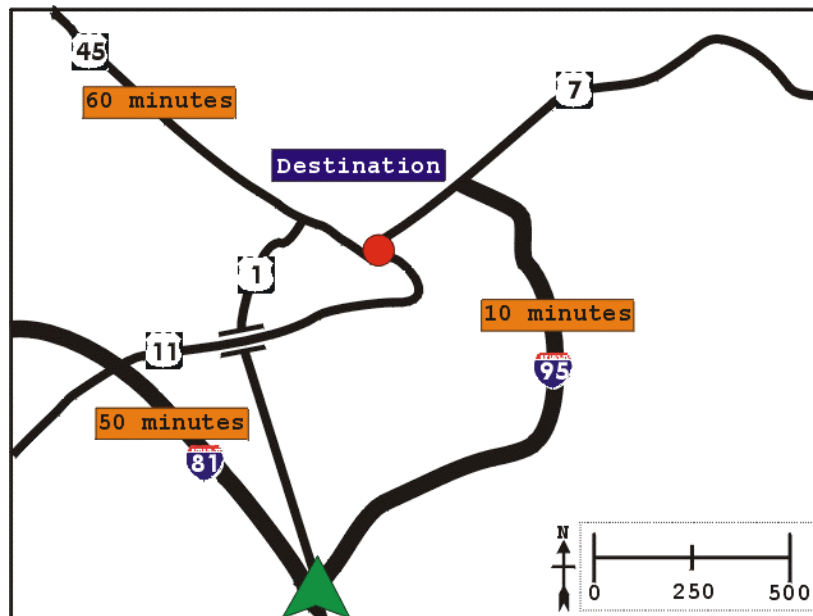
Figure 3.4 Example of a screen of graphics with text format with a medium level of information density (three categories of information and three alternatives)

***Figure 3.5 Example of a screen in graphics with icons format with a high level of
information density (four categories of information and five alternatives)***

A baseline condition was collected several times during the study. This category receives
the name of baseline because, at the moment in which it was collected, the driver did not receive
any secondary task, but the performance measures were recorded in the same way as for the IVIS
tasks. This level can be considered normal driving, since the only task the participant was
performing was the primary task of driving. The purpose of these measures is to compare the
normal driving conditions with the performance while completing the secondary tasks.

3.4 Dependent Variables

The dependent variables were obtained to analyze the attention demand that the IVIS
tasks placed on the CVO driver. The attention resource requirements of the different tasks were
measured in terms of two different categories: mental workload and situation awareness.
Specific measurements were taken for both mental workload and situation awareness, including
subjective ratings. Direct and leading measures of performance were taken to infer how safe the
task given is to the driver. The direct measures of performance are the ones related to lane
position and eye glances to the IVIS display, while the leading measures were based on the
mental workload and situational awareness of the driver. Both categories, mental workload and

situation awareness, were measured by characterizing driver performance on the primary task and the IVIS presentations (secondary task).

A total of 22 dependent variables were analyzed. These dependent variables are divided into five major categories: (1) eye glance measures, (2) longitudinal driving performance, (3) lateral driving performance, (4) secondary task performance, and (5) subjective measures.

3.5 Subjective Ratings

Subjective ratings have been shown to be sensitive to a variety of task demand manipulations (Wierwille and Eggemeier, 1993). They have also been shown to be reliable and to have significant concurrent validity with performance measures (Wierwille and Casali, 1983). Reid and Nygren's (1988) Subjective Workload Assessment Technique (SWAT), and Hart and Staveland's (1988) Task Load indeX (NASA-TLX) procedures represent globally-sensitive measures of operator workload. NASA-TLX and SWAT permit the operator to rate the task on the basis of several dimensions. In both cases, the operator provides an absolute rating immediately after task performance. NASA-TLX sub-scales are mental demand, physical demand, temporal demand, performance, effort, and frustration level. SWAT sub-scales are time load, mental effort load, and psychological stress load. The TLX methodology calculates a weighted average for each operator, and the SWAT determines a derived workload scale for each operator. These are both standard procedures (weighted average and derived workload scale), but there has been some recent debate over the merits of each (Salvendy, 1997). Nygren (1991) compared the psychometric properties of the SWAT and TLX procedures and concluded that neither was generally preferable to the other. SWAT is viewed as having the greatest potential for identification of factors such as cognitive mechanisms affecting mental workload judgments. TLX is seen as appropriate for problems in applied settings and is considered potentially more sensitive than SWAT at low levels of workload (Wierwille and Eggemeier, 1993). Wickens (1992) suggests that the TLX technique, which has a greater number of scales and better resolution per scale, will allow more information to be conveyed. Based on this analysis, a subset of the TLX scales was the subjective measure used for this study.

3.6 Tasks

The on-road driving study was performed on four-lane divided roadways section of U.S. Highway 460 between Blacksburg, Virginia and Bluefield, Virginia (Figure 3.6). There was a vehicle-following situation for the duration of the drive. A lead vehicle was driven in front of the test vehicle during the drive. Experimental tasks (IVIS tasks and conventional tasks) occurred only in weather that does not adversely affect visibility or roadway traction. Participants were instructed to maintain posted speeds and observe all traffic regulations (e.g., turn restrictions, traffic lights, regulatory and warning signs, etc.). The recording of driving performance measures when no secondary task was performed provided a baseline measure of driving performance.
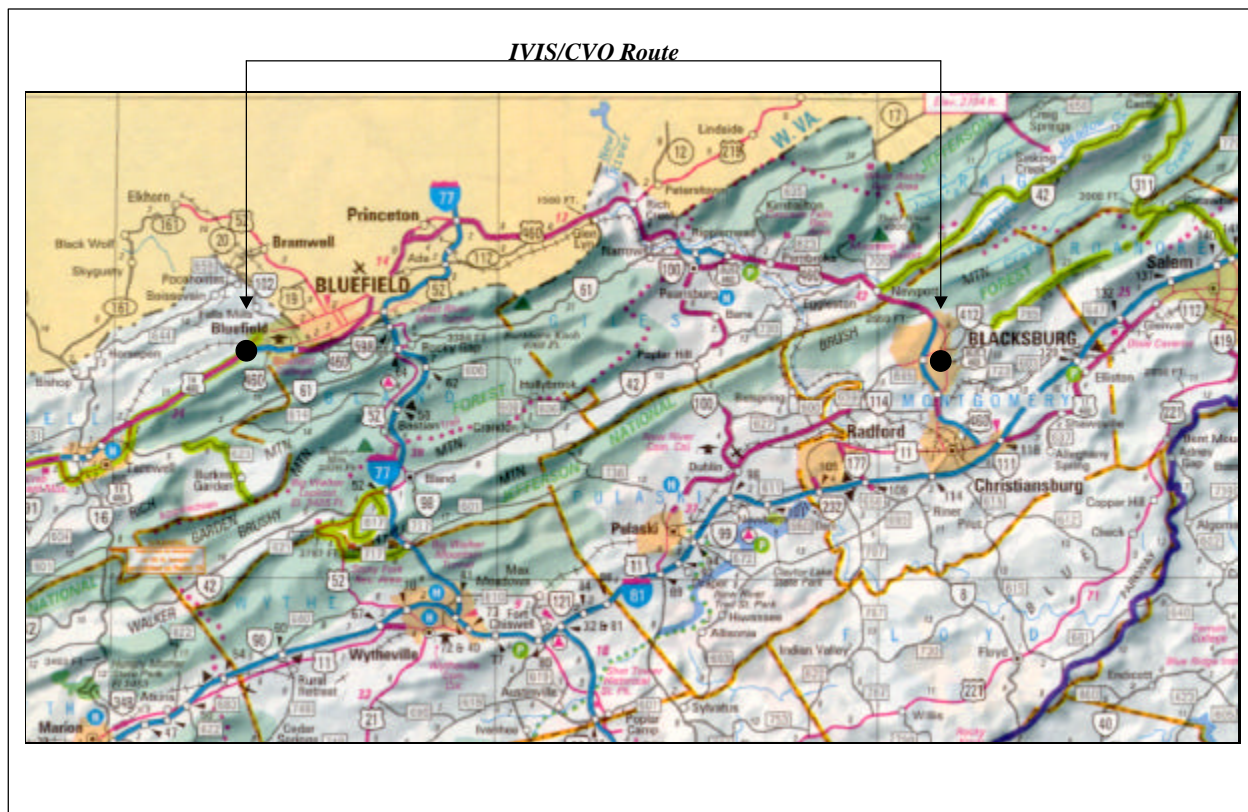
Figure 3.6 Experimental route: U.S. Highway 460 between Blacksburg, VA and Bluefield, VA

An IVIS task consisted of three parts: (1) an auditory cue (a "beep" announcing that a new task will start), (2) an auditory instruction according to the type of task (Table 3.5), and (3) a visual representation (graphic, table, or paragraph). The participant was asked to state the

answer verbally. The task was considered completed as soon as the answer was fully stated by the participant.

Table 3.5 Auditory instructions for the IVIS tasks

Type of Task	Auditory Instruction
Search	Which route has no delay?
	Is there an Interstate 95 on the map?
	Which route has a construction delay?
	Which route has no restrictions?
	Which roadway has a 10 min delay?
	Which roadway has a 15 min delay?
	Which route has a school crossing delay?
	Which roadway has a 45 min delay?
	Which roadway has no delay?
	Which roadway has a speed limit of 60 mph?
	Which roadway has a flammable material restriction?
	Which roadway has a speed limit of 70 mph?
	Which roadway has a hazardous cargo restriction?
	Which roadway has a traffic signal delay?
	Which roadway has a construction delay?
	Which roadway has a drawbridge delay?
	Which roadway has a railroad crossing delay?
Search-Compute	Select the quickest route to the delivery destination.
Search-Plan	Select a route to the delivery destination.
Search-Plan-Compute	Select a route to the delivery destination.
Search-Plan-Interpret	Select a route to the delivery destination.
Search-Plan-Interpret-Compute	Select a route to the delivery destination.

The general procedure for presenting the tasks was the following. The participant performed the primary driving task. A secondary IVIS task or a conventional task instruction was presented to the participant by the computer or verbally by the experimenter, respectively. After the participant was instructed to do so, he executed the secondary task presented on the display (IVIS task) or a conventional automotive secondary task while concurrently performing the primary driving task. During this time period, data was collected on driving performance. Probe questions and subjective measures were taken afterward. Following the completion of the

task and a rest period, which consists of the driving task by itself, a new secondary task scenario was presented. Finally, after all the secondary tasks were completed, the participant returns to the starting point of the drive (Center for Transportation Research).

3.7 Safety Measures

Safety measures were provided as part of the instrumented vehicle system. Such measures were taken as a precaution to help minimize risks to participants during the experiment: (1) all data collection equipment was mounted such that, to the greatest extent possible, it did not pose a hazard to the driver in any foreseeable instance; (2) participants were required to wear the lap and shoulder belt restraint system anytime the car was on the road; (3) a driver-side air bag was provided; (4) a fire extinguisher, first aid kit, and cellular phone were located in the experimental vehicle; (5) none of the data collection equipment interfered with any part of the driver's normal field-of-view; (6) a trained in-vehicle experimenter was in the vehicle at all times; and (7) an emergency protocol was established prior to testing.

3.8 Apparatus and Materials

The participants' performance and behavior was measured using an instrumented 1997 Volvo/GM Heavy Truck with a 48-foot trailer as the experimental vehicle (Figure 3.7). The primary tools that were used in the study are: (1) the heavy truck, (2) cameras and sensors, (3) software and hardware interfaces for information portrayal and data collection, (4) the IVIS, (5) the information portrayed, and (6) the lead vehicle.

Figure 3.7 Experimental vehicle: Instrumented 1997 Volvo/GM Heavy Truck

The system consisted of video cameras to record pertinent events and eye movement data. The experimenter control panel was used to record time and duration of events and information on an IVIS display, sensors for the detection of variations in driving performance and behavior, and a custom analog-to-digital interface and computer to log the data in the required form for analysis. The vehicle's data collection system allowed for the collection and storage of several forms of data. The system provided the capability to store data on a computer in the form of one line of numerical data every 0.1 seconds during a data run. The videotape record provided by the cameras' view was time stamped and synchronized with the computer data stream so that post-test data reduction and data set merging could occur in the laboratory. All data collection records were time stamped to an accuracy of +/- 0.1 second.

3.8.1 Cameras. The experimental vehicle was instrumented with four different cameras. One camera was used for eye glance, one was used for the forward-view and two cameras were used to capture the lane markers at both sides of the vehicle. The eye glance camera allowed for monitoring of eye movements. Its field-of-view accommodated drivers of varying heights and seating positions. The view of the participant's eyes was clear and in focus, allowing eye movement classification in the laboratory. The eye glance camera was located in the top center section of the cabin and did not obscure the driver's view. The forward-view camera provided a wide view of the forward roadway without substantial distortion. The camera had an auto-iris and provides a high quality picture in all but the most severe daylight glare conditions. The forward-view camera serves to collect relevant data from the forward scene (e.g., traffic density, signs and markers). The lane marker cameras provided a view of the right and left side roadway. The lane marker cameras were located inside the right and left rearview mirrors. The cameras did not obscure the driver's view of the roadway nor interfere with his use of the mirrors.

3.8.2 Sensors. The steering wheel, speedometer, accelerator, and brake were all instrumented. The steering wheel sensor provided steering position data accurate to within +/- 1 degree. The brake and accelerator sensors provided brake position to within +/- 0.1 inch. An accelerometer provided acceleration readings in the lateral and longitudinal planes of the vehicle. The accelerometer provided values for vehicle acceleration and deceleration up to, and including,

hard braking behavior as well as intense turning. The sensors provided a signal that is read by the A/D interface at a rate of 10 times per second.

   3.8.3 Audio Data Collection System. An audio track of the videotape record of the experiment contained the commentaries of the experimenter, driver communication, and system-generated audio.

   3.8.4 Software and Hardware Interfaces. A quad-multiplexer integrated the four camera views and a time stamp onto a single videotape record. A PC-VCR received a time stamp from the data collection computer and displayed the time stamp continuously on the multiplexed view of the videotaped record. In addition, the PC-VCR had the capability to read and mark event data provided by the data collection computer and perform high-speed searches for event marks. The PC-VCR operated in an S-VHS format so that each multiplexed camera view had 200 horizontal lines of resolution. The data collection computer provided reliable data collection, manipulation, and hard drive storage under conditions present in a vehicle environment. The computer had a 16-channel analog-to-digital capability, standard QWERTY keyboard, and a 9-inch diagonal color monitor. Computer memory and processing capabilities were: 12 megabytes RAM, 1.2 gigabyte hard drive, and a Pentium processor. A custom interface was constructed to integrate the data from the experimenter control panel, driving performance sensors, and speedometer with the data collection computer. In addition, the interface provided a means to accurately read and log the time stamp from the PC-VCR to an accuracy of +/- 0.1 second. The time stamp was coded such that a precise location could be synchronized from any of the videotaped records to the computer data record for post-test laboratory reduction and file integration. A small FM band transmitter/receiver unit was used to communicate with the lead vehicle. When a key was depressed on the experimenter's keyboard to activate the screen presentation, the transmitter sent a signal that instantaneously activated a buzzer in the lead vehicle.

   3.8.5 In-vehicle Information System (IVIS). A tone was presented to the driver to alert him that a task was going to begin. Auditory instructions for the task to be performed were presented to the driver. At the conclusion of the instructions, the information was

instantaneously displayed on the screen. A 10-inch display was mounted on the dash to the right of the driver. Table 3.6 lists the specifications of the visual display and Figure 3.8 shows where the display was positioned.

Table 3.6. Mechanical specifications of the Dolch Computer Systems, Inc. 10-inch VGA Data View Display

Parameter	Specification
Display Addressability	640 x 480 pixels
Active Viewing Area	8.31" x 6.24" (211.2mm x 158.4mm)
Diagonal of Viewing Area	10.4" (26cm)
Display Technology	TFT Active Matrix
Colors	262,144 (R/G/B 6 bits each)
Contrast Ratio	100:1 Typ.
Vertical Viewing Area	10° center-to-top/ 30° center-to-right
Horizontal Viewing Area	40° center-to left/ 40° center-to-right
Luminance	70 cd/m^{2}Typ.
Lamp MTBF	10,000 POH
Response Time	30ms Typ.
Faceplate Material	Tempered antiglare glass: 60±20 Gloss Units (per ASTMD 1003). Thin film anti-reflective coating

Figure 3.8 Placement of the display inside the experimental vehicle

3.9 Experimental Procedure

3.9.1 Participant Screening. Participants were screened over the telephone regarding age and driving experience (Appendix 3). If the participant qualified, a time was scheduled for testing. Participants were instructed to meet the experimenter at the Center for Transportation Research (CTR), Blacksburg, VA. After arriving at the CTR, an overview of the study was presented to the participant. Subsequently, they were asked to complete the informed consent form (Appendix 4), health-screening questionnaire (Appendix 5), and take a vision test using a Snellen chart. The vision test was performed to ensure that all participants had at least 20/40 distance vision. After these steps were completed and if no health problems were identified, the participant was trained on the in-vehicle tasks to be performed during the drive. A detailed experimenter protocol for assessment of subject suitability is presented in Appendix 6.

3.9.2 Training. The participant was instructed on how to perform the tasks associated with the in-vehicle information system. Sample tasks were demonstrated on a computer set-up

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in the CTR lab (refer to Appendix 2 for more details). The icons and symbols that appeared during the drive as part of the IVIS tasks were shown and explained to the participant. After training, a test was administered to determine whether the participant could identify all the icon symbols that were presented during the drive. Additional training and retest was performed as needed. The conventional tasks were discussed during the training in the CTR lab and were repeated again once the participant adjusted the seat and mirrors of the truck.

3.9.3 *Truck and System Familiarization*. While the truck was parked, the experimenter reviewed general information concerning the operation of the test vehicle (e.g., lights, seat adjustment, mirrors, windshield wipers, etc). The participant was asked to operate each control and set it for his driving comfort. When the participant felt comfortable with the controls, the experimenter explained the IVIS tasks.

3.9.4 *Testing Hearing Abilities*. Once the participant was comfortable with the vehicle controls and was familiarized with the IVIS display, an informal hearing test was administered to determine the participant's ability to understand verbal navigational commands and hear the auditory alert cues (Appendix 6).

3.9.5 *Driving Instructions*. Drivers were told to remain in the right-hand lane unless instructed to pass a slow-moving vehicle. Drivers were instructed to drive the speed at which they felt comfortable, not to exceed the speed limit, and to observe all traffic regulations (e.g., turn restrictions, traffic lights, regulatory and warning signs, etc.). The driver was instructed to simply say "skip" if he felt that an IVIS task was too difficult to safely perform while driving.

3.9.6 *Driving and Task Practice*. Drivers drove around a practice route to become familiar with the handling of the vehicle; during this time, the IVIS was not used. Once the participant stated that he was comfortable with the handling of the vehicle, training on IVIS tasks while driving was begun. Drivers drove around the practice route again and an IVIS task was presented, probe questions were asked, and the driver performed subjective evaluation of the tasks. The experimenter stated what she heard the driver say and what this meant to her, the experimenter. She asked the driver if this was the intended answer. If the driver felt comfortable

performing IVIS tasks, then he was instructed to drive to Route 460. On Route 460, additional training tasks were presented. At this time, the participant was not aware that these were practice tasks. IVIS tasks in tabular, paragraph, graphics with text, and graphics with icons formats were presented for at least one of the following task types: Search, Search-Plan, Search-Compute, and Search-Plan-Interpret.

3.9.7 Probe Questioning.   After each task presentation, probe questions were asked of the drivers in order to recall what data he used in his decision-making process. Table 3.7 presents the probe questioning that was performed after each task depending on the type of task that was performed.

Table 3.7 Probe questioning based on the type of tasked that was performed

Task Type	Questions
Search-Compute	(1) Which categories of information did you use to perform the calculation(s)?
Search-Plan	(1) Which categories of information did you use to make a decision?
Search-Plan-Compute	(1) Which categories of information did you use to make a decision? (2) Did you perform any calculation(s), and if so (3) Which categories of information were used to perform calculation(s)?
Search-Plan-Interpret	(1) Which categories of information did you use to make a decision?
Search-Plan-Interpret-Compute	(1) Which categories of information did you use to make a decision? (2) Did you perform any calculation(s), and if so (3) Which categories of information were used to perform calculation(s)?

3.9.8 General On-Road Procedure.   Data was collected during the time in which each task was performed and during baseline conditions when no tasks were being performed except the primary task of driving. The experimenter was seated in the passenger seat, where she gave

navigational instructions, asked probe questions, and asked subjective evaluation questions. The experimenter also controlled the presentation of information. The data set was flagged automatically when new information was presented on the IVIS display. The IVIS task presentation was stored as a slide format in a computer located in front of the vehicle's passenger seat.

       3.9.9 Sequence of Data Collection. The next sequence of events was followed with each of the participants in order to collect the data for each of the IVIS tasks and conventional tasks: (1) a task was performed; (2) driver was probed to determine what information was used [only for IVIS tasks]; (3) driver was asked for a subset of scales of the NASA-TLX subjective evaluation [Mental Demand, Frustration Level, Awareness of Surroundings, and Timesharing Demand]; (4) a brief rest period (approximately 10 seconds in length); (5) these series of events were repeated until all tasks were completed [tasks were not performed during parts of the route that had poor visibility and/or sharp curves]; (6) once all tasks were completed, the driver was instructed to return to the CTR where the driver was debriefed, and was paid for the portion of time of the study; and (7) breaks were provided at rest areas and gas stations along the route, as needed by the participant.

       3.9.10 Sequence of Visual Tasks. The next sequence of events was followed with each of the participants in order to present the IVIS tasks: (1) a beep sounds, notifying the participant that a task was going to be presented; (2) auditory instructions were presented over the vehicle's sound system (i.e., "Select a route to the delivery destination"); (3) visual information was displayed on the IVIS display at the conclusion of the auditory instructions; (4) the participant verbally stated an answer; and (5) end of task and data collection for that task.

       3.9.11 IVIS Task Presentation. IVIS tasks were presented to the driver in the order shown in Appendix 7. The baseline measures were inserted periodically between them in a random order. If the driver said "skip" when an IVIS task was presented, then it was assumed that a "redline" was reached.

3.10 Dependent Measure Definition

As previously discussed in the Apparatus and Materials section, driving performance data was collected on real-time since a PC-VCR received a time stamp from the data collection computer and displayed the time stamp continuously on the multiplexed view of the videotaped record. Each of the dependent measures was used to characterize each of the IVIS tasks, conventional tasks, and baselines. All the dependent measures are explained below. Each measure definition includes the description of the measure as it was collected and reduced into its final form. The recording of driving performance measures when no secondary task was performed provided a baseline measure of driving performance. As explained in section 3.6, an IVIS task consisted of three parts: (1) an auditory cue (a "beep" announcing that a new task will start), (2) an auditory instruction according to the type of task, and (3) a visual representation (graphic, table, or paragraph). The participant was asked to state the answer verbally. The dependent measures for the IVIS tasks were recorded from the point where the auditory instructions ended through the point where the answer was fully stated by the participant. For the conventional tasks the experimenter presented a verbal instruction to the participant, which started performing the conventional task as soon as they heard an auditory cue (a "beep" announcing that they could start the conventional task). The dependent measures for the conventional tasks were recorded from the point where the auditory cue ended through the point where the answer was fully stated by the participant. All the dependent measures that are explained below were taken for each of the 12 participants, and classified for each of the 47 IVIS/CVO tasks, 16 baselines (normal driving for 5, 10, 20, and 30 seconds), and 5 conventional tasks.

3.10.1 Eye Glance Measures. Frequency and duration of eye glances have been widely used as measures of driving performance in interface evaluation studies (Gallagher, 1999; Popp and Farber, 1991; Voss and Haller, 1982). The data presented at the time stamped videotape (see Figure 3.7) was reduced and classified in order to obtain five eye glance measures. The glances of interest for the data analysis of this study are the ones that were classified into the display or mirror categories. The eye glance measures were used to evaluate how the driver was updating the information about his surroundings and how much time they spent looking at the display.

After all the eye glance data was reduced, a program was developed to process the data. A counter determined the number of glances that were associated with the display (NEGDISP) and the number of glances associated with the mirrors (NEGMIR). Taking advantage of the SAS statistical package, the peak or longest eye glance length to display (LEGDISP), mean single glance time (MSGT), and total glance time (TGT) were calculated (units: seconds). Most of these measures are frequently referenced in the literature as sensitive measures of performance and safety. Verwey (1991) suggests number of glances as more sensitive than glance duration. Labiale (1989) used number of glances together with mean glance time to evaluate driving performance for navigation systems with map displays.

Figure 3.9 Example of a the type of image used for data reduction of eye glance data

3.10.2 Longitudinal Driving Performance. The speed of the tractor-trailer was recorded at a rate of 10 times per second. The speed data was processed with the SAS statistical package in order to calculate five out of the six longitudinal driving performance measures. Among the five measures based on vehicle speed (units: mph) are the minimum speed driven during completion of the tasks or baseline (MNSPEED) and decrease in speed (DECSPEED). The last

one mentioned, decrease in speed, is suggested by Labiale (1989) as a reliable longitudinal performance measure to evaluate. The decrease in speed measure was computed by calculating the difference between the speed at the start of the task, or baseline, and the minimum speed reached during the span of time that was recorded for that specific task or baseline. Mean (MSPEED) and standard deviation (STDSPEED) of speed were also calculated as part of these longitudinal measures, since they are suggested in the literature (Dingus, 1987; Hardee, Johnston, Kuiper, and Thomas, 1990; Kuiken, Miltengurg, and van Winsum, 1992; Noy, 1990; Verwey, 1991) as unswerving measures for this type of performance evaluation. Some other research suggests the use of variance in speed (VSPEED) instead (Gallagher, 1999). Therefore, both measures were calculated. The last measure in the set of longitudinal performance measures is the peak longitudinal deceleration (MXLONDCL). The data for this measure was obtained by means of an accelerometer that provided acceleration readings (units: g), in the longitudinal plane of the vehicle.

     3.10.3 Lateral Driving Performance. Five measures were calculated for the lateral driving performance evaluation. The number of lane deviations (NLANEDEV) were calculated by counting lane deviations while watching the recorded videotapes. The following definition of lane deviation was used: "counting the occurrence of any of the wheels of the vehicle going over the outside edge of either the right or the left lane markers, during the completion time of the task or baseline" (T.A. Dingus, personal communication, March 16, 1999). Lane deviations have been analyzed by Antin (1987) and Dingus, Hulse, Mollenhauer, Fleischman, McGehee, and Manakkal (1997) for in-vehicle systems evaluation. The measures related to steering wheel velocity data for this measure were obtained by means of a steering wheel sensor which provided steering position data accurate to within +/- 1 degree. Using the steering wheel velocity, the peak value (MAXSTVEL), mean value (MSTVEL), and variance (VSTVEL) were calculated (the units are degrees/sec, degrees/sec, and (degrees/sec)^2, respectively). Refer to Dingus (1987), Godthelp (1988), Hicks and Wierwille (1979), and Wierwille and Gutmamm (1978) for other studies and application of steering behavior measures. The last measure that falls into this category is peak lateral acceleration (MXLACLMG). Data for this measure were obtained by means of an accelerometer that provided acceleration readings (units: g) in the lateral plane of the vehicle.

3.10.4 Secondary Task Performance. Task-Completion-Time (TIME) was calculated for the secondary, IVIS and conventional tasks (units: seconds). For the IVIS tasks the task-completion-time comprehends the time span from the moment the task instruction ended to the moment the driver's answer was fully stated. The task-completion-time for the conventional tasks started with a beep (instruction to start performing the conventional task) and ended when the hand went back to the steering wheel position in the case of the tasks that included manual actions (i.e. adjust vent, adjust power mirror, activate turn signal) or when the answer was stated for the monitoring tasks (i.e. monitoring vehicle speed, monitoring fuel level). Task-completion-time has been suggested as a good surrogate for visual demand while driving (Farber, Blanco, Curry, Greenberg, Foley, and Serafin, 1999). The following three measures were recorded with paper and pencil by the experimenter specifically for the IVIS tasks: (1) number of drivers who skipped a task (SKIPPED), (2) number of participants who answered incorrectly (ERRORS), and (3) number of participants that performed a task that involved a calculation by simply comparing the alternatives (WRONGTSK).

3.10.5 Subjective Measures. A subset of scales from the NASA-TLX, or modified NASA-TLX, were used in order to assess the mental workload of the driver (COMBMWK). A subjective measure of the situational awareness was also provided by the participants (SITUAWAR). Both measures were collected by the experimenter at the end of each IVIS and conventional task. The modified NASA-TLX, which is considered the global measure of subjective mental workload, was calculated by adding the following three subscales: Mental Demand, Frustration Level, and Timesharing Demand. The participant gave a score from 0 – 100. The sum of the three scores was divided by three in order to obtain COMBMWK. These two measures were also used by Gallagher (1999) to assess attention demand related to IVIS tasks for automobile drivers. More details of the instructions that the participants received for the rating scales can be found in Appendix 8.

3.11 Hypotheses of Expected Results

The following are the hypotheses of the expected results for the IVIS tasks. They are discussed in terms of visual attention demand. The attention demand for the IVIS/CVO study is "the attention required of the driver for the total driving task including any secondary task" (Dingus, 1987, p. 9). The hypotheses for eye glance measures and task-completion-time are that the greater the attention demand of the task, the greater the number of glances to display (NEGDISP) and the times related to eye glance (i.e. LEGDISP, MSGT, TGT). Therefore, the task-completion-time will be greater for tasks with greater attention demand, and the attention devoted to the surveying of the surroundings will be less. Consequently, NEGMIR and SITUAWAR will be lower and the COMBMWK will be higher.

With respect to the longitudinal performance measures, the greater the attention demand of the task, the lower the minimum speed (MNSPEED) reached. Drivers will tend to slow down to provide themselves with an "unconscious safety margin". Therefore, the decrease in speed (DECSPEED) will be greater with greater attention demand, as well as the peak longitudinal deceleration (MXLONDCL). Since the driver will attend to speed less with greater attention demand, the speed will be more variable, which will lead to greater mean speed (MSPEED), variance (VSPEED), and standard deviation (STDSPEED).

The lateral performance will also be affected by higher attention demand. The greater the attention demand the greater the number of lane deviations (NLANEDEV). Higher attention demand of the IVIS task will cause the driver to pay less attention to the steering task which will lead to fewer path corrections, but the corrections will be larger. Therefore, the measures related to steering wheel velocity will increase (i.e. MAXSTVEL, VSTVEL, MSTVEL). The predicted behavior could also lead to greater lateral acceleration.

3.12 Data Analysis

The data analysis followed several steps: (1) data reduction, (2) data evaluation, and (3) red-line and yellow-line development. The data reduction process consisted of analyzing the recorded task frame by frame. This data reduction process provided the dependent measures related to lane position and eye glances. For the other dependent measures related to

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performance, the data was reduced taking advantage of specialized code and statistical packages. These data, coupled with the subjective measures, were evaluated to examine the driver's performance under each of the different treatments. Due to the "skip" option (which was explained to drivers as the alternative to use when they felt that performing the task could cause an unsafe situation), the model used had empty cells or treatments with no numerical data for a given participant. Although the quantitative data is not available for these treatments, the "skip" option is a good signal that the treatment represents a safety threat to the driver if completion is attempted. At that point, a "red-line" was reached. The following sections discuss how the different tools and measures were employed for the data analysis of this study.

**3.12.1 ANOVAs.** The analysis of variance (ANOVA) was performed by running a General Linear Model (GLM) procedure. The traditional ANOVA procedure is designed to work on balanced data. Balanced data implies that there is the same number of response observations for each combination of classification variables. Since the data for this study is not balanced, a traditional ANOVA would not produce valid results. Instead, a "PROC GLM" was used in SAS (statistical package), which is designed to compute analysis of variance for unbalanced data. An $\alpha = 0.05$ was chosen for all the ANOVAs performed in this study. Table 3.8 shows the main degrees of freedom for the full model of the experimental design of IVIS/CVO as it was run for the data analysis (DF_1) and their appropriate values (DF_2) had the use of a regular ANOVA procedure been possible.

Table 3.8 Degrees of Freedom for the ANOVAs performed to evaluate IVIS tasks

Source	DF$_1$	DF$_2$
Between		
AGE	1	1
SUBNUM(AGE)	10	10
Within		
ELEMENT	5	5
AGE*ELEMENT	5	5
*ELEMENT*SUBNUM(AGE)*	50	50
DISTYPE	3	3
AGE*DISTYPE	3	3
*DISTYPE*SUBNUM(AGE)*	30	30
DISTYPE*ELEMENT	12	**15**
AGE*DISTYPE*ELEMENT	12	**15**
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	**150**
DENSITY	2	2
AGE*DENSITY	2	2
*DENSITY*SUBNUM(AGE)*	20	20
DENSITY*ELEMENT	6	**10**
AGE*DENSITY*ELEMENT	6	**10**
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	**100**
DENSITY*DISTYPE	5	**6**
AGE*DENSITY*DISTYPE	5	**6**
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	**60**
DENSITY*DISTYPE*ELEMENT	13	**30**
AGE*DENSITY*DISTYPE*ELEMENT	13	**30**
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	**300**
TOTAL	543	863

ANOVAs were performed to evaluate if the IVIS tasks are significantly different among themselves based on their characteristics. The main effects that characterize these tasks are information density (DENSITY), type of format (DISTYPE), and type of task (ELEMENT). The relevant question whether age caused a significant effect on the performance results would also be answered by this analysis. At the moment in which the experiment was performed no noticeable age effects were observed, but statistical corroboration of the on-the-road observations was necessary. Nineteen dependent variables were analyzed for these purposes. ANOVAs were also performed to compare the IVIS tasks to baseline driving for 12 dependent measures. The conventional tasks were also tested versus the IVIS tasks for 13 dependent measures.

Post-Hoc analysis was performed for the significant main effects (p < 0.05) using the Student-Newman-Keuls (SNK) test. Least Square Means (LSMs) were computed for the Post-Hoc analysis in order to calculate the Bonferroni t (BON) when the SNK did not have enough resolution. A Post-Hoc analysis is very important because it assists in the identification of which experimental levels cause the significance of the main effect or interaction. A significant main effect, or interaction, does not make all levels inside it significantly different. These tests, however, explain only main effects and two-way interactions, an important limitation in the current data analysis. The reader interested in a detailed discussion of post-hoc tests in general, and of the Student-Newman-Keuls and Bonferroni-t tests in particular, is referred to Winer, et al. (1991). Due to the incomplete set of data available and its distribution, detailed interaction effects were not estimable under any Post-Hoc analysis used.

3.12.2 Correlation Analysis. Correlations were calculated for all pairs of dependent variables that did not contain a large number of zeros (i.e. SKIPPED, ERRORS, WRONGTSK). The purpose for this type of analysis was to determine which of the 19 dependent measures, if any, covaried. Due to the large number of tasks to evaluate, only measures with correlations over 0.60 were taken into consideration for further analysis.

3.12.3 Ranking of Attentional Demand. Based on previous research performed by Dingus (1987), the IVIS tasks were classified under Low, Medium, High, or Very High attention demands. This a-priori criteria suggests that tasks can be ranked in an ascending order according to their total glance time (TGT) to the display, which would rank them from lowest attention demand to highest attention demand. Then, in theory at least, the tasks could be divided into the previously mentioned four attention demand categories, depending on their position after the ranking. Table 3.9 shows the details of the different categories.

Table 3.9 Attentional Demand Categories (Dingus, 1987)

Criteria	Total Glance Time [TGT]
Low Attentional Demand	TGT < 1.0 sec
Medium Attentional Demand	$1.0 \leq TGT < 2.5$ sec
High Attentional Demand	$2.5 \leq TGT < 4.0$ sec
Very High Attentional Demand	TGT ≥ 4.0 sec

3.12.4 Red-Lines and Yellow-Lines. In order to determine red-lines and yellow-lines, two different procedures were used. Performance limits suggested as a threshold (i.e. before driving would be substantially degraded), by both experts in the field of Human Factors in Transportation and previous research, were used to determine the red-lines. The five dependent measures evaluated in the search for red-lines were NEGDISP, LEGDISP, SKIPPED, TASKS DIFFICULTY, and TIME. Due to the limited literature available in the field of CVO driving performance, there are not critical values available to compare to the CVO lateral and longitudinal driving performance measures.

The procedure used to determine yellow-lines was slightly different. The purpose of this measure is to highlight tasks that represent a driving performance significantly different from the driving performance obtained during the baseline task ($p < 0.05$). The measurements used were those most sensitive to the statistical differences between the different IVIS tasks based on the ANOVA results. A Paired T-test was used for this purpose.

Chapter 4. RESULTS

The results of this study comprise several types of data analysis. This chapter is divided into four major sections: (1) Analysis of Variance (ANOVA), (2) Correlations, (3) Ranking for Attention Demand, and (4) Red-Lines and Yellow-Lines. A detailed explanation of the data analysis performed in order to obtain these results is presented in the Data Analysis section. All the measures collected and used for the analysis of this study are presented in Table 4.1. The table below is a quick reference for the meaning of each of the variables used throughout this section. Section 3.10 presents a detailed definition for each of the dependent measures.

Table 4.1 Summary of measures and variables used in the Results

No.	DEPENDENT MEASURES	VARIABLE NAME
	Eye Glance Measures	
1	Number of eye glances to display (number)	NEGDISP
2	Peak eye glance length to display (seconds)	LEGDISP
3	Mean single glance time (seconds)	MSGT
4	Total Glance Time (seconds)	TGT
5	Number of eye glances to mirror (number)	NEGMIR
	Longitudinal Driving Performance	
6	Minimum speed (mph)	MNSPEED
7	Decrease in speed (mph)	DECSPEED
8	Variance in speed (mph^2)	VSPEED
9	Mean speed (mph)	MSPEED
10	Standard Deviation of speed (mph)	STDSPEED
11	Peak longitudinal deceleration (g)	MXLONDCL
	Lateral Driving Performance	
12	Number of Lane deviation (number)	NLANEDEV
13	Peak steering wheel velocity (degrees/sec)	MAXSTVEL
14	Variance in steering wheel velocity ($[degrees/sec]^2$)	VSTVEL
15	Mean steering wheel velocity (degrees/sec)	MSTVEL
16	Peak lateral acceleration (g)	MXLACLMG
	Secondary Task Performance	
17	Task completion time (seconds)	TIME
18	Number of drivers who skipped a task (number)	SKIPPED
19	Number of drivers who answered incorrectly (number)	ERRORS
20	Wrong Task (number)	WRONGTSK
	Subjective Assessment	
21	Modified NASA-TLX (number)	COMBMWK
22	Subjective assessment of situation awareness (number)	SITUAWAR

4.1 ANOVAs

   4.1.1 Comparing IVIS tasks. The model for this portion of the study is a 2 x 6 x 4 x 3 incomplete factor design (see Table 4.2).   For the ANOVAs of the full model, only the first 17 and last two measures shown in Table 4.1 will be used. Table 4.3 shows the portion of the ANOVA summary table that classifies the sources and degrees of freedom.   A total of 564 observations were obtained from the experiment. Data representing each of these observations were collected for both of the subjective measures, but since 20 tasks were skipped, only 544 observations are available for the analysis of the 17 objective measures (see Table 4.4). The 19 ANOVA summary tables are shown as part of Appendix 9. Table 4.5 presents the main effects and two-way interactions that were significant for each of the dependent measures. Each of the tables represents one of the five groups of measures (i.e. eye glance, longitudinal driving performance, lateral driving performance, secondary task performance, subjective assessment). The Post-Hoc results are presented in Tables 4.6 through 4.9. The means with the same letter in their grouping are not significantly different. As explained in the Data Analysis section, interactions were not estimable under any Post-Hoc analysis due to the limited amount of data available and its distribution.

Table 4.2 Levels of the factors for the experimental design full model

	Factor	Variable	Levels					
Between	Age	AGE	Middle [35-45]	Older [55-70]				
Within	Type of Task	ELEMENT	Search [S]	Search-Compute [SC]	Search-Plan [SP]	Search-Plan-Compute [SPC]	Search-Plan-Interpret [SPI]	Search-Plan-Interpret-Compute [SPIC]
	Type of Format	DISTYPE	Table	Paragraph	Graphic with Text	Graphic with Icons		
	Information Density	DENSITY	Low [2 X 3]	Medium [3 X 3]	High [4 X 5]			

   Based on results presented in Table 4.5, mean single glance time (MSGT), number of eye glances to the mirrors (NEGMIR), variance in speed (VSPEED), variance in steering wheel velocity (VSTVEL), and mean steering wheel velocity (MSTVEL) will not be included in the

analysis since they do not represent measurements that are sensitive to the statistical differences between the different IVIS tasks. The emphasis of the discussion will be placed on those measures where the category main effect is significant. Also, the AGE main effect was only significant in decrease in speed (DECSPEED) and the difference is less than 0.6 mph, which does not represent a major safety issue in this matter. These results provide a good statistical corroboration of the on-the-road observations that CVO driving performance does not varied inside the ages analyzed (i.e. 35 - 70 years old). Therefore, no further analysis was performed for this main effect.

Table 4.3 Main effects, interactions, and degrees of freedom

Source	DF
Between	
AGE	1
SUBNUM(AGE)	10
Within	
ELEMENT	5
AGE*ELEMENT	5
*ELEMENT*SUBNUM(AGE)*	50
DISTYPE	3
AGE*DISTYPE	3
*DISTYPE*SUBNUM(AGE)*	30
DISTYPE*ELEMENT	12
AGE*DISTYPE*ELEMENT	12
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117
DENSITY	2
AGE*DENSITY	2
*DENSITY*SUBNUM(AGE)*	20
DENSITY*ELEMENT	6
AGE*DENSITY*ELEMENT	6
*DENSITY*ELEMENT*SUBNUM(AGE)*	60
DENSITY*DISTYPE	5
AGE*DENSITY*DISTYPE	5
*DENSITY*DISTYPE*SUBNUM(AGE)*	50
DENSITY*DISTYPE*ELEMENT	13
AGE*DENSITY*DISTYPE*ELEMENT	13
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113
TOTAL	543

Table 4.4 Data Available and Skipped Tasks

ELEMENT					
Search	Search-Compute	Search-Plan	Search-Plan-Compute	Search-Plan-Interpret	Search-Plan-Interpret-Compute

Each ELEMENT group is divided into: Tabular, Paragraph, Graph w/Text, Graph w/Icon — each subdivided into L, M, H (DENSITY).

AGE	DENSITY (DISTYPE)
Middle	1
Middle	3
Middle	5
Middle	6
Middle	9
Middle	12
Older	2
Older	4
Older	7
Older	8
Older	10
Older	11

■ = SKIPPED   ▨ = UNABLE TO PRESENT

Table 4.5 Summary table for the results of the full model ANOVAs

Source	Variable				
	NEGDISP	LEGDISP	MSGT	TGT	NEGMIR
AGE					
ELEMENT	X			X	
AGE*ELEMENT					
DISTYPE	X			X	
AGE*DISTYPE					
DISTYPE*ELEMENT	X			X	
DENSITY	X	X		X	
AGE*DENSITY					
DENSITY*ELEMENT	X			X	
DENSITY*DISTYPE	X	X		X	

X = Significant ($p < 0.05$)

(a) Eye Glance Measures

Source	Variable					
	MNSPEED	DECSPEED	VSPEED	MSPEED	STDSPEED	MXLONDCL
AGE		X				
ELEMENT		X			X	X
AGE*ELEMENT						
DISTYPE		X			X	X
AGE*DISTYPE						
DISTYPE*ELEMENT		X				
DENSITY						
AGE*DENSITY						
DENSITY*ELEMENT	X			X		
DENSITY*DISTYPE						

X = Significant ($p < 0.05$)

(b) Longitudinal Driving Performance

Table 4.5 Summary table for the results of the full model ANOVAs (continued)

Source	Variable NLANEDEV	MAXSTVEL	VSTVEL	MSTVEL	MXLACLMG
AGE					
ELEMENT		X			X
AGE*ELEMENT					
DISTYPE		X			X
AGE*DISTYPE					
DISTYPE*ELEMENT					
DENSITY	X	X			X
AGE*DENSITY					
DENSITY*ELEMENT					
DENSITY*DISTYPE					

X = Significant (p < 0.05)

(c) Lateral Driving Performance

Source	Variable TIME	COMBMWK	SITUAWAR
AGE			
ELEMENT	X	X	X
AGE*ELEMENT			X
DISTYPE	X	X	X
AGE*DISTYPE			
DISTYPE*ELEMENT	X	X	X
DENSITY	X	X	X
AGE*DENSITY			
DENSITY*ELEMENT	X		
DENSITY*DISTYPE	X	X	X

X = Significant (p < 0.05)

(d) Secondary Task Performance and Subjective Assessment

Table 4.6 Post-Hoc results for the AGE main effect (Longitudinal Driving Performance)

SNK Grouping	Mean DECSPEED	AGE
A	2.660	Older
B	2.103	Middle

Table 4.7 Post-Hoc results for the ELEMENT main effect

SNK Grouping	Mean NEGDISP	ELEMENT
A	14.4118	SPIC
B	11.8636	SC
B	11.6316	SPI
B	11.1449	SPC
B	10.9535	SP
C	4.1439	S

SNK Grouping	Mean TGT	ELEMENT
A	18.4544	SPIC
B	15.9454	SPC
B	15.9244	SC
B	15.0790	SPI
B	14.6263	SP
C	5.7198	S

(a) Eye Glance Measures

SNK Grouping	Mean DECSPEED	ELEMENT
A	3.0727	SPI
A	2.9770	SPIC
A	2.7753	SPC
A	2.5889	SC
A	2.5055	SP
B	1.2076	S

SNK Grouping	Mean STDSPEED	ELEMENT
A	1.3326	SPIC
A	1.1709	SPI
A	1.1035	SPC
A	1.0617	SC
A	0.9774	SP
B	0.5465	S

SNK Grouping	Mean MXLONDCL	ELEMENT
A	0.0523	SPIC
A	0.0457	SPC
A	0.0440	SP
A	0.0411	SC
A	0.0390	SPI
B	0.0192	S

(b) Longitudinal Driving Performance

SNK Grouping	Mean MAXSTVEL	ELEMENT
A	99.336	SC
A	93.353	SPIC
A	86.935	SPI
A	84.532	SPC
A	84.422	SP
B	68.566	S

SNK Grouping	Mean MXLACLMG	ELEMENT
A	0.1308	SPIC
A	0.1253	SP
A	0.1207	SPC
A	0.1189	SPI
A	0.1187	SC
B	0.0982	S

(c) Lateral Driving Performance

SNK Grouping	Mean TIME	ELEMENT
A	29.225	SPIC
B	23.998	SC
B	23.448	SPC
B	22.738	SPI
B	21.529	SP
C	8.088	S

SNK Grouping	Mean COMBMWK	ELEMENT
A	24.028	SPIC
A	20.889	SC
A	20.217	SPI
A	19.472	SPC
A	19.263	SP
B	9.381	S

SNK Grouping	Mean SITUAWAR	ELEMENT
A	91.053	S
B	86.818	SP
B	85.069	SPC
B	85.000	SPI
B	84.917	SC
B	83.889	SPIC

(d) Secondary Task Performance and Subjective Assessment

Table 4.8 Post-Hoc results for the DENSITY main effect

SNK Grouping	Mean NEGDISP	DENSITY
A	12.176	High
B	8.214	Med
B	7.552	Low

SNK Grouping	Mean LEGDISP	DENSITY
A	2.503	High
A	2.460	Med
B	2.267	Low

SNK Grouping	Mean TGT	DENSITY
A	16.403	High
B	11.067	Med
B	9.773	Low

(a) Eye Glance Measures

SNK Grouping	Mean NLANEDEV	DENSITY
A	0.472	High
B	0.292	Low
B	0.274	Med

SNK Grouping	Mean MAXSTVEL	DENSITY
A	90.023	High
B	81.832	Med
C	71.303	Low

SNK Grouping	Mean MXLACLMG	DENSITY
A	0.1209	High
A	0.1148	Med
B	0.1086	Low

(b) Lateral Driving Performance

SNK Grouping	Mean TIME	DENSITY
A	24.629	High
B	16.248	Med
B	14.588	Low

SNK Grouping	Mean COMBMWK	DENSITY
A	22.004	High
B	14.850	Med
B	12.764	Low

SNK Grouping	Mean SITUAWAR	DENSITY
A	89.948	Low
B	88.032	Med
C	84.476	High

(c) Secondary Task Performance and Subjective Assessment

Table 4.9 Post-Hoc results for the DISTYPE main effect

SNK Grouping	Mean NEGDISP	DISTYPE	SNK Grouping	Mean TGT	DISTYPE
A	13.147	Paragraph	A	18.058	Paragraph
B	9.415	Graph w/text	B	12.493	Graph w/text
B	8.649	Table	C B	11.278	Table
C	7.073	Graph w/icon	C	9.501	Graph w/icon

(a) Eye Glance Measures

SNK Grouping	Mean DECSPEED	DISTYPE	SNK Grouping	Mean STDSPEED	DISTYPE	SNK Grouping	Mean MXLONDCL	DISTYPE
A	3.140	Paragraph	A	1.230	Paragraph	A	0.0503	Paragraph
B	2.218	Graph w/text	B	0.908	Graph w/text	B	0.0350	Table
B	2.214	Table	B	0.901	Table	B	0.0312	Graph w/text
B	1.720	Graph w/icon	B	0.721	Graph w/icon	B	0.0294	Graph w/icon

(b) Longitudinal Driving Performance

SNK Grouping	Mean MAXSTVEL	DISTYPE	SNK Grouping	Mean MXLACLMG	DISTYPE
A	93.129	Paragraph	A	0.1255	Paragraph
B	85.835	Graph w/text	B	0.1161	Graph w/text
B	80.032	Table	B	0.1148	Table
C	71.263	Graph w/icon	C	0.1049	Graph w/icon

(c) Lateral Driving Performance

SNK Grouping	Mean TIME	DISTYPE	SNK Grouping	Mean COMBMWK	DISTYPE	SNK Grouping	Mean SITUAWAR	DISTYPE
A	27.199	Paragraph	A	23.877	Paragraph	A	90.458	Graph w/icon
B	18.997	Graph w/text	B	17.235	Graph w/text	B	87.911	Table
C B	16.610	Table	C B	14.813	Table	B	87.424	Graph w/text
C	13.463	Graph w/icon	C	12.531	Graph w/icon	C	83.006	Paragraph

(d) Secondary Task Performance and Subjective Assessment

The IVIS tasks were compared in terms of the influence of type of task (ELEMENT), information density (DENSITY), and type of format (DISTYPE) on the driving performance. Several dependent measures assisted in explaining the statistical differences between the different IVIS tasks. Although several of the measures were not sensitive enough to capture the statistical difference between the different IVIS tasks, enough measures remain to cover the five categories originally selected to characterize attention demand for driving performance (i.e. eye glance measures, longitudinal driving performance, lateral driving performance, secondary task performance, subjective assessment). The "surviving" eye glance measures are: number of eye glances to display (NEGDISP), peak eye glance to display (LEGDISP), and total glance time (TGT). The longitudinal measures are: decrease in speed (DECSPEED), standard deviation of speed (STDSPEED), and peak longitudinal deceleration (MXLONDCL). The lateral driving performance used the number of lane deviations (NLANEDEV), peak steering wheel velocity (MAXSTVEL), and peak lateral acceleration (MXLACLMG). Task-completion-time (TIME) represents the secondary task performance measure. The modified NASA-TLX (COMBMWK) and situation awareness (SITUAWAR) comprise the subjective assessment measures.

The results of the Post-Hoc analysis for the different types of task (ELEMENT) show a consistent pattern. For the eye glance measures, the six different types of tasks are divided into three groups. Search represents one group by itself. It was the type of task with the smallest number of eye glances to the display and with the shortest total glance time. On the other end of the continuum lies Search-Plan-Interpret-Compute, which had the highest number of glances to the display and the longest total glance time. The other four types of tasks (i.e. Search-Plan, Search-Compute, Search-Plan-Interpret, Search-Plan-Compute) conform the third group. Based on Table 4.7, all but the Search task exceed the suggested maximum of nine eye glances to the display.

For the longitudinal driving performance measures, the six types of tasks were divided into two groups. Search was the type of task with the smallest decrease of speed (1.2 mph), the smallest standard deviation of speed (0.5 mph), and the least peak longitudinal deceleration (0.02g). The other five types of tasks were significantly different from Search, but not among themselves, in terms of longitudinal performance. Their decrease in speed was larger than 2.5 mph, the standard deviation of speed ranged for 0.98 to 1.33, and the lowest peak longitudinal deceleration among them doubled the value obtained for Search.

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The lateral driving performance followed the same grouping as the longitudinal driving performance. The peak steering velocity for the Search was 68.6 degrees/sec while the other five types of tasks had peak steering velocity values over 84 degrees/sec, a statistically significant difference. The peak lateral acceleration measure followed the same pattern. The results for task-completion-time follow the pattern of the eye glance measures, which is not surprising since the correlation between them is 0.99. Again, the Search type of task is significantly different from the other five. The Search mean task-completion-time was 8 seconds while the Search-Plan-Interpret-Compute was performed in 29.2 seconds, on average. For the third classification, which included the remaining task groups, average task-completion-times ranged from 21.5 - 24.0 seconds. Although this last classification group is significantly different from the Search task, it still complies with the "15-seconds rule," since the average task-completion-times for all of the group's components fall under 25.9 seconds (i.e. the translation of the "15-second rule," which is static time, to dynamic time). The subjective assessment followed the pattern of the driving performance measures, where Search represents the type of task with the lowest subjective rating for mental workload and the type of task that allows greater situation awareness. For the other five types of task, the subjective mental workload was twice higher than for Search, but not significantly different among them. Based on these findings, it is determined that the Search-Plan, Search-Compute, Search-Plan-Interpret, Search-Plan-Compute, and Search-Plan-Interpret-Compute have significantly different attention demands than Search. Search is the type of task with the least attention demand.

When the information density (DENSITY) category, or amount of information presented to the driver, is considered, again the number of eye glances to the display and the total glance time follow the same patterns observed for the ELEMENT category, which is not a surprising finding. It seems logical to think that both categories are directly proportional, corroborated by the fact that the correlation between them is 0.99. The Low and Medium densities are not significantly different in terms of the number of glances to the display and total glance time, but the peak eye glance to the display was significantly longer for the Medium density. The tasks with High density had the highest number of glances to the display (over nine) and the longest total glance time. Although the peak eye glance to the display for this High density was significantly longer than for the Low density, it did not differ from the peak eye glance for the Medium density. No conclusions in terms of longitudinal driving performance using DENSITY

can be reached, since none of the measures in this classification were significant for DENSITY. In terms of lateral driving performance, the number of lane deviations was significantly higher for the High-density tasks than for the Medium- and Low-density tasks. Medium- and Low-Density tasks were not significantly different among them. For all levels of DENSITY the mean value of lane deviations was less than one, which is a relatively small number considering the reduced width of the road relative to the size of a tractor-trailer. All DENSITY levels were significantly different among them in terms of peak steering wheel velocity. The Low-density tasks had the lowest value (71.3 degrees/sec), while the High-density tasks had the highest (90.0 degrees/sec). The peak lateral acceleration also increased with the density of the task, but the Medium and High-density levels are not significantly different. The tasks with Low and Medium density had significantly shorter task-completion-time and less mental workload than the High-density tasks. On average, the High-density tasks took 10 seconds longer than the Low-density tasks, but the average time value for both was still under 25.9 seconds. The subjective evaluation of situation awareness tends to significantly decrease as the information density tends to increase. The previous discussion reveals that the attention demand tends to increase with the information density, but the extent of the difference depends on the measures used for the evaluation.

The Post-Hoc results for type of format (DISTYPE) confirms the experimental observations, where the tasks presented in the Paragraph format tend to degrade driving performance and the enhancement of the driving experience, which is contrary to the goals of IVIS. The Paragraph format is significantly different from the other three formats for all the performance measures in which DISTYPE was significant. Furthermore, 18 of the 20 tasks that were skipped are in the Paragraph format. The mean number of eye glances to the display was 13.1 and the task-completion-time was 27.2 seconds. Several of the participants needed to point at the screen in order to be able to perform the task. Some of the participant's comments for this type of format were: "I would need to stop to do this one," "too many lines at one time," and "I won't do it while driving, skip." On the other hand, the Graphics with Icons format consistently resulted in better performance.

There is no significant difference between the Table format and the Graphics with Text for any of the measures in which DISTYPE was significant. Interestingly, the values for the dependent measures corresponding to the Table format tend to be closer to the Graphics with

Icons that to the Paragraph measures, an unexpected result when the similarity in presentation (i.e. all textual) is considered. Overall, in terms of attention demand, the Graphics with Icons presentation method has a significantly lower attention demand than the Paragraph format.

An explanation for the highest-order significant interactions (up to three-way interactions) for each dependent variable is presented as part of Appendix 10. The objective of these plots is to allow the visualization of the variation of the dependent measures according to the levels of the different main effects when two or more of these effects are manipulated at the same time. These plots are a representation of the mean values for the significant interactions, they do not show statistical results for combinations of the levels inside those interactions. The graphs for the two-way interactions are presented as Bar graphs since the dependent variables type of task, type of format, and information density are non-continuous variables. Although the three-way interactions are also based on non-continuous variables, a line graph was used in order to be able to represent the interaction of the three factors. Due to the amount of data and their grouping, Post-Hoc tests for the unconfounded interactions are not estimable.

The trends presented by several of the interactions confirm the findings from the Post-Hoc analysis of the main effects. They suggest that a Low information density presented in a Graph with Icons for a Search task represents the best level of each of the within factors, leading to a lower attentional demand (better secondary task, driving, and eye glance performance), when compared to the other possible combinations of levels.

__4.1.2 Comparing IVIS Tasks vs. Baseline Driving.__ This component of the data analysis uses One-Way ANOVAs to evaluate the different main effects. Its purpose is to determine if there are significant differences in the appropriate dependent variables when the baseline is included as a level for each of the main effects. For the IVIS vs. Baseline ANOVAs only the number of glances to the mirror and the 11 driving performance measures were used. Table 4.10 shows the portion of the ANOVA summary table that classifies the sources and degrees of freedom.

Table 4.10 Source and degrees of freedom for the ANOVAs performed to evaluate IVIS vs. Baseline

Source	DF
AGE	1
SUBNUM(AGE)	10
Error	580
TOTAL	591

(a)Age effect compared to baseline

Source	DF
Between	
SUBNUM	11
Within	
ELEMENT	6
*SUBNUM*ELEMENT*	66
Error	508
TOTAL	591

(b)Element effect compared to baseline

Source	DF
Between	
SUBNUM	11
Within	
DISTYPE	4
*SUBNUM*DISTYPE*	44
Error	532
TOTAL	591

(c)Distype effect compared to baseline

Source	DF
Between	
SUBNUM	11
Within	
DENSITY	3
*SUBNUM*DENSITY*	33
Error	544
TOTAL	591

(d)Density effect compared to baseline

The total amount of observations for this portion of the analysis is 612, but since 20 tasks were skipped, only 592 observations are available for the analysis of the 12 dependent measures. The four ANOVA summary tables for each of the 12 dependent measures are included as part of Appendix 11. Table 4.11 presents the main effects that were significant for each of the dependent measures. Consistently with the results from the previous section, AGE was not significant for any of the measures. Also, the dependent measures number of eye glances to mirrors (NEGMIR), variance in speed (VSPEED), and mean speed (MSPEED) do not represent measurements that assist in explaining the statistical difference between the IVIS task and baseline driving. The Post-Hoc results are presented in Tables 4.12 through 4.14. The means with the same letter in their grouping are not significantly different.

Table 4.11 Summary table for the results of the IVIS vs. Baseline ANOVAs

	Variable	AGE	Source ELEMENT	Source DISTYPE	Source DENSITY
Eye Glance	NEGMIR				
Longitudinal Driving Performance	MNSPEED				X
	DECSPEED		X	X	X
	VSPEED				
	MSPEED				
	STDSPEED		X	X	X
	MXLONDCL		X	X	
Lateral Driving Performance	NLANEDEV		X		X
	MAXSTVEL		X	X	X
	VSTVEL		X	X	X
	MSTVEL		X	X	X
	MXLACLMG		X	X	X

X = Significant (p < 0.05)

Table 4.12 Post-Hoc results for the ELEMENT main effect

SNK Grouping	Mean DECSPEED	ELEMENT
A	3.0727	SPI
A	2.9770	SPIC
A	2.7753	SPC
A	2.5889	SC
A	2.5055	SP
B	1.4101	Baseline
B	1.2076	S

SNK Grouping	Mean STDSPEED	ELEMENT
A	1.333	SPIC
B A	1.171	SPI
B A	1.104	SPC
B A	1.062	SC
B A	0.977	SP
B	0.854	Baseline
C	0.547	S

SNK Grouping	Mean MXLONDCL	ELEMENT
A	0.0523	SPIC
A	0.0457	SPC
A	0.0440	SP
A	0.0411	SC
A	0.0390	SPI
A	0.0334	Baseline
B	0.0192	S

(a) Longitudinal Driving Performance

SNK Grouping	Mean VSTVEL	ELEMENT
A	218.81	SC
A	215.91	SPIC
A	196.85	S
A	192.30	SP
A	189.95	SPI
A	185.11	SPC
B	91.13	Baseline

SNK Grouping	Mean MAXSTVEL	ELEMENT
A	99.34	SC
B A	93.35	SPIC
B A	86.94	SPI
B	84.53	SPC
B	84.42	SP
C	68.57	S
D	53.02	Baseline

SNK Grouping	Mean MSTVEL	ELEMENT
A	12.09	SPIC
A	12.05	SC
A	11.54	SP
A	11.42	SPI
A	11.30	S
A	11.29	SPC
B	7.55	Baseline

SNK Grouping	Mean MXLACLMG	ELEMENT
A	0.1308	SPIC
B A	0.1253	SP
B A	0.1207	SPC
B A	0.1189	SPI
B A	0.1187	SC
B	0.1122	Baseline
C	0.0982	S

(b) Lateral Driving Performance

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Table 4.13 Post-Hoc results for the DISTYPE main effect

SNK Grouping	Mean DECSPEED	DISTYPE	SNK Grouping	Mean STDSPEED	DISTYPE	SNK Grouping	Mean MXLONDCL	DISTYPE
A	3.1403	Paragraph	A	1.2303	Paragraph	A	0.0503	Paragraph
B	2.2178	Graph w/text	B	0.9083	Graph w/text	B	0.0350	Table
B	2.2144	Table	B	0.9009	Table	B	0.0334	Baseline
B	1.7196	Graph w/icon	B	0.8539	Baseline	B	0.0312	Graph w/text
B	1.4101	Baseline	B	0.7214	Graph w/icon	B	0.0294	Graph w/icon

(a) Longitudinal Driving Performance

SNK Grouping	Mean VSTVEL	DISTYPE	SNK Grouping	Mean MAXSTVEL	DISTYPE	SNK Grouping	Mean MSTVEL	DISTYPE
A	217.1500	Paragraph	A	93.1290	Paragraph	A	12.0487	Paragraph
A	198.7000	Graph w/text	B A	85.8350	Graph w/text	B A	11.5404	Table
A	189.6300	Table	B	80.0320	Table	B A	11.4622	Graph w/text
A	174.3600	Graph w/icon	C	71.2630	Graph w/icon	B	10.7483	Graph w/icon
B	91.1300	Baseline	D	53.0200	Baseline	C	7.5457	Baseline

SNK Grouping	Mean MXLACLMG	DISTYPE
A	0.1255	Paragraph
B A	0.1161	Graph w/text
B A	0.1148	Table
B	0.1122	Baseline
B	0.1049	Graph w/icon

(b) Lateral Driving Performance

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Table 4.14 Post-Hoc results for the DENSITY main effect

BON Grouping	Mean MNSPEED	DENSITY		SNK Grouping	Mean DECSPEED	DENSITY		BON Grouping	Mean STDSPEED	DENSITY
A	47.68	Med		A	2.640	High		A	1.07	High
B A	47.41	Baseline		A	2.354	Low		B A	0.92	Low
B A	46.98	Low		A	2.118	Med		B A	0.85	Baseline
B	46.48	High		B	1.410	Baseline		B	0.85	Med

(a) Longitudinal Driving Performance

SNK Grouping	Mean NLANEDEV	DENSITY		SNK Grouping	Mean MAXSTVEL	DENSITY		SNK Grouping	Mean VSTVEL	DENSITY
A	0.472	High		A	90.02	High		A	202.06	High
B	0.292	Low		B	81.83	Med		A	198.15	Med
B	0.274	Med		C	71.30	Low		A	180.37	Low
B	0.240	Baseline		D	53.02	Baseline		B	91.13	Baseline

SNK Grouping	Mean MSTVEL	DENSITY		SNK Grouping	Mean MXLACLMG	DENSITY
A	11.754	High		A	0.1209	High
A	11.453	Med		B A	0.1148	Med
A	11.115	Low		B	0.1122	Baseline
B	7.546	Baseline		B	0.1086	Low

(b) Lateral Driving Performance

The IVIS tasks were compared to the baseline driving in terms of how the different levels of type of task (ELEMENT), information density (DENSITY), and type of format (DISTYPE) influenced the driving performance relative to baseline. The dependent measures that were most sensitive to the statistical differences between the different levels of the categories that characterize the IVIS tasks and the baseline driving are discussed next. Although several of the measures were not sensitive enough to capture the statistical difference, there are still enough measures to discuss both driving performance categories. The longitudinal measures are: decrease in speed (DECSPEED), standard deviation of speed (STDSPEED), and peak longitudinal deceleration (MXLONDCL). The lateral driving performance will use the number of lane deviations (NLANEDEV), peak steering wheel velocity (MAXSTVEL), variance in steering wheel velocity (VSTVEL), mean steering wheel velocity (MSTVEL), and peak lateral acceleration (MXLACLMG).

In terms of the type of task (ELEMENT) characteristic, baseline driving is significantly different from all types of tasks in terms of lateral driving performance for three out of four dependent measures. VSTVEL and MSTVEL were not used for comparing IVIS tasks amongst themselves because none of the main effects, or their interactions, were significant under these measures. The Post-Hoc results for these two measures show no significant differences among the types of task, but significant differences exist between the types of task and the baselines. Variability of steering wheel velocity, mean steering wheel velocity, and peak steering wheel velocity present the same pattern. The six types of task appear to have a more "erratic" steering wheel behavior due to the increased attention demand required by the introduction of a secondary task. For the longitudinal driving performance, baseline driving is significantly different from Search-Plan, Search-Compute, Search-Plan-Interpret, and Search-Plan-Compute but not from Search in terms of decrease in speed. For peak longitudinal deceleration and standard deviation of speed, there is no difference between the baseline driving and the majority of the types of task. Thus, Search, Search-Plan, Search-Compute, Search-Plan-Interpret, Search-Plan-Compute, and Search-Plan-Interpret-Compute are different from the baseline driving in terms of lateral driving performance, but there is no clear trend in the longitudinal performance that could be inferred as an increase in driving attention demand.

The longitudinal driving performance showed the same pattern when the type of display format (DISTYPE) was compared to baseline driving. For all three measures (i.e. decrease in

speed, standard deviation of speed, peak longitudinal deceleration) baseline driving does not differ significantly from Graphics with Icons, Graphics with Text, or Table format, but it does differ from the Paragraph format. Baseline driving is significantly different from all formats, with baseline driving representing the best lateral driving performance, for variance in steering wheel velocity, maximum steering wheel velocity, and mean steering wheel velocity. However, baseline only differs from the Paragraph performance in terms of peak lateral acceleration. Eight out of the eight performance measures indicate Paragraph driving performance is significantly different from baseline driving which confirms the finding of the previous section: attention demand created by this type of format is not only different from the other formats but it also differs significantly from normal driving.

The last set of Post-Hoc tests completed for the ANOVA results of IVIS tasks vs. baseline driving address information density (DENSITY). Baseline driving differs significantly from the three density levels for four out of eight of the measures where DENSITY was a significant factor (i.e. decrease in speed, peak steering wheel velocity, variance in steering wheel velocity, mean steering wheel velocity). However, no significant decrease in speed or standard deviation of speed was found between baseline driving and the driving performance while performing a task with any of the three densities.   For this set of results, only the lateral driving performance measures were consistent. Lateral driving performance measures clearly showed that High-density tasks were consistently higher in attention demand than baseline driving.

4.1.3 Comparing IVIS Tasks vs. Conventional Tasks. This part of the analysis uses One-Way ANOVAs to evaluate the different main effects. Its purpose is to determine if there is a significant difference in the appropriate dependent variables when the conventional task is included as a level for each of the main effects. For the IVIS vs. Conventional tasks ANOVAs, only the number of glances to mirror, task-completion-time, and the 11 driving performance measures were used. Table 4.15 shows the portion of the ANOVA summary table that classifies the sources and degrees of freedom.

Table 4.15 Source and degrees of freedom for the ANOVAs performed to evaluate IVIS vs. Conventional tasks

Source	DF
AGE	1
SUBNUM(AGE)	10
Error	592
TOTAL	603

(a)Age effect compared to conventional

Source	DF
Between	
SUBNUM	11
Within	
ELEMENT	6
*SUBNUM*ELEMENT*	66
Error	520
TOTAL	603

(b)Element effect compared to conventional

Source	DF
Between	
SUBNUM	11
Within	
DISTYPE	4
*SUBNUM*DISTYPE*	44
Error	544
TOTAL	603

(c)Distype effect compared to conventional

Source	DF
Between	
SUBNUM	11
Within	
DENSITY	3
*SUBNUM*DENSITY*	33
Error	556
TOTAL	603

(d)Density effect compared to conventional

The total amount of observations for this portion of the analysis is 624, but since 20 tasks were skipped, only 604 observations are available for the analysis of the 13 dependent measures. The four ANOVA summary tables for each of the 13 dependent measures are included as part of Appendix 12. Table 4.16 presents the main effects that were significant for each of the dependent measures. Consistently with the result from the previous two sections, AGE was not significant for any of the measures. The dependent measure number of eye glances to mirrors (NEGMIR) does not help to explain the statistical difference between the IVIS and conventional tasks. The Post-Hoc results are presented in Tables 4.17 through 4.19. The means with the same letter in their grouping are not significantly different.

Table 4.16 Summary table for the results of the IVIS vs. Conventional ANOVAs

	Variable	AGE	ELEMENT	DISTYPE	DENSITY
			Source		
Eye Glance	NEGMIR				
Longitudinal Driving Performance	MNSPEED				X
	DECSPEED		X	X	X
	VSPEED		X	X	
	MSPEED				X
	STDSPEED		X	X	X
	MXLONDCL		X	X	X
Lateral Driving Performance	NLANEDEV		X	X	X
	MAXSTVEL		X	X	X
	VSTVEL		X	X	X
	MSTVEL		X	X	X
	MXLACLMG		X	X	X
Secondary Task	TIME		X	X	X

X = Significant ($p < 0.05$)

Table 4.17 Post-Hoc results for the ELEMENT main effect

SNK Grouping	Mean DECSPEED	ELEMENT
A	3.07	SPI
A	2.98	SPIC
A	2.78	SPC
A	2.59	SC
A	2.51	SP
B	1.21	S
C	0.27	Conventional

BON Grouping	Mean VSPEED	ELEMENT
A	2.81	SPI
B A	2.34	SPIC
B A	2.08	SPC
B A	1.66	SC
B A	1.48	SP
B	0.56	S
B	0.10	Conventional

SNK Grouping	Mean STDSPEED	ELEMENT
A	1.33	SPIC
A	1.17	SPI
A	1.10	SPC
A	1.06	SC
A	0.98	SP
B	0.55	S
C	0.22	Conventional

SNK Grouping	Mean MXLONDCL	ELEMENT
A	0.0523	SPIC
A	0.0457	SPC
A	0.0440	SP
A	0.0411	SC
A	0.0390	SPI
B	0.0192	S
B	0.0115	Conventional

(a) Longitudinal Driving Performance

SNK Grouping	Mean NLANEDEV	ELEMENT
A	0.4706	SPIC
A	0.4242	SC
A	0.4109	SP
A	0.3913	SPC
A	0.3860	SPI
B A	0.2197	S
B	0.0833	Conventional

SNK Grouping	Mean MAXSTVEL	ELEMENT
A	99.34	SC
B A	93.35	SPIC
B A	86.94	SPI
B	84.53	SPC
B	84.42	SP
C	68.57	S
D	37.23	Conventional

SNK Grouping	Mean VSTVEL	ELEMENT
A	218.81	SC
A	215.91	SPIC
A	196.85	S
A	192.30	SP
A	189.95	SPI
A	185.11	SPC
B	111.95	Conventional

SNK Grouping	Mean MSTVEL	ELEMENT
A	12.0926	SPIC
A	12.0458	SC
A	11.5437	SP
A	11.4227	SPI
A	11.2967	S
A	11.2948	SPC
B	9.2970	Conventional

SNK Grouping	Mean MXLACLMG	ELEMENT
A	0.1308	SPIC
A	0.1253	SP
A	0.1207	SPC
A	0.1189	SPI
A	0.1187	SC
B	0.0982	S
C	0.0857	Conventional

(b) Lateral Driving Performance

SNK Grouping	Mean TIME	ELEMENT
A	29.2250	SPIC
B	23.9980	SC
B	23.4480	SPC
B	22.7380	SPI
B	21.5290	SP
C	8.0880	S
D	2.8210	Conventional

(c) Secondary Task Performance

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Table 4.18 Post-Hoc results for the DISTYPE main effect

SNK Grouping	Mean DECSPEED	DISTYPE
A	3.14	Paragraph
B	2.22	Graph w/text
B	2.21	Table
B	1.72	Graph w/icon
C	0.27	Conventional

SNK Grouping	Mean VSPEED	DISTYPE
A	2.71	Paragraph
B A	1.48	Table
B A	1.36	Graph w/text
B	0.92	Graph w/icon
B	0.10	Conventional

SNK Grouping	Mean STDSPEED	DISTYPE
A	1.23	Paragraph
B	0.91	Graph w/text
B	0.90	Table
B	0.72	Graph w/icon
C	0.22	Conventional

SNK Grouping	Mean MXLONDCL	DISTYPE
A	0.0503	Paragraph
B	0.0350	Table
B	0.0312	Graph w/text
B	0.0294	Graph w/icon
C	0.0115	Conventional

(a) Longitudinal Driving Performance

SNK Grouping	Mean NLANEDEV	DISTYPE
A	0.4800	Paragraph
A	0.3308	Graph w/text
A	0.3214	Table
A	0.2917	Graph w/icon
B	0.0833	Conventional

SNK Grouping	Mean MAXSTVEL	DISTYPE
A	93.13	Paragraph
B A	85.84	Graph w/text
B	80.03	Table
C	71.26	Graph w/icon
D	37.23	Conventional

SNK Grouping	Mean VSTVEL	DISTYPE
A	217.15	Paragraph
A	198.70	Graph w/text
A	189.63	Table
A	174.36	Graph w/icon
B	111.95	Conventional

SNK Grouping	Mean MXLACLMG	DISTYPE
A	0.1255	Paragraph
A	0.1161	Graph w/text
A	0.1148	Table
B	0.1049	Graph w/icon
C	0.0857	Conventional

SNK Grouping	Mean MSTVEL	DISTYPE
A	12.05	Paragraph
B A	11.54	Table
B A	11.46	Graph w/text
B	10.75	Graph w/icon
C	9.30	Conventional

(b) Lateral Driving Performance

SNK Grouping	Mean TIME	DISTYPE
A	27.20	Paragraph
B	19.00	Graph w/text
C B	16.61	Table
C	13.46	Graph w/icon
D	2.82	Conventional

(c) Secondary Task Performance

Table 4.19 Post-Hoc results for the DESNITY main effect

BON Grouping	Mean MNSPEED	DENSITY
A	47.68	Med
B A	46.98	Low
B A	46.69	Conventional
B	46.48	High

SNK Grouping	Mean DECSPEED	DENSITY
A	2.64	High
A	2.35	Low
A	2.12	Med
B	0.27	Conventional

SNK Grouping	Mean MSPEED	DENSITY
A	49.00	Med
A	48.55	Low
A	48.18	High
B	47.04	Conventional

SNK Grouping	Mean STDSPEED	DENSITY
A	1.08	High
B A	0.92	Low
B	0.85	Med
C	0.22	Conventional

SNK Grouping	Mean MXLONDCL	DENSITY
A	0.0403	High
A	0.0352	Med
A	0.0348	Low
B	0.0115	Conventional

(a) Longitudinal Driving Performance

SNK Grouping	Mean NLANEDEV	DENSITY
A	0.4721	High
B	0.2917	Low
B	0.2744	Med
C	0.0833	Conventional

SNK Grouping	Mean MAXSTVEL	DENSITY
A	90.02	High
B	81.83	Med
C	71.30	Low
D	37.23	Conventional

SNK Grouping	Mean VSTVEL	DENSITY
A	202.06	High
A	198.15	Med
A	180.37	Low
B	111.95	Conventional

SNK Grouping	Mean MSTVEL	DENSITY
A	11.75	High
A	11.45	Med
A	11.11	Low
B	9.30	Conventional

SNK Grouping	Mean MXLACLMG	DENSITY
A	0.1209	High
B A	0.1148	Med
B	0.1086	Low
C	0.0857	Conventional

(b) Lateral Driving Performance

SNK Grouping	Mean TIME	DENSITY
A	24.63	High
B	16.25	Med
B	14.59	Low
C	2.82	Conventional

(c) Secondary Task Performance

The IVIS tasks were compared to the conventional tasks in terms of the way in which the different levels of type of task (ELEMENT), information density (DENSITY), and type of format (DISTYPE) influenced the driving performance relative to conventional task performance. The dependent measures that were most sensitive to the statistical differences between the different levels of the categories that characterize the IVIS tasks and conventional tasks are discussed next. Although several of the measures were not sensitive enough to capture the statistical difference, there are still enough measures to discuss both driving performance categories, as well as task-completion-time (TIME). The longitudinal measures remaining are: minimum speed (MNSPEED), variance in speed (VSPEED), mean speed (MSPEED), decrease in speed (DECSPEED), standard deviation of speed (STDSPEED), and peak longitudinal deceleration (MXLONDCL). The lateral driving performance will use number of lane deviations (NLANEDEV), peak steering wheel velocity (MAXSTVEL), variance in steering wheel velocity (VSTVEL), mean steering wheel velocity (MSTVEL), and peak lateral acceleration (MXLACLMG).

When the type of task (ELEMENT) characteristic is considered, the longitudinal driving performance of the conventional tasks is best described as significantly different from all six types of tasks in terms of decreases in speed and standard deviation of speed. The decrease in speed for the conventional task was less than 1 mph while the other tasks ranged from 1-3 mph on average. The variance in speed does not seem to discriminate among the performance of the conventional tasks and the performance of Search, Search-Plan, Search-Compute, Search-Plan-Interpret, and Search-Plan-Compute, but it does show that Search-Plan-Interpret-Compute differs significantly from the conventional tasks. For the lateral driving performance, five out of six of the driving performance measures showed that conventional task performance was significantly different from the performance in the other six types of tasks. As noted in the previous section, VSTVEL and MSTVEL were not used for comparing IVIS tasks among themselves because none of the main effects, or the interactions, were significant for these measures. However, these two measures did show a significant difference between the IVIS tasks and the conventional tasks. The variability of steering wheel velocity, mean steering wheel velocity, and peak steering wheel velocity present the same pattern for IVIS vs. conventional tasks as previously shown for baseline driving. For peak steering wheel velocity, conventional tasks are also significantly different from the other types of tasks. Therefore, the same conclusion presented for baseline

driving applies to the conventional task comparison. That is, the six types of tasks seem to have a more "erratic" steering wheel behavior due to the increased attention demand required by the introduction of a secondary task. Task-completion-time was not the exception in this case. Hence, it followed the trend of describing the conventional task as differing significantly from the performance of the six IVIS types of task, with the conventional tasks exhibiting the shortest task-completion-time. When conventional tasks are considered (as opposed to baseline tasks), a clearer trend in the longitudinal and lateral performance exists. This trend can be described as an increase in driving attention demand when a secondary task of any of the types analyzed is introduced.

When the comparison against conventional tasks is shifted to the type of format (DISTYPE) in which the IVIS tasks were presented, it is observed that conventional tasks differ significantly from the Graphics with Icons, Graphics with Text, Table, and Paragraph formats for all lateral driving performance measures used for this portion of the analysis, as well as for task-completion-time. For the longitudinal driving performance, three out of four measures showed the same pattern: for conventional tasks the decreases in speed, standard deviation of speed, and peak longitudinal deceleration were significantly lower than those for any of the four types of display formats. Once again, this reveals that the attention demand increased when a secondary task was introduced. More specifically, the trend observed in the comparison of IVIS tasks among themselves prevails: although a significant increase in attentional demand is still present, the Graphs with Icons display resulted in significantly better performance than the other three types of formats. The Paragraph format still lies on the opposite side of the continuum with ten out of the ten performance measures indicating that driving performance while reading a Paragraph is significantly different from driving performance during conventional tasks.

The last set of Post-Hoc tests completed for the ANOVA results of IVIS tasks vs. conventional tasks are those related to information density (DENSITY). This set of results show that conventional tasks differ significantly from the three density levels in terms of task-completion-time. Whereas conventional tasks had a mean task-completion-time of 2.82 seconds, the IVIS tasks for the Low, Medium and High densities took 14.59, 16.25, and 24.63 seconds, respectively. Five out of five lateral driving performance measures showed that conventional task performance was significantly different from the performance obtained for the three different amounts of information density presented to the participants. For the longitudinal

driving performance, conventional tasks once again differ from all three densities significantly for three out of four performance measures (i.e. decrease in speed, standard deviation of speed and peak longitudinal deceleration). All densities consistently differ from the conventional tasks in most of the measures evaluated, with performance measures of the High density level differing significantly from the conventional tasks values for all measures evaluated. Therefore, based on these findings, it is concluded that attention demand increased significantly for the High-density level tasks compared to conventional tasks such as activating a turn signal, adjusting an A/C vent, adjusting a power mirror, monitoring vehicle speed, or monitoring the fuel level of the vehicle.

4.2 Correlation Analysis

As previously discussed in the Data Analysis section, two sets of correlations were calculated. The first set presents the correlation between the eye glance measures and the performance/subjective measures (see Table 4.20). The second set presents the correlations between task-completion-time/subjective measures and driving performance measures (see Table 4.21). The purpose of these analyses was to determine if any of the performance and subjective measures consistently covaried with the eye glance measures. It has been demonstrated with empirical data, in previous research, that task-completion-time is a good surrogate of performance when driving an automobile and completing in-vehicle tasks. Therefore, it was of great interest to observe the relationship of the task-completion-time (TIME) and driving performance measures for CVO drivers. The mean values used for these correlations are presented as part of Appendix 13. Correlations were calculated using the majority of the measures. The dependent measures SKIPPED, ERRORS, WRONGTSK were not used in the correlation analysis due to large number of zero values in the data for these measures. Only correlations with values over 0.60 were considered of interest. These high correlations indicate that there is a degree of meaningful covariance among the dependent measures considered.

Based on Table 4.20, the MNSPEED (minimum speed), DECSPEED (decrease in speed), STDSPEED (standard deviation of speed, MXLONDCL (peak longitudinal deceleration), NLANEDEV (number of lane deviations), MAXSTVEL (maximum steering velocity), MXLACLMG (peak lateral acceleration), TIME (task-completion-time), SITUAWAR

(subjective situational awareness), and COMBMWK (modified NASA-TLX) show high correlation with NEGDISP (number of eye glances to display) and TGT (total glance time). Also, MXLONDCL (peak longitudinal deceleration), TIME (task-completion-time), SITUAWAR (subjective situational awareness), and COMBMWK (modified NASA-TLX) are highly correlated with NEGMIR (number of eye glances to mirrors) and total glance time (TGT).

The second set of correlations (Table 4.21) presents a similar pattern, where MNSPEED (minimum speed), DECSPEED (decrease in speed), STDSPEED (standard deviation of speed, MXLONDCL (peak longitudinal deceleration), NLANEDEV (number of lane deviations), MAXSTVEL (maximum steering velocity), and MXLACLMG (peak lateral acceleration) exhibit a substantially high correlation with TIME (task-completion-time) and COMBMWK (modified NASA-TLX). SITUAWAR (subjective situational awareness) seems to just correlate with a subset of these measures, i.e. STDSPEED (standard deviation of speed, MXLONDCL (peak longitudinal deceleration), NLANEDEV (number of lane deviations), MAXSTVEL (maximum steering velocity), and MXLACLMG (peak lateral acceleration).

Table 4.20 Correlations for the Eye Glance Measures vs. Performance and Subjective Measures

		Eye Glance Measures				
		NEGDISP	LEGDISP	MSGT	TGT	NEGMIR
Longitudinal Driving Performance	MNSPEED	-0.621*	-0.036	0.180	-0.611*	-0.370*
	DECSPEED	0.634*	0.341*	-0.150	0.625*	0.387*
	VSPEED	0.446*	0.230	-0.083	0.442*	0.224
	MSPEED	-0.397*	0.130	0.181	-0.381*	-0.204
	STDSPEED	0.799*	0.353*	-0.109	0.797*	0.560*
	MXLONDCL	0.773*	0.374*	0.038	0.792*	0.605*
Lateral Driving Performance	NLANEDEV	0.709*	0.113	-0.119	0.708*	0.533*
	MAXSTVEL	0.729*	0.259	-0.074	0.730*	0.519*
	VSTVEL	0.208	0.060	0.061	0.216	0.081
	MSTVEL	0.305*	0.047	-0.001	0.306*	0.171
	MXLACLMG	0.716*	0.358*	-0.005	0.724*	0.529*
Secondary Task Performance	TIME	0.993*	0.290*	-0.118	0.995*	0.802*
Subjective Measure	SITUAWAR	-0.855*	-0.205	0.066	-0.865*	-0.708*
	COMBMWK	0.927*	0.260	-0.040	0.931*	0.789*

* p < 0.05 (significant)

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Table 4.21 Correlations for Task-Completion-Time and Subjective vs. Performance

		Secondary Task Performance	Subjective Measures	
		TIME	SITUAWAR	COMBMWK
Longitudinal Driving Performance	MNSPEED	-0.616*	0.538*	-0.609*
	DECSPEED	0.630*	-0.486*	0.505*
	VSPEED	0.447*	-0.313*	0.364*
	MSPEED	-0.390*	0.359*	-0.431*
	STDSPEED	0.804*	-0.673*	0.715*
	MXLONDCL	0.788*	-0.673*	0.719*
Lateral Driving Performance	NLANEDEV	0.722*	-0.608*	0.652*
	MAXSTVEL	0.745*	-0.790*	0.745*
	VSTVEL	0.238	-0.415*	0.294*
	MSTVEL	0.326*	-0.485*	0.380*
	MXLACLMG	0.724*	-0.594*	0.615*

* $p < 0.05$ (significant)

Table 4.20 shows that longitudinal driving performance measures such as minimum speed, decrease in speed, standard deviation of speed, and peak longitudinal deceleration seem to correlate highly with number of eye glances to display and total glance time ($|r| > 0.60$). The lateral driving performance measures exhibiting a high correlation ($r > 0.70$) with number of eye glances to display and total glance time were number of lane deviations, maximum steering velocity, and peak lateral acceleration. The highest correlation with number of eye glances to display and total glance time occurred for task-completion-time, which was equal to 0.99 for both measures. Following task-completion-time, the next two highest correlations with number of eye glances to display and total glance time were those for subjective situational awareness and the modified NASA-TLX, with values $|r| > .86$ for situational awareness and $|r| > 0.93$ for the subjective mental workload. These correlations indicate that longer task-completion-times are associated with more glances to the display. An increase in the number of glances to the display is related to a decrease in situation awareness. The mental workload seems to increase as the number of glances increases. In terms of driving performance, as the number of glances to the

display increase, there is a tendency to decrease the speed of the vehicle and exhibit a more "erratic" steering wheel behavior.

In terms of task-completion-time, it was found that the highest correlations related time and both lateral and longitudinal driving performance measures. The measures for longitudinal driving performance that are highly correlated ($|r| > 0.62$) with task-completion-time for this study are minimum speed, decrease in speed, standard deviation of speed, and peak longitudinal deceleration. For the lateral driving performance, task-completion-time had the highest correlations ($r > 0.72$) with number of lane deviations, maximum steering velocity, and peak lateral acceleration. The Modified NASA-TLX followed for the most part the same pattern as task-completion-time; the only measure that did not correlate over the pre-stipulated limit for further analysis ($|r| > 0.60$) was decrease in speed, although this correlation was still over 0.50. The subjective situational awareness correlates highly ($|r| > 0.61$) with a subset of these measures: standard deviation of speed, peak longitudinal deceleration, number of lane deviations, maximum steering velocity, and peak lateral acceleration. Similar results were found in the literature for research of in-vehicle secondary tasks for private vehicles, where task-completion-time exhibited high correlations with steering behavior. Most of these results can be explained by the relatively large period of time required for a tractor-trailer to drift off-track, therefore, large steering corrections would for the most part be present for tasks with longer task-completion-time and higher mental workload. The results can also be explained by low situational awareness, which would be needed for the "erratic" steering behavior. In any case, both scenarios point to a high attention demand task.

4.3 Ranking of Attentional Demand

Means and standard deviations for each of the IVIS tasks were calculated for the total glance time measure. The tasks were then ranked in an ascending order from lowest attention demand to highest attention demand following the procedure explained at the Data Analysis section. Table 4.22 shows the results.   The abbreviations used in the table are defined below. The task number column helps to relate the results to the actual tasks presented to the participants, which are shown in Appendix 1.

Type of Task:

S = search

SC = search-compute

SP = search-plan

SPC = search-plan-compute

SPI = search-plan-interpret

SPIC = search-plan-interpret-compute

Density: (*categories of information* **X** *number of alternatives***)**

L = low (2 x 3)

M = medium (3 x 3)

H = high (4 x 5)

Table 4.22 Total glance times to display (TGT) for each IVIS task

Type of Display	Type of Task	Density	Task #	TGT Mean	TGT SD	Attentional Demand
Graph w/icon	S	L	403	2.11	0.94	Medium
Graph w/text	S	M	406	3.09	1.01	High
Graph w/icon	S	M	407	3.21	1.16	High
Table	S	L	401	3.60	0.76	
Table	S	M	404	4.29	1.35	
Graph w/text	S	H	410	4.33	1.25	
Table	S	H	408	5.45	2.02	
Paragraph	S	L	402	5.79	1.47	
Graph w/text	SPC	M	440	7.82	1.74	
Graph w/icon	S	H	411	8.11	4.93	
Graph w/text	SP	M	432	9.56	3.24	
Graph w/text	SPI	M	448	10.02	3.29	
Table	SP	M	430	10.10	1.90	
Table	SC	M	421	10.18	3.81	
Graph w/icon	SP	M	433	10.31	4.42	
Table	SPI	L	444	10.52	4.07	
Table	SPC	M	438	10.94	3.87	
Graph w/icon	SP	L	429	11.00	3.36	
Paragraph	S	M	405	11.11	1.61	
Graph w/icon	SPI	M	449	11.44	3.59	
Graph w/text	SC	M	423	11.66	4.28	
Paragraph	S	H	409	11.83	4.15	
Table	SPI	M	446	12.34	4.84	
Table	SC	H	424	13.59	5.26	
Table	SPC	H	441	13.67	5.00	
Table	SP	L	427	13.79	6.43	Very High
Graph w/icon	SP	H	437	13.85	4.59	
Paragraph	SP	L	428	14.70	7.49	
Table	SPI	H	450	14.72	4.56	
Graph w/icon	SPI	H	453	15.99	6.29	
Graph w/text	SP	H	436	16.46	8.10	
Table	SP	H	434	16.47	5.73	
Paragraph	SC	M	422	16.68	9.44	
Paragraph	SPI	L	445	16.69	4.20	
Graph w/text	SPIC	H	456	17.39	7.08	
Graph w/text	SPC	H	443	17.93	7.24	
Paragraph	SP	M	431	17.99	5.91	
Graph w/text	SPI	H	452	18.09	9.11	
Paragraph	SPI	M	447	18.17	5.76	
Table	SPIC	H	454	18.23	9.31	
Paragraph	SC	H	425	18.27	10.80	
Paragraph	SPC	M	439	19.51	6.82	
Graph w/text	SC	H	426	20.65	9.03	
Paragraph	SPIC	H	455	21.72	12.69	
Paragraph	SPI	H	451	22.39	15.09	
Paragraph	SPC	H	442	24.89	14.44	
Paragraph	SP	H	435	26.07	15.26	

Based on the results of the ranking (Table 4.22) and their comparison to the results obtained for previous research in private vehicles, IVIS tasks present a large amount of attention demand to the CVO driver. Based on Dingus' (1987) classification technique for attention demand, none of the tasks in this study represents a Low attentional demand. Only a Search task with a Low information density and presented in a Graphics with Icons format can be considered under the category of Medium attentional demand. A puzzling result, which nonetheless seems completely logical based on the driving performance results obtained on the Post-Hoc analysis performed to compare conventional task performance to IVIS tasks. These driving performance results demonstrated a significant difference between conventional tasks and IVIS tasks for all the factors evaluated (i.e. DISTYPE, ELEMENT, DENSITY), which suggests that only the conventional tasks required Low attentional demand. When the results for the comparison of IVIS vs. conventional tasks are considered, there is a possible explanation as to why there is only one IVIS task under the category of Medium attention demand. If the discussion of the ANOVAs is recalled, the best performance following conventional tasks occurred, for each set of analysis (Tables 4.18 through 4.19), under the Search for the ELEMENT analysis, Graphics with Icons for the DISTYPE analysis and Low for the DENSITY analysis, which is exactly the outcome for the Medium attentional demand category. The same logic can be used to explain each of the other rankings of attentional demand. Taking advantage of this ranking and the Appendix 13, other measures of performance can be derived from the characteristics of the tasks. For instance, if we use Appendix 13 and the measures exhibiting the highest correlation with total glance time, the characteristics of an IVIS task with a moderate attention demand for CVO drivers can be described. For example, the characteristics of this Moderate IVIS/CVO task include a standard deviation of speed of 0.21 mph or less, and a peak steering wheel velocity not higher than 37.45 degrees/second.

4.4 Red-Lines and Yellow-Lines

4.4.1 Red-Lines. As mentioned in the Data Analysis section, the five dependent measures that were evaluated to determine red-lines are NEGDISP, LEGDISP, SKIPPED, TASKS DIFFICULTY, and TIME. Each of the thresholds will be discussed individually before presenting the results.

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For the NEGDISP measure, the suggested threshold is nine or more glances to the display (T.A. Dingus, personal communication, March 16, 1999). Bhise, Forbes, and Farber (1986) have suggested that any single display glance longer than 2.5 seconds is inherently dangerous. Based on this research, 2.5 seconds was used as the criterion for the LEGDISP measure that assesses instances of potentially unsafe behavior. The SKIPPED measure represents a task in which the driver felt that performing the task could cause an unsafe situation. Therefore, any skipped task represents automatically a red-line (Gallagher, 1999; T.A. Dingus, personal communication, March 16, 1999). TASK DIFFICULTY is a composite measure (see Equation 1). Hanowski suggests it as a reliable measure for in-vehicle systems attention demand evaluation (R. Hanowski, personal communication, November 11, 1999).

$$\textbf{Task Difficulty} \; = \; \frac{\text{Number of Tasks Performed Correctly}}{\text{Total Number of Tasks Presented}} \qquad \qquad \text{[EQ. 1]}$$

$$= \; \frac{\text{Total Number of Tasks Presented} \; - (\text{ERRORS} + \text{SKIPPED} + \text{WRONGTSK})}{\text{Total Number of Tasks Presented}}$$

For this specific study a TASK DIFFICULTY measure lower than 0.83, which represents 10 out of 12 tasks performed correctly, will be considered a red-line. Based on the "15-seconds rule" (Society of Automotive Engineers, 1999) and the surrogate measures of driving performance developed by Farber, Blanco, Curry, Greenberg, Foley, and Serafin (1999), a TIME measure higher than 25.9 seconds will be considered a red-line. If a task complies with any of the five characteristics of a red-line then a red-line was reached for that task.

Following the procedure explained above to discover Red-Lines, all the tasks that meet a given criterion were marked with an "X" and highlighted. The results of this procedure are shown in Table 4.23.

Table 4.23 Red-Lines for IVIS tasks

Type of Display	Type of Task	Density	Task #	Eye Glance Measures				Secondary Task Performance					
				NEGDISP		LEGDISP		SKIPPED		TASK DIFFICULTY		TIME	
				Mean	Red-Line	Mean	Red-Line	Total	Red-Line	Measure	Red-Line	Mean	Red-Line
Table	S	L	401	3.17		1.75		0		1		5.66	
Paragraph	S	L	402	4.00		2.56	X	0		1		8.13	
Graph w/icon	S	L	403	1.83		1.67		0		1		2.60	
Table	S	M	404	3.08		2.37		0		1		5.77	
Paragraph	S	M	405	7.67		2.59	X	0		1		15.53	
Graph w/text	S	M	406	2.58		2.02		0		1		4.36	
Graph w/icon	S	M	407	2.58		1.97		0		1		4.35	
Table	S	H	408	3.67		2.47		0		1		7.09	
Paragraph	S	H	409	8.17		2.31		0		1		18.55	
Graph w/text	S	H	410	3.25		2.45		0		1		6.04	
Graph w/icon	S	H	411	5.58		2.49		0		1		10.91	
Table	SC	M	421	7.33		2.48		0		1		14.59	
Paragraph	SC	M	422	12.67	X	2.42		1	X	0.92		26.51	X
Graph w/text	SC	M	423	9.25	X	2.39		0		1		18.03	
Table	SC	H	424	9.92	X	2.32		0		1		19.21	
Paragraph	SC	H	425	13.33	X	2.30		4	X	0.67	X	27.82	X
Graph w/text	SC	H	426	15.50	X	2.18		1	X	0.92		30.95	X
Table	SP	L	427	10.92	X	1.97		0		1		20.06	
Paragraph	SP	L	428	10.67	X	2.90	X	0		1		23.93	
Graph w/icon	SP	L	429	8.17		2.77	X	0		1		14.84	
Table	SP	M	430	7.92		2.10		0		1		14.55	
Paragraph	SP	M	431	13.33	X	2.20		0		1		26.54	X
Graph w/text	SP	M	432	6.50		2.93	X	0		1		13.66	
Graph w/icon	SP	M	433	8.33		2.10		0		1		14.53	
Table	SP	H	434	12.58	X	2.42		0		1		23.84	
Paragraph	SP	H	435	19.50	X	2.58	X	3	X	0.75	X	39.58	X
Graph w/text	SP	H	436	13.25	X	2.51	X	0		1		25.77	
Graph w/icon	SP	H	437	9.58	X	3.08	X	0		1		19.92	
Table	SPC	M	438	8.00		2.68	X	0		1		16.05	
Paragraph	SPC	M	439	13.17	X	3.34	X	0		1		29.23	X
Graph w/text	SPC	M	440	5.17		2.72	X	0		1		10.64	
Table	SPC	H	441	9.75	X	2.48		0		1		19.77	
Paragraph	SPC	H	442	18.00	X	2.46		3	X	0.75	X	37.72	X
Graph w/text	SPC	H	443	12.42	X	2.40		0		1		26.58	X
Table	SPI	L	444	9.00	X	1.96		0		1		16.19	
Paragraph	SPI	L	445	12.67	X	2.56	X	0		1		25.29	
Table	SPI	M	446	9.92	X	2.79	X	0		1		18.58	
Paragraph	SPI	M	447	13.17	X	2.18		0		1		25.94	X
Graph w/text	SPI	M	448	7.42		2.47		0		1		14.40	
Graph w/icon	SPI	M	449	9.25	X	2.41		0		1		18.22	
Table	SPI	H	450	11.83	X	2.40		0		1		22.27	
Paragraph	SPI	H	451	16.92	X	2.46		5	X	0.58	X	35.68	X
Graph w/text	SPI	H	452	14.92	X	2.29		1	X	0.92		29.54	X
Graph w/icon	SPI	H	453	11.25	X	2.83	X	0		1		22.33	
Table	SPIC	H	454	14.00	X	2.61	X	0		0.42	X	28.90	X
Paragraph	SPIC	H	455	16.58	X	2.38		2	X	0.33	X	34.43	X
Graph w/text	SPIC	H	456	13.25	X	2.60	X	0		0.25	X	28.22	X

**4.4.2 Yellow-Lines.** The procedure to discover yellow-lines was slightly different. The purpose of this measure is to highlight tasks that present a driving performance significantly different from the driving performance that was taken during baseline ($p<0.05$). In order to determine which dependent measures would best define a yellow-line, the results from the ANOVAs were used. The measurements used were those that were most sensitive to the statistical differences between the different IVIS tasks based on the ANOVA results. Therefore, the seven measures that will be part of the statistical analysis for the yellow-lines were: MNSPEED, DECSPEED, STDSPEED, MXLONDCL, NLANEDEV, MAXSTVEL, and MXLACLMG.

Baselines were taken for four different time durations, 5, 10, 20, and 30 seconds; for each of the participants. The IVIS tasks, for each participant, were match based on its task-completion-time to an appropriate baseline (e.g. a task with a completion time of 21.1 seconds for participant # 5 will be compared to the 20 seconds baseline of participant # 5). Then, the difference for each of the seven measures was calculated for each task (47 tasks total) per participant. The set of differences that characterized the task were tested using a Paired T-test, for a total of 329 Paired T-tests. If a significant difference was found for one or more of the measures of a given task, then a yellow-line was reached for that task.

Following the previously outlined procedure to discover Yellow-Lines, all tasks whose performance was significantly different from baseline driving were marked with an "X" and highlighted. The results of this process are shown in Table 4.24.

Table 4.24 Yellow-Lines for IVIS tasks

| Type of Display | Type of Task | Density | Task # | Longitudinal Driving Performance | | | | | | | | Lateral Driving Performance | | | | | |
| | | | | MNSPEED | | DECSPEED | | STDSPEED | | MXLONDCL | | NLANEDEV | | MAXSTVEL | | MXLACLMG | |
				P values	Yellow-Line	P values	Yellow-Line	P values	Yellow-Line	P values	Yellow-Line	P values	Yellow-Line	P values	Yellow-Line	P values	Yellow-Line
Table	S	L	401	0.9232		0.1961		0.4176		0.8551		1.0000		0.0018	X	0.0740	
Paragraph	S	L	402	0.4557		0.5018		0.3927		0.1278		0.5863		0.1340		0.0326	*
Graph w/icon	S	L	403	0.1252		0.7733		0.0675		0.0997		0.6119		0.6908		0.3329	
Table	S	M	404	0.5685		0.9209		0.9668		0.2960		0.3582		0.0270	X	0.4857	
Paragraph	S	M	405	0.0631		0.0400	X	0.4699		0.5568		0.5387		0.0250	X	0.3040	
Graph w/text	S	M	406	0.5649		0.5205		0.7981		0.4892		0.1039		0.1557		0.9395	
Graph w/icon	S	M	407	0.4557		0.7376		0.6330		0.0580		0.6514		0.0444	X	0.0318	*
Table	S	H	408	0.1879		0.1968		0.3538		0.9231		0.3582		0.0025	X	0.3089	
Paragraph	S	H	409	0.8699		0.1640		0.2636		0.9853		0.0527		0.0081	X	0.7172	
Graph w/text	S	H	410	0.0573		0.3025		0.7483		0.8422		1.0000		0.0369	X	0.9433	
Graph w/icon	S	H	411	0.8417		0.6099		0.7486		0.9501		0.0626		0.0887		0.7539	
Table	SC	M	421	0.8353		0.2462		0.2925		0.5439		0.1661		0.0390	X	0.0625	
Paragraph	SC	M	422	0.4475		0.0371	X	0.8337		0.7626		0.3246		0.0004	X	0.6583	
Graph w/text	SC	M	423	0.6940		0.0835		0.7863		0.6721		1.0000		0.0001	X	0.7106	
Table	SC	H	424	0.2978		0.8222		0.6389		0.8638		0.7227		0.0002	X	0.7835	
Paragraph	SC	H	425	0.4643		0.0277	*	0.0351	*	0.4313		0.6767		0.0151	X	0.8420	
Graph w/text	SC	H	426	0.5051		0.0208	X	0.4824		0.2907		0.1738		0.0059	X	0.4210	
Table	SP	L	427	0.3583		0.1387		0.8383		0.3857		0.7545		0.1268		0.6131	
Paragraph	SP	L	428	0.2062		0.1007		0.1952		0.3930		0.2176		0.0307	X	0.2698	
Graph w/icon	SP	L	429	0.1855		0.4278		0.8774		0.7723		0.8936		0.2462		0.7991	
Table	SP	M	430	0.3780		0.1906		0.8372		0.9252		0.2254		0.0153	X	0.3423	
Paragraph	SP	M	431	0.9174		0.3590		0.4598		0.0986		0.8995		0.0059	X	0.3243	
Graph w/text	SP	M	432	0.0605		0.9741		0.5022		0.6692		1.0000		0.0182	X	0.1058	
Graph w/icon	SP	M	433	0.1819		0.1126		0.6856		0.5013		0.7318		0.0026	X	0.8306	
Table	SP	H	434	0.7317		0.1807		0.7161		0.4985		0.5791		0.0706		0.5444	
Paragraph	SP	H	435	0.1216		0.1345		0.8659		0.3046		0.1375		0.0339	X	0.9343	
Graph w/text	SP	H	436	0.6017		0.8754		0.0777		0.2191		0.6703		0.0053	X	0.3796	
Graph w/icon	SP	H	437	0.3782		0.2309		0.7330		0.3076		0.1255		0.0012	X	0.4220	
Table	SPC	M	438	0.2499		0.1011		0.2514		0.2488		0.1080		0.0330	X	0.8391	
Paragraph	SPC	M	439	0.0686		0.1653		0.9102		0.1408		0.7774		0.0181	X	0.3156	
Graph w/text	SPC	M	440	0.8571		0.8294		0.6765		0.5584		0.2549		0.0024	X	0.8987	
Table	SPC	H	441	0.3491		0.2070		0.4384		0.5335		0.1034		0.0080	X	0.2194	
Paragraph	SPC	H	442	0.5181		0.0459	X	0.9693		0.4682		0.5121		0.0043	*	0.7611	
Graph w/text	SPC	H	443	0.4599		0.6210		0.6157		0.5992		0.3889		0.0061	X	0.5322	
Table	SPI	L	444	0.0011	X	0.7957		0.5225		0.4243		0.2581		0.0001	X	0.9059	
Paragraph	SPI	L	445	0.1977		0.1610		0.2604		0.9505		0.5288		0.0626		0.1487	
Table	SPI	M	446	0.5377		0.0814		0.2751		0.6363		0.2360		0.0150	X	0.7208	
Paragraph	SPI	M	447	0.9813		0.2797		0.9341		0.6802		0.4366		0.0126	X	0.3278	
Graph w/text	SPI	M	448	0.1314		0.3151		0.7842		0.1200		0.7401		0.0103	X	0.3061	
Graph w/icon	SPI	M	449	0.1116		0.5484		0.5470		0.6290		0.6052		0.0729		0.5173	
Table	SPI	H	450	0.2716		0.0007	X	0.2671		0.5558		0.2873		0.0047	X	0.9837	
Paragraph	SPI	H	451	0.7762		0.2622		0.3548		0.4208		0.3665		0.0103	X	0.9696	
Graph w/text	SPI	H	452	0.0088	X	0.0278	X	0.2206		0.9945		0.7809		0.0094	X	0.7293	
Graph w/icon	SPI	H	453	0.1072		0.0698		0.7204		0.7085		0.9343		0.0353	X	0.7372	
Table	SPIC	H	454	0.6603		0.1950		0.8436		0.3509		0.2925		0.0441	X	0.6413	
Paragraph	SPIC	H	455	0.3193		0.4127		0.8689		0.7240		0.7304		0.0127	X	0.0611	
Graph w/text	SPIC	H	456	0.3478		0.0207	X	0.2893		0.6289		0.5411		0.1186		0.7403	

X = Significant (p<0.05)   * = Significant, but opposite than the direction expected

Chapter 5. DISCUSSION

As mentioned in the Research Objective section, the primary objective of this research was to collect on-road data with the purpose of evaluating the effects of different types of IVIS tasks on the information processing demands of a commercial vehicle operations driver. The results that will be discussed in this section help to characterize the decision-making process in information processing terms.

This study was performed with two main goals in mind. The first goal was to understand and predict "red-lines" and "yellow-lines" in terms of what the CVO driver can process without hindering the primary task of driving (please refer to section 2.2 for the operational definition of red and yellow-lines). The second goal was to collect conventional secondary task data for CVO driving performance. The results and data collected for this study were also used in the IVIS Demand Model that the Center for Transportation Research is developing.

Limited empirical data existed that could be used to model the attention demands placed on commercial vehicle operations drivers when interacting with IVIS based on the specific design characteristics (e.g. type of task, type of format, information density). The collection of data performed by this study (Appendix 13) can be integrated into the IVIS evaluation as a very important tool. These data can be used to support designers and developers of in-vehicle systems for CVO drivers, as well as to help ensure that future systems developed and marketed by manufacturers do not adversely affect the driving task, thereby creating unsafe circumstances.

Three important findings, besides the red and yellow-lines, have stemmed out of this research effort. These findings are discussed in detail below, and they are: (1) a group of dependent measures that are more sensitive to the characterization of IVIS/CVO tasks, (2) how the different dependent measures of driving performance vary as visual attentional demand increases, and (3) a tool for visual attentional demand assessment by the sole measurement of the task-completion-time.

This work has proposed that in order to analyze the different characteristics of an IVIS/CVO task not all measures are equally sensitive. Before any further evaluation, the dependent measures that are consistently sensitive to the statistical differences evaluated are presented. In terms of eye glance measures, the two best measures are number of eye glances to the display and total glance time to the display. The longitudinal driving performance measures

that were most sensitive to the statistical differences are minimum speed, decrease in speed, standard deviation of speed, and peak longitudinal deceleration. For the lateral driving performance, the measures that better explained attention demand for CVO drivers are peak steering wheel velocity and peak longitudinal acceleration. In addition, task-completion-time and the two subjective assessment measures are highly correlated with both eye glance and the driving performance measures.

It is not surprising to have this final subset of objective measures as the most sensitive measures used to evaluate attentional demand when performing a secondary task while driving. These measures have a high face and construct validity since they have been evaluated and used previously as attention demand predictors for secondary tasks while driving (Antin, 1987; Dingus, 1987; Farber, Blanco, Curry, Greenberg, Foley, and Serafin, 1999). The two subjective measures had not been used previously in the same format utilized for this study, but the subset of scales by themselves are taken from the NASA-TLX, which is widely known as a good predictor of mental workload. Furthermore, these subjective measures exhibit a substantially high correlation with the objective measures of this study.

Most of the hypotheses that were stipulated in the beginning of this document have been successfully validated. Total-glance-time to the display increases as the attentional demand of a task tends to be higher. This fact, combined with the direct relationship exhibited between objective and subjective measures, translates to a very helpful assessment of attention demand that was confirmed by driving performance measures.

The task-completion-time tends to increase as total glance time and number of glances to display increase. In addition, the subjective measure of situational awareness presented a high correlation with total glance time and number of glances to display, which implies that as the total glance time increased the situation awareness of the driver decreased. The subjective rating of mental workload was also highly correlated with the eye glance measures. This set of results certainly validates the first hypothesis that relates eye glance measures to task-completion-time and subjective measures of mental workload and situation awareness.

Not all the longitudinal measures were as highly correlated as expected, but the pattern described by the second hypothesis in terms of longitudinal performance can still be observed. Therefore, the effect of an increase in total glance time is to lower the minimum speed of a task.

The decrease in speed tends to be larger when the total glance time increases. The sudden changes in speed resulted in a larger standard deviation of speed.

In terms of lateral driving performance, the amount of visual attention demand directly affected the steering behavior, number of eye glances to display, and total glance time. In addition, number of lane deviations and the peak lateral acceleration were affected by the amount of visual attention demand required by the IVIS/CVO task.

Although CVO driving performance does not vary inside the ages analyzed (i.e. 35 - 70 years old), several of the characteristics that describe an IVIS/CVO task tend to affect driving performance. The only type of task that exhibits a moderate attention demand compared to the conventional tasks is the Search task. The analysis performed suggests that any other type of task will increase attention demand, which could lead to an unsafe driving scenario. The previous explanation also describes the findings in terms of best density and type of display that could be used for IVIS/CVO tasks. A low information density, which is composed of two categories of information and three alternatives from which the driver could choose from, is the highest density that could be presented without causing a high attention demand. Graphics with Icons is the display type with the lowest attention demand. On the other hand, the Paragraph represents the highest visual attention demand among all types of formats. However, a Search task that takes advantage of a Graphic with Icons format with a Low information density still represents a higher attentional demand than that presented by a conventional task. An example of the Post-Hoc results that lead to this conclusion are presented as Figures 5.1 – 5.3. The levels of a given main effect with the same letter denote that the performance of those levels do not significantly differ.
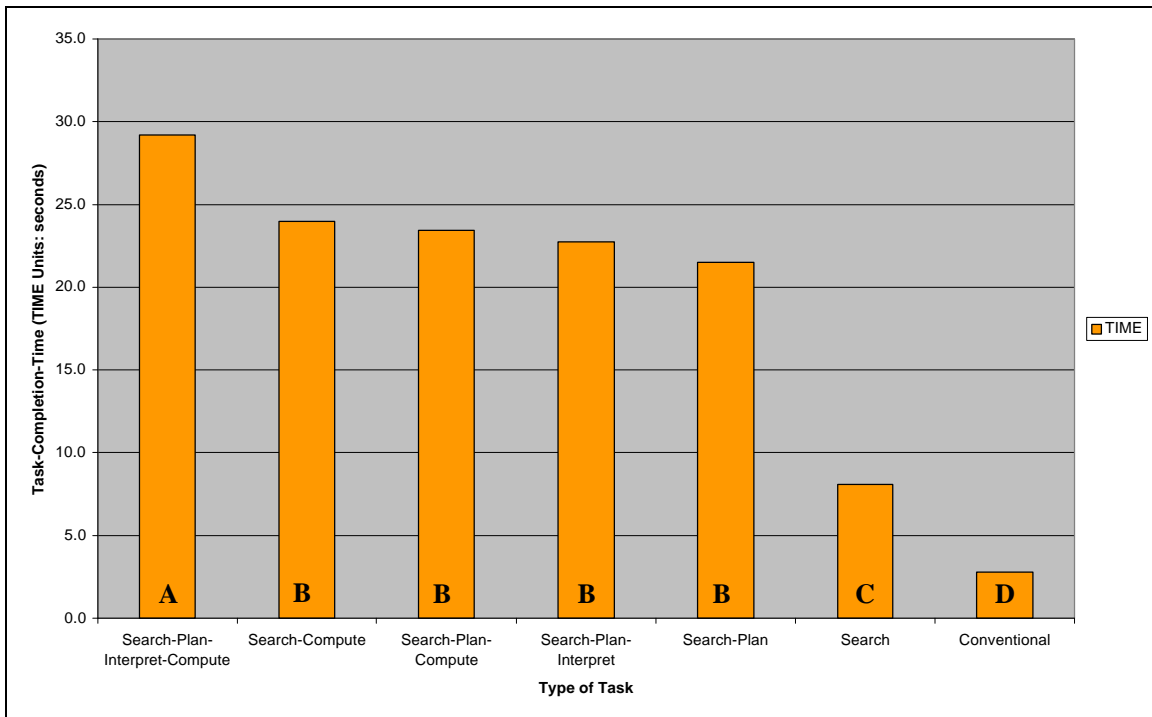
*Figure 5.1 Example of the grouping of the different types of tasks compared to the conventional tasks*
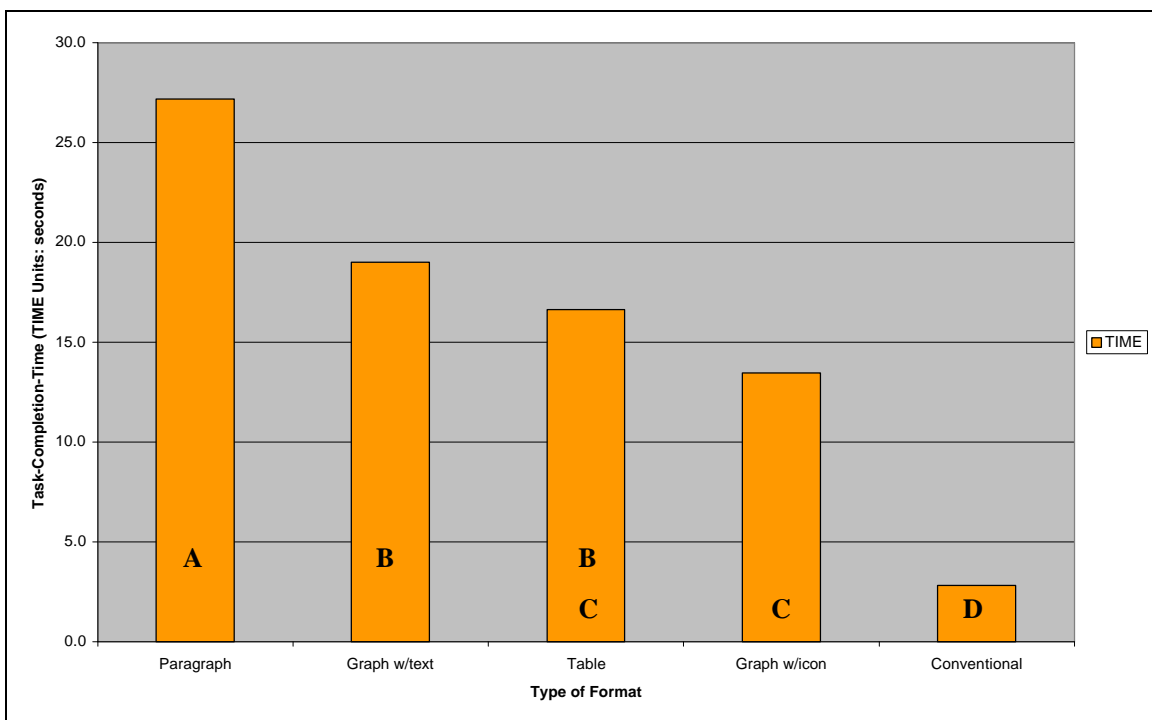
Figure 5.2 Example of the grouping of the different types of format compared to the conventional tasks

83
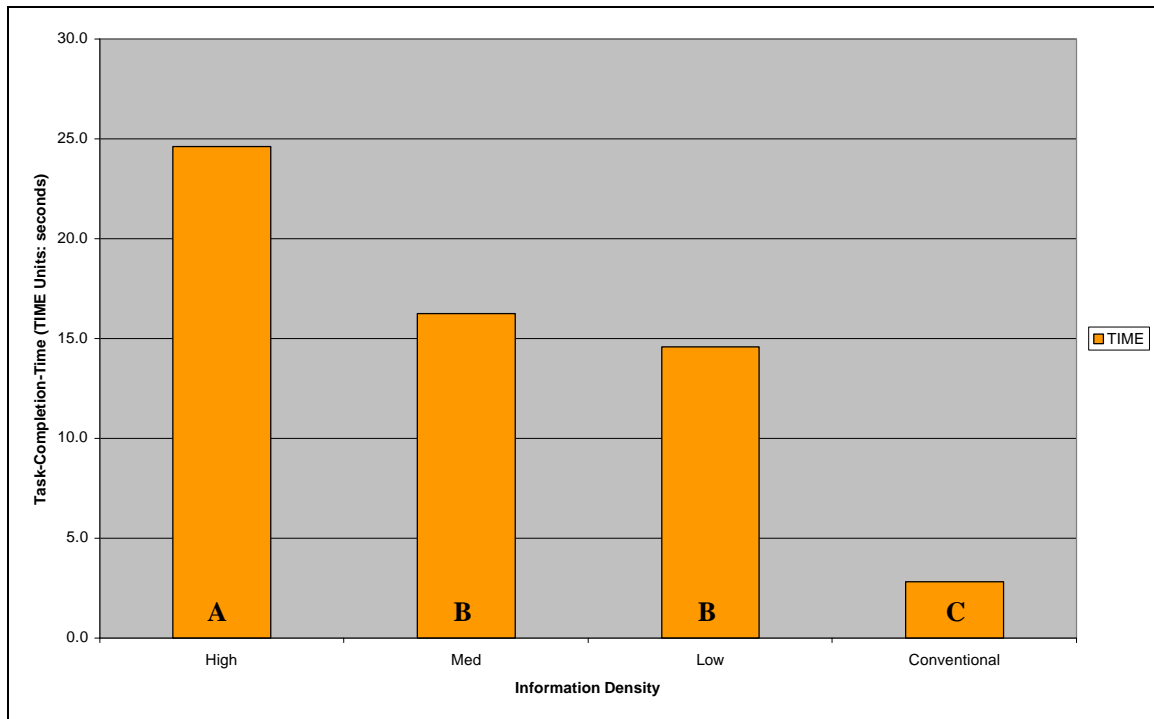
***Figure 5.3 Example of the grouping of the different information densities compared to the
conventional tasks***

In addition, any other combination of task characteristics for IVIS/CVO represents a
high, or even a very high, visual attention demand while driving. Since task-completion-time is
a good surrogate of driving performance, the plot of the three-way interaction of type of task,
type of format, and information density for task-completion-time (see Figure 5.1) represents a
good summary of the results previously discussed. The characteristics of an IVIS/CVO task that
substantially degrade driving performance could be easily identified by comparing the values
presented in Figure 5.4 to the critical value of the "15 second rule" (Society of Automotive
Engineers, 1999) for task-completion-time while driving (i.e. 25.9 seconds). Although the three-
way interactions are non-continuous variables, a line graph was used in order to be able to
represent the interaction of the three factors.
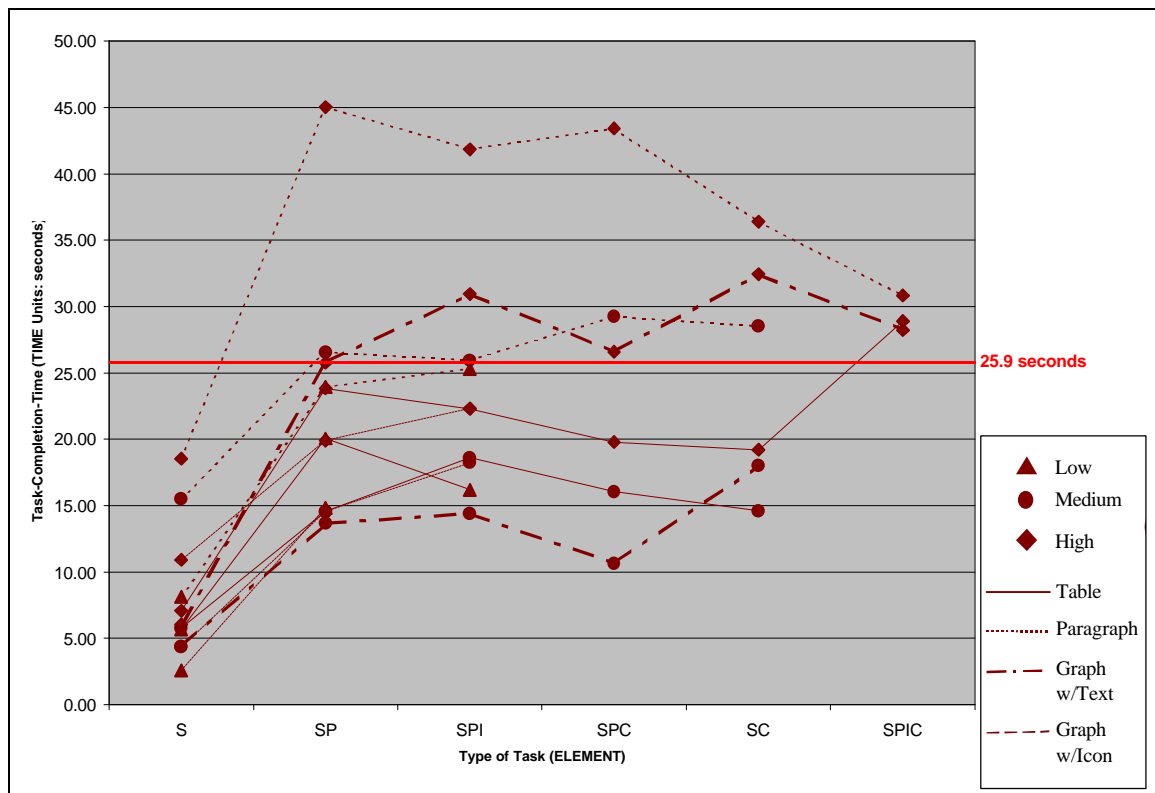
Figure 5.4 Task-Completion-Time for the three-way interaction of type of task, type of format, and information density

A very interesting finding obtained by analyzing the plots for significant interactions (Appendix 10) is that the trend that describes the eye glance behavior used to collect information from the surroundings using the mirrors is affected by the information density and how demanding the task performed is. Tasks that are more difficult required drivers to monitor their surroundings more times than easier tasks in order to compensate for a decrease in situational awareness that these types of tasks tend to create. Although driving performance does not depend on the age of the driver, the situational awareness and the eye scanning behavior vary depending on the age of the driver. Older drivers do not need to scan the environment as often as middle age CVO drivers do in order to feel highly aware of their surroundings.

It is not suggested that all other characteristics besides Graphics with Icons, Search, and Low density must be eliminated from IVIS. However, these characteristics are the ones that describe the IVIS/CVO tasks that should be allowed while the vehicle is in motion.

Several of the analyses demonstrate that the different IVIS/CVO characteristics differed significantly among them in terms of driving performance. However, if the values obtained are

studied carefully, it is apparent that the driving performance itself was not severely changed for some of the measures. This could be partially explained by the population subset studied, which represent experienced CVO drivers that are used to performing several secondary tasks while driving.

Previous research (Farber, Blanco, Curry, Greenberg, Foley, and Serafin, 1999) has demonstrated that there is a high correlation between driving performance and task-completion-time. Farber et al. (1999) empirical demonstration shows that task-completion-time is a good surrogate measure for driving performance as suggested by the Society of Automotive Engineers (1999). The results of several of the analyses performed to evaluate the IVIS/CVO tasks suggest that the relationship suggested by Farber et al. (1999) could be taken one step further. Starting with the assumption that task-completion-time is a good surrogate measure for driving performance, an equation can be created that describes the visual attention demand, in terms of total glance time, based on the task-completion-time. The resultant equation that describes total glance time (TGT) in term of task-completion-time (TIME) is presented as Equation 2. This equation represents a practical assessment of visual attentional demand by only measuring the task-completion-time. Figure 5.5 presents the plot for the line fit for this equation. This equation is valid for a task-completion-time that lies inside the range of 2.6 – 39.6 seconds.

$$TGT = 0.814 + 0.627 * TIME \qquad (R^2 = 0.99) \qquad [EQ.\ 2]$$

Since the typical measures used to measure visual behavior of drivers while performing a task of interest are technically difficult and time consuming to obtain, this equation represents a practical tool for designers and engineers. It is a quick and empirically based estimate of visual attention demand for CVO drivers without requiring the time consuming task of eye glance data reduction.
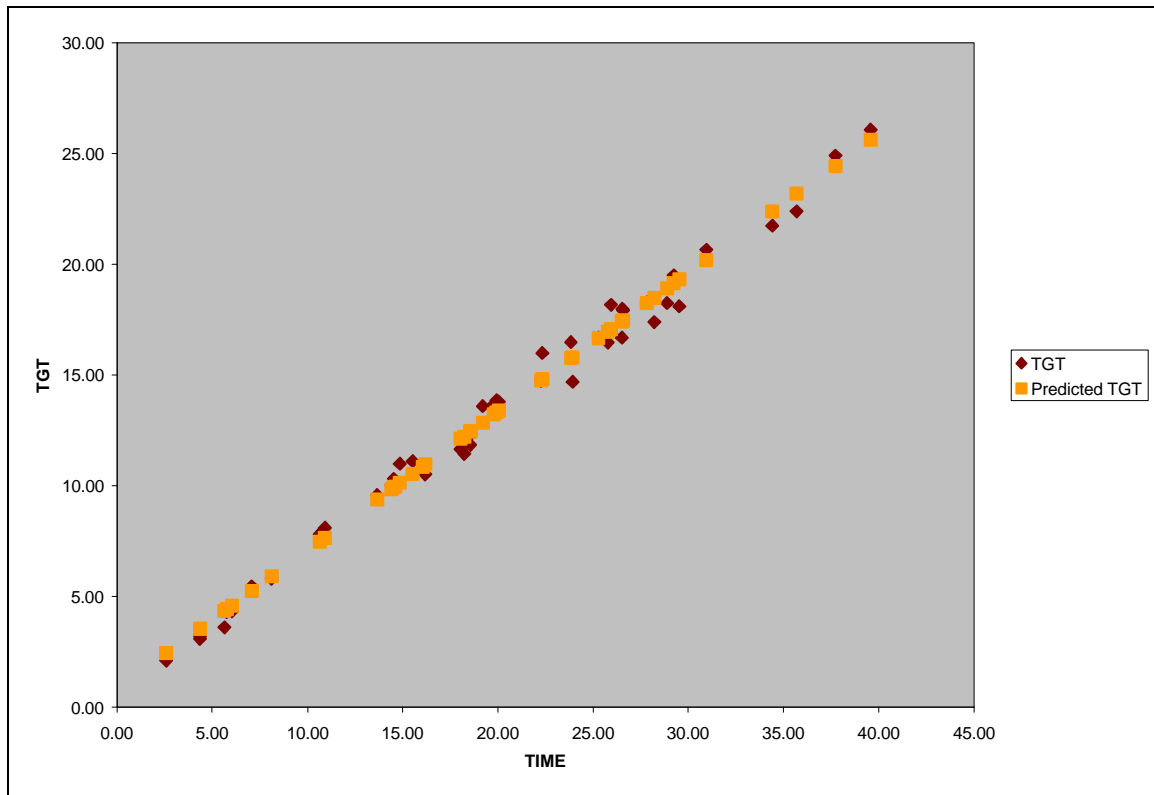
Figure 5.5 Line fit plot for the regression performed for Equation 2

The first and primary objective of this study was to understand and predict red-lines and yellow-lines in terms of the information that the CVO driver can process without hindering the primary task of driving. In order to fulfill the main goal of this study, a summary of the findings is presented in Table 5.1. To create this summary, the results presented in Tables 4.23 and 4.24 were used. Any task that complies with one or more of the criteria used for Red-Lines will appear in the Line Class column in Table 5.1 as a Red. Afterwards, the tasks that reached a Yellow-Line were revised. If a task is not marked as a Red-Line and it has reached a Yellow-Line, the Line Class will be read as Yellow.

The findings of this study, together with the comments from the CVO drivers with respect to the different IVIS tasks, do not limit the options of the designers. On the contrary, they suggest that in-vehicle information systems should take into account the differing information processing capabilities of different driving ability groups by providing a range of levels of information. Ideally, drivers should be able to tailor IVIS to suit their particular needs, the purpose of their trip, and their personal comfort level.

The ranking of attentional demand, the summary table for Red and Yellow-Lines, and the summary tables of performance data (included in Appendix 13) represent a new tool for design and analysis of IVIS/CVO tasks.

Table 5.1 Summary of Red and Yellow-Line characteristics for IVIS/CVO tasks

Type of Display	Type of Task	Density	Task #	Line Class
Table	S	L	401	Yellow
Paragraph	S	L	402	Red
Graph w/icon	S	L	403	
Table	S	M	404	Yellow
Paragraph	S	M	405	Red
Graph w/text	S	M	406	
Graph w/icon	S	M	407	Yellow
Table	S	H	408	Yellow
Paragraph	S	H	409	Yellow
Graph w/text	S	H	410	Yellow
Graph w/icon	S	H	411	
Table	SC	M	421	Yellow
Paragraph	SC	M	422	Red
Graph w/text	SC	M	423	Red
Table	SC	H	424	Red
Paragraph	SC	H	425	Red
Graph w/text	SC	H	426	Red
Table	SP	L	427	Red
Paragraph	SP	L	428	Red
Graph w/icon	SP	L	429	Red
Table	SP	M	430	Yellow
Paragraph	SP	M	431	Red
Graph w/text	SP	M	432	Red
Graph w/icon	SP	M	433	Yellow
Table	SP	H	434	Red
Paragraph	SP	H	435	Red
Graph w/text	SP	H	436	Red
Graph w/icon	SP	H	437	Red
Table	SPC	M	438	Red
Paragraph	SPC	M	439	Red
Graph w/text	SPC	M	440	Red
Table	SPC	H	441	Red
Paragraph	SPC	H	442	Red
Graph w/text	SPC	H	443	Red
Table	SPI	L	444	Red
Paragraph	SPI	L	445	Red
Table	SPI	M	446	Red
Paragraph	SPI	M	447	Red
Graph w/text	SPI	M	448	Yellow
Graph w/icon	SPI	M	449	Red
Table	SPI	H	450	Red
Paragraph	SPI	H	451	Red
Graph w/text	SPI	H	452	Red
Graph w/icon	SPI	H	453	Red
Table	SPIC	H	454	Red
Paragraph	SPIC	H	455	Red
Graph w/text	SPIC	H	456	Red

Chapter 6. CONCLUSION

The market for in-vehicle information systems (IVIS) is expanding rapidly. Permissible navigation systems, functions, and information accessibility while driving are the subject of many discussions for standardization by the International Standard Organization and the Society of Automotive Engineers. The in-vehicle information system tasks evaluated for this study are a good representation of the type of information that is or will be presented in the near future in navigation systems. For example, the Paragraph format is very similar to the traffic messaging systems that will update the driver on real-time about possible delays in their route. Since navigation and route guidance systems are becoming so popular, close attention must be placed on the way in which information is presented in order to minimize the visual attention demand of the driver. Therefore, the following findings and suggestions may be of great help for designers, researchers, and engineers.

6.1 Design Guidelines

The following guidelines are based on the findings of this study. The results strongly suggest that:

- Paragraphs should not be used under any circumstance to present information to the driver while the vehicle is in motion.
- Graphics with Icons represents the most appropriate format in which driving instructions and information related to the route(s) of interest should be presented for IVIS/CVO tasks.
- In order to avoid a high visual attentional demand from the driver due to a secondary task, the IVIS/CVO shall only require a simple Search task from the driver.
- Only the most important information (i.e. "Low" information density) concerning the route(s) shall be presented.

Although the suggested format, type of task, and information density represent a higher visual attention demand than a conventional secondary task (e.g. activating a turn signal, adjusting an A/C vent, adjusting a power mirror, monitoring vehicle speed, or monitoring the

fuel level of the vehicle) these characteristics seem to bind a task with a moderate attentional demand. Other combinations of format, type of task, and information density will cause an increase in the driver's attentional demand that will consequently deteriorate their driving performance causing unsafe driving situations.

6.2 Surrogate Assessment of Visual Attentional Demand

As presented in the discussion section, this study also provides human-machine interface designers and engineers with a tool to translate task-completion-time (TIME) to visual attention demand in terms of total glance time (TGT). Please refer to the Discussion section for details of the equation used for this purpose (see Equation 2).

A new tool for visual attentional demand assessment of IVIS/CVO is provided by the following procedure:

- Measuring the task-completion-time of the IVIS/CVO task
- Using the equation: $TGT = 0.814 + 0.627 * TIME$
- Applying the criteria presented by Dingus (1987) to translate the results to the appropriate level of attention demand (see Table 3.9).

6.3 Future Research Implications

The gap in the literature that served as a motivation for this research has been partially filled, since a large amount of the driving behavior modification resulting from IVIS/CVO tasks has been addressed by the results obtained. However, future research implications stem out of these findings. One of the research implications for this matter is to find if the attention demand for the CVO driver will vary if the information is presented to drivers in the form of spoken directions with a computerized map available for reference. In the same line of thought lies the need to create an algorithm that will optimize, in terms of safety and efficiency, the type of format used to display the information to the driver based on the type of task and the information density.

All of the participants of this research were experienced CVO drivers. Therefore, several of the measures related to performance, although significant, do not represent great amount of change in driving performance. This might be different if new CVO drivers performed the tasks.

In addition, the change in attention demands can be studied for IVIS/CVO tasks where the driver sets their preferences for the parameters that define a given display, versus using pre-set displays like the ones utilized in this research.

This type of research, which evaluates new IVIS/CVO systems, could have a novelty effect as a confounded factor. This effect can be studied in order to determine if part of the decrease in attention demand is explained by this effect, or if simply IVIS/CVO tasks tend to have higher attention demands due to the nature of the task itself.

Some additional information can be obtained if the current research is combined with other investigations. For example, the CVO conventional tasks can be compared to automotive conventional task data (Dingus, 1987), and IVIS/CVO tasks can be compared with automotive IVIS task data (Gallagher, 1999) in order to create a "CVO Modifier" to translate other existing automotive task data to CVO task data. More extensive research should be performed in order to identify specific information needs, develop effective guidance for designers of IVIS, and determining the best method to present information to CVO drivers.

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APPENDICES

```
                Route  Planning
          Route                    Delay


          I-90,
          I-25                     Construction

          I-80,
          I-76                     None

          I-29,
          US-Rte. 20               Accident
```
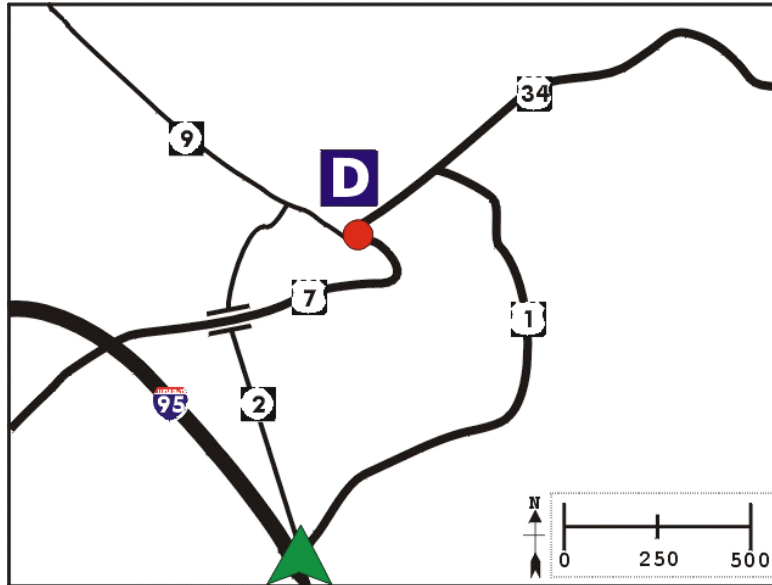
- **Instruction:** *Which route has no delay?* [Task # 401]
- **Format:** *Table*
- **Information Density:** *Low* (2 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type* and *Delay*
- **Type of Task:** *Search*

```
            Route  Planning



        I-90, I-25 has a weigh station.

        I-80, I-76 has an accident

        delay. I-29, US-Rte. 20 has no

        delay.
```

- **Instruction:** *Which route has no delay?* [Task # 402]
- **Format:** *Paragraph*
- **Information Density:** *Low* (2 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type* and *Delay*
- **Type of Task:** *Search*

- **Instruction:** *Is there an Interstate 95 on the map?* [Task # 403]
    Select a route to the delivery destination. [Task # 429]
- **Format:** *Graphics with icons*
- **Information Density:** *Low* (2 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type* and *Distance*
- **Type of Task:** *Search* [Task # 403], *Search-Plan* [Task # 429]


Route Planning

Route	Delay	Restriction
I-95, I-87	Construction	Height-13'6"
I-81, I-88	Accident	25 TON
US-Rte. 1, US-Rte. 9	Railroad	Radioactive

- **Instruction:** *Which route has a construction delay?* [Task # 404]
- **Format:** *Table*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type, Delay* and *Restriction*
- **Type of Task:** *Search*

Route Planning

I-95, US-Rte. 33 has a construction delay, and has a 13'6" height restriction. US-Rte. 9, US-Rte. 278 has an accident delay, and has a radioactive cargo restriction. US-Rte. 32, I-490 has a railroad delay, and has no restrictions.

- **Instruction:** *Which route has no restrictions?* [Task # 405]
- **Format:** *Paragraph*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Delay* and *Restriction*
- **Type of Task:** *Search*
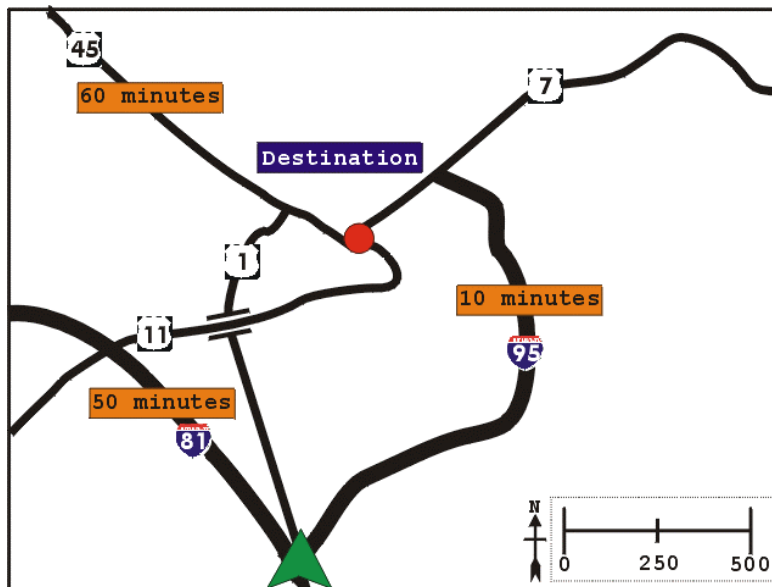
- **Instruction:** *Which roadway has a 10 min delay?* [Task # 406]
      Select a route to the delivery destination. [Task # 432]
- **Format:** *Graphics with text*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Distance* and *Delay*
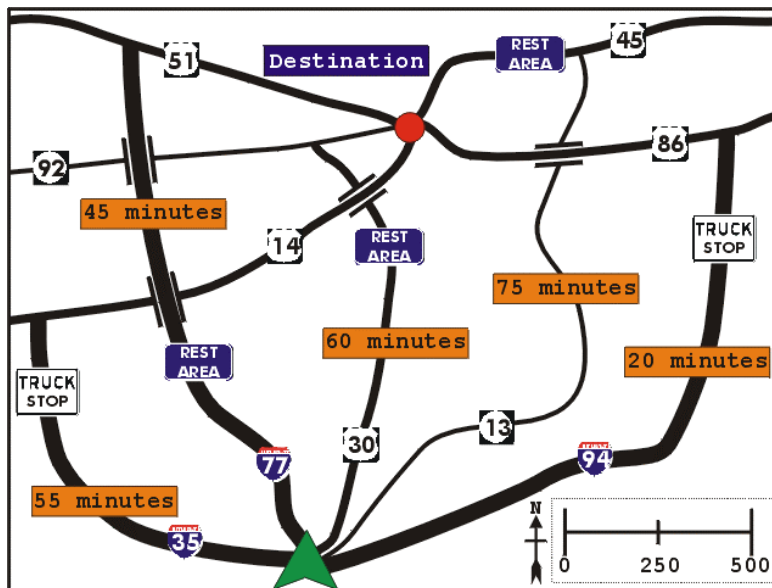- **Type of Task:** *Search* [Task # 406]*, Search-Plan* [Task # 432]
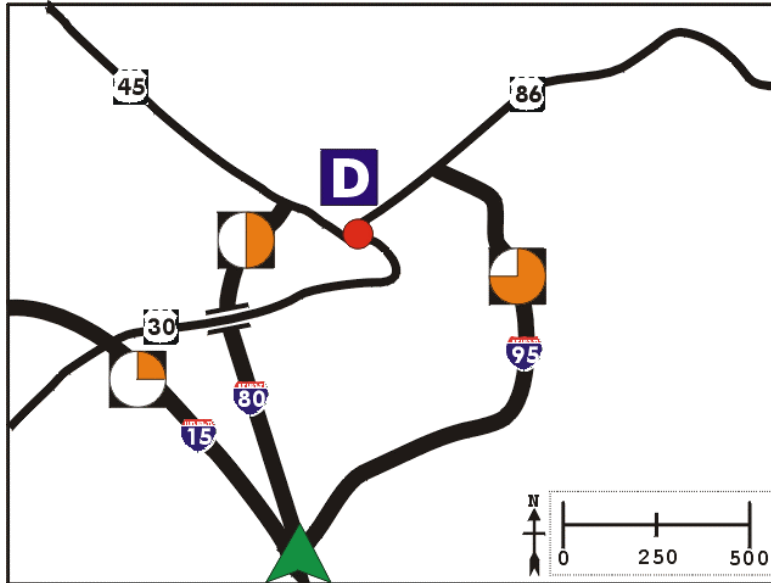
- **Instruction:** *Which roadway has a 15 min delay?* [Task # 407]
        Select a route to the delivery destination. [Task # 433]
- **Format:** *Graphics with icons*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type, Distance* and *Delay*
- **Type of Task:** *Search* [Task # 407], *Search-Plan* [Task # 433]

Route	Distance	Delay	Rest Area / Truck Stop
I-70, US-Rte. 38	678 miles	Accident	Truck
US-Rte. 34, US-Rte. 30	564 miles	Railroad	Rest
Hwy. 92, US-Rte. 24	681 miles	School crossing	Rest
US-Rte. 6, US-Rte. 28	675 miles	Construction	Rest
Hwy. 33, US-Rte. 28	592 miles	Farm machinery	Rest

Route Planning

- **Instruction:** *Which route has a school crossing delay?* [Task # 408]
- **Format:** *Table*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
    - **Categories of Information Used:** *Road Type, Distance, Delay* and *Rest Areas/Truck Stops*
- **Type of Task:** *Search*

Route Planning

I-43, US-Rte. 45 is 325 miles, has a
drawbridge delay, and has a rest area. I-
94, US-Rte. 8 is 422 miles, has an accident
delay, and has a truck stop. I-94, Hwy. 13
is 295 miles, has no delay, and has a truck
stop. I-90, US-Rte. 51 is 350 miles, has a
construction delay, and has a rest area.
I-90, Hwy. 13 is 276 miles, has a
construction delay, and has a rest area.

- **Instruction:** *Which route has no delay?* [Task # 409]
- **Format:** *Paragraph*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Delay* and *Rest Areas/Truck Stops*
- **Type of Task:** *Search*

- **Instruction:** *Which roadway has a 45 min delay?* [Task # 410]
  Select a route to the delivery destination. [Task # 436]
- **Format:** *Graphics with text*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Delay* and *Rest Areas/Truck Stops*
- **Type of Task:** *Search* [Task # 410], *Search-Plan* [Task # 436]
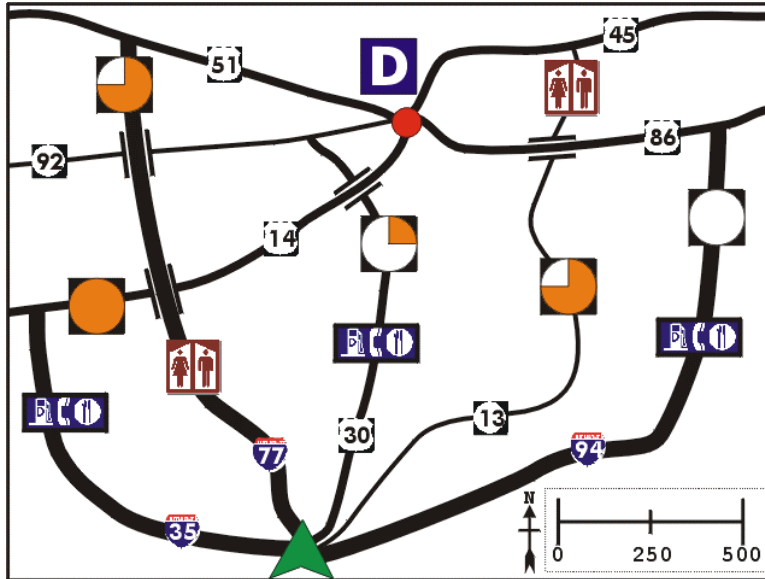
- **Instruction:** *Which roadway has no delay?* [Task # 411]
    Select a route to the delivery destination. [Task # 437]
- **Format:** *Graphics with icons*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
    - **Categories of Information Used:** *Road Type, Distance, Delay* and *Rest Areas/Truck Stops*
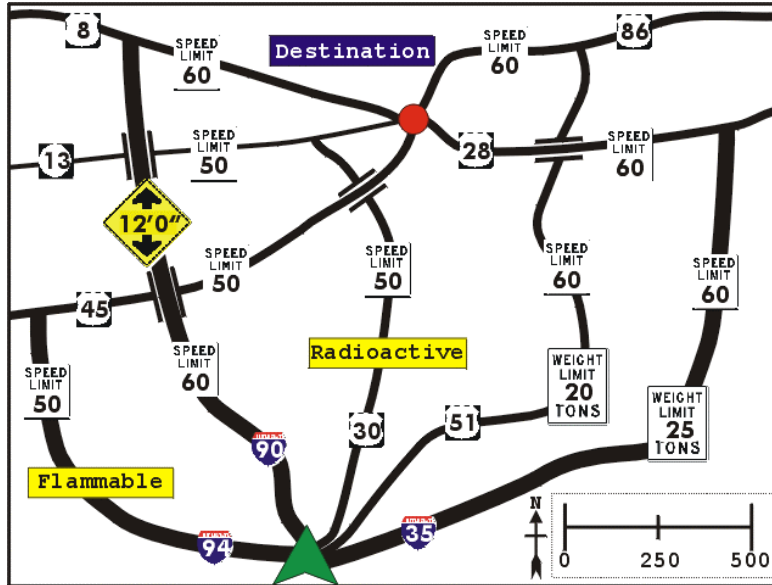- **Type of Task:** *Search* [Task # 411]*, Search-Plan* [Task # 437]

- **Instruction:** *Select the quickest route to the delivery destination.* [Task # 421]
- **Format:** *Table*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type, Distance* and *Speed Limit*
- **Type of Task:** *Search-Compute*

Route Planning

US-Rte. 1, I-87 is 165 miles, and has a 55 mph speed limit. I-81, US-Rte. 11 is 240 miles, and has a 60 mph speed limit. I-95, I-91 is 260 miles, and has a 65 mph speed limit.

- **Instruction:** *Select the quickest route to the delivery destination.* [Task # 422]
- **Format:** *Paragraph*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type, Distance* and *Speed Limit*
- **Type of Task:** *Search-Compute*
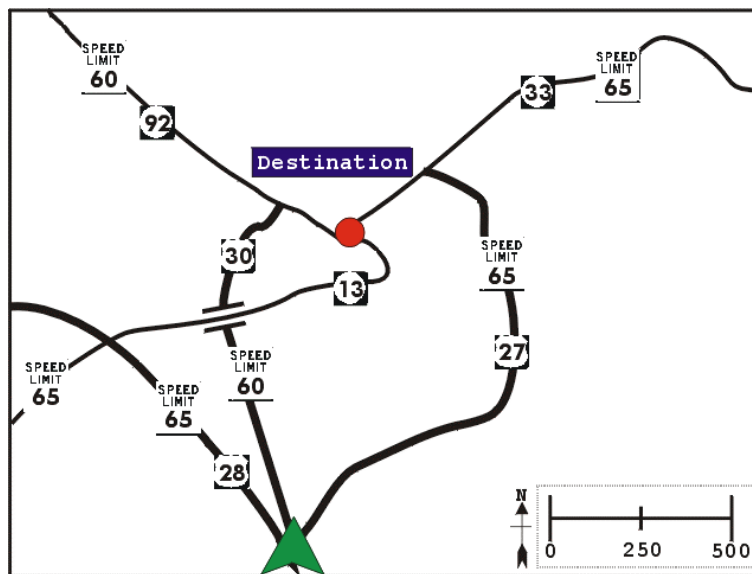
- **Instruction:** *Select the quickest route to the delivery destination.* [Task # 423]
- **Format:** *Graphics with Text*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type, Distance* and *Speed Limit*
- **Type of Task:** *Search-Compute*

Route Planning

Route	Distance	Restriction	Speed Limit
US-Rte. 1, I-87	220 miles	16 TON	55 mph
I-81, Hwy. 37	260 miles	Height-12'	65 mph
I-95, US-Rte. 7	210 miles	25 TON	70 mph
I-81, US-Rte. 11	240 miles	20 TON	60 mph
US-Rte. 1, US-Rte. 7	220 miles	None	55 mph

- **Instruction:** *Select the quickest route to the delivery destination.* [Task # 424]
- **Format:** *Table*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Restriction, and Speed Limit*
- **Type of Task:** *Search-Compute*

Route Planning

US-Rte. 1, I-87 is 220 miles, has a flammable material restriction, and has a 55 mph speed limit. I-81, Hwy. 37 is 210 miles, has no restrictions, and has a 70 mph speed limit. I-95, US-Rte. 7 is 260 miles, has 12' height restriction, and has a 65 mph speed limit. I-81, US-Rte. 11 is 240 miles, has 20 TON weigh restriction, and has a 60 mph speed limit. US-Rte. 1, US-Rte. 7 is 220 miles, has a radioactive materials restriction, and has a 55 mph speed limit.

- **Instruction:** *Select the quickest route to the delivery destination.* [Task # 425]
- **Format:** *Paragraph*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Restriction, and Speed Limit*
- **Type of Task:** *Search-Compute*

- **Instruction:** *Select the quickest route to the delivery destination.* [Task # 426]
- **Format:** *Graphics with text*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
    - **Categories of Information Used:** *Road Type, Distance, Restriction,* and *Speed Limit*
- **Type of Task:** *Search-Compute*

- **Instruction:** *Select a route to the delivery destination.* [Task # 427]
- **Format:** *Table*
- **Information Density:** *Low* (2 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type* and *Distance*
- **Type of Task:** *Search-Plan*

```
              Route Planning


      US-Rte. 1, I-87 is 748 miles.  I-81,

      Hwy. 37 is 890 miles.  I-95, US-Rte. 7

      is 695 miles.
```

- **Instruction:** *Select a route to the delivery destination.* [Task # 428]
- **Format:** *Paragraph*
- **Information Density:** *Low* (2 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type* and *Distance*
- **Type of Task:** *Search-Plan*

```
              Route Planning
      Route          Distance           Delay

      I-95,
      US-Rte. 7      210 miles          10 minutes

      Hwy. 2,
      Hwy. 9         240 miles          50 minutes

      US-Rte. 1,
      US-Rte. 7      220 miles          60 minutes
```

- **Instruction:** *Select a route to the delivery destination.* [Task # 430]
- **Format:** *Table*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type, Distance* and *Delay*
- **Type of Task:** *Search-Plan*

Route Planning

```
I-15, US-Rte. 30 is 256 miles, and has a
60 minute delay.  I-80, US-Rte. 30 is
215 miles, and has a 5 minute delay.
I-15, US-Rte. 86 is 198 miles, and has a
45 minute delay.
```

- **Instruction:** *Select a route to the delivery destination.* [Task # 431]
- **Format:** *Paragraph*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Distance* and *Delay*
- **Type of Task:** *Search-Plan*

Route Planning

Route	Distance	Rest Area / Truck Stop	Delay
I-43, US-Rte. 45	750 miles	Truck	55 minutes
I-94, US-Rte. 8	620 miles	None	45 minutes
I-94, Hwy. 13	525 miles	Truck	None
I-90, US-Rte. 51	595 miles	Rest	60 minutes
I-77, Hwy. 13	676 miles	Rest	15 minutes

- **Instruction:** *Select a route to the delivery destination.* [Task # 434]
- **Format:** *Table*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Delay* and *Rest Areas/Truck Stops*
- **Type of Task:** *Search-Plan*

```
                Route Planning

I-35, US-Rte. 14 is 770 miles, has a rest area, and

has a 55 minute delay.  I-29, US-Rte. 81 is 612

miles, has a truck stop, and has a 15 minute delay.

US-Rte. 59, Hwy. 9 is 785 miles, has no rest areas

or truck stops, and has a 10 minute delay.  US-Rte.

77, US-Rte. 14 is 895 miles, has a rest areas, and

has a 60 minute delay.  US-Rte. 75, Hwy. 9 is 702

miles, has a rest areas, and has 15 minute delay.
```

- **Instruction:** *Select a route to the delivery destination.* [Task # 435]
- **Format:** *Paragraph*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Delay* and *Rest Areas/Truck Stops*
- **Type of Task:** *Search-Plan*

```
              Route Planning
     Route          Distance        Speed Limit

   I-81,
   Hwy. 37         260 miles         65 mph

   I-95,
   US-Rte. 7       210 miles         70 mph

   I-87,
   US-Rte. 11      240 miles         60 mph
```
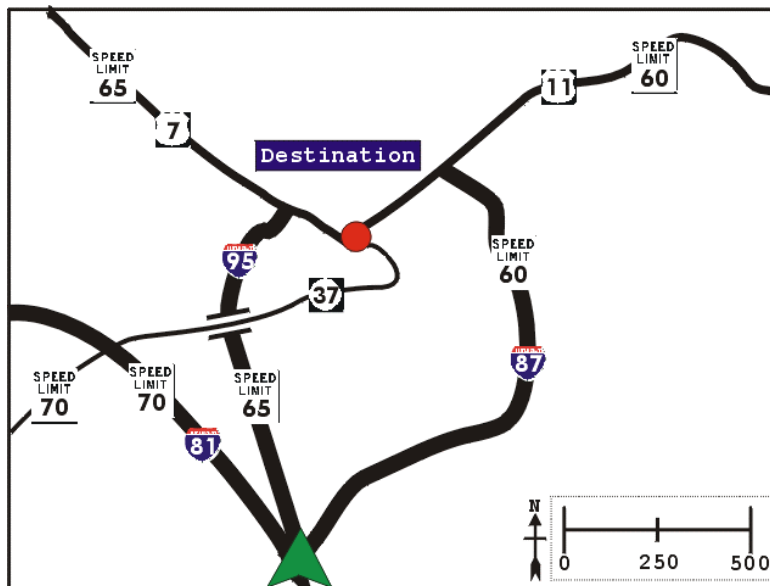
- **Instruction:** *Select a route to the delivery destination.* [Task # 438]
- **Format:** *Table*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Distance* and *Speed Limit*
- **Type of Task:** *Search-Plan-Compute*

Route Planning

I-94, Hwy. 13 is 210 miles, and has 70
mph speed limit. I-90, US-Rte. 51 is
260 miles, and has a 65 mph speed limit.
I-77, Hwy.13 is 240 miles, and has a 60
mph speed limit.

- **Instruction:** *Select a route to the delivery destination.* [Task # 439]
- **Format:** *Paragraph*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Distance* and *Speed Limit*
- **Type of Task:** *Search-Plan-Compute*

- **Instruction:** *Select a route to the delivery destination.* [Task # 440]
- **Format:** *Graphics with text*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Distance* and *Speed Limit*
- **Type of Task:** *Search-Plan-Compute*

```
              Route Planning
    Route      Distance      Restriction       Speed
                                               Limit

  US-Rte. 1,
  I-87         165 miles     16 TON            55 mph

  I-81,
  Hwy. 37      260 miles     20 TON            65 mph

  I-95,
  US-Rte. 7    210 miles     Flammable         70 mph

  I-81,
  US-Rte. 11   240 miles     Radioactive       60 mph

  US-Rte. 1,
  US-Rte. 7    220 miles     Width-11'         55 mph
```
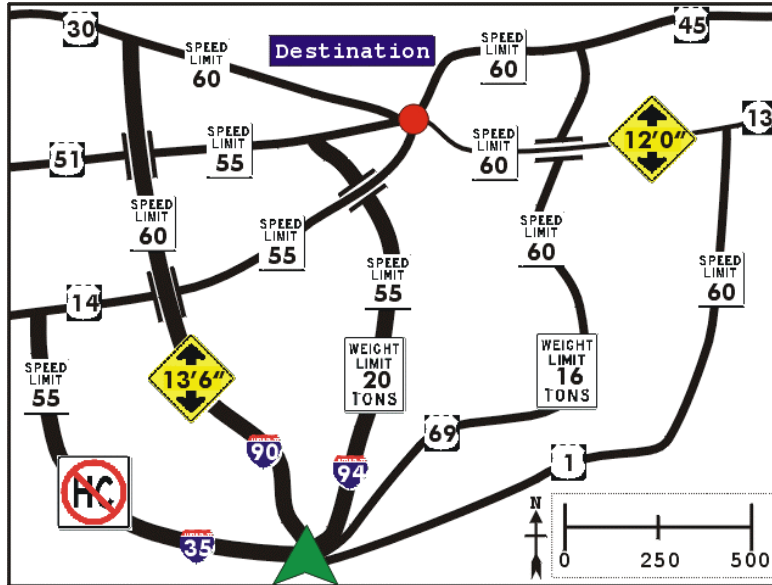
- **Instruction:** *Select a route to the delivery destination.* [Task # 441]
- **Format:** *Table*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Restriction* and *Speed Limit*
- **Type of Task:** *Search-Plan-Compute*

```
            Route Planning

  US-Rte. 1, I-87 is 220 miles, has a biohazardous
  materials restriction, and has a 55 mph speed
  limit.  I-81, Hwy. 37 is 210 miles, has a 25 TON
  restriction, and has a 70 mph speed limit.  I-95,
  US-Rte. 7 is 195 miles, has no restriction, and
  has a 65 mph speed limit.  I-81, US-Rte. 11 is 240
  miles, has 20 TON restriction, and has a 60 mph
  speed limit.  US-Rte. 1, US-Rte. 7 is 220 miles,
  has a 12' height restriction, and has a 55 mph
  speed limit.
```

- **Instruction:** *Select a route to the delivery destination.* [Task # 442]
- **Format:** *Paragraph*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Restriction* and *Speed Limit*
- **Type of Task:** *Search-Plan-Compute*

- **Instruction:** *Select a route to the delivery destination.* [Task # 443]
- **Format:** *Graphics with text*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
    - **Categories of Information Used:** *Road Type, Distance, Restriction* and *Speed Limit*
- **Type of Task:** *Search-Plan-Compute*

Route	Delay
I-90, I-25	Construction
I-80, I-76	Drawbridge
I-29, US-Rte. 20	Accident

- **Instruction:** *Select a route to the delivery destination.* [Task # 444]
- **Format:** *Table*
- **Information Density:** *Low* (2 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*

```
              Route Planning

        US-Rte. 38, Hwy. 27 has a railroad
        delay.  Hwy. 92, US-Rte. 24 has a bike
        race delay.  Hwy. 33, US-Rte. 28 has a
        school crossing delay.
```

- **Instruction:** *Select a route to the delivery destination.* [Task # 445]
- **Format:** *Paragraph*
- **Information Density:** *Low* (2 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*

```
              Route Planning
     Route          Lanes            Delay
                     Closed

   US-Rte. 38,
   Hwy. 27         2 of 2          Railroad

   Hwy. 92,
   US-Rte. 24      1 of 1          Construction

   Hwy. 33,
   US-Rte. 28      1 of 2          Bike race
```

- **Instruction:** *Select a route to the delivery destination.* [Task # 446]
- **Format:** *Table*
- **Information Density:** Medium (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Lane Closed* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*

Route Planning

I-15, US-Rte. 30 has 2 of 2 lanes
closed, and has an accident delay. I-
80, US-Rte. 30 has 1 of 2 lanes closed,
and has a construction delay. I-45, US-
Rte. 86 has 2 of 2 lanes closed, and has
a drawbridge delay.

- **Instruction:** *Select a route to the delivery destination.* [Task # 447]
- **Format:** *Paragraph*
- **Information Density:** Medium (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Lane Closed* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*
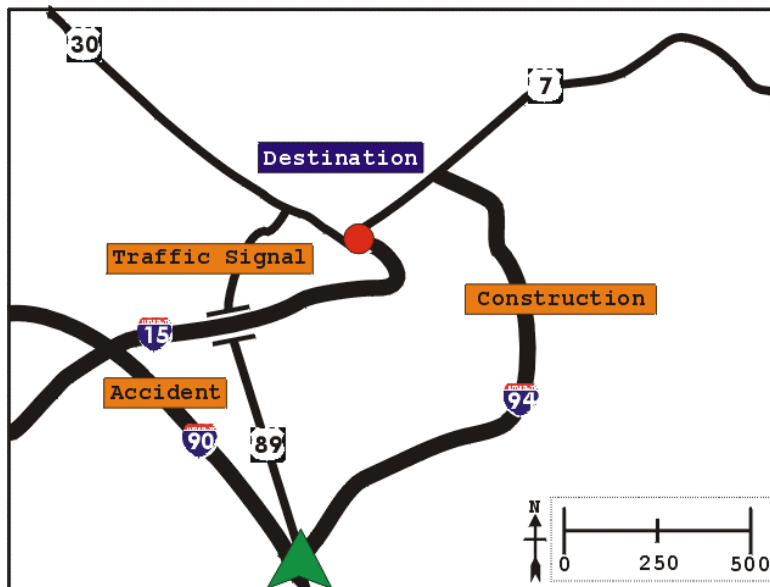
- **Instruction:** *Select a route to the delivery destination.* [Task # 448]
- **Format:** *Graphics with text*
- **Information Density:** Medium (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Distance* and *Delay*
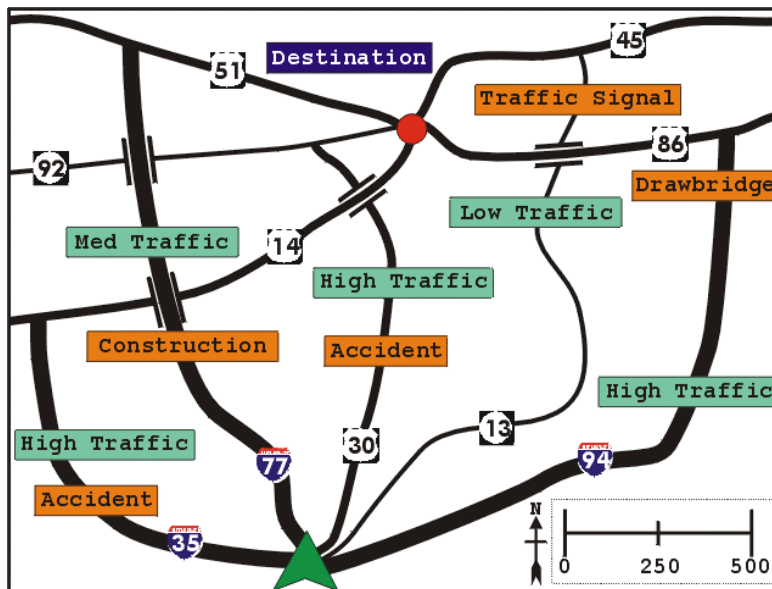- **Type of Task:** *Search-Plan-Interpret*
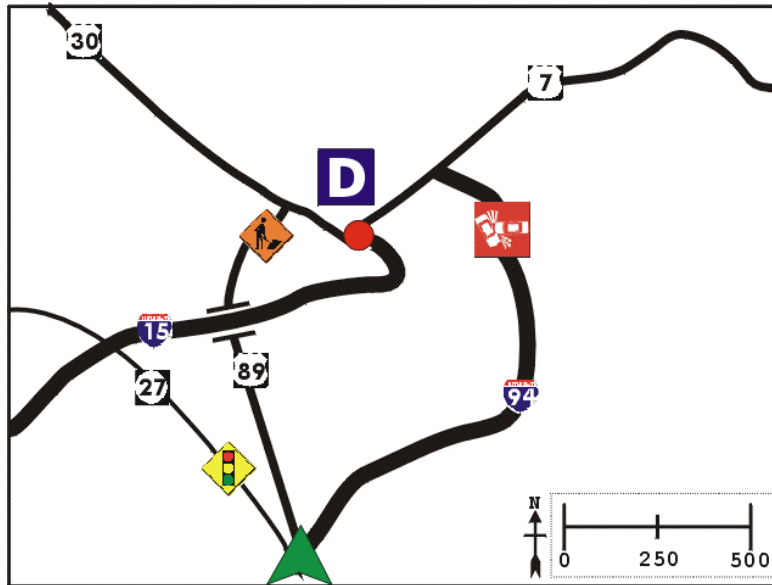
- **Instruction:** *Select a route to the delivery destination.* [Task # 449]
- **Format:** *Graphics with icons*
- **Information Density:** Medium (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type, Distance* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*

- **Instruction:** *Select a route to the delivery destination.* [Task # 450]
- **Format:** *Table*
- **Information Density:** High (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Lane Closed, Traffic Density* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*

Route Planning

I-35, US-Rte. 14 has 2 of 2 lanes closed, has an accident delay, and has a high traffic density. I-29, US-Rte. 81 has 1 of 2 lanes closed, has a construction delay, and has a medium traffic density. US-Rte. 59, Hwy. 9 has 1 of 2 lanes closed, has bike race delay, and has a low traffic density. US-Rte. 77, US-Rte. 14 has 2 of 2 lanes closed, has an accident delay, and has a high traffic density. US-Rte. 75, Hwy. 9 has 2 of 2 lanes closed, has a drawbridge delay, and has a high traffic density.

- **Instruction:** *Select a route to the delivery destination.* [Task # 451]
- **Format:** *Paragraph*
- **Information Density:** High (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Lane Closed, Traffic Density* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*

- **Instruction:** *Select a route to the delivery destination.* [Task # 452]
- **Format:** *Graphics with text*
- **Information Density:** High (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Traffic Density* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*
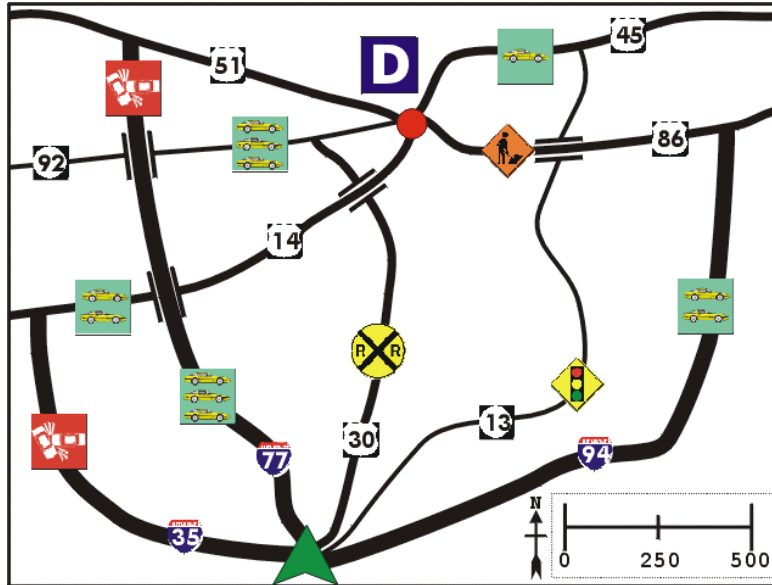
- **Instruction:** *Select a route to the delivery destination.* [Task # 453]
- **Format:** *Graphics with icons*
- **Information Density:** High (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Traffic Density* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*

Route Planning

Route	Distance	Speed Limit	Delay
US-Rte. 70, I-5	240 miles	60 mph	Traffic signal
US-Rte. 20, Hwy. 49	180 miles	60 mph	Funeral procession
I-80, I-5	280 miles	70 mph	Accident
Hwy. 16, Hwy. 33	250 miles	50 mph	Bike race
Hwy. 65, I-5	300 miles	50 mph	School crossing

- **Instruction:** *Select a route to the delivery destination.* [Task # 454]
- **Format:** *Table*
- **Information Density:** High (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Speed Limit* and *Delay*
- **Type of Task:** *Search-Plan-Interpret-Compute*

Route Planning

I-35, US-Rte. 14 is 210 miles, has a 70 mph speed limit, and has no delay. I-29, US-Rte. 81 is 280 miles, has a 70 mph speed limit, and has a construction delay. US-Rte. 59, Hwy. 9 is 180 miles, has a 60 mph speed limit, and has an accident delay. US-Rte. 77, US-Rte. 14 is 300 miles, has a 60 mph speed limit, and has an accident delay. US-Rte. 75, Hwy. 9 is 240 miles, has a 60 mph speed limit, and has a drawbridge delay.

- **Instruction:** *Select a route to the delivery destination.* [Task # 455]
- **Format:** *Paragraph*
- **Information Density:** High (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Speed Limit* and *Delay*
- **Type of Task:** *Search-Plan-Interpret-Compute*
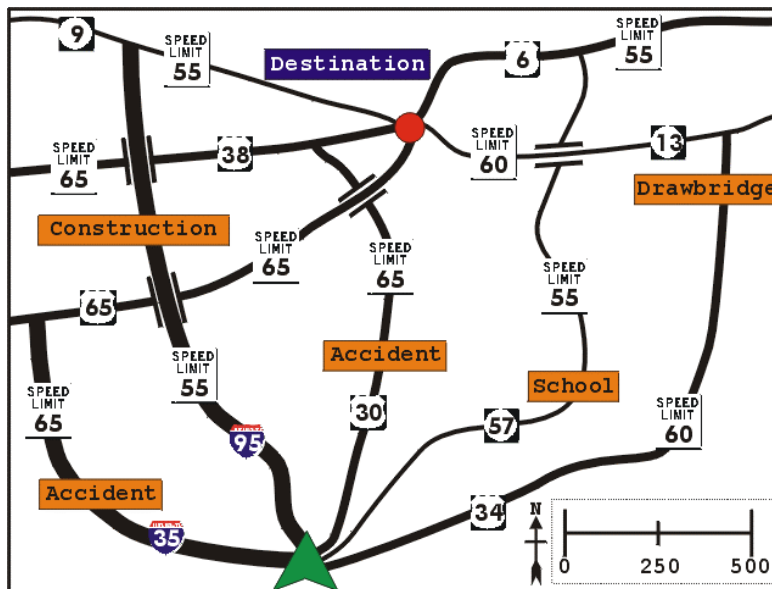
- **Instruction:** *Select a route to the delivery destination.* [Task # 456]
- **Format:** *Graphics with text*
- **Information Density:** High (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Speed Limit* and *Delay*
- **Type of Task:** *Search-Plan-Interpret-Compute*

Schedule

- What is IVIS/CVO? (5min)
- Informed Consent (5 min)
- Driving License Verification
- Health Screening Questionnaire (5 min)
- Vision Test (5 min)
- Lab Training (30 min)
- Truck Training/Familiarization (15)
- Hearing Test (5 min)
- IVIS/CVO Study (2.5 - 3 hrs)

Virginia Tech
Virginia Polytechnic Institute and State University

What is IVIS/CVO study?

- Purpose of the study
- Why your help is so important?
- Vehicle
  - Display
  - Tasks
  - Data Collection
- Scenario
  - U.S. Highway 460 between Blacksburg, Virginia and West Virginia
  - Vehicle-following situation
  - Day time, Good weather
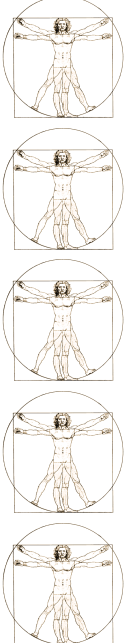
Virginia Tech
Virginia Polytechnic Institute and State University

Schedule

- What is IVIS/CVO? (5min)
- Informed Consent (5 min)
- Driving License Verification
- Health Screening Questionnaire (5 min)
- Vision Test (5 min)
- Lab Training (30 min)
- Truck Training/Familiarization (15)
- Hearing Test (5 min)
- IVIS/CVO Study (2.5 - 3 hrs)

Virginia Tech
Virginia Polytechnic Institute and State University

Lab Training

IVIS CVO

Virginia Tech
Virginia Polytechnic Institute and State University

IVIS/CVO Display
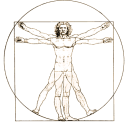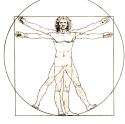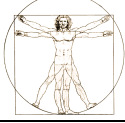
Formats

- Text
  - Tables
  - Paragraphs
- Graphics
  - Maps with text
  - Maps with icons

Type of Information
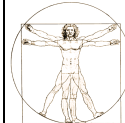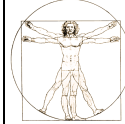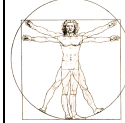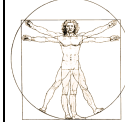
- Routes
  - Road Type
  - Distance
  - Speed Limit
- Delays
- Lanes Closed
- Rest Areas/Truck Stop
- Restrictions
- Traffic Congestion

Tables & Paragraphs

- Routes
  - Road Type (i.e. Interstate, US-Rte., or Hwy.)
  - Distance (i.e. 795 miles)
  - Speed Limit (i.e. 70 mph)
- Rest Areas/Truck Stop
  - Availability on route (Truck or Rest)
- Restrictions
  - Material Hauled (i.e. flammable,radioactive, etc.)
  - Height, Weigh, Width
- Traffic Congestion
  - Low, Med or High

- Delays
  - Construction
  - Weight Station
  - Accident
  - Railroad crossing
  - Bike race
  - Funeral procession
  - School crossing
  - Farm machinery
  - Drawbridge
  - Traffic Signal
  - 10 minutes
- Lanes Closed
  - 1 of 2
  - 2 of 2
  - 1 of 1

Table Example:

Route Planning

Route	Distance	Restriction	Speed Limit
US-Rte. 1, I-87	165 miles	16 TON	55 mph
I-81, Hwy. 37	260 miles	20 TON	65 mph
I-95, US-Rte. 7	210 miles	Flammable	70 mph
I-81, US-Rte. 11	240 miles	Radioactive	60 mph
US-Rte. 1, US-Rte. 7	220 miles	Width-11'	55 mph

Paragraph Example:

Route Planning

I-35, US-Rte. 14 is 770 miles, has a rest area, and has a 55 minute delay. I-29, US-Rte. 81 is 612 miles, has a truck stop, and has a 15 minute delay. US-Rte. 59, Hwy. 9 is 785 miles, has no rest areas or truck stops, and has a 10 minute delay. US-Rte. 77, US-Rte. 14 is 895 miles, has a rest areas, and has a 60 minute delay. US-Rte. 75, Hwy. 9 is 702 miles, has a rest areas, and has 15 minute delay.
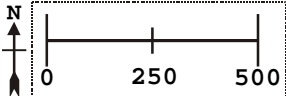
Graphics with Icons

- **Roadways**

Interstate	US Route	State Highway

- **Route Number**

Interstate	US Route	State Highway

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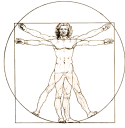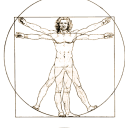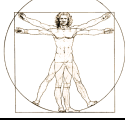
Graphics with Icons (cont.)

- **Distance**

N
0   250   500

- **Location**

- **Delivery Destination**

D

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Graphics with Icons (cont.)

- Delays

Construction Work	Accident	Railroad Crossing	Traffic Light	School Crossing
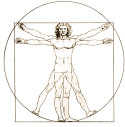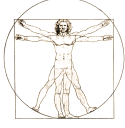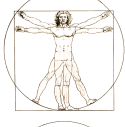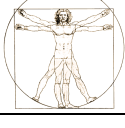
No Delay	15 Minute Delay	30 Minute Delay	45 Minute Delay	60 Minute Delay

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Graphics with Icons (cont.)

- Rest Area/Truck Stop

Rest Area	Truck Stop

- Traffic Density

Low Traffic Density	Medium Traffic Density	High Traffic Density

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Graphics with Icons Example:
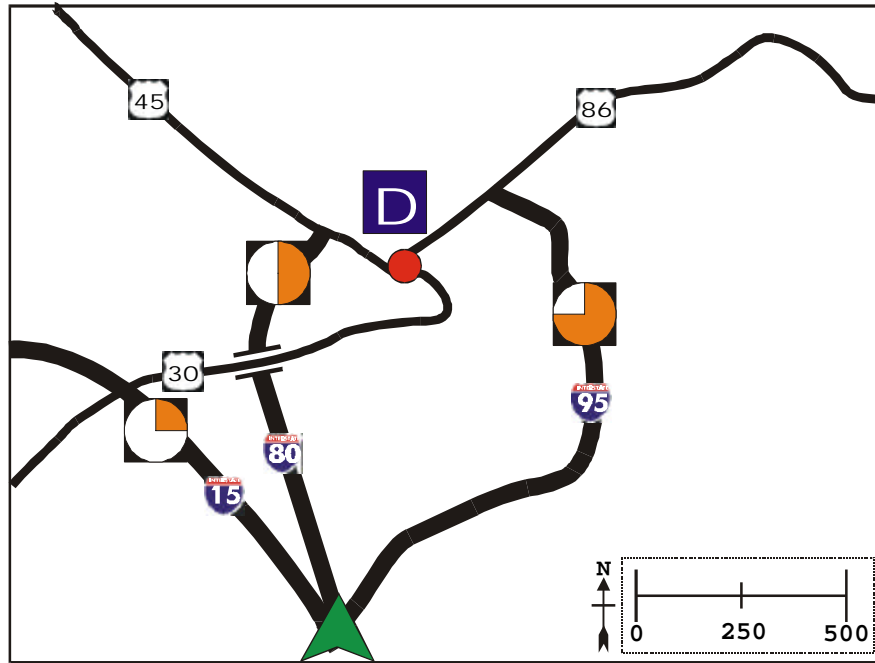
Graphics with Text
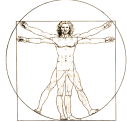
- Roadways

| Interstate | US Route | State Highway |

- Route Number
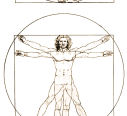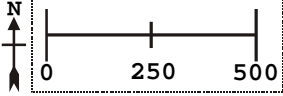
| Interstate | US Route | State Highway |

Graphics with Text (cont.)

- Distance

- Location
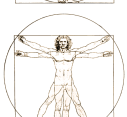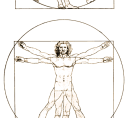
- Delivery Destination

Destination

Graphics with Text (cont.)

- Delays

| 10 minutes | Construction | Traffic Signal |
| Accident | School | Drawbridge |

- Restrictions

| Weight Restriction | Height Restriction | Material Restriction |

Flammable

Radioactive

Graphics with Text (cont.)

- Traffic Density

  Low Traffic   Med Traffic   High Traffic

- Rest Area/Truck Stop

  REST AREA   TRUCK STOP

- Speed Limit

  SPEED LIMIT 65

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Graphics with Text Example:
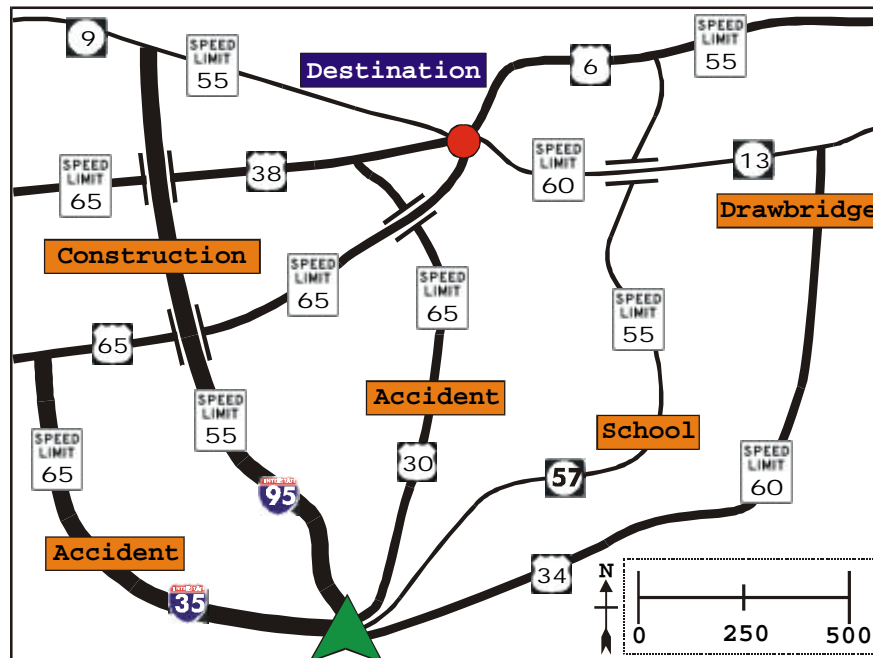
Conventional Tasks

- **Activate Turn Signal**
  - Locate turn signal
  - Activate turn signal (LEFT)
- **Adjust Vent**
  - Locate vent
  - Adjust left vent so that air flow is away
- **Adjust Power Mirror**
  - Check mirror adjustment
  - Locate mirror control

- **Monitoring Fuel Level**
  - Locate fuel gauge
  - Read fuel gauge

E \ | / F

- **Monitoring Vehicle Speed**
  - Locate speedometer
  - Read speedometer
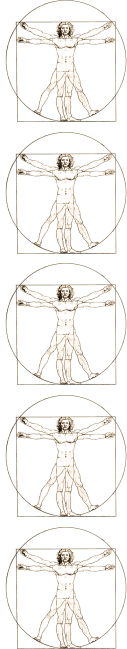
IVIS Tasks to be Completed

- Which route has no delay?
- Is there an Interstate ___ on the map?
- Which route has a construction delay?
- Which **route** has no restrictions?
- Which **roadway** has a ___ minute delay?
- Which route has a school crossing delay?
- Which roadway has no delay?
- Which route has a speed limit of ___ mph?
- Which roadway has a flammable material restriction?
- Which roadway has a hazardous cargo restriction?
- Which roadway has a traffic signal delay?
- Which roadway has a construction delay?
- Which roadway has a drawbridge delay?
- Which roadway has a railroad crossing delay?
- Select the quickest route to the delivery destination.
- Select a route to the delivery destination.

Tasks

- Tasks
  - IVIS/CVO
    - Table
    - Paragraph
    - Graph w/Text
    - Graph w/Icon
  - Conventional
    - Activate turn signal
    - Adjust vent
    - Adjust power mirror
    - Monitoring fuel level
    - Monitoring vehicle speed

- Answers
  - IVIS/CVO
    - YES or NO
    - Route or Roadway
    - **SKIP**
  - Conventional
    - Action
    - Specific Number

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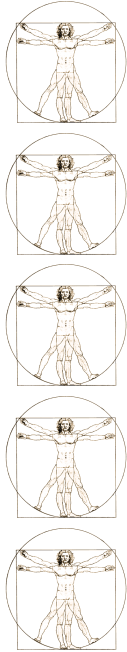Virginia Polytechnic Institute and State University

Tasks (cont.)

- Tasks

  Questions & Survey
  - Information used & Calculations
  - Ratings
    - Mental Demand
    - Frustration Level
    - Time Sharing Demand
    - Awareness of Surroundings

- Answers

  Questions & Survey
  - Short Answers and/or number calculated
  - Score
    - Mental Demand
      - **1**: Easy
      - **100**: Hard
    - Frustration
      - **1**: Low
      - **100**: High
    - Time Sharing
      - **1**: Easy
      - **100**: Hard
    - Awareness
      - **1**: Low
      - **100**: High

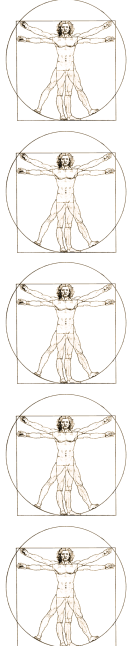Virginia Tech
Virginia Polytechnic Institute and State University
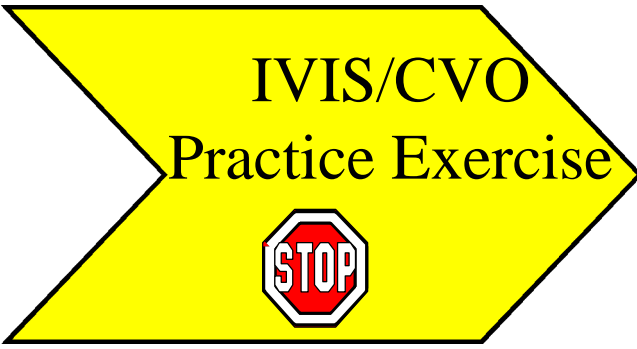
Tractor Trailer Characteristics

- Weigh
  - Tractor + Trailer + Cargo = 22 TON
- Height = 12' 6"
- Width = 8'
- Material Hauled = Radioactive
  - Hazardous
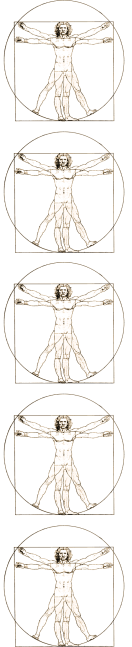
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IVIS/CVO Practice Exercise

STOP

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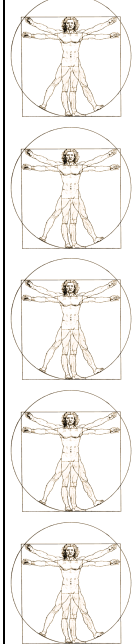
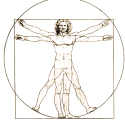# Truck Training/Familiarization

- Seat and Mirrors Adjustment
- Instrument Panel & Controls Familiarization
- Explain Conventional Tasks
- Hearing Test
- IVIS Task Practice
- Driving Familiarization
- Driving + IVIS Task Practice

Note: Sunglasses are not allow during the study

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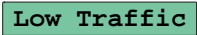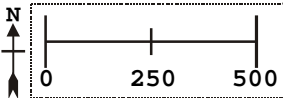
Questions

Virginia Tech

IVIS/CVO Driver Screening

No.	First Name	Last Name	Age	Preferred Time to called for scheduling participation	Phone No.	E-mail address	Driver's License Type [confirm if it is **Class A**] (YES or No)	Last time he/she drove a tractor trailer (e.g. yesterday, last week, last month, 6 month ago)	Years of Experience
1					( ) -				
2					( ) -				
3					( ) -				
4					( ) -				
5					( ) -				
6					( ) -				
7					( ) -				
8					( ) -				
9					( ) -				
10					( ) -				
11					( ) -				
12					( ) -				
13					( ) -				
14					( ) -				
15					( ) -				
16					( ) -				
17					( ) -				
18					( ) -				
19					( ) -				
20					( ) -				
21					( ) -				
22					( ) -				
23					( ) -				
24					( ) -				
25					( ) -				
26					( ) -				
27					( ) -				
28					( ) -				
29					( ) -				
30					( ) -				

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants
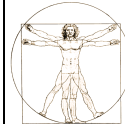### of Investigative Projects

Title of Project: Effects of In-Vehicle Information System (IVIS) Tasks on the Information Processing Demands of a Commercial Vehicle Operations (CVO) Driver

Investigators: Mrs. Myra Blanco, Industrial and Systems Engineering Graduate Student and Graduate Research Assistant at the Virginia Tech Center for Transportation Research

Dr. Thomas A. Dingus, Industrial and Systems Engineering Professor and Director of the Virginia Tech Center for Transportation Research

I. The Purpose of this Research Project

The purpose of this experiment is to evaluate driving behavior and performance while drivers concurrently perform in-vehicle tasks. These tasks will include reading information from in-vehicle displays, navigating with the aid of an Advanced Traveler Information System (ATIS), and performing conventional secondary tasks (activate turn signal, adjust vent, adjust power mirror, monitor fuel level, and monitor vehicle speed). The data obtained will be used to evaluate the attention demand of different in-vehicle information systems. Twelve participants, each tested individually, will participate in this experiment.

II. Procedures

In the study, you will be asked to perform specific in-vehicle tasks as you drive on 4-lane divided roadways on U.S. Highway 460 between Blacksburg, Virginia and Princeton, West Virginia, and other primary and secondary roads in the New River Valley area. A trained experimenter will ride in the research vehicle with you during the experiment to assist in the data-gathering process and to help ensure the safe operation of the experimental vehicle. It is your responsibility as the driver to obey all traffic regulations and to maintain safe operation of the vehicle at all times. You must treat the driving task as the primary task and perform the other instructed tasks only when it is safe to do so. You will be required to have the lap/shoulder belt restraint system securely fastened while driving.

The experimental vehicle is an instrumented class 8 tractor pulling a 48-foot trailer. The tractor is equipped with a standard transmission, analog instrument cluster, cellular phone, and entertainment (audio), climate-control, and driver-information systems. The truck is also equipped with an advanced traveler information system. In this study, you will drive and perform a variety of in-vehicle tasks.

The vehicle is also outfitted with devices designed to monitor various relevant aspects of your driving behavior (for example, video cameras and recorder, microphones, and computers). These measurement devices do not require that your attention be diverted from the driving task. All equipment will be placed in the vehicle and secured such that it will not present a hazard. In

addition, a fire extinguisher, a first-aid kit, and a cellular phone will be carried in the vehicle at all times in case of an emergency.

The study will consist of four experimental stages. The experimental stages will proceed as follows:

1. Introductory Stage
    This stage consists of preliminaries. You will thoroughly read the informed consent form. Assuming that you sign the informed consent form, we will ask you to fill out a brief medical screening questionnaire. Next, we will give you a simple vision test and we will also ask to see your driver's license. Once you successfully complete all of these preliminaries, we will begin your training. The first stage is expected to last about 10 minutes.

2. Training Stage
    You will be instructed on how to perform the tasks associated with the in-vehicle information systems. Sample tasks will be demonstrated on a computer set-up in the lab. You will then be taken to the research vehicle where training on the use of the different in-vehicle information systems will be performed. Since the instrument panels and controls may differ from the vehicle you normally drive, it is necessary to train you on the in-vehicle tasks that you will be performing throughout the experiment. You will then be asked to perform a series of tasks using the different in-vehicle information systems on which you were just trained. This stage should take approximately 50 minutes.

3. Driving Stage
    After a rest break, you will begin driving the vehicle on a pre-selected route and you will be asked to begin performing a series of instructed in-vehicle tasks. The driving stage will alternate between periods of regular driving and driving while performing the various tasks for which you have been trained. This stage is expected to last approximately 3 hours depending on the amount of re-training required. At the end of the drive, you will return to the Center for Transportation Research (CTR).

4. Debriefing and Payment Stage
    On returning to CTR, you will be asked to read an experiment debriefing statement. You will then be paid and dismissed. This stage should take about 10 minutes.

Your total participation time will be approximately four hours, but may be somewhat shorter or longer depending on the length of rest breaks and the amount of training needed.

If during the study you feel that you cannot continue for any reason, you have the right to terminate your participation; you will be paid for the amount of time that you participated. This includes the right to withdraw at any time after having read and signed the informed consent form. If you choose to withdraw while driving, we will ask you to drive back to the Center for Transportation Research by the best feasible route. If you do not wish to drive further, we will arrange for a qualified driver to meet with us and take over. You will be driven back to the Center in a car.

If you have any questions about the experiment or your rights as a participant after reading the informed consent form, please do not hesitate to ask. We will answer your questions as openly and honestly as possible.

III. Risks

There are some risks and discomforts to which participants are exposed in volunteering for this research. The risks are:

(1) The risk of an accident normally associated with driving a truck in light or moderate traffic, as well as on straight and curved roadways.

(2) The slight additional risk of an accident while performing instructed in-vehicle tasks. Past research indicates that this risk is minimal.

(3) Possible fatigue due to the length of the experiment. However, you will be given short rest breaks during the experimental session.

(4) While you are driving the vehicle, you will be videotaped by cameras. As a result, we will ask you not to wear sunglasses. If this at any time during the course of the experiment impairs your ability to drive the vehicle safely, you should notify the experimenter.

The following precautions will be taken to ensure minimal risk to the participants:

(1) The experimenter will monitor your driving and will ask you to stop if she feels the risks are too great to continue. However, as long as you are driving the research vehicle, it remains your responsibility to drive in a safe, legal manner.

(2) You will be required to wear the lap and shoulder belt restraint system anytime the truck is on the road. The vehicle is also equipped with a driver's side airbag supplemental restraint system.

(3) The vehicle is equipped with a fire extinguisher, first-aid kit, and a cellular phone.

(4) If an accident does occur, the experimenter will arrange medical transportation to a nearby hospital emergency room. You will be required to undergo examination by medical personnel in the emergency room.

IV. Benefits of this Research Project

While there are no direct benefits to you from this research (other than payment), you may find the experiment interesting. No promise or guarantee of benefits has been made to encourage you to participate. Your participation, along with that of the other volunteers, should make it possible to improve the design of in-vehicle systems. Improvements in the design of heavy truck in-vehicle systems may have a significant impact on driving safety, system usability, and consumer satisfaction.

V. Extent of Anonymity and Confidentiality

The data gathered in this experiment will be treated with anonymity. Shortly after you have participated, your name will be separated from your data. A coding scheme will be employed to identify your data by participant number only (e.g., Participant No. 3).

Eye movement behavior is measured using a video camera and recorder during the experiment. A camera, positioned inside the truck cab, is used to record drivers' eye movements. The video image recorded is of the driver's head with some additional space around the head to

accommodate any head movements by the driver during data collection. The videotapes will be stored in a locked filing cabinet at the Virginia Tech Center for Transportation Research. Access to the tapes will be under the supervision of Dr. Thomas Dingus. Myra Blanco will have access to the tapes and will score the eye movement behavior using "frame-by-frame" analysis. The video tapes will be erased one year after the data has been analyzed and the results documented.

At no time will the researchers release the videotapes from the study to anyone other than individuals working on the project without your written consent.

VI. Compensation
You will be paid $20 per hour for the time you actually spend in the experiment. Payment will be made immediately after you have finished your participation.

VII. Freedom to Withdraw
You should know that at any time you are free to withdraw from participation in this research program without penalty. No one will try to make you continue if you do not want to continue, and you will be paid for the amount of time you actually participated.

VIII. Approval of Research
This research project has been approved, as required by the Institutional Review Board for Research Involving Human Participants at Virginia Polytechnic Institute and State University, the Department of Industrial and Systems Engineering, and the Virginia Tech Center for Transportation Research.

IX. Participant's Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities:
> (1) I should not volunteer for participation in this research if I am younger than 21 years of age, or if I do not have a valid class A commercial driver's license, or if I am not in good health.
> (2) I should not take part in the driving task if I have taken any drug, alcoholic beverage, or medication within the previous 24 hours that might affect my ability to safely operate a truck. It is my responsibility to inform the experimenters of any additional conditions that might interfere with my ability to drive. Such conditions would include inadequate sleep, hangover, headache, cold symptoms, depression, allergies, emotional upset, visual or hearing impairment, seizures (fits), nerve or muscle disease, or other similar conditions.
> (3) As the driver of the research vehicle, I must obey all traffic regulations and maintain safe operation of the vehicles at all times. I will treat the driving task as the primary task and perform the other instructed tasks only when it is safe to do so.

X. Participant's Permission
I have read and understand the Informed Consent and conditions of this research project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this research project.

_____   _____
               Signature   Date

Should I have any questions about this research or its conduct, I may contact:

Mrs. Myra Blanco   552-5695
Principal Investigator

Dr. Thomas A. Dingus   231-8831
Faculty Advisor

H.T. Hurd   231-5281
Director, Sponsored Programs

EFFECTS OF IN-VEHICLE INFORMATION SYSTEM (IVIS) TASKS ON THE INFORMATION PROCESSING DEMANDS OF A COMMERCIAL VEHICLE OPERATIONS (CVO) DRIVER

Health Screening Questionnaire

1. Are you in good general health?   Yes   No

   If no, list any health-related conditions you are experiencing or have experienced in the recent past.

   _____
   _____
   _____

2. Have you, in the last 24 hours, experienced any of the following conditions?

Inadequate sleep	Yes	No
Hangover	Yes	No
Headache	Yes	No
Cold symptoms	Yes	No
Depression	Yes	No
Allergies	Yes	No
Emotional upset	Yes	No

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

   Visual Impairment   Yes   No

   (If yes, please describe.)
   _____
   _____
   _____

   Hearing Impairment   Yes   No

   (If yes, please describe.)
   _____
   _____
   _____

   Seizures or other lapses of
   consciousness   Yes   No

   (If yes, please describe.)
   _____
   _____
   _____

Any disorders similar to the
above or that would impair
your driving ability   Yes   No

(If yes, please describe.)

_____
_____
_____

4. List any prescription or non-prescription drugs you are currently taking or have taken in the
    last 24 hours.

_____
_____

5. List the approximate amount of alcohol (beer, wine, fortified wine, or liquor) you have
    consumed in the last 24 hours.

_____
_____

6. Are you taking any drugs of any kind other than those listed in 4 or 5 above?

Yes   No

_____   _____
         Signature   Date

Virginia Polytechnic Institute and State University
Center for Transportation Research
IVIS/CVO Experimenter Protocol for Assessment of Participant Suitability:
Informed Consent, Proof of License, Health Screening, Vision Test, and Hearing Test

1. Greet Participant

2. Informed Consent

The first thing you need to do is to read and complete an Informed Consent form. It outlines what is expected of you during this experiment and what you can expect of the researchers. Please read it carefully. If you have any questions, please ask. When you are finished, and all your questions have been answered, please sign and date the form if you agree to participate.

- Give informed consent to participant.
- Answer any questions the participant may have.
- Have participant sign and date form.
- Give participant a copy of the informed consent.

3. Show driver's license. Must be a valid Class A driver's license. Out of state is okay.

4. Administer "Health Screening Questionnaire"

This is a health questionnaire. Your answers to these questions will be treated confidentially. We ask these questions to ensure that driving the experimental vehicle will not pose a greater than normal risk to you.

- Give health-screening questionnaire to the participant.
- Answer any questions the participant may have.
- Have the participant sign and date the form.

NOTE TO EXPERIMENTER: The participant must be in good general health, have revealed no medical conditions, and be taking no medication that would adversely affect his driving, and have not been drinking.

5. Vision Test

Follow me and I'll administer the vision test.

- Take the subject to the Snellen chart in the CTR lab.
- Have the subject place his or her toes on the back edge of the tape line on the floor.
- Make sure the subject is wearing the glasses or contacts he wears while driving.

Look at the wall and read aloud the smallest line you can comfortably make out.

- If the subject reads every letter on the 1st line correctly, have him try the next line.

- Repeat this until they miss a letter, and record the acuity of the last line they got completely correct.
- If the subject does not correctly read every letter on the first line correctly, move up a line and have him try again.
- Repeat as needed and record the acuity of the first line they get completely correct.

Acuity Score: _____

6. Informal Hearing Test (administered in car with engine running).

I'm going to play the instructions of one set of training tasks, one at a time. After the computer says the instruction, please repeat it back to me. Do you have any questions?

	CORRECT	INCORRECT
Task 1	_____	_____
Task 2	_____	_____
Task 3	_____	_____
Task 4	_____	_____

In order to participate, the subject must:

1) Have a valid Class A driver's license.

2) Have visual acuity of 20/40 or better.

3) Pass the health screening questionnaire.

4) Pass a hearing test.

5) Not wear sunglasses

If a subject does not qualify, thank him for his time, pay him for his time, and let him go.

Appendix 7 - Randomization for IVIS/CVO

Age	Info Part.No.	Search Tabular L	M	H	Search Paragraph L	M	H	Search Graph w/Text L	M	H	Search Graph w/Icon L	M	H	SearchCompute Tabular L	M	H	SearchCompute Paragraph L	M	H	SearchCompute Graph w/Text L	M	H	SearchPlan Tabular L	M	H	SearchPlan Paragraph L	M	H	SearchPlan Graph w/Text L	M	H	SearchPlan Graph w/Icon L	M	H	SearchPlanCompute Tabular L	M	H	SearchPlanCompute Paragraph L	M	H	SearchPlanCompute Graph w/Text L	M	H	SearchPlanInterpret Tabular L	M	H	SearchPlanInterpret Paragraph L	M	H	SearchPlanInterpret Graph w/Text L	M	H	SearchPlanInterpret Graph w/Icon L	M	H	SearchPlanInterpretCompute Tabular L	M	H	SearchPlanInterpretCompute Paragraph L	M	H	SearchPlanInterpretCompute Graph w/Text L	M	H
Middle	1	13	47	15	42	63	9	3	49	51	20	61	26	10	33	19	62	16	24	5	4	41	59	34	21	52	43	17	39	12	48	14	45	2	54	32	8	40	36	11	50	29	23	38	44	53	35	22	55	58	28	6	57	37	1	31	7	25	60	56	46	27	18	30
Middle	2	60	51	46	40	52	37	11	39	5	21	35	15	34	1	23	56	12	61	28	53	22	25	47	6	26	10	50	41	19	48	8	57	4	3	36	58	59	27	7	31	44	20	13	9	43	54	24	62	45	30	63	49	32	55	42	14	38	2	16	18	33	17	29
Middle	3	8	20	1	44	16	46	61	5	31	27	36	23	6	38	58	13	29	19	4	57	45	34	24	52	60	59	14	40	63	25	3	7	11	10	17	55	33	9	32	53	37	21	49	42	18	47	43	22	15	12	26	56	50	35	28	41	39	62	54	2	48	51	30
Middle	4	34	8	56	36	7	40	54	50	57	38	49	31	21	14	26	22	15	51	17	47	6	25	12	35	53	18	59	28	58	44	11	62	27	48	41	32	3	4	37	10	9	39	20	52	33	5	63	16	23	2	19	1	30	45	43	55	61	13	29	42	46	60	24
Middle	5	21	60	8	53	28	55	46	14	11	37	61	35	44	40	16	15	4	33	24	36	43	54	42	25	10	1	6	30	38	47	59	45	27	56	41	17	19	20	3	62	23	52	26	22	7	5	58	18	31	50	48	12	34	51	39	13	2	49	29	63	32	9	57
Middle	6	29	61	58	40	53	4	1	19	12	6	48	23	14	37	32	9	47	36	18	27	31	56	2	17	41	20	28	8	55	26	34	11	15	3	5	42	49	39	22	30	7	38	13	60	16	33	62	25	35	57	45	46	51	59	43	21	44	63	50	52	24	10	54
Older	7	15	13	21	44	49	50	4	23	10	11	27	41	18	52	40	24	14	12	32	38	31	9	59	1	26	51	36	5	34	28	56	48	8	29	3	37	17	30	61	25	45	19	39	55	2	63	60	46	43	57	47	54	42	62	7	58	16	22	35	53	6	20	33
Older	8	50	3	60	8	41	7	40	47	57	53	58	11	5	62	35	61	28	4	17	13	39	26	25	6	56	30	16	52	34	9	37	19	43	33	32	14	46	59	38	45	15	2	44	23	12	10	31	55	27	1	54	42	18	22	51	36	63	29	48	49	21	24	20
Older	9	48	38	60	37	55	4	42	21	24	51	22	29	52	8	44	27	16	18	2	34	17	50	61	20	43	26	25	10	36	39	54	3	45	31	32	6	62	33	23	14	5	58	47	41	30	1	57	53	59	12	19	35	13	49	7	56	9	40	28	63	15	46	11
Older	10	41	48	18	62	17	36	26	5	14	31	7	49	16	11	24	59	54	34	1	10	30	39	60	9	43	44	19	55	42	57	40	35	45	13	3	51	15	50	28	4	25	8	52	38	53	46	12	22	2	29	56	58	23	6	21	61	32	63	47	37	20	27	33
Older	11	39	53	37	21	43	6	49	42	5	29	62	56	1	31	13	52	27	59	10	46	44	22	15	14	51	2	32	4	60	45	55	26	3	9	38	20	17	48	24	34	8	47	54	28	25	16	58	19	11	50	35	18	36	23	7	57	40	12	41	61	63	33	30
Older	12	59	48	54	19	46	56	45	29	35	39	60	37	61	58	23	41	16	8	63	36	15	18	3	31	57	49	47	4	13	33	52	26	27	6	50	20	42	38	51	9	14	2	5	21	10	17	53	30	34	1	40	55	44	24	43	7	22	25	12	28	32	11	62

**VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
CENTER FOR TRANSPORTATION RESEARCH**

**Instructions for the In-vehicle Information System/Commercial Vehicle Operations
(IVIS/CVO) Study**

Thanks for offering to help with this study. Information about the procedures for the study is provided below. Please feel free to ask any questions you may have.

Tasks to be Completed During the Drive
- Your primary task is to safely drive the tractor trailer; you should allow nothing to interfere with this. To simulate medium traffic density, there will be an automobile driven in front of you by personnel from the Center for Transportation Research.
- As you are driving, you will be provided information on a visual display and will be asked to make decisions or actions from this information. These are secondary tasks and you should NOT allow them to interfere with safely driving the vehicle.
- Periodically along the route you will hear a tone; following the tone, you will hear instructions provided by the computer on how to complete the task, i.e. select a route to the delivery destination. After the instructions are completed, information will be presented on the visual display. You will also hear instructions provided by the experimenter, i.e. activate turn signal. After the instructions you will be asked to perform the action or give an answer to the task.

   IVIS Tasks
   - Visual information will remain on the screen until you state your decision, i.e. selecting a route based on the information provided.
   - There is no time limit – take as much time as you need to.
   - You may provide an answer at any time.

   Conventional Tasks
   - Auditory instructions will be given by the experimenter while driving. Once she finishes the instructions, you will be asked to perform the task that this instruction suggests. These instructions and tasks will be discussed in detail during the training section.
   - You may provide an answer at any time if the task requires it.

Task Description
You will be asked to perform a variety of tasks. Some tasks will ask you to choose a roadway or to select a route; with these tasks, it is desired that you search the information and identify and use the information you find useful in making your decision. We realize that not everyone will choose to use the same criteria when making a decision. It doesn't matter to us which criteria you use or how many you use. However, it is important that we know which information you used to arrive at your decision (i.e. If five items of information were presented, it is important for us to know that you used 1, 2, 3, 4 or 5 items, and which items you used). Therefore, at the conclusion of each task, the experimenter will ask why you selected your answer. At this time,

indicate which criteria you used (for example, you might have considered distance, truck stops, and speed limit when selecting a route).

When given the task of selecting a route to the delivery destination, you are not in a rush to get it. Imagine you have enough time to get there.

Some tasks will require that you perform calculations (i.e. select the quickest route), while other tasks will provide you with the option of doing a calculation. It is important that we know if you performed a calculation and what type of calculation you performed.

> ➢ When you are asked to determine the quickest route, we would like you to perform a calculation with the information provided. We will prompt you for a numeric answer after you have stated your selected route. As with any task, you can always say "**skip**" if you do not wish to perform the task while driving.

> ➢ If you are asked to select a route and speed limit, distance, and/or time delays are provided, you have the option of performing one or more calculations. When asked to select a route, use the information as you normally would while driving. After you provide your route selection, we will ask you if you performed a calculation and if so, what type.

❖ If at any time you feel a task requires too much attention to ensure safe driving, simply say "**skip**" and the task will end.
❖ If at any time you wish to stop and take a break, indicate your desire to the experimenters.
❖ If at any time you wish to end your participation in the study, simply state your desire to the experimenters and we will return to the Center for Transportation Research.

Rating of Task Difficulty

After each task is completed, we will ask you to rate the mental demand, frustration level, and time sharing demand of the task. You will also be asked to rate how aware of your surroundings you were while completing the task.

Rating scales have been developed for you to use in evaluating your experiences during the different tasks. Please read the descriptions of the scales carefully. It is <u>extremely important</u> that they be clear to you; please ask if you have any questions. You may request a description of the scales at any time during the experiment.

After performing each task, you will be asked to evaluate the task by selecting a value from 1 to 100 for each of the scales. Each line has two endpoint descriptors that describe the scale. For example, Frustration Level goes from 1 (low frustration) to 100 (high frustration). The experimenter will say the name of each scale, at which point you will respond with your evaluation of the task you just completed on a scale from 1 to100. Please consider your responses carefully in distinguishing among the task conditions. Consider each scale

individually. Your ratings will play an important role in the evaluation being conducted; thus, your active participation is essential to the success of this experiment, and is greatly appreciated.

RATING SCALE DEFINITIONS		
Title	Endpoints	Descriptions
Mental Demand	/--/--/--/--/--/--/--/--/--/ 1 20 40 60 80 100 *Easy* *Hard*	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex?
Frustration Level	/--/--/--/--/--/--/--/--/--/ 1 20 40 60 80 100 *Low* *High*	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?
Time Sharing Demand	/--/--/--/--/--/--/--/--/--/ 1 20 40 60 80 100 *Easy* *Hard*	How easy did you find it to perform the task and safely drive the vehicle? Was it easy to divide your attention between the two tasks (driving and the secondary task)?
Situation Awareness	/--/--/--/--/--/--/--/--/--/ 1 20 40 60 80 100 *Low* *High*	How aware were you of surrounding traffic when you were performing the secondary task? If you had wanted to slam on the brakes or swerve right or left, did you know if you could do so without hitting another vehicle?

Sequence of Events

- Prior to going outside to the vehicle, you will be shown examples of each type of task.
- After going outside to the vehicle but prior to driving, sample information will be presented on the display.
- You will be shown the controls of the vehicle you will drive.
- Once any questions you have are answered, we will drive around the block so that you can familiarize yourself with the handling of the tractor trailer.
- When you feel comfortable with driving the tractor trailer, another short drive will be taken to allow you to practice performing tasks with the information presented by the computer (controlled by the experimenter).
- When you feel comfortable performing the tasks, we will then drive to Route 460.

List of Tasks to be Completed on the Drive

Listed below is a complete list of tasks you will be asked to perform. Information to complete these tasks will be provided on the visual display in different formats, on the drive today.

- Which route has no delay?
- Is there an Interstate ___ on the map?
- Which route has a construction delay?
- Which route has no restrictions?
- Which roadway has a ___ minute delay?
- Which route has a school crossing delay?
- Which roadway has no delay?
- Which roadway has a speed limit of ___ mph?
- Which roadway has a flammable material restriction?
- Which roadway has a hazardous cargo restriction?
- Which roadway has a traffic signal delay?
- Which roadway has a construction delay?
- Which roadway has a drawbridge delay?
- Which roadway has a railroad crossing delay?
- Select the quickest route to the delivery destination.
- Select a route to the delivery destination.

Table A.9.1 Dependent Measure: Number of Eye Glances to Display

Source	DF	SS	MS	F value	P value
Between					
AGE	1	72.82	72.82	0.13	0.7219
SUBNUM(AGE)	10	5433.32	543.33		
Within					
ELEMENT	5	4784.87	956.97	37.05	0.0001 *
AGE*ELEMENT	5	80.16	16.03	0.62	0.6847
*ELEMENT*SUBNUM(AGE)*	50	1291.54	25.83		
DISTYPE	3	2268.90	756.30	22.94	0.0001 *
AGE*DISTYPE	3	80.07	26.69	0.81	0.4986
*DISTYPE*SUBNUM(AGE)*	30	989.03	32.97		
DISTYPE*ELEMENT	12	431.52	35.96	2.58	0.0045 *
AGE*DISTYPE*ELEMENT	12	158.58	13.21	0.95	0.5022
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	1630.55	13.94		
DENSITY	2	1905.72	952.86	31.27	0.0001 *
AGE*DENSITY	2	81.92	40.96	1.34	0.2833
*DENSITY*SUBNUM(AGE)*	20	609.40	30.47		
DENSITY*ELEMENT	6	279.60	46.60	4.78	0.0005 *
AGE*DENSITY*ELEMENT	6	94.11	15.68	1.61	0.1608
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	585.46	9.76		
DENSITY*DISTYPE	5	535.71	107.14	8.01	0.0001 *
AGE*DENSITY*DISTYPE	5	66.50	13.30	0.99	0.4310
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	669.01	13.38		
DENSITY*DISTYPE*ELEMENT	13	313.16	24.09	2.56	0.0039 *
AGE*DENSITY*DISTYPE*ELEMENT	13	163.41	12.57	1.34	0.2024
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	1062.68	9.40		
TOTAL	543	23588.05			

* $p < 0.05$ (significant)

Table A.9.2 Dependent Measure: Peak Eye Glance Length to Display

Source	DF	SS	MS	F value	P value
Between					
AGE	1	1.24	1.24	0.08	0.7781
SUBNUM(AGE)	10	147.35	14.74		
Within					
ELEMENT	5	10.59	2.12	1.99	0.0956
AGE*ELEMENT	5	2.05	0.41	0.39	0.8560
*ELEMENT*SUBNUM(AGE)*	50	53.12	1.06		
DISTYPE	3	5.30	1.77	2.46	0.0818
AGE*DISTYPE	3	1.17	0.39	0.54	0.6581
*DISTYPE*SUBNUM(AGE)*	30	21.55	0.72		
DISTYPE*ELEMENT	12	9.55	0.80	0.72	0.7259
AGE*DISTYPE*ELEMENT	12	7.50	0.62	0.57	0.8638
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	128.71	1.10		
DENSITY	2	2.16	1.08	4.23	0.0293 *
AGE*DENSITY	2	0.28	0.14	0.56	0.5820
*DENSITY*SUBNUM(AGE)*	20	5.09	0.25		
DENSITY*ELEMENT	6	9.27	1.54	1.89	0.0968
AGE*DENSITY*ELEMENT	6	3.96	0.66	0.81	0.5676
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	48.96	0.82		
DENSITY*DISTYPE	5	9.42	1.88	2.93	0.0214 *
AGE*DENSITY*DISTYPE	5	3.89	0.78	1.21	0.3179
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	32.16	0.64		
DENSITY*DISTYPE*ELEMENT	13	10.98	0.84	1.08	0.3818
AGE*DENSITY*DISTYPE*ELEMENT	13	9.38	0.72	0.92	0.5303
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	88.19	0.78		
TOTAL	543	611.87			

* p < 0.05 (significant)

Appendix 9 – ANOVAs for Full Model for IVIS tasks

Table A.9.3 Dependent Measure: Mean Single Glance Time

Source	DF	SS	MS	F value	P value
Between					
AGE	1	0.002	0.002	0.00	0.9846
SUBNUM(AGE)	10	42.868	4.287		
Within					
ELEMENT	5	1.770	0.354	1.61	0.1733
AGE*ELEMENT	5	0.846	0.169	0.77	0.5748
*ELEMENT*SUBNUM(AGE)*	50	10.962	0.219		
DISTYPE	3	0.543	0.181	0.82	0.4941
AGE*DISTYPE	3	0.262	0.087	0.39	0.7579
*DISTYPE*SUBNUM(AGE)*	30	6.636	0.221		
DISTYPE*ELEMENT	12	1.999	0.167	0.75	0.6986
AGE*DISTYPE*ELEMENT	12	1.203	0.100	0.45	0.9380
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	25.944	0.222		
DENSITY	2	0.456	0.228	3.15	0.0647
AGE*DENSITY	2	0.115	0.058	0.79	0.4654
*DENSITY*SUBNUM(AGE)*	20	1.447	0.072		
DENSITY*ELEMENT	6	0.677	0.113	0.76	0.6042
AGE*DENSITY*ELEMENT	6	1.066	0.178	1.20	0.3208
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	8.908	0.148		
DENSITY*DISTYPE	5	2.389	0.478	1.81	0.1283
AGE*DENSITY*DISTYPE	5	0.579	0.116	0.44	0.8201
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	13.217	0.264		
DENSITY*DISTYPE*ELEMENT	13	1.842	0.142	0.73	0.7264
AGE*DENSITY*DISTYPE*ELEMENT	13	3.204	0.246	1.28	0.2375
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	21.818	0.193		
TOTAL	543	148.753			

* p < 0.05 (significant)

Table A.9.4 Dependent Measure: Total Glance Time

Source	DF	SS	MS	F value	P value
Between					
AGE	1	272.53	272.53	0.68	0.4294
SUBNUM(AGE)	10	4018.47	401.85		
Within					
ELEMENT	5	8138.39	1627.68	50.06	0.0001 *
AGE*ELEMENT	5	201.59	40.32	1.24	0.3047
*ELEMENT*SUBNUM(AGE)*	50	1625.86	32.52		
DISTYPE	3	4901.02	1633.67	32.78	0.0001 *
AGE*DISTYPE	3	95.00	31.67	0.64	0.5981
*DISTYPE*SUBNUM(AGE)*	30	1495.32	49.84		
DISTYPE*ELEMENT	12	864.56	72.05	3.17	0.0006 *
AGE*DISTYPE*ELEMENT	12	274.17	22.85	1.01	0.4478
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	2656.60	22.71		
DENSITY	2	4078.21	2039.11	45.95	0.0001 *
AGE*DENSITY	2	132.73	66.36	1.5	0.2481
*DENSITY*SUBNUM(AGE)*	20	887.44	44.37		
DENSITY*ELEMENT	6	515.48	85.91	5.46	0.0001 *
AGE*DENSITY*ELEMENT	6	139.12	23.19	1.47	0.2023
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	943.35	15.72		
DENSITY*DISTYPE	5	896.88	179.38	10.58	0.0001 *
AGE*DENSITY*DISTYPE	5	55.15	11.03	0.65	0.6622
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	847.54	16.95		
DENSITY*DISTYPE*ELEMENT	13	562.99	43.31	2.81	0.0016 *
AGE*DENSITY*DISTYPE*ELEMENT	13	279.02	21.46	1.39	0.1734
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	1740.88	15.41		
TOTAL	543	35622.30			

* p < 0.05 (significant)

Table A.9.5 Dependent Measure: Number of Eye Glances to Mirror

Source	DF	SS	MS	F value	P value
Between					
AGE	1	77.76	77.76	1.35	0.2729
SUBNUM(AGE)	10	577.75	57.77		
Within					
ELEMENT	5	24.40	4.88	1.90	0.1107
AGE*ELEMENT	5	11.09	2.22	0.86	0.5114
*ELEMENT*SUBNUM(AGE)*	50	128.30	2.57		
DISTYPE	3	17.77	5.92	2.29	0.0983
AGE*DISTYPE	3	4.57	1.52	0.59	0.6264
*DISTYPE*SUBNUM(AGE)*	30	77.51	2.58		
DISTYPE*ELEMENT	12	14.73	1.23	1.05	0.4045
AGE*DISTYPE*ELEMENT	12	13.38	1.12	0.96	0.4925
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	136.17	1.16		
DENSITY	2	11.71	5.86	2.35	0.1216
AGE*DENSITY	2	6.82	3.41	1.37	0.2777
*DENSITY*SUBNUM(AGE)*	20	49.93	2.50		
DENSITY*ELEMENT	6	5.31	0.89	1.67	0.1452
AGE*DENSITY*ELEMENT	6	8.04	1.34	2.52	0.0305 *
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	31.88	0.53		
DENSITY*DISTYPE	5	3.88	0.78	0.76	0.5827
AGE*DENSITY*DISTYPE	5	3.50	0.70	0.69	0.6360
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	51.06	1.02		
DENSITY*DISTYPE*ELEMENT	13	14.62	1.12	1.56	0.1062
AGE*DENSITY*DISTYPE*ELEMENT	13	27.53	2.12	2.94	0.0010 *
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	81.27	0.72		
TOTAL	543	1379.00			

* $p < 0.05$ (significant)

Table A.9.6 Dependent Measure: Minimum Speed

Source	DF	SS	MS	F value	P value
Between					
AGE	1	1549.32	1549.32	3.34	0.0977
SUBNUM(AGE)	10	4641.53	464.15		
Within					
ELEMENT	5	182.52	36.50	1.31	0.2739
AGE*ELEMENT	5	112.19	22.44	0.81	0.5503
*ELEMENT*SUBNUM(AGE)*	50	1390.56	27.81		
DISTYPE	3	118.48	39.49	1.62	0.2062
AGE*DISTYPE	3	63.75	21.25	0.87	0.4675
*DISTYPE*SUBNUM(AGE)*	30	732.81	24.43		
DISTYPE*ELEMENT	12	168.41	14.03	0.89	0.5564
AGE*DISTYPE*ELEMENT	12	250.06	20.84	1.33	0.2132
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	1839.15	15.72		
DENSITY	2	116.56	58.28	3.08	0.0680
AGE*DENSITY	2	34.07	17.03	0.90	0.4219
*DENSITY*SUBNUM(AGE)*	20	378.03	18.90		
DENSITY*ELEMENT	6	258.97	43.16	2.98	0.0130 *
AGE*DENSITY*ELEMENT	6	62.92	10.49	0.72	0.6319
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	869.03	14.48		
DENSITY*DISTYPE	5	102.98	20.60	1.43	0.2315
AGE*DENSITY*DISTYPE	5	19.82	3.96	0.27	0.9250
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	722.54	14.45		
DENSITY*DISTYPE*ELEMENT	13	302.24	23.25	1.37	0.1843
AGE*DENSITY*DISTYPE*ELEMENT	13	295.91	22.76	1.34	0.1993
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	1916.18	16.96		
TOTAL	543	16128.01			

* p < 0.05 (significant)

Appendix 9 – ANOVAs for Full Model for IVIS tasks

Table A.9.7 Dependent Measure: Decrease in Speed

Source	DF	SS	MS	F value	P value
Between					
AGE	1	44.28	44.28	5.86	0.0360 *
SUBNUM(AGE)	10	75.56	7.56		
Within					
ELEMENT	5	232.86	46.57	5.12	0.0007 *
AGE*ELEMENT	5	23.07	4.61	0.51	0.7695
*ELEMENT*SUBNUM(AGE)*	50	454.90	9.10		
DISTYPE	3	90.62	30.21	3.71	0.0222 *
AGE*DISTYPE	3	17.43	5.81	0.71	0.5520
*DISTYPE*SUBNUM(AGE)*	30	244.55	8.15		
DISTYPE*ELEMENT	12	127.25	10.60	2.06	0.0249 *
AGE*DISTYPE*ELEMENT	12	73.50	6.13	1.19	0.2989
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	602.68	5.15		
DENSITY	2	17.56	8.78	1.37	0.2778
AGE*DENSITY	2	0.96	0.48	0.07	0.9285
*DENSITY*SUBNUM(AGE)*	20	128.52	6.43		
DENSITY*ELEMENT	6	57.86	9.64	1.56	0.1733
AGE*DENSITY*ELEMENT	6	28.47	4.75	0.77	0.5966
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	369.80	6.16		
DENSITY*DISTYPE	5	51.91	10.38	1.78	0.1350
AGE*DENSITY*DISTYPE	5	46.54	9.31	1.59	0.1795
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	292.34	5.85		
DENSITY*DISTYPE*ELEMENT	13	122.08	9.39	1.30	0.2230
AGE*DENSITY*DISTYPE*ELEMENT	13	76.28	5.87	0.81	0.6460
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	816.06	7.22		
TOTAL	543	3995.07			

* p < 0.05 (significant)

Table A.9.8 Dependent Measure: Variance in Speed

Source	DF	SS	MS	F value	P value
Between					
AGE	1	102.11	102.11	1.34	0.2740
SUBNUM(AGE)	10	762.23	76.22		
Within					
ELEMENT	5	405.68	81.14	1.67	0.1587
AGE*ELEMENT	5	141.40	28.28	0.58	0.7131
*ELEMENT*SUBNUM(AGE)*	50	2426.75	48.54		
DISTYPE	3	164.72	54.91	1.59	0.2116
AGE*DISTYPE	3	55.10	18.37	0.53	0.6632
*DISTYPE*SUBNUM(AGE)*	30	1033.76	34.46		
DISTYPE*ELEMENT	12	174.99	14.58	0.65	0.7952
AGE*DISTYPE*ELEMENT	12	255.95	21.33	0.95	0.4996
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	2624.52	22.43		
DENSITY	2	85.82	42.91	0.78	0.4728
AGE*DENSITY	2	52.30	26.15	0.47	0.6293
*DENSITY*SUBNUM(AGE)*	20	1103.27	55.16		
DENSITY*ELEMENT	6	178.07	29.68	0.71	0.6416
AGE*DENSITY*ELEMENT	6	216.33	36.06	0.86	0.5263
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	2502.42	41.71		
DENSITY*DISTYPE	5	206.16	41.23	1.50	0.2057
AGE*DENSITY*DISTYPE	5	131.73	26.35	0.96	0.4509
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	1371.50	27.43		
DENSITY*DISTYPE*ELEMENT	13	343.81	26.45	0.96	0.4941
AGE*DENSITY*DISTYPE*ELEMENT	13	443.95	34.15	1.24	0.2604
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	3110.38	27.53		
TOTAL	543	17892.94			

* p < 0.05 (significant)

Appendix 9 – ANOVAs for Full Model for IVIS tasks

Table A.9.9 Dependent Measure: Mean Speed

Source	DF	SS	MS	F value	P value
Between					
AGE	1	1538.50	1538.50	3.32	0.0985
SUBNUM(AGE)	10	4635.64	463.56		
Within					
ELEMENT	5	24.93	4.99	0.27	0.9268
AGE*ELEMENT	5	97.23	19.45	1.06	0.3950
*ELEMENT*SUBNUM(AGE)*	50	919.37	18.39		
DISTYPE	3	59.00	19.67	1.01	0.4026
AGE*DISTYPE	3	59.42	19.81	1.02	0.3995
*DISTYPE*SUBNUM(AGE)*	30	585.03	19.50		
DISTYPE*ELEMENT	12	154.09	12.84	0.95	0.4996
AGE*DISTYPE*ELEMENT	12	209.01	17.42	1.29	0.2336
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	1579.93	13.50		
DENSITY	2	53.13	26.56	1.65	0.2173
AGE*DENSITY	2	26.00	13.00	0.81	0.4602
*DENSITY*SUBNUM(AGE)*	20	322.11	16.11		
DENSITY*ELEMENT	6	175.15	29.19	2.31	0.0451 *
AGE*DENSITY*ELEMENT	6	38.08	6.35	0.50	0.8043
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	758.44	12.64		
DENSITY*DISTYPE	5	80.27	16.05	1.22	0.3127
AGE*DENSITY*DISTYPE	5	6.66	1.33	0.10	0.9914
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	656.90	13.14		
DENSITY*DISTYPE*ELEMENT	13	228.10	17.55	1.42	0.1590
AGE*DENSITY*DISTYPE*ELEMENT	13	193.51	14.89	1.21	0.2825
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	1392.01	12.32		
TOTAL	543	13792.51			

* p < 0.05 (significant)

Table A.9.10 Dependent Measure: Standard Deviation of Speed

Source	DF	SS	MS	F value	P value
Between					
AGE	1	0.55	0.55	0.53	0.4838
SUBNUM(AGE)	10	10.40	1.04		
Within					
ELEMENT	5	29.49	5.90	6.72	0.0001 *
AGE*ELEMENT	5	0.78	0.16	0.18	0.9696
*ELEMENT*SUBNUM(AGE)*	50	43.90	0.88		
DISTYPE	3	12.72	4.24	5.69	0.0033 *
AGE*DISTYPE	3	0.57	0.19	0.25	0.8580
*DISTYPE*SUBNUM(AGE)*	30	22.35	0.75		
DISTYPE*ELEMENT	12	6.96	0.58	1.14	0.3315
AGE*DISTYPE*ELEMENT	12	8.40	0.70	1.38	0.1842
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	59.30	0.51		
DENSITY	2	3.85	1.92	3.10	0.0673
AGE*DENSITY	2	0.16	0.08	0.13	0.8788
*DENSITY*SUBNUM(AGE)*	20	12.41	0.62		
DENSITY*ELEMENT	6	3.15	0.52	0.73	0.6278
AGE*DENSITY*ELEMENT	6	3.60	0.60	0.83	0.5491
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	43.17	0.72		
DENSITY*DISTYPE	5	6.45	1.29	2.18	0.0706
AGE*DENSITY*DISTYPE	5	3.53	0.71	1.20	0.3251
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	29.52	0.59		
DENSITY*DISTYPE*ELEMENT	13	10.34	0.80	1.31	0.2169
AGE*DENSITY*DISTYPE*ELEMENT	13	10.26	0.79	1.30	0.2228
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	68.54	0.61		
TOTAL	543	390.39			

* p < 0.05 (significant)

Appendix 9 – ANOVAs for Full Model for IVIS tasks

Table A.9.11 Dependent Measure: Peak Longitudinal Deceleration

Source	DF	SS	MS	F value	P value
Between					
AGE	1	0.00008	0.00008	0.02	0.8811
SUBNUM(AGE)	10	0.03315	0.00332		
Within					
ELEMENT	5	0.05211	0.01042	5.38	0.0005 *
AGE*ELEMENT	5	0.00370	0.00074	0.38	0.8587
*ELEMENT*SUBNUM(AGE)*	50	0.09688	0.00194		
DISTYPE	3	0.02675	0.00892	6.75	0.0013 *
AGE*DISTYPE	3	0.00315	0.00105	0.80	0.5060
*DISTYPE*SUBNUM(AGE)*	30	0.03962	0.00132		
DISTYPE*ELEMENT	12	0.01522	0.00127	0.87	0.5814
AGE*DISTYPE*ELEMENT	12	0.02025	0.00169	1.15	0.3243
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	0.17104	0.00146		
DENSITY	2	0.00489	0.00244	2.28	0.1285
AGE*DENSITY	2	0.00422	0.00211	1.97	0.1663
*DENSITY*SUBNUM(AGE)*	20	0.02146	0.00107		
DENSITY*ELEMENT	6	0.00345	0.00057	0.47	0.8259
AGE*DENSITY*ELEMENT	6	0.00398	0.00066	0.55	0.7709
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	0.07291	0.00122		
DENSITY*DISTYPE	5	0.00896	0.00179	0.89	0.4962
AGE*DENSITY*DISTYPE	5	0.00547	0.00109	0.54	0.7436
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	0.10086	0.00202		
DENSITY*DISTYPE*ELEMENT	13	0.01236	0.00095	0.60	0.8531
AGE*DENSITY*DISTYPE*ELEMENT	13	0.01295	0.00100	0.62	0.8292
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	0.18023	0.00159		
TOTAL	543	0.8937			

* p < 0.05 (significant)

Appendix 9 – ANOVAs for Full Model for IVIS tasks

Table A.9.12 Dependent Measure: Number of Lane Deviations

Source	DF	SS	MS	F value	P value
Between					
AGE	1	0.01	0.01	0.01	0.9378
SUBNUM(AGE)	10	16.21	1.62		
Within					
ELEMENT	5	3.18	0.64	1.86	0.1175
AGE*ELEMENT	5	0.84	0.17	0.49	0.7826
*ELEMENT*SUBNUM(AGE)*	50	17.08	0.34		
DISTYPE	3	2.11	0.70	1.88	0.1540
AGE*DISTYPE	3	0.57	0.19	0.51	0.6817
*DISTYPE*SUBNUM(AGE)*	30	11.23	0.37		
DISTYPE*ELEMENT	12	4.99	0.42	0.98	0.4753
AGE*DISTYPE*ELEMENT	12	2.99	0.25	0.59	0.8505
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	49.87	0.43		
DENSITY	2	4.30	2.15	7.58	0.0035 *
AGE*DENSITY	2	0.17	0.09	0.30	0.7407
*DENSITY*SUBNUM(AGE)*	20	5.68	0.28		
DENSITY*ELEMENT	6	0.43	0.07	0.20	0.9744
AGE*DENSITY*ELEMENT	6	2.19	0.36	1.03	0.4158
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	21.28	0.35		
DENSITY*DISTYPE	5	0.21	0.04	0.13	0.9856
AGE*DENSITY*DISTYPE	5	1.33	0.27	0.81	0.5478
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	16.47	0.33		
DENSITY*DISTYPE*ELEMENT	13	4.75	0.37	0.89	0.5685
AGE*DENSITY*DISTYPE*ELEMENT	13	2.78	0.21	0.52	0.9085
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	46.57	0.41		
TOTAL	543	215.27			

* p < 0.05 (significant)

Table A.9.13 Dependent Measure: Peak Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
Between					
AGE	1	16404.98	16404.98	3.78	0.0807
SUBNUM(AGE)	10	43452.74	4345.27		
Within					
ELEMENT	5	33801.60	6760.32	6.52	0.0001 *
AGE*ELEMENT	5	8474.28	1694.86	1.64	0.1678
*ELEMENT*SUBNUM(AGE)*	50	51811.28	1036.23		
DISTYPE	3	16158.21	5386.07	6.52	0.0016 *
AGE*DISTYPE	3	2815.52	938.51	1.14	0.3502
*DISTYPE*SUBNUM(AGE)*	30	24775.49	825.85		
DISTYPE*ELEMENT	12	12812.27	1067.69	1.14	0.3355
AGE*DISTYPE*ELEMENT	12	10205.96	850.50	0.91	0.5416
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	109622.54	936.94		
DENSITY	2	14895.30	7447.65	8.62	0.0020 *
AGE*DENSITY	2	1166.53	583.26	0.67	0.5204
*DENSITY*SUBNUM(AGE)*	20	17282.82	864.14		
DENSITY*ELEMENT	6	2441.00	406.83	0.48	0.8194
AGE*DENSITY*ELEMENT	6	7442.31	1240.38	1.47	0.2045
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	50684.59	844.74		
DENSITY*DISTYPE	5	6927.23	1385.45	1.51	0.2051
AGE*DENSITY*DISTYPE	5	7480.91	1496.18	1.63	0.1705
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	46027.67	920.55		
DENSITY*DISTYPE*ELEMENT	13	7744.89	595.76	0.64	0.8188
AGE*DENSITY*DISTYPE*ELEMENT	13	11998.82	922.99	0.99	0.4694
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	105762.23	935.95		
TOTAL	543	610189.17			

* p < 0.05 (significant)

Table A.9.14 Dependent Measure: Variance in Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
Between					
AGE	1	336568.32	336568.32	2.83	0.1233
SUBNUM(AGE)	10	1188214.07	118821.41		
Within					
ELEMENT	5	61878.91	12375.78	1.00	0.4301
AGE*ELEMENT	5	94382.19	18876.44	1.52	0.2009
*ELEMENT*SUBNUM(AGE)*	50	621556.32	12431.13		
DISTYPE	3	67565.52	22521.84	1.19	0.3306
AGE*DISTYPE	3	79450.28	26483.43	1.40	0.2626
*DISTYPE*SUBNUM(AGE)*	30	568333.42	18944.45		
DISTYPE*ELEMENT	12	131945.78	10995.48	0.79	0.6581
AGE*DISTYPE*ELEMENT	12	182160.47	15180.04	1.09	0.3724
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	1624846.26	13887.57		
DENSITY	2	34360.51	17180.26	1.35	0.2824
AGE*DENSITY	2	9948.30	4974.15	0.39	0.6819
*DENSITY*SUBNUM(AGE)*	20	254936.19	12746.81		
DENSITY*ELEMENT	6	35119.13	5853.19	0.63	0.7074
AGE*DENSITY*ELEMENT	6	61885.06	10314.18	1.11	0.3695
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	559463.59	9324.39		
DENSITY*DISTYPE	5	92637.05	18527.41	0.90	0.4873
AGE*DENSITY*DISTYPE	5	70226.93	14045.39	0.68	0.6379
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	1027185.09	20543.70		
DENSITY*DISTYPE*ELEMENT	13	96989.48	7460.73	0.55	0.8873
AGE*DENSITY*DISTYPE*ELEMENT	13	146346.59	11257.43	0.83	0.6264
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	1530315.21	13542.61		
TOTAL	543	8876314.67			

* p < 0.05 (significant)

Table A.9.15 Dependent Measure: Mean in Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
Between					
AGE	1	424.73	424.73	3.57	0.0880
SUBNUM(AGE)	10	1188.25	118.82		
Within					
ELEMENT	5	42.36	8.47	0.94	0.4648
AGE*ELEMENT	5	72.69	14.54	1.61	0.1748
*ELEMENT*SUBNUM(AGE)*	50	451.65	9.03		
DISTYPE	3	71.89	23.96	2.15	0.1145
AGE*DISTYPE	3	27.82	9.27	0.83	0.4866
*DISTYPE*SUBNUM(AGE)*	30	334.16	11.14		
DISTYPE*ELEMENT	12	131.44	10.95	1.12	0.3483
AGE*DISTYPE*ELEMENT	12	84.49	7.04	0.72	0.7276
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	1141.13	9.75		
DENSITY	2	23.65	11.83	1.61	0.2240
AGE*DENSITY	2	1.36	0.68	0.09	0.9119
*DENSITY*SUBNUM(AGE)*	20	146.55	7.33		
DENSITY*ELEMENT	6	30.75	5.12	0.57	0.7507
AGE*DENSITY*ELEMENT	6	30.37	5.06	0.57	0.7561
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	537.10	8.95		
DENSITY*DISTYPE	5	97.91	19.58	1.53	0.1977
AGE*DENSITY*DISTYPE	5	23.64	4.73	0.37	0.8673
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	640.26	12.81		
DENSITY*DISTYPE*ELEMENT	13	100.24	7.71	0.92	0.5367
AGE*DENSITY*DISTYPE*ELEMENT	13	54.44	4.19	0.50	0.9213
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	948.89	8.40		
TOTAL	543	6605.77			

* p < 0.05 (significant)

Appendix 9 – ANOVAs for Full Model for IVIS tasks

Table A.9.16 Dependent Measure: Peak Lateral Acceleration

Source	DF	SS	MS	F value	P value
Between					
AGE	1	0.0054	0.0054	1.25	0.2900
SUBNUM(AGE)	10	0.0431	0.0043		
Within					
ELEMENT	5	0.0555	0.0111	8.68	0.0001 *
AGE*ELEMENT	5	0.0112	0.0022	1.75	0.1398
*ELEMENT*SUBNUM(AGE)*	50	0.0639	0.0013		
DISTYPE	3	0.0191	0.0064	6.75	0.0013 *
AGE*DISTYPE	3	0.0033	0.0011	1.18	0.3343
*DISTYPE*SUBNUM(AGE)*	30	0.0282	0.0009		
DISTYPE*ELEMENT	12	0.0129	0.0011	1.00	0.4515
AGE*DISTYPE*ELEMENT	12	0.0091	0.0008	0.71	0.7375
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	0.1251	0.0011		
DENSITY	2	0.0088	0.0044	6.45	0.0069 *
AGE*DENSITY	2	0.0004	0.0002	0.27	0.7643
*DENSITY*SUBNUM(AGE)*	20	0.0136	0.0007		
DENSITY*ELEMENT	6	0.0044	0.0007	0.72	0.6375
AGE*DENSITY*ELEMENT	6	0.0055	0.0009	0.89	0.5090
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	0.0617	0.0010		
DENSITY*DISTYPE	5	0.0103	0.0021	1.41	0.2353
AGE*DENSITY*DISTYPE	5	0.0069	0.0014	0.95	0.4575
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	0.0727	0.0015		
DENSITY*DISTYPE*ELEMENT	13	0.0101	0.0008	0.56	0.8817
AGE*DENSITY*DISTYPE*ELEMENT	13	0.0137	0.0011	0.76	0.7006
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	0.1564	0.0014		
TOTAL	543	0.7412			

* p < 0.05 (significant)

Appendix 9 – ANOVAs for Full Model for IVIS tasks

Table A.9.17 Dependent Measure: Task Completion Time

Source	DF	SS	MS	F value	P value
Between					
AGE	1	2195.80	2195.80	1.37	0.2683
SUBNUM(AGE)	10	15984.18	1598.42		
Within					
ELEMENT	5	19619.99	3924.00	36.18	0.0001 *
AGE*ELEMENT	5	1112.77	222.55	2.05	0.0873
*ELEMENT*SUBNUM(AGE)*	50	5423.53	108.47		
DISTYPE	3	12059.52	4019.84	22.56	0.0001 *
AGE*DISTYPE	3	440.03	146.68	0.82	0.4914
*DISTYPE*SUBNUM(AGE)*	30	5345.64	178.19		
DISTYPE*ELEMENT	12	1961.99	163.50	2.79	0.0022 *
AGE*DISTYPE*ELEMENT	12	968.18	80.68	1.38	0.1874
*DISTYPE*ELEMENT*SUBNUM(AGE)*	117	6863.68	58.66		
DENSITY	2	9066.25	4533.12	30.66	0.0001 *
AGE*DENSITY	2	269.29	134.64	0.91	0.4184
*DENSITY*SUBNUM(AGE)*	20	2957.50	147.88		
DENSITY*ELEMENT	6	1178.92	196.49	4.93	0.0004 *
AGE*DENSITY*ELEMENT	6	368.23	61.37	1.54	0.1806
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	2390.41	39.84		
DENSITY*DISTYPE	5	2287.50	457.50	10.08	0.0001 *
AGE*DENSITY*DISTYPE	5	74.72	14.94	0.33	0.8930
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	2269.98	45.40		
DENSITY*DISTYPE*ELEMENT	13	1142.23	87.86	2.29	0.0099 *
AGE*DENSITY*DISTYPE*ELEMENT	13	601.01	46.23	1.21	0.2832
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	113	4326.99	38.29		
TOTAL	543	98908.35			

* p < 0.05 (significant)

Appendix 9 – ANOVAs for Full Model for IVIS tasks

Table A.9.18 Dependent Measure: Modified NASA TLX

Source	DF	SS	MS	F value	P value
Between					
AGE	1	7.59	7.59	0.00	0.9653
SUBNUM(AGE)	10	38027.28	3802.73		
Within					
ELEMENT	5	8857.43	1771.49	10.34	0.0001 *
AGE*ELEMENT	5	560.16	112.03	0.65	0.6600
*ELEMENT*SUBNUM(AGE)*	50	8567.92	171.36		
DISTYPE	3	6365.39	2121.80	11.75	0.0001 *
AGE*DISTYPE	3	1054.13	351.38	1.95	0.1436
*DISTYPE*SUBNUM(AGE)*	30	5418.66	180.62		
DISTYPE*ELEMENT	12	1416.90	118.08	2.72	0.0027 *
AGE*DISTYPE*ELEMENT	12	553.07	46.09	1.06	0.3981
*DISTYPE*ELEMENT*SUBNUM(AGE)*	120	5207.38	43.39		
DENSITY	2	6233.91	3116.96	16.61	0.0001 *
AGE*DENSITY	2	116.04	58.02	0.31	0.7375
*DENSITY*SUBNUM(AGE)*	20	3754.13	187.71		
DENSITY*ELEMENT	6	816.21	136.03	2.14	0.0616
AGE*DENSITY*ELEMENT	6	451.09	75.18	1.18	0.3275
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	3812.83	63.55		
DENSITY*DISTYPE	5	2688.89	537.78	7.21	0.0001 *
AGE*DENSITY*DISTYPE	5	217.00	43.40	0.58	0.7136
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	3728.51	74.57		
DENSITY*DISTYPE*ELEMENT	13	940.64	72.36	2.08	0.0194 *
AGE*DENSITY*DISTYPE*ELEMENT	13	302.11	23.24	0.67	0.7910
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	130	4522.32	34.79		
TOTAL	563	103619.59			

* $p < 0.05$ (significant)

Table A.9.19 Dependent Measure: Subjective Assessment of Situation Awareness

Source	DF	SS	MS	F value	P value
Between					
AGE	1	2668.76	2668.76	1.08	0.3233
SUBNUM(AGE)	10	24720.66	2472.07		
Within					
ELEMENT	5	2121.02	424.20	8.17	0.0001 *
AGE*ELEMENT	5	888.23	177.65	3.42	0.0098 *
*ELEMENT*SUBNUM(AGE)*	50	2595.96	51.92		
DISTYPE	3	2506.59	835.53	15.48	0.0001 *
AGE*DISTYPE	3	228.50	76.17	1.41	0.2588
*DISTYPE*SUBNUM(AGE)*	30	1619.11	53.97		
DISTYPE*ELEMENT	12	1531.82	127.65	3.54	0.0002 *
AGE*DISTYPE*ELEMENT	12	339.96	28.33	0.78	0.6651
*DISTYPE*ELEMENT*SUBNUM(AGE)*	120	4331.87	36.10		
DENSITY	2	2142.47	1071.24	24.66	0.0001 *
AGE*DENSITY	2	213.42	106.71	2.46	0.1112
*DENSITY*SUBNUM(AGE)*	20	868.69	43.43		
DENSITY*ELEMENT	6	321.49	53.58	1.48	0.1994
AGE*DENSITY*ELEMENT	6	620.63	103.44	2.86	0.0161 *
*DENSITY*ELEMENT*SUBNUM(AGE)*	60	2167.99	36.13		
DENSITY*DISTYPE	5	942.11	188.42	5.04	0.0008 *
AGE*DENSITY*DISTYPE	5	238.35	47.67	1.27	0.2896
*DENSITY*DISTYPE*SUBNUM(AGE)*	50	1869.83	37.40		
DENSITY*DISTYPE*ELEMENT	13	318.03	24.46	0.78	0.6838
AGE*DENSITY*DISTYPE*ELEMENT	13	672.53	51.73	1.64	0.0817
*DENSITY*DISTYPE*ELEMENT*SUBUM(AGE)*	130	4096.84	31.51		
TOTAL	563	58024.85			

* p < 0.05 (significant)

Appendix 10 – Plots for the significant interactions of the ANOVA Full Model
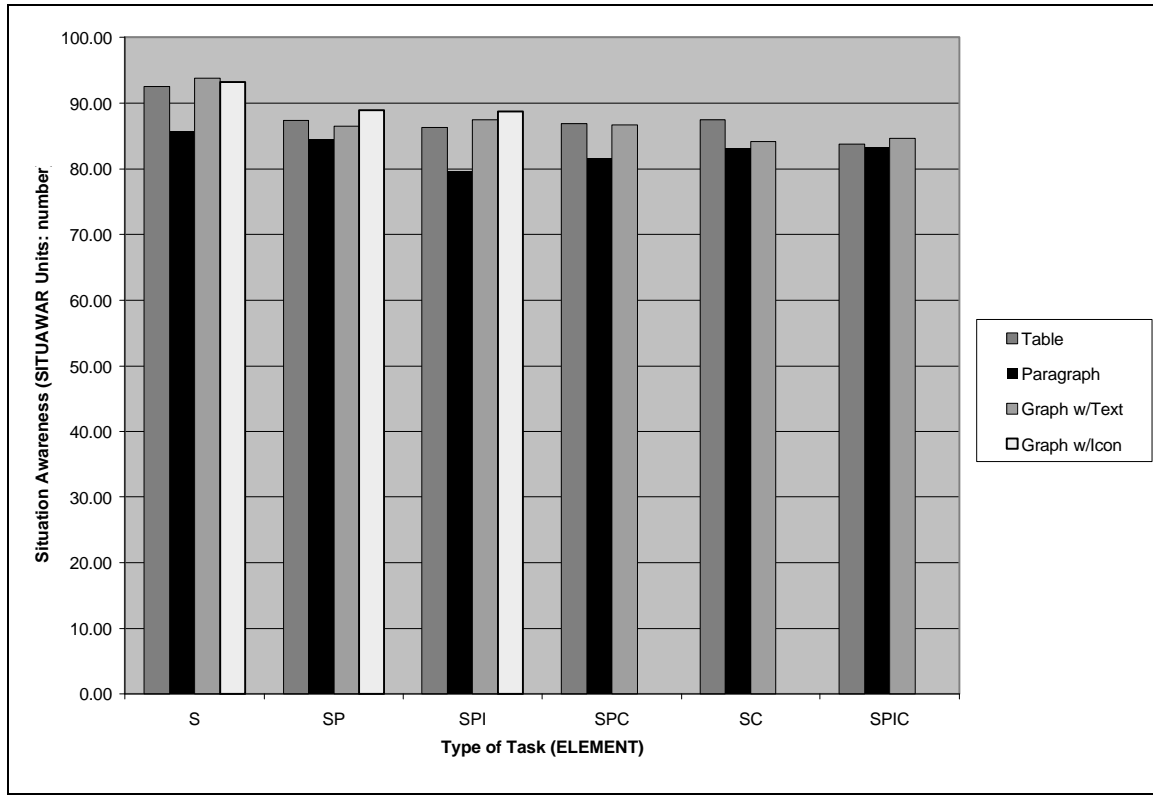
DISTYPE*ELEMENT

DISTYPE	ELEMENT	SITUAWAR	N
Table	S	92.50	36
Table	SP	87.36	36
Table	SPI	86.25	36
Table	SPC	86.88	24
Table	SC	87.46	24
Table	SPIC	83.75	12
Paragraph	S	85.69	36
Paragraph	SP	84.44	36
Paragraph	SPI	79.58	36
Paragraph	SPC	81.67	24
Paragraph	SC	83.13	24
Paragraph	SPIC	83.33	12
Graph w/Text	S	93.75	24
Graph w/Text	SP	86.46	24
Graph w/Text	SPI	87.50	24
Graph w/Text	SPC	86.67	24
Graph w/Text	SC	84.17	24
Graph w/Text	SPIC	84.58	12
Graph w/Icon	S	93.17	36
Graph w/Icon	SP	88.89	36
Graph w/Icon	SPI	88.75	24

Situation Awareness (SITUAWAR)
The Search is the type of task with the highest situational awareness among all six types of tasks. All the combinations of Table and Graphs with the Search task present a low decrease in situational awareness (less than 10%). The Paragraph represents the lowest situational awareness when compared with the other three formats for all six types of tasks.

170
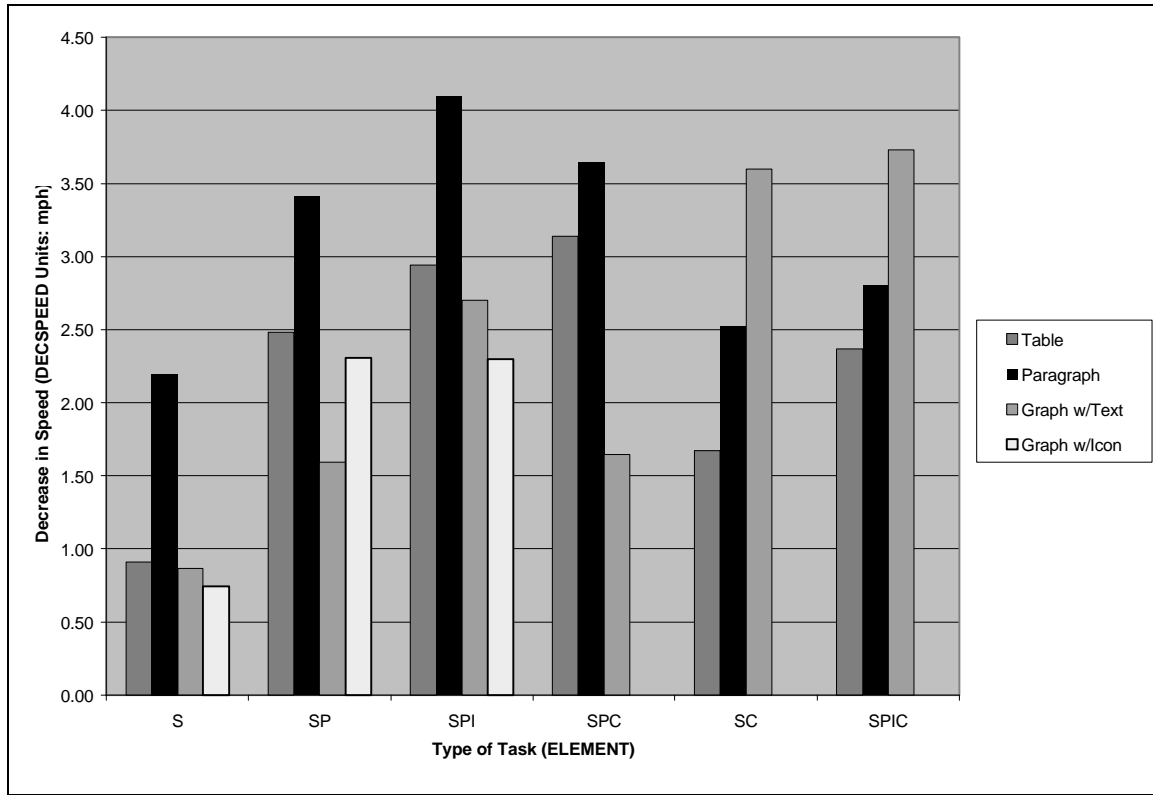
DISTYPE*ELEMENT

DISTYPE	ELEMENT	DECSPEED	N
Table	S	0.91	36
Table	SP	2.48	36
Table	SPI	2.95	36
Table	SPC	3.14	24
Table	SC	1.67	24
Table	SPIC	2.37	12
Paragraph	S	2.20	36
Paragraph	SP	3.41	36
Paragraph	SPI	4.09	36
Paragraph	SPC	3.65	24
Paragraph	SC	2.53	24
Paragraph	SPIC	2.80	12
Graph w/Text	S	0.87	24
Graph w/Text	SP	1.59	24
Graph w/Text	SPI	2.70	24
Graph w/Text	SPC	1.65	24
Graph w/Text	SC	3.60	24
Graph w/Text	SPIC	3.73	12
Graph w/Icon	S	0.74	36
Graph w/Icon	SP	2.31	36
Graph w/Icon	SPI	2.30	24

Decrease in Speed (DECSPEED)

The Paragraph format represents the highest decrease in speed for four out of the six types of tasks (i.e. search, search-plan, search-plan-interpret, search-plan-compute). The combination of Search and Graph with Icons levels represent the lowest decrease in speed. Although the Paragraph has a trend of higher decrease in speed, the combinations of the Search-Compute and Search-Plan-Interpret-Compute with Graphs with Text exhibit worse performance than the Paragraph or Table format. The maximum decrease in speed occurs under the Paragraph format when trying to perform a Search-Plan-Interpret (4.09 mph).

DENSITY*ELEMENT
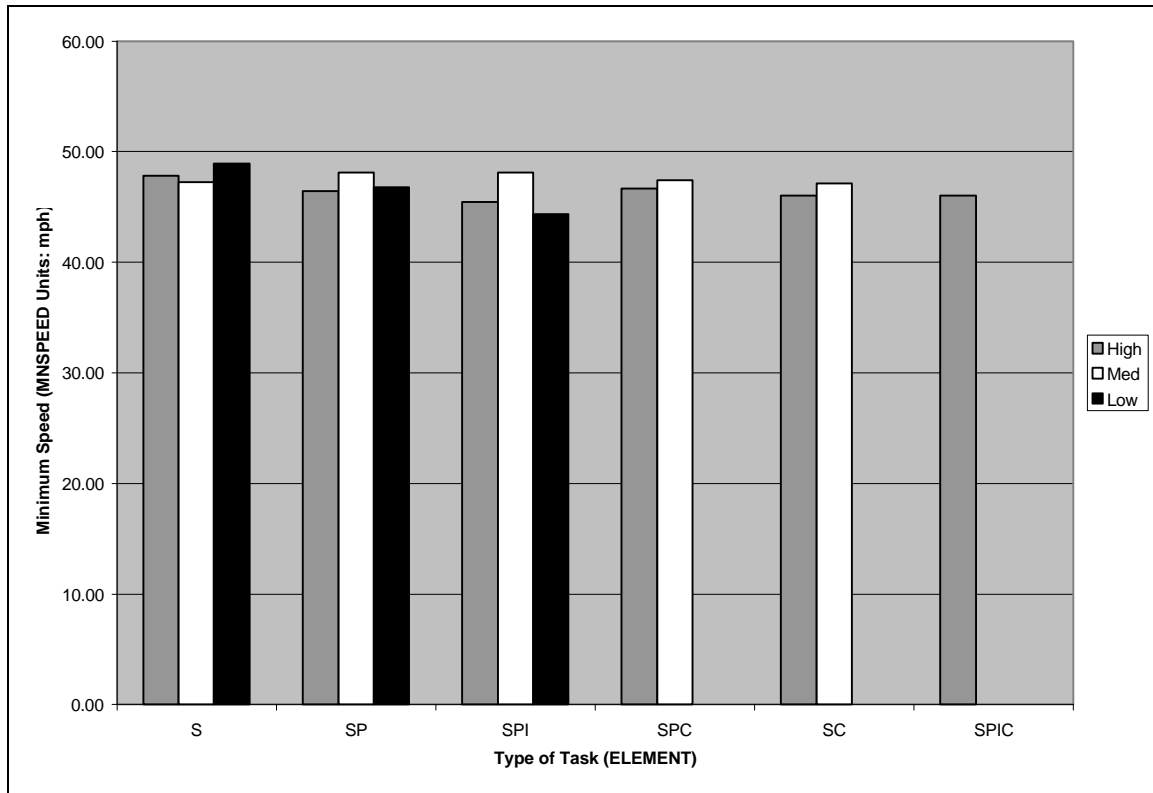
DENSITY	ELEMENT	MNSPEED	N
Low	S	48.93	36
Low	SP	46.81	36
Low	SPI	44.33	24
Med	S	47.29	48
Med	SP	48.15	48
Med	SPI	48.14	48
Med	SPC	47.40	36
Med	SC	47.12	36
High	S	47.83	48
High	SP	46.43	48
High	SPI	45.44	48
High	SPC	46.67	36
High	SC	46.02	36
High	SPIC	46.07	36

Minimum Speed (MNSPEED)

The minimum speed ranged from 44.3 – 48.9 mph. The Search type of task with the lowest information density represents the highest minimum speed. A Medium level of information density seems to create the least decrease in speed for the Search-Plan, Search-Plan-Interpret, and Search-Plan-Compute.

Appendix 10 – Plots for the significant interactions of the ANOVA Full Model
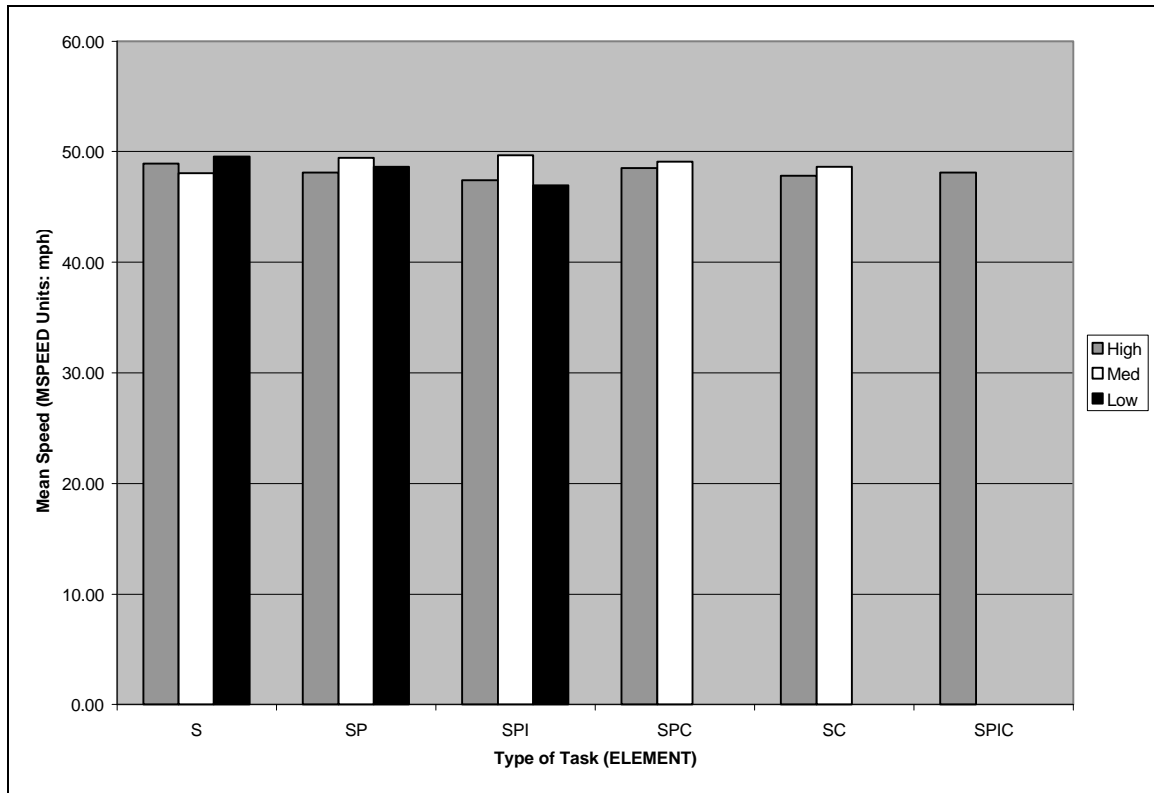
DENSITY*ELEMENT

DENSITY	ELEMENT	MSPEED	N
Low	S	49.56	36
Low	SP	48.62	36
Low	SPI	46.95	24
Med	S	48.06	48
Med	SP	49.47	48
Med	SPI	49.67	48
Med	SPC	49.08	36
Med	SC	48.64	36
High	S	48.93	48
High	SP	48.10	48
High	SPI	47.43	48
High	SPC	48.56	36
High	SC	47.85	36
High	SPIC	48.11	36

Mean Speed (MSPEED)

The mean value of speed follows the same pattern created by the minimum speed reached during the task-completion-time.

DENSITY*DISTYPE
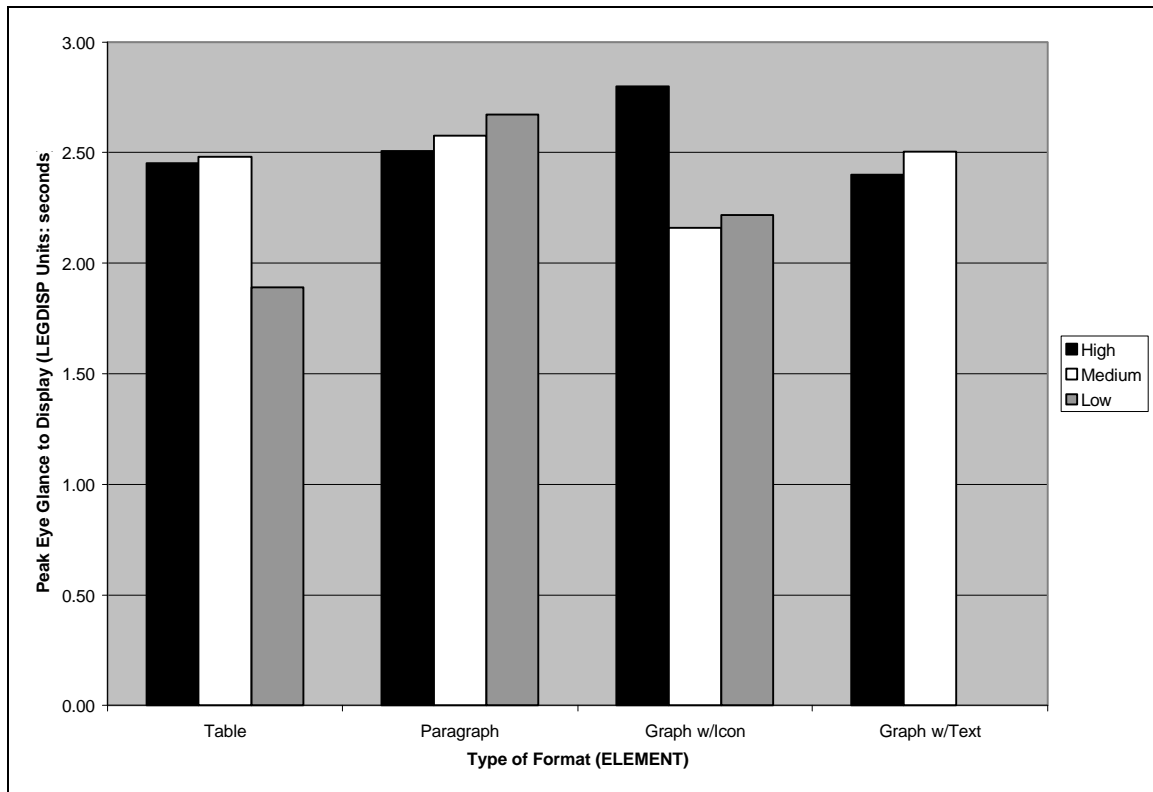
DENSITY	DISTYPE	LEGDISP	N
Low	Table	1.89	36
Low	Paragraph	2.67	36
Low	Graph w/Icon	2.22	24
Med	Table	2.48	60
Med	Paragraph	2.58	60
Med	Graph w/Icon	2.16	36
Med	Graph w/Text	2.50	60
High	Table	2.45	72
High	Paragraph	2.51	72
High	Graph w/Icon	2.80	36
High	Graph w/Text	2.40	72

Peak Eye Glance to Display (LEGDISP)

The Table format with a Low information density represents the task with the shortest peak eye glance to the display (1.9 seconds). Following the Table with Low information density, the next two lowest values for peak eye glance are those for the Graph with Icons in a low or medium information density. Although the Graph with Icons represents one of the lowest values for peak eye glance, if a high information density is introduced in this type of format, the peak eye glance time tends to increase drastically.

DENSITY*DISTYPE
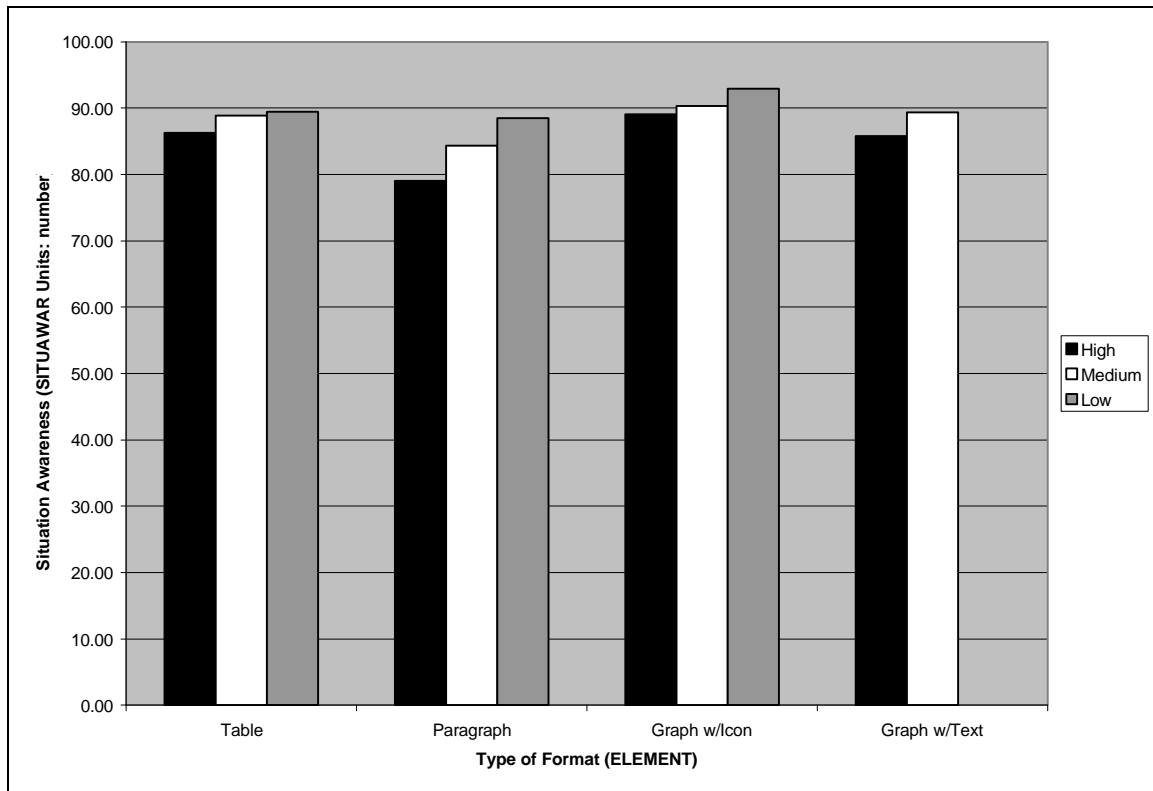
DENSITY	DISTYPE	SITUAWAR	N
Low	Table	89.44	36
Low	Paragraph	88.47	36
Low	Graph w/Icon	92.92	24
Med	Table	88.92	60
Med	Paragraph	84.42	60
Med	Graph w/Icon	90.28	36
Med	Graph w/Text	89.42	60
High	Table	86.31	72
High	Paragraph	79.10	72
High	Graph w/Icon	89.00	36
High	Graph w/Text	85.76	72

Situation Awareness (SITUAWAR)

The highest situational awareness is obtained by presenting a Low information density in a Graph with Icons format. The Low information density represents the highest situational awareness for the Graph with Icons, Table, and Paragraph, followed by Medium information density as the second best option for all types of formats. The lowest values of this measure occur in the Paragraph format.

DENSITY*DISTYPE*ELEMENT
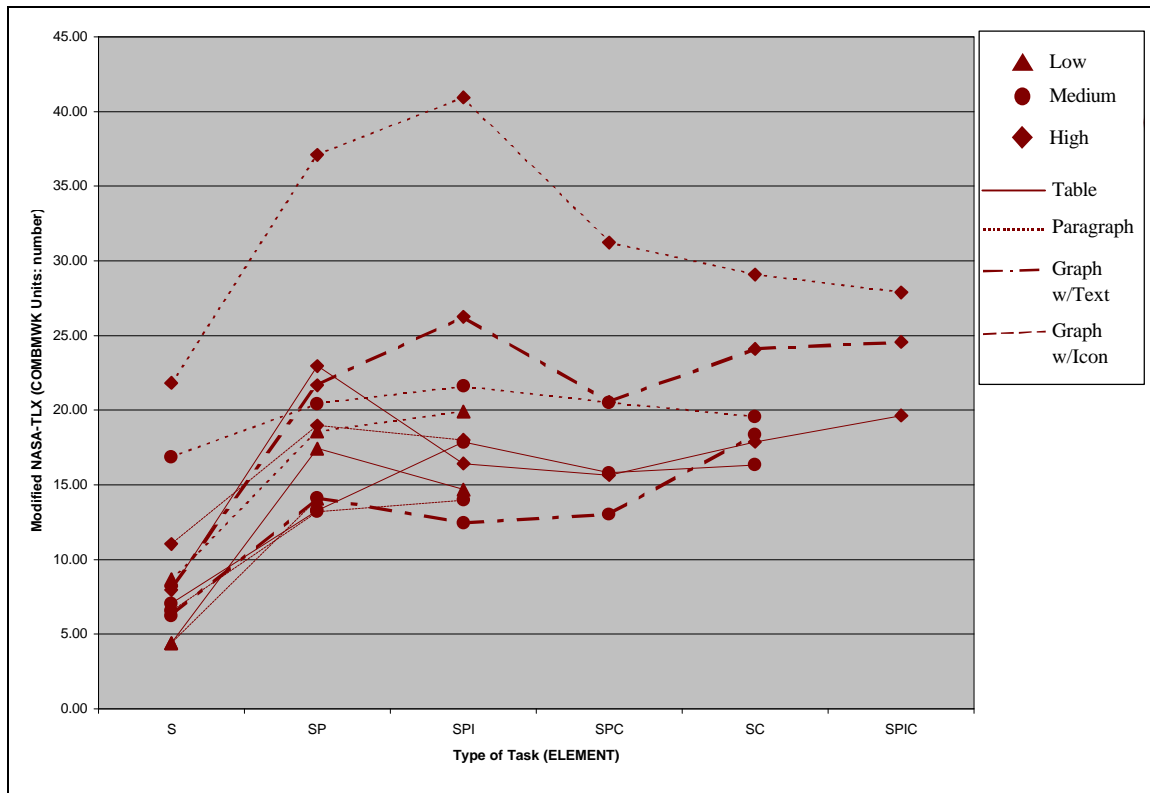
Modified NASA-TLX (COMBMWK)

The Paragraph with a high information density represents the highest mental workload for all six types of tasks. The next two highest sets of values for mental workload are represented by the Graph with text, and the Paragraph, with High and Medium levels of information density, respectively. The lowest mental workload is represented by the Graph with Icons and the Table format, both with a low information density, when a search task is performed.

Appendix 10 – Plots for the significant interactions of the ANOVA Full Model

DENSITY	DISTYPE	ELEMENT	COMBMWK	N
Low	Graph w/Icon	S	4.39	12
Low	Graph w/Icon	SP	14.06	12
Low	Paragraph	S	8.69	12
Low	Paragraph	SP	18.56	12
Low	Paragraph	SPI	19.92	12
Low	Table	S	4.39	12
Low	Table	SP	17.42	12
Low	Table	SPI	14.69	12
Med	Graph w/Icon	S	6.56	12
Med	Graph w/Icon	SP	13.22	12
Med	Graph w/Icon	SPI	13.97	12
Med	Graph w/Text	S	6.22	12
Med	Graph w/Text	SP	14.14	12
Med	Graph w/Text	SPI	12.44	12
Med	Graph w/Text	SPC	13.03	12
Med	Graph w/Text	SC	18.36	12
Med	Paragraph	S	16.86	12
Med	Paragraph	SP	20.44	12
Med	Paragraph	SPI	21.61	12
Med	Paragraph	SPC	20.53	12
Med	Paragraph	SC	19.56	12
Med	Table	S	7.06	12
Med	Table	SP	13.31	12
Med	Table	SPI	17.86	12
Med	Table	SPC	15.81	12
Med	Table	SC	16.33	12
High	Graph w/Icon	S	11.06	12
High	Graph w/Icon	SP	18.97	12
High	Graph w/Icon	SPI	18.03	12
High	Graph w/Text	S	8.19	12
High	Graph w/Text	SP	21.69	12
High	Graph w/Text	SPI	26.28	12
High	Graph w/Text	SPC	20.56	12
High	Graph w/Text	SC	24.11	12
High	Graph w/Text	SPIC	24.56	12
High	Paragraph	S	21.83	12
High	Paragraph	SP	37.11	12
High	Paragraph	SPI	40.94	12
High	Paragraph	SPC	31.25	12
High	Paragraph	SC	29.08	12
High	Paragraph	SPIC	27.89	12
High	Table	S	7.94	12
High	Table	SP	22.97	12
High	Table	SPI	16.42	12
High	Table	SPC	15.67	12
High	Table	SC	17.89	12
High	Table	SPIC	19.64	12

DENSITY*DISTYPE*ELEMENT
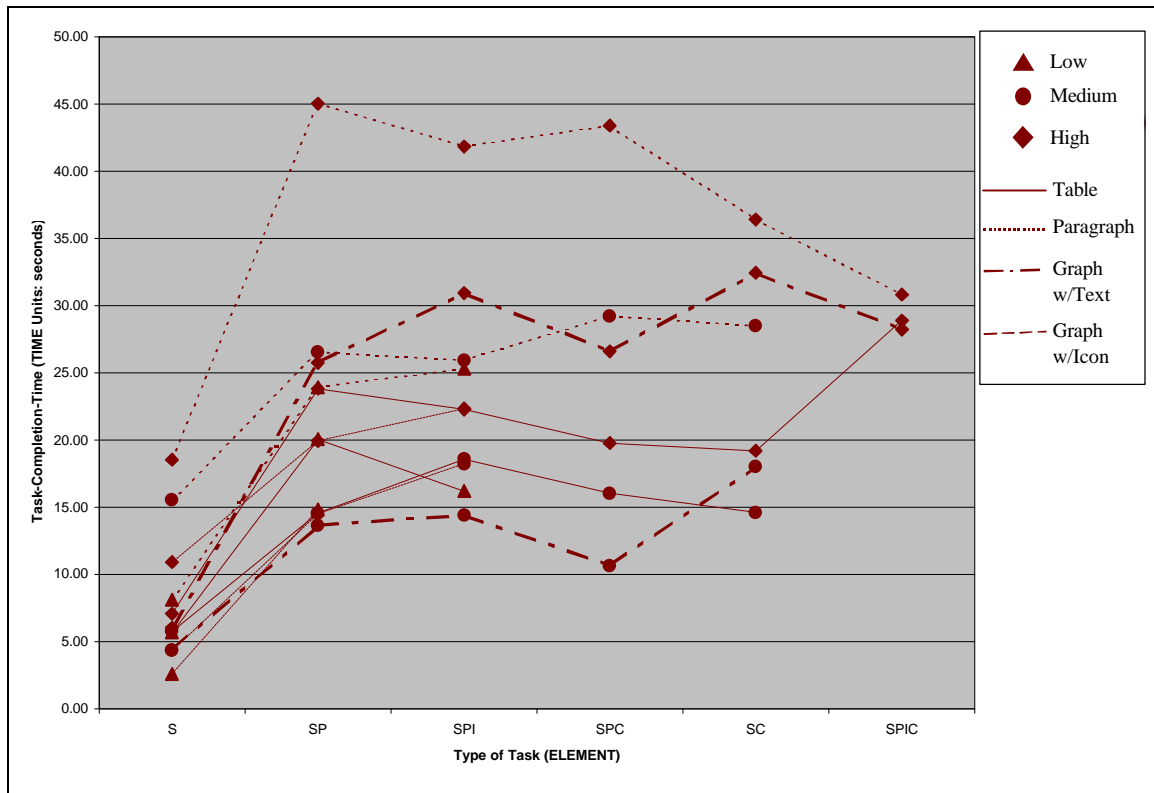
Task-Completion-Time (TIME)

Following the trend shown by the mental workload values, the Paragraph with High and Medium information densities, together with the Graph with Text with a High information density, represent the longest task completion time. Once again, the Graph with Icons represents the best performance for this interaction. In this case, the lowest task-completion-time is represented by the Graph with Icons with a low information density, when a Search task is performed.

Appendix 10 – Plots for the significant interactions of the ANOVA Full Model

DENSITY	DISTYPE	ELEMENT	TIME	N
Low	Graph w/Icon	S	2.60	12
Low	Graph w/Icon	SP	14.84	12
Low	Paragraph	S	8.13	12
Low	Paragraph	SP	23.93	12
Low	Paragraph	SPI	25.29	12
Low	Table	S	5.66	12
Low	Table	SP	20.06	12
Low	Table	SPI	16.19	12
Med	Graph w/Icon	S	4.35	12
Med	Graph w/Icon	SP	14.53	12
Med	Graph w/Icon	SPI	18.22	12
Med	Graph w/Text	S	4.36	12
Med	Graph w/Text	SP	13.66	12
Med	Graph w/Text	SPI	14.40	12
Med	Graph w/Text	SPC	10.64	12
Med	Graph w/Text	SC	18.03	12
Med	Paragraph	S	15.53	12
Med	Paragraph	SP	26.54	12
Med	Paragraph	SPI	25.94	12
Med	Paragraph	SPC	29.23	12
Med	Paragraph	SC	28.51	12
Med	Table	S	5.77	12
Med	Table	SP	14.55	12
Med	Table	SPI	18.58	12
Med	Table	SPC	16.05	12
Med	Table	SC	14.59	12
High	Graph w/Icon	S	10.91	12
High	Graph w/Icon	SP	19.92	12
High	Graph w/Icon	SPI	22.33	12
High	Graph w/Text	S	6.04	12
High	Graph w/Text	SP	25.77	12
High	Graph w/Text	SPI	30.94	12
High	Graph w/Text	SPC	26.58	12
High	Graph w/Text	SC	32.44	12
High	Graph w/Text	SPIC	28.22	12
High	Paragraph	S	18.55	12
High	Paragraph	SP	45.05	12
High	Paragraph	SPI	41.84	12
High	Paragraph	SPC	43.40	12
High	Paragraph	SC	36.42	12
High	Paragraph	SPIC	30.82	12
High	Table	S	7.09	12
High	Table	SP	23.84	12
High	Table	SPI	22.27	12
High	Table	SPC	19.77	12
High	Table	SC	19.21	12
High	Table	SPIC	28.90	12

Appendix 10 – Plots for the significant interactions of the ANOVA Full Model

DENSITY*DISTYPE*ELEMENT
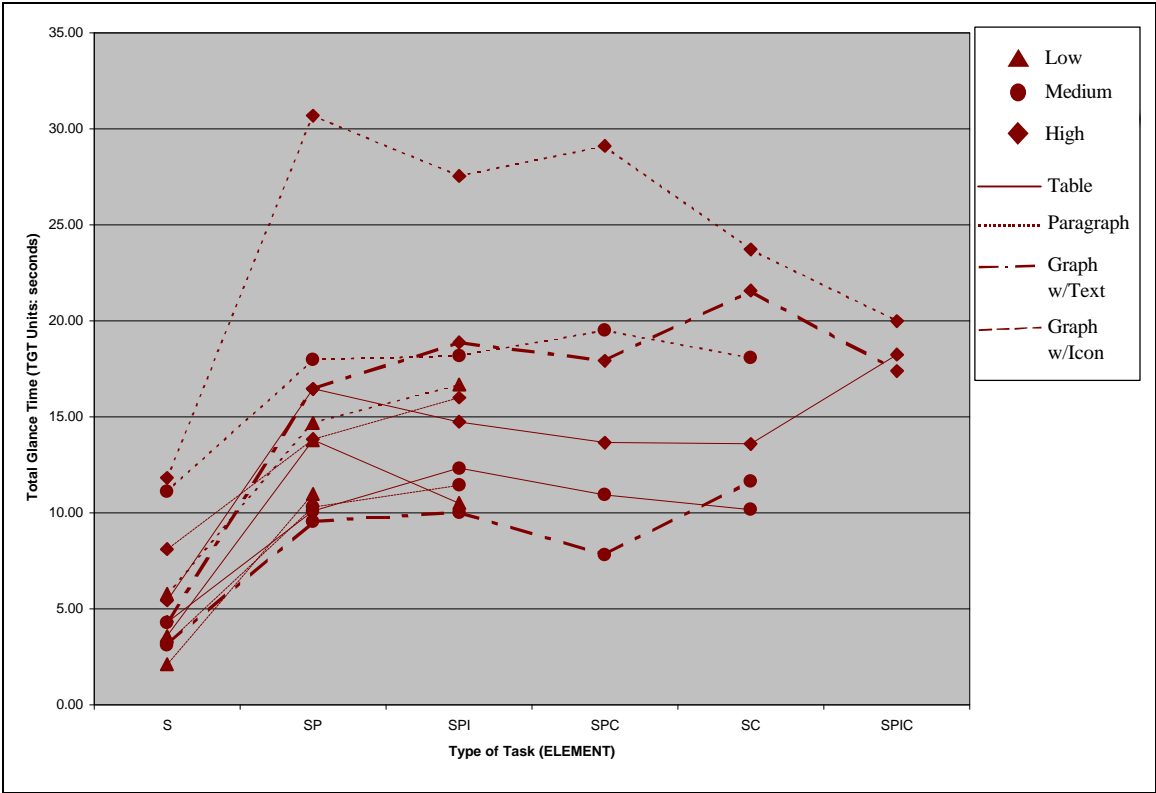
Total Glance Time (TGT)

The total glance time follows the same pattern as task-completion-time and mental workload, where Paragraph with a High and Medium information density represent the longest total glance time for all types of tasks, and the Graph with Icons with a Low information density for a Search task is the best performer. Search appears to constantly represent the shortest total glance time when it is compared to the other types of tasks for a given information density and format.

Appendix 10 – Plots for the significant interactions of the ANOVA Full Model

DENSITY	DISTYPE	ELEMENT	TGT	N
Low	Graph w/Icon	S	2.11	12
Low	Graph w/Icon	SP	11.00	12
Low	Paragraph	S	5.79	12
Low	Paragraph	SP	14.70	12
Low	Paragraph	SPI	16.69	12
Low	Table	S	3.60	12
Low	Table	SP	13.79	12
Low	Table	SPI	10.52	12
Med	Graph w/Icon	S	3.21	12
Med	Graph w/Icon	SP	10.31	12
Med	Graph w/Icon	SPI	11.44	12
Med	Graph w/Text	S	3.09	12
Med	Graph w/Text	SP	9.56	12
Med	Graph w/Text	SPI	10.02	12
Med	Graph w/Text	SPC	7.82	12
Med	Graph w/Text	SC	11.66	12
Med	Paragraph	S	11.11	12
Med	Paragraph	SP	17.99	12
Med	Paragraph	SPI	18.17	12
Med	Paragraph	SPC	19.51	12
Med	Paragraph	SC	18.06	12
Med	Table	S	4.29	12
Med	Table	SP	10.10	12
Med	Table	SPI	12.34	12
Med	Table	SPC	10.94	12
Med	Table	SC	10.18	12
High	Graph w/Icon	S	8.11	12
High	Graph w/Icon	SP	13.85	12
High	Graph w/Icon	SPI	15.99	12
High	Graph w/Text	S	4.33	12
High	Graph w/Text	SP	16.46	12
High	Graph w/Text	SPI	18.87	12
High	Graph w/Text	SPC	17.93	12
High	Graph w/Text	SC	21.58	12
High	Graph w/Text	SPIC	17.39	12
High	Paragraph	S	11.83	12
High	Paragraph	SP	30.68	12
High	Paragraph	SPI	27.55	12
High	Paragraph	SPC	29.11	12
High	Paragraph	SC	23.73	12
High	Paragraph	SPIC	20.00	12
High	Table	S	5.45	12
High	Table	SP	16.47	12
High	Table	SPI	14.72	12
High	Table	SPC	13.67	12
High	Table	SC	13.59	12
High	Table	SPIC	18.23	12

DENSITY*DISTYPE*ELEMENT
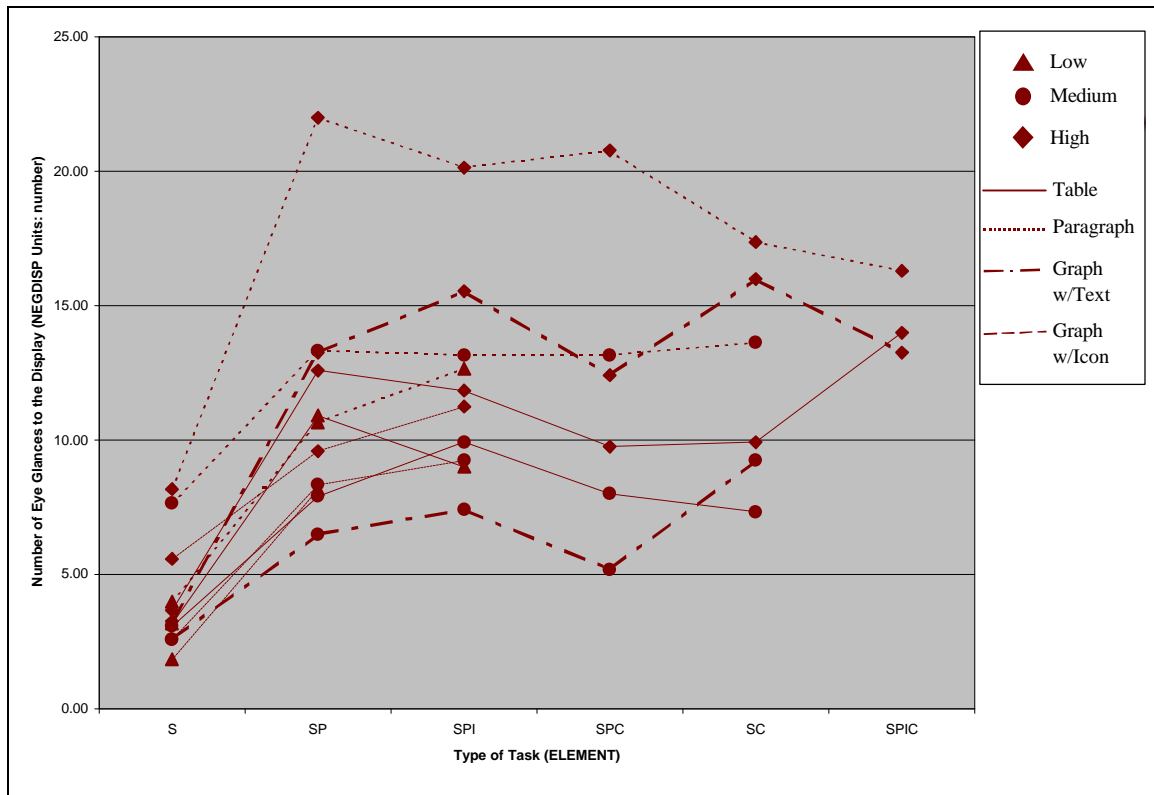
Number of Eye Glances to the Display (NEGDISP)

The trend for the number of eye glances to the display is no exception. The Paragraph (High and Medium information densities) continues to lead, this time with the greatest number of eye glances to th display, followed once again by Graph with text with a High information density. The Search task continues to lead (everything else constant) with the least number of eye glances to display when compared to the other five types of tasks.

Appendix 10 – Plots for the significant interactions of the ANOVA Full Model

DENSITY	DISTYPE	ELEMENT	NEGDISP	N
Low	Graph w/Icon	S	1.83	12
Low	Graph w/Icon	SP	8.17	12
Low	Paragraph	S	4.00	12
Low	Paragraph	SP	10.67	12
Low	Paragraph	SPI	12.67	12
Low	Table	S	3.17	12
Low	Table	SP	10.92	12
Low	Table	SPI	9.00	12
Med	Graph w/Icon	S	2.58	12
Med	Graph w/Icon	SP	8.33	12
Med	Graph w/Icon	SPI	9.25	12
Med	Graph w/Text	S	2.58	12
Med	Graph w/Text	SP	6.50	12
Med	Graph w/Text	SPI	7.42	12
Med	Graph w/Text	SPC	5.17	12
Med	Graph w/Text	SC	9.25	12
Med	Paragraph	S	7.67	12
Med	Paragraph	SP	13.33	12
Med	Paragraph	SPI	13.17	12
Med	Paragraph	SPC	13.17	12
Med	Paragraph	SC	13.64	12
Med	Table	S	3.08	12
Med	Table	SP	7.92	12
Med	Table	SPI	9.92	12
Med	Table	SPC	8.00	12
Med	Table	SC	7.33	12
High	Graph w/Icon	S	5.58	12
High	Graph w/Icon	SP	9.58	12
High	Graph w/Icon	SPI	11.25	12
High	Graph w/Text	S	3.25	12
High	Graph w/Text	SP	13.25	12
High	Graph w/Text	SPI	15.55	12
High	Graph w/Text	SPC	12.42	12
High	Graph w/Text	SC	16.00	12
High	Graph w/Text	SPIC	13.25	12
High	Paragraph	S	8.17	12
High	Paragraph	SP	22.00	12
High	Paragraph	SPI	20.14	12
High	Paragraph	SPC	20.78	12
High	Paragraph	SC	17.38	12
High	Paragraph	SPIC	16.30	12
High	Table	S	3.67	12
High	Table	SP	12.58	12
High	Table	SPI	11.83	12
High	Table	SPC	9.75	12
High	Table	SC	9.92	12
High	Table	SPIC	14.00	12

AGE*DENSITY*ELEMENT
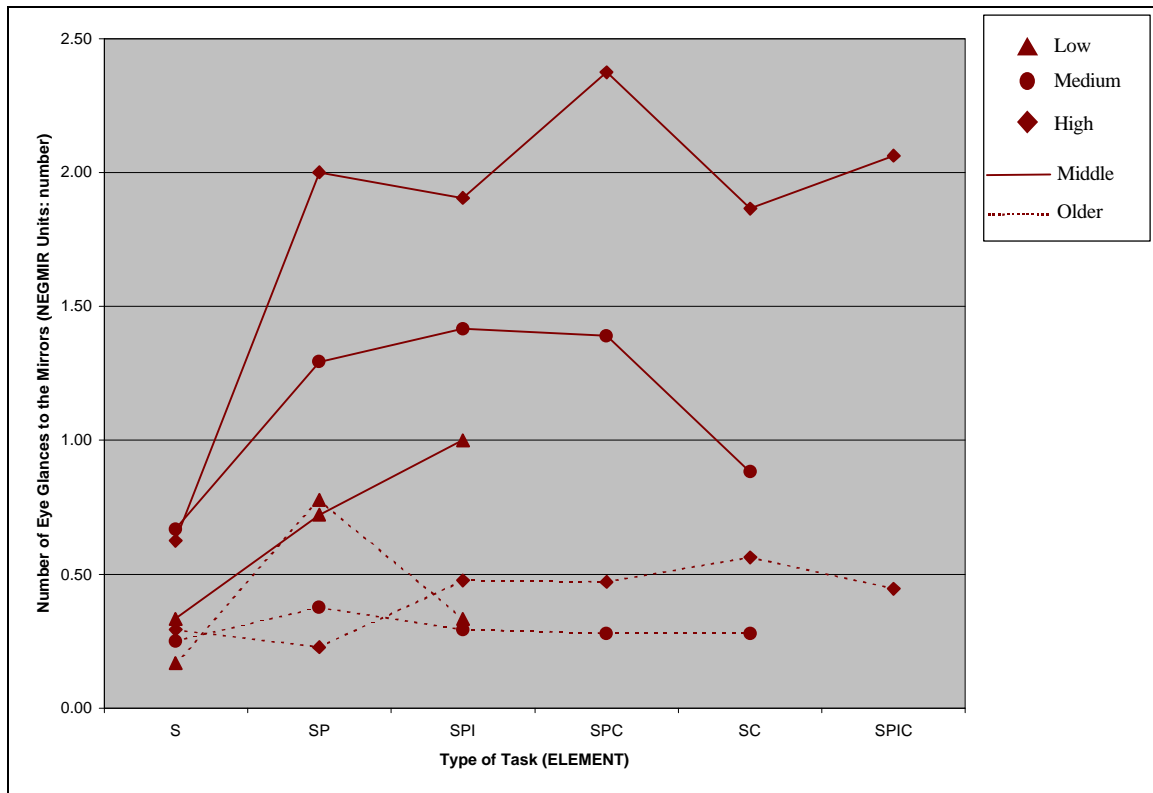
Number of Eye Glances to the Mirrors (NEGMIR)

The number of eye glances to the mirrors for older drivers tend to be low compared to the middle age group, for all the six different types of tasks. It seems that older drivers tend to allocate less time scanning their surrounding environment (other than the front road) while a secondary task is in process. The eye glance behavior for the middle age group lies on the opposite side. They follow a trend that probably represents a need to collect more information from the environment as the task tends to increase in difficulty (i.e. higher information density and more complicated types of tasks).

AGE	DENSITY	ELEMENT	NEGMIR	N
Older	Low	S	0.17	18
Older	Low	SP	0.78	18
Older	Low	SPI	0.33	12
Older	Med	S	0.25	24
Older	Med	SP	0.38	24
Older	Med	SPI	0.29	24
Older	Med	SPC	0.28	18
Older	Med	SC	0.28	18
Older	High	S	0.29	24
Older	High	SP	0.23	24
Older	High	SPI	0.48	24
Older	High	SPC	0.47	18
Older	High	SC	0.56	18
Older	High	SPIC	0.44	18
Middle	Low	S	0.33	18
Middle	Low	SP	0.72	18
Middle	Low	SPI	1.00	12
Middle	Med	S	0.67	24
Middle	Med	SP	1.29	24
Middle	Med	SPI	1.42	24
Middle	Med	SPC	1.39	18
Middle	Med	SC	0.88	18
Middle	High	S	0.63	24
Middle	High	SP	2.00	24
Middle	High	SPI	1.90	24
Middle	High	SPC	2.38	18
Middle	High	SC	1.87	18
Middle	High	SPIC	2.06	18

AGE*DENSITY*ELEMENT
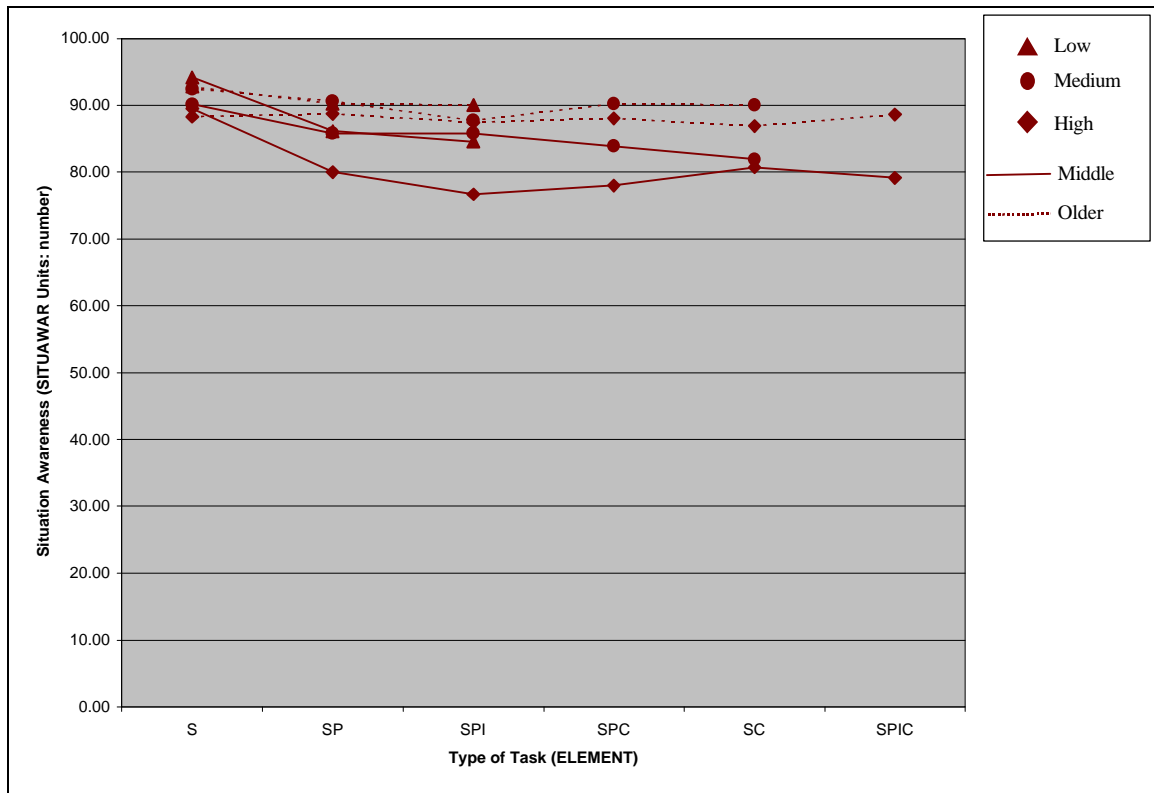
Situation Awareness (SITUAWAR)

The previous trend of number of eye glances to the mirrors (collecting information from their surroundings) seems to describe the way in which the two age groups attempt to compensate for the decrease in situational awareness caused by an increase in the task's attentional demand.

Appendix 10 – Plots for the significant interactions of the ANOVA Full Model

AGE	DENSITY	ELEMENT	SITUAWAR	N
Older	Low	S	92.78	18
Older	Low	SP	90.28	18
Older	Low	SPI	90.00	12
Older	Med	S	92.50	24
Older	Med	SP	90.63	24
Older	Med	SPI	87.71	24
Older	Med	SPC	90.28	18
Older	Med	SC	90.00	18
Older	High	S	88.33	24
Older	High	SP	88.75	24
Older	High	SPI	87.50	24
Older	High	SPC	88.06	18
Older	High	SC	86.94	18
Older	High	SPIC	88.61	18
Middle	Low	S	94.17	18
Middle	Low	SP	86.11	18
Middle	Low	SPI	84.58	12
Middle	Med	S	90.21	24
Middle	Med	SP	85.83	24
Middle	Med	SPI	85.83	24
Middle	Med	SPC	83.89	18
Middle	Med	SC	81.94	18
Middle	High	S	89.54	24
Middle	High	SP	80.00	24
Middle	High	SPI	76.67	24
Middle	High	SPC	78.06	18
Middle	High	SC	80.78	18
Middle	High	SPIC	79.17	18

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.1 Dependent Measure: Number of Eye Glances to Mirror

Source	DF	SS	MS	F value	P value
AGE	1	108.15	108.15	1.25	0.2895
SUBNUM(AGE)	10	864.37	86.44		
Error	580	911.02	1.57		
TOTAL	591	1883.55			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	925.30	84.12		
Within					
ELEMENT	6	44.68	7.45	2.08	0.0679
*SUBNUM*ELEMENT*	66	236.77	3.59		
Error	508	628.60	1.24		
TOTAL	591	1835.36			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	651.17	59.20		
Within					
DISTYPE	4	34.40	8.60	2.36	0.0681
*SUBNUM*DISTYPE*	44	160.49	3.65		
Error	532	715.17	1.34		
TOTAL	591	1561.23			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	423.01	38.46		
Within					
DENSITY	3	30.72	10.24	1.99	0.1342
*SUBNUM*DENSITY*	33	169.56	5.14		
Error	544	709.91	1.30		
TOTAL	591	1333.19			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.2 Dependent Measure: Minimum Speed

Source	DF	SS	MS	F value	P value
AGE	1	1738.21	1738.21	2.53	0.143
SUBNUM(AGE)	10	6878.78	687.88		
Error	580	10620.60	18.31		
TOTAL	591	19237.59			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	6786.37	616.94		
Within					
ELEMENT	6	218.86	36.48	1.56	0.1720
*SUBNUM*ELEMENT*	66	1540.51	23.34		
Error	508	8867.60	17.46		
TOTAL	591	17413.34			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	7025.07	638.64		
Within					
DISTYPE	4	209.61	52.40	2.55	0.0527
*SUBNUM*DISTYPE*	44	905.76	20.59		
Error	532	9498.73	17.85		
TOTAL	591	17639.17			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	5593.98	508.54		
Within					
DENSITY	3	166.88	55.63	3.96	0.0162 *
*SUBNUM*DENSITY*	33	463.38	14.04		
Error	544	9986.72	18.36		
TOTAL	591	16210.96			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.3 Dependent Measure: Decrease in Speed

Source	DF	SS	MS	F value	P value
AGE	1	37.28	37.28	2.8	0.1252
SUBNUM(AGE)	10	133.10	13.31		
Error	580	4221.35	7.28		
TOTAL	591	4391.73			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	131.77	11.98		
Within					
ELEMENT	6	297.08	49.51	7.70	0.0001 *
*SUBNUM*ELEMENT*	66	424.37	6.43		
Error	508	3498.34	6.89		
TOTAL	591	4351.55			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	82.12	7.47		
Within					
DISTYPE	4	163.32	40.83	6.09	0.0005 *
*SUBNUM*DISTYPE*	44	295.05	6.71		
Error	532	3758.90	7.07		
TOTAL	591	4299.39			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	79.89	7.26		
Within					
DENSITY	3	67.81	22.60	4.39	0.0105 *
*SUBNUM*DENSITY*	33	170.07	5.15		
Error	544	3983.74	7.32		
TOTAL	591	4301.50			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.4 Dependent Measure: Variance in Speed

Source	DF	SS	MS	F value	P value
AGE	1	41.96	41.96	1.37	0.2682
SUBNUM(AGE)	10	305.26	30.53		
Error	580	19110.78	32.95		
TOTAL	591	19458.00			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	228.62	20.78		
Within					
ELEMENT	6	344.91	57.48	2.06	0.0703
*SUBNUM*ELEMENT*	66	1844.93	27.95		
Error	508	16933.59	33.33		
TOTAL	591	19352.04			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	178.56	16.23		
Within					
DISTYPE	4	229.42	57.36	2.46	0.0595
*SUBNUM*DISTYPE*	44	1027.15	23.34		
Error	532	17848.99	33.55		
TOTAL	591	19284.13			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	423.24	38.48		
Within					
DENSITY	3	99.84	33.28	0.71	0.5532
*SUBNUM*DENSITY*	33	1547.70	46.90		
Error	544	17463.05	32.10		
TOTAL	591	19533.84			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.5 Dependent Measure: Mean Speed

Source	DF	SS	MS	F value	P value
AGE	1	1777.59	1777.59	2.61	0.1373
SUBNUM(AGE)	10	6812.31	681.23		
Error	580	8058.70	13.89		
TOTAL	591	16648.59			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	6688.42	608.04		
Within					
ELEMENT	6	43.80	7.30	0.43	0.8586
*SUBNUM*ELEMENT*	66	1129.01	17.11		
Error	508	6886.49	13.56		
TOTAL	591	14747.71			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	6972.20	633.84		
Within					
DISTYPE	4	86.61	21.65	1.2	0.3223
*SUBNUM*DISTYPE*	44	790.74	17.97		
Error	532	7179.95	13.50		
TOTAL	591	15029.49			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	5569.06	506.28		
Within					
DENSITY	3	79.03	26.34	2.39	0.0861
*SUBNUM*DENSITY*	33	363.28	11.01		
Error	544	7613.24	13.99		
TOTAL	591	13624.61			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.6 Dependent Measure: Standard Deviation of Speed

Source	DF	SS	MS	F value	P value
AGE	1	0.32	0.32	0.26	0.6216
SUBNUM(AGE)	10	12.43	1.24		
Error	580	420.94	0.73		
TOTAL	591	433.69			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	10.11	0.92		
Within					
ELEMENT	6	34.35	5.73	9.52	0.0001 *
*SUBNUM*ELEMENT*	66	39.68	0.60		
Error	508	346.73	0.68		
TOTAL	591	430.87			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	6.76	0.61		
Within					
DISTYPE	4	16.30	4.07	7.26	0.0001 *
*SUBNUM*DISTYPE*	44	24.69	0.56		
Error	532	379.19	0.71		
TOTAL	591	426.94			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	7.59	0.69		
Within					
DENSITY	3	5.90	1.97	4.4	0.0103 *
*SUBNUM*DENSITY*	33	14.75	0.45		
Error	544	400.32	0.74		
TOTAL	591	428.56			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.7 Dependent Measure: Peak Longitudinal Deceleration

Source	DF	SS	MS	F value	P value
AGE	1	0.00048	0.00048	0.12	0.7363
SUBNUM(AGE)	10	0.04043	0.00404		
Error	580	0.89679	0.00155		
TOTAL	591	0.93771			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0281	0.0026		
Within					
ELEMENT	6	0.0612	0.0102	6.31	0.0001 *
SUBNUM*ELEMENT	66	0.1067	0.0016		
Error	508	0.7263	0.0014		
TOTAL	591	0.9224			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0321	0.0029		
Within					
DISTYPE	4	0.0361	0.0090	8.06	0.0001 *
SUBNUM*DISTYPE	44	0.0492	0.0011		
Error	532	0.8101	0.0015		
TOTAL	591	0.9275			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0255	0.0023		
Within					
DENSITY	3	0.0042	0.0014	1.48	0.2387
SUBNUM*DENSITY	33	0.0311	0.0009		
Error	544	0.8612	0.0016		
TOTAL	591	0.9220			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.8 Dependent Measure: Number of Lane Deviations

Source	DF	SS	MS	F value	P value
AGE	1	0.02	0.02	0.01	0.9256
SUBNUM(AGE)	10	18.59	1.86		
Error	580	212.08	0.37		
TOTAL	591	230.68			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	17.0308	1.5483		
Within					
ELEMENT	6	4.6341	0.7723	2.39	0.0379 *
*SUBNUM*ELEMENT*	66	21.3556	0.3236		
Error	508	186.1738	0.3665		
TOTAL	591	229.1943			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	13.47	1.22		
Within					
DISTYPE	4	3.11	0.78	2.22	0.0825
*SUBNUM*DISTYPE*	44	15.41	0.35		
Error	532	192.90	0.36		
TOTAL	591	224.89			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	11.5932	1.0539		
Within					
DENSITY	3	6.2231	2.0744	7.54	0.0006 *
*SUBNUM*DENSITY*	33	9.0765	0.2750		
Error	544	197.1287	0.3624		
TOTAL	591	224.0216			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.9 Dependent Measure: Peak Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
AGE	1	23940.74	23940.74	4.09	0.0706
SUBNUM(AGE)	10	58491.80	5849.18		
Error	580	629716.87	1085.72		
TOTAL	591	712149.42			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	54353.91	4941.26		
Within					
ELEMENT	6	86405.51	14400.92	15.27	0.0001 *
*SUBNUM*ELEMENT*	66	62243.45	943.08		
Error	508	478240.24	941.42		
TOTAL	591	681243.12			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	57725.46	5247.77		
Within					
DISTYPE	4	66548.86	16637.22	20.94	0.0001 *
*SUBNUM*DISTYPE*	44	34952.55	794.38		
Error	532	525938.40	988.61		
TOTAL	591	685165.28			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	44718.23	4065.29		
Within					
DENSITY	3	63838.38	21279.46	28.23	0.0001 *
*SUBNUM*DENSITY*	33	24878.37	753.89		
Error	544	541325.00	995.08		
TOTAL	591	674759.97			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.10 Dependent Measure: Variance in Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
AGE	1	485201.95	485201.95	3.12	0.1079
SUBNUM(AGE)	10	1556009.33	155600.93		
Error	580	7811654.57	13468.37		
TOTAL	591	9852865.85			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1365516.90	124137.90		
Within					
ELEMENT	6	527319.70	87886.62	7.75	0.0001 *
*SUBNUM*ELEMENT*	66	748364.60	11338.86		
Error	508	6521473.15	12837.55		
TOTAL	591	9162674.35			

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1364789.24	124071.75		
Within					
DISTYPE	4	568609.84	142152.46	8.78	0.0001 *
*SUBNUM*DISTYPE*	44	712705.59	16197.85		
Error	532	6516873.78	12249.76		
TOTAL	591	9162978.45			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1076211.37	97837.40		
Within					
DENSITY	3	513415.05	171138.35	12.68	0.0001 *
*SUBNUM*DENSITY*	33	445557.95	13501.76		
Error	544	6855749.60	12602.48		
TOTAL	591	8890933.97			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.11 Dependent Measure: Mean Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
AGE	1	599.40	599.40	3.75	0.0814
SUBNUM(AGE)	10	1596.70	159.67		
Error	580	5713.81	9.85		
TOTAL	591	7909.91			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1543.35	140.30		
Within					
ELEMENT	6	709.80	118.30	13.64	0.0001 *
*SUBNUM*ELEMENT*	66	572.50	8.67		
Error	508	4420.37	8.70		
TOTAL	591	7246.02			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1476.76	134.25		
Within					
DISTYPE	4	766.06	191.51	18.96	0.0001 *
*SUBNUM*DISTYPE*	44	444.37	10.10		
Error	532	4501.35	8.46		
TOTAL	591	7188.54			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1170.29	106.39		
Within					
DENSITY	3	711.97	237.32	28.39	0.0001 *
*SUBNUM*DENSITY*	33	275.89	8.36		
Error	544	4729.77	8.69		
TOTAL	591	6887.92			

* p < 0.05 (significant)

Appendix 11 – ANOVA Summary Tables for IVIS Tasks vs Baseline Driving

Table A.11.12 Dependent Measure: Peak Lateral Acceleration

Source	DF	SS	MS	F value	P value
AGE	1	0.0045	0.0045	0.98	0.3458
SUBNUM(AGE)	10	0.0463	0.0046		
Error	580	0.7378	0.0013		
TOTAL	591	0.7886			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0481	0.0044		
Within					
ELEMENT	6	0.0647	0.0108	8.45	0.0001 *
*SUBNUM*ELEMENT*	66	0.0843	0.0013		
Error	508	0.5886	0.0012		
TOTAL	591	0.7857			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0432	0.0039		
Within					
DISTYPE	4	0.0275	0.0069	6.53	0.0003 *
*SUBNUM*DISTYPE*	44	0.0463	0.0011		
Error	532	0.6641	0.0012		
TOTAL	591	0.7811			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0411	0.0037		
Within					
DENSITY	3	0.0120	0.0040	8.15	0.0003 *
*SUBNUM*DENSITY*	33	0.0162	0.0005		
Error	544	0.7094	0.0013		
TOTAL	591	0.7787			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.1 Dependent Measure: Number of Eye Glances to Mirror

Source	DF	SS	MS	F value	P value
AGE	1	108.15	108.15	1.25	0.2895
SUBNUM(AGE)	10	864.37	86.44		
Error	592	911.02	1.57		
TOTAL	603	1883.55			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	888.59	80.78		
Within					
ELEMENT	6	36.85	6.14	1.46	0.2065
*SUBNUM*ELEMENT*	66	278.08	4.21		
Error	520	621.65	1.20		
TOTAL	603	1825.17			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	614.91	55.90		
Within					
DISTYPE	4	26.37	6.59	1.44	0.2377
*SUBNUM*DISTYPE*	44	201.85	4.59		
Error	544	708.22	1.30		
TOTAL	603	1551.35			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	383.61	34.87		
Within					
DENSITY	3	22.88	7.63	1.19	0.3275
*SUBNUM*DENSITY*	33	210.94	6.39		
Error	556	702.95	1.26		
TOTAL	603	1320.38			

* p < 0.05 (significant)

Table A.12.2 Dependent Measure: Minimum Speed

Source	DF	SS	MS	F value	P value
AGE	1	1729.85	1729.85	2.58	0.1392
SUBNUM(AGE)	10	6701.16	670.12		
Error	592	11341.57	19.16		
TOTAL	603	19772.58			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	6638.78	603.53		
Within					
ELEMENT	6	219.45	36.57	1.42	0.2215
*SUBNUM*ELEMENT*	66	1704.00	25.82		
Error	520	9426.70	18.13		
TOTAL	603	17988.94			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	7053.11	641.19		
Within					
DISTYPE	4	210.93	52.73	2.17	0.0883
*SUBNUM*DISTYPE*	44	1070.18	24.32		
Error	544	10057.84	18.49		
TOTAL	603	18392.05			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	5631.44	511.95		
Within					
DENSITY	3	167.85	55.95	2.94	0.0472 *
*SUBNUM*DENSITY*	33	627.06	19.00		
Error	556	10545.83	18.97		
TOTAL	603	16972.17			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.3 Dependent Measure: Decrease in Speed

Source	DF	SS	MS	F value	P value
AGE	1	34.83	34.83	2.57	0.1401
SUBNUM(AGE)	10	135.62	13.56		
Error	592	4371.64	7.38		
TOTAL	603	4542.09			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	133.49	12.14		
Within					
ELEMENT	6	492.07	82.01	12.91	0.0001 *
*SUBNUM*ELEMENT*	66	419.37	6.35		
Error	520	3456.67	6.65		
TOTAL	603	4501.61			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	87.79	7.98		
Within					
DISTYPE	4	358.67	89.67	13.61	0.0001 *
*SUBNUM*DISTYPE*	44	289.85	6.59		
Error	544	3717.23	6.83		
TOTAL	603	4453.53			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	93.20	8.47		
Within					
DENSITY	3	264.51	88.17	17.61	0.0001 *
*SUBNUM*DENSITY*	33	165.19	5.01		
Error	556	3942.06	7.09		
TOTAL	603	4464.97			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.4 Dependent Measure: Variance in Speed

Source	DF	SS	MS	F value	P value
AGE	1	50.07	50.07	1.63	0.2312
SUBNUM(AGE)	10	308.07	30.81		
Error	592	19057.49	32.19		
TOTAL	603	19415.63			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	252.69	22.97		
Within					
ELEMENT	6	476.93	79.49	2.91	0.0141 *
*SUBNUM*ELEMENT*	66	1805.08	27.35		
Error	520	16788.59	32.29		
TOTAL	603	19323.29			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	213.93	19.45		
Within					
DISTYPE	4	359.94	89.98	4.01	0.0074 *
*SUBNUM*DISTYPE*	44	987.10	22.43		
Error	544	17703.98	32.54		
TOTAL	603	19264.95			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	516.75	46.98		
Within					
DENSITY	3	231.42	77.14	1.69	0.1885
*SUBNUM*DENSITY*	33	1507.89	45.69		
Error	556	17318.04	31.15		
TOTAL	603	19574.10			

* p < 0.05 (significant)

Table A.12.5 Dependent Measure: Mean Speed

Source	DF	SS	MS	F value	P value
AGE	1	1754.14	1754.14	2.62	0.1369
SUBNUM(AGE)	10	6706.98	670.70		
Error	592	8933.24	15.09		
TOTAL	603	17394.37			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	6610.89	600.99		
Within					
ELEMENT	6	167.43	27.90	1.44	0.2147
*SUBNUM*ELEMENT*	66	1283.35	19.44		
Error	520	7483.08	14.39		
TOTAL	603	15544.75			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	7120.81	647.35		
Within					
DISTYPE	4	211.55	52.89	2.46	0.0591
*SUBNUM*DISTYPE*	44	945.61	21.49		
Error	544	7776.54	14.30		
TOTAL	603	16054.51			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	5724.25	520.39		
Within					
DENSITY	3	204.26	68.09	4.33	0.0111 *
*SUBNUM*DENSITY*	33	518.46	15.71		
Error	556	8209.84	14.77		
TOTAL	603	14656.80			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.6 Dependent Measure: Standard Deviation of Speed

Source	DF	SS	MS	F value	P value
AGE	1	0.41	0.41	0.32	0.5856
SUBNUM(AGE)	10	12.91	1.29		
Error	592	436.90	0.74		
TOTAL	603	450.22			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	10.79	0.98		
Within					
ELEMENT	6	63.32	10.55	18.1	0.0001 *
*SUBNUM*ELEMENT*	66	38.49	0.58		
Error	520	334.82	0.64		
TOTAL	603	447.43			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	7.73	0.70		
Within					
DISTYPE	4	45.09	11.27	21.13	0.0001 *
*SUBNUM*DISTYPE*	44	23.47	0.53		
Error	544	367.28	0.68		
TOTAL	603	443.57			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	9.76	0.89		
Within					
DENSITY	3	34.98	11.66	28.39	0.0001 *
*SUBNUM*DENSITY*	33	13.55	0.41		
Error	556	388.41	0.70		
TOTAL	603	446.70			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.7 Dependent Measure: Peak Longitudinal Deceleration

Source	DF	SS	MS	F value	P value
AGE	1	0.0005	0.0005	0.12	0.7382
SUBNUM(AGE)	10	0.0422	0.0042		
Error	592	0.9372	0.0016		
TOTAL	603	0.9799			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0309	0.0028		
Within					
ELEMENT	6	0.0964	0.0161	10	0.0001 *
SUBNUM*ELEMENT	66	0.1060	0.0016		
Error	520	0.7321	0.0014		
TOTAL	603	0.9654			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0392	0.0036		
Within					
DISTYPE	4	0.0712	0.0178	16.14	0.0001 *
SUBNUM*DISTYPE	44	0.0486	0.0011		
Error	544	0.8159	0.0015		
TOTAL	603	0.9749			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0309	0.0028		
Within					
DENSITY	3	0.0393	0.0131	14.25	0.0001 *
SUBNUM*DENSITY	33	0.0304	0.0009		
Error	556	0.8670	0.0016		
TOTAL	603	0.9676			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.8 Dependent Measure: Number of Lane Deviations

Source	DF	SS	MS	F value	P value
AGE	1	0.0173	0.0173	0.01	0.9192
SUBNUM(AGE)	10	15.9776	1.5978		
Error	592	218.4544	0.3690		
TOTAL	603	234.4493			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	14.23	1.29		
Within					
ELEMENT	6	8.20	1.37	3.94	0.0020 *
*SUBNUM*ELEMENT*	66	22.91	0.35		
Error	520	187.46	0.36		
TOTAL	603	232.79			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	10.0782	0.9162		
Within					
DISTYPE	4	6.5946	1.6487	4.28	0.0052 *
*SUBNUM*DISTYPE*	44	16.9678	0.3856		
Error	544	194.1807	0.3569		
TOTAL	603	227.8214			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	8.44	0.77		
Within					
DENSITY	3	9.84	3.28	10.18	0.0001 *
*SUBNUM*DENSITY*	33	10.64	0.32		
Error	556	198.41	0.36		
TOTAL	603	227.33			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.9 Dependent Measure: Peak Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
AGE	1	24148.44	24148.44	4.11	0.0702
SUBNUM(AGE)	10	58809.87	5880.99		
Error	592	721884.60	1219.40		
TOTAL	603	804842.90			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	56746.43	5158.77		
Within					
ELEMENT	6	160144.05	26690.68	27.06	0.0001 *
*SUBNUM*ELEMENT*	66	65093.24	986.26		
Error	520	493371.80	948.79		
TOTAL	603	775355.52			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	64159.44	5832.68		
Within					
DISTYPE	4	140117.35	35029.34	40.8	0.0001 *
*SUBNUM*DISTYPE*	44	37778.62	858.60		
Error	544	541069.96	994.61		
TOTAL	603	783125.36			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	49827.30	4529.75		
Within					
DENSITY	3	137972.08	45990.69	54.78	0.0001 *
*SUBNUM*DENSITY*	33	27707.45	839.62		
Error	556	556456.55	1000.82		
TOTAL	603	771963.38			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.10 Dependent Measure: Variance in Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
AGE	1	504524.79	504524.79	3.04	0.1117
SUBNUM(AGE)	10	1658166.19	165816.62		
Error	592	8324245.34	14061.23		
TOTAL	603	10486936.33			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1588518.09	144410.74		
Within					
ELEMENT	6	424129.68	70688.28	6.33	0.0001 *
*SUBNUM*ELEMENT*	66	737531.68	11174.72		
Error	520	7147740.05	13745.65		
TOTAL	603	9897919.50			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1730607.70	157327.97		
Within					
DISTYPE	4	465448.71	116362.18	7.3	0.0001 *
*SUBNUM*DISTYPE*	44	701169.96	15935.68		
Error	544	7143140.68	13130.77		
TOTAL	603	10040367.04			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1413943.95	128540.36		
Within					
DENSITY	3	410131.85	136710.62	10.38	0.0001 *
*SUBNUM*DENSITY*	33	434434.93	13164.69		
Error	556	7482016.50	13456.86		
TOTAL	603	9740527.24			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.11 Dependent Measure: Mean Steering Wheel Velocity

Source	DF	SS	MS	F value	P value
AGE	1	604.29	604.29	3.6	0.0869
SUBNUM(AGE)	10	1677.58	167.76		
Error	592	6126.66	10.35		
TOTAL	603	8408.53			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1724.37	156.76		
Within					
ELEMENT	6	285.15	47.52	4.78	0.0004 *
*SUBNUM*ELEMENT*	66	655.65	9.93		
Error	520	5176.15	9.95		
TOTAL	603	7841.32			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1801.70	163.79		
Within					
DISTYPE	4	340.19	85.05	7.1	0.0002 *
*SUBNUM*DISTYPE*	44	527.25	11.98		
Error	544	5257.13	9.66		
TOTAL	603	7926.26			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	1478.63	134.42		
Within					
DENSITY	3	285.13	95.04	8.74	0.0002 *
*SUBNUM*DENSITY*	33	358.95	10.88		
Error	556	5485.55	9.87		
TOTAL	603	7608.26			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.12 Dependent Measure: Peak Lateral Acceleration

Source	DF	SS	MS	F value	P value
AGE	1	0.0031	0.0031	0.65	0.4377
SUBNUM(AGE)	10	0.0469	0.0047		
Error	592	0.8122	0.0014		
TOTAL	603	0.8621			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0473	0.0043		
Within					
ELEMENT	6	0.1147	0.0191	14.74	0.0001 *
*SUBNUM*ELEMENT*	66	0.0856	0.0013		
Error	520	0.6121	0.0012		
TOTAL	603	0.8596			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0428	0.0039		
Within					
DISTYPE	4	0.0774	0.0193	17.8	0.0001 *
*SUBNUM*DISTYPE*	44	0.0478	0.0011		
Error	544	0.6875	0.0013		
TOTAL	603	0.8555			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	0.0407	0.0037		
Within					
DENSITY	3	0.0620	0.0207	39.03	0.0001 *
*SUBNUM*DENSITY*	33	0.0175	0.0005		
Error	556	0.7328	0.0013		
TOTAL	603	0.8530			

* p < 0.05 (significant)

Appendix 12 – ANOVA Summary Tables for IVIS vs Conventional Tasks

Table A.12.13 Dependent Measure: Task-Completion-Time

Source	DF	SS	MS	F value	P value
AGE	1	1447.03	1447.03	0.86	0.3752
SUBNUM(AGE)	10	16796.90	1679.69		
Error	592	102642.96	173.38		
TOTAL	603	120886.89			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	18446.49	1676.95		
Within					
ELEMENT	6	39581.80	6596.97	46.86	0.0001 *
*SUBNUM*ELEMENT*	66	9291.69	140.78		
Error	520	53737.17	103.34		
TOTAL	603	121057.15			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	12017.63	1092.51		
Within					
DISTYPE	4	28473.99	7118.50	42.86	0.0001 *
*SUBNUM*DISTYPE*	44	7308.64	166.11		
Error	544	66525.10	122.29		
TOTAL	603	114325.37			

* p < 0.05 (significant)

Source	DF	SS	MS	F value	P value
Between					
SUBNUM	11	8283.44	753.04		
Within					
DENSITY	3	25460.38	8486.79	47.6	0.0001 *
*SUBNUM*DENSITY*	33	5883.09	178.28		
Error	556	71018.75	127.73		
TOTAL	603	110645.66			

* p < 0.05 (significant)

Appendix 13 – Means and Standard Deviations for IVIS Tasks, Conventional Tasks, and Baselines

Type of Display	Type of Task	Density	Task #	Eye Glance Measures									
				NEGDISP		LEGDISP		MSGT		TGT		NEGMIR	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Baseline 5 seconds			205	*	*	*	*	*	*	*	*	0.72	0.75
Baseline 10 seconds			210	*	*	*	*	*	*	*	*	0.75	0.79
Baseline 20 seconds			220	*	*	*	*	*	*	*	*	1.48	1.34
Baseline 30 seconds			230	*	*	*	*	*	*	*	*	2.29	1.97
Table	S	L	401	3.17	1.34	1.75	0.34	1.26	0.39	3.60	0.76	0.00	0.00
Paragraph	S	L	402	4.00	1.86	2.56	0.81	1.63	0.58	5.79	1.47	0.50	0.67
Graph w/icon	S	L	403	1.83	0.72	1.67	0.87	1.33	0.87	2.11	0.94	0.25	0.45
Table	S	M	404	3.08	1.51	2.37	1.11	1.56	0.58	4.29	1.35	0.33	0.49
Paragraph	S	M	405	7.67	2.81	2.59	0.78	1.57	0.42	11.11	1.61	0.75	1.71
Graph w/text	S	M	406	2.58	1.98	2.02	0.78	1.57	0.74	3.09	1.01	0.42	0.67
Graph w/icon	S	M	407	2.58	1.31	1.97	0.80	1.37	0.56	3.21	1.16	0.33	0.49
Table	S	H	408	3.67	1.92	2.47	0.86	1.65	0.50	5.45	2.02	0.42	0.67
Paragraph	S	H	409	8.17	3.93	2.31	0.78	1.63	0.66	11.83	4.15	0.67	1.23
Graph w/text	S	H	410	3.25	1.48	2.45	1.05	1.45	0.44	4.33	1.25	0.58	1.00
Graph w/icon	S	H	411	5.58	3.55	2.49	0.73	1.58	0.44	8.11	4.93	0.17	0.39
Table	SC	M	421	7.33	3.26	2.48	0.89	1.48	0.40	10.18	3.81	0.58	1.00
Paragraph	SC	M	422	12.67	7.87	2.42	1.21	1.41	0.52	16.68	9.44	0.42	0.67
Graph w/text	SC	M	423	9.25	5.46	2.39	0.82	1.41	0.40	11.66	4.28	0.67	1.72
Table	SC	H	424	9.92	4.23	2.32	0.83	1.49	0.50	13.59	5.26	0.58	1.44
Paragraph	SC	H	425	13.33	9.63	2.30	0.87	1.51	0.43	18.27	10.80	1.50	2.61
Graph w/text	SC	H	426	15.50	6.40	2.18	0.38	1.36	0.30	20.65	9.03	1.17	1.75
Table	SP	L	427	10.92	5.73	1.97	0.37	1.37	0.31	13.79	6.43	0.83	1.03
Paragraph	SP	L	428	10.67	5.52	2.90	1.25	1.48	0.44	14.70	7.49	0.92	1.62
Graph w/icon	SP	L	429	8.17	4.17	2.77	2.04	1.56	0.65	11.00	3.36	0.50	1.17
Table	SP	M	430	7.92	2.35	2.10	0.52	1.34	0.32	10.10	1.90	0.58	1.00
Paragraph	SP	M	431	13.33	5.71	2.20	0.56	1.43	0.35	17.99	5.91	1.00	2.30
Graph w/text	SP	M	432	6.50	3.21	2.93	1.69	1.74	0.93	9.56	3.24	1.00	1.48
Graph w/icon	SP	M	433	8.33	5.00	2.10	0.51	1.35	0.31	10.31	4.42	0.75	0.87
Table	SP	H	434	12.58	4.68	2.42	0.57	1.34	0.24	16.47	5.73	0.92	1.38
Paragraph	SP	H	435	19.50	14.21	2.58	1.05	1.54	0.59	26.07	15.26	1.33	2.15
Graph w/text	SP	H	436	13.25	8.93	2.51	1.03	1.35	0.31	16.46	8.10	1.58	3.20
Graph w/icon	SP	H	437	9.58	4.52	3.08	2.70	1.79	1.42	13.85	4.59	0.75	1.48
Table	SPC	M	438	8.00	3.25	2.68	1.73	1.55	0.75	10.94	3.87	0.50	0.90
Paragraph	SPC	M	439	13.17	6.13	3.34	1.90	1.68	0.65	19.51	6.82	1.42	3.68
Graph w/text	SPC	M	440	5.17	3.01	2.72	1.14	1.85	0.75	7.82	1.74	0.58	1.00
Table	SPC	H	441	9.75	5.01	2.48	1.00	1.55	0.58	13.67	5.00	1.17	2.86
Paragraph	SPC	H	442	18.00	11.54	2.46	1.13	1.51	0.53	24.89	14.44	2.00	3.57
Graph w/text	SPC	H	443	12.42	5.74	2.40	0.59	1.49	0.31	17.93	7.24	1.25	2.83
Table	SPI	L	444	9.00	3.44	1.96	0.70	1.21	0.27	10.52	4.07	0.67	0.98
Paragraph	SPI	L	445	12.67	4.01	2.56	1.06	1.42	0.52	16.69	4.20	0.67	0.98
Table	SPI	M	446	9.92	5.95	2.79	1.35	1.42	0.51	12.34	4.84	0.92	1.44
Paragraph	SPI	M	447	13.17	3.90	2.18	0.53	1.41	0.31	18.17	5.76	0.83	1.47
Graph w/text	SPI	M	448	7.42	3.12	2.47	0.87	1.50	0.55	10.02	3.29	1.00	2.04
Graph w/icon	SPI	M	449	9.25	4.43	2.41	0.94	1.36	0.37	11.44	3.59	0.67	0.98
Table	SPI	H	450	11.83	2.98	2.40	1.62	1.26	0.37	14.72	4.56	1.00	2.00
Paragraph	SPI	H	451	16.92	13.39	2.46	0.68	1.43	0.33	22.39	15.09	1.58	2.68
Graph w/text	SPI	H	452	14.92	9.23	2.29	0.61	1.34	0.33	18.09	9.11	2.17	4.75
Graph w/icon	SPI	H	453	11.25	5.33	2.83	1.10	1.54	0.44	15.99	6.29	0.58	0.79
Table	SPIC	H	454	14.00	7.80	2.61	1.35	1.48	0.59	18.23	9.31	0.92	1.83
Paragraph	SPIC	H	455	16.58	9.45	2.38	0.88	1.40	0.40	21.72	12.69	1.67	2.81
Graph w/text	SPIC	H	456	13.25	8.15	2.60	0.87	1.49	0.44	17.39	7.08	1.17	2.55
Activate turn signal			501	*	*	*	*	*	*	*	*	*	*
Adjust A/C vent			502	*	*	*	*	*	*	*	*	*	*
Adjust power mirror			503	*	*	*	*	*	*	*	*	*	*
Monitoring fuel level			504	*	*	*	*	*	*	*	*	*	*
Monitoring vehicle speed			505	*	*	*	*	*	*	*	*	*	*

Appendix 13 – Means and Standard Deviations for IVIS Tasks, Conventional Tasks, and Baselines

Type of Display	Type of Task	Density	Task #	Longitudinal Driving Performance											
				MNSPEED		DECSPEED		VSPEED		MSPEED		STDSPEED		MXLONDCL	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Baseline 5 seconds			205	47.87	5.51	0.50	0.67	0.12	0.18	48.37	5.48	0.29	0.20	0.02	0.03
Baseline 10 seconds			210	47.79	5.36	0.96	1.24	0.45	0.56	48.77	5.13	0.57	0.37	0.02	0.03
Baseline 20 seconds			220	47.89	5.82	1.74	2.32	1.39	1.97	49.61	5.27	1.01	0.82	0.04	0.04
Baseline 30 seconds			230	46.09	6.48	2.44	2.78	3.50	6.08	48.82	5.54	1.54	1.09	0.05	0.03
Table	S	L	401	48.03	3.82	0.78	0.77	0.19	0.24	48.59	3.77	0.36	0.25	0.02	0.02
Paragraph	S	L	402	49.12	4.96	1.21	1.44	0.57	1.21	50.10	5.00	0.59	0.50	0.04	0.03
Graph w/icon	S	L	403	49.65	5.93	0.45	0.54	0.06	0.08	49.99	5.85	0.21	0.14	0.01	0.01
Table	S	M	404	48.80	5.97	0.64	0.67	0.15	0.10	49.34	6.01	0.36	0.16	0.01	0.02
Paragraph	S	M	405	44.86	3.19	2.89	1.81	1.32	1.13	46.42	3.45	1.05	0.50	0.03	0.04
Graph w/text	S	M	406	48.84	5.95	0.65	0.66	0.11	0.10	49.29	6.10	0.28	0.17	0.01	0.01
Graph w/icon	S	M	407	46.64	6.11	0.59	0.74	0.13	0.14	47.17	6.19	0.32	0.18	0.00	0.01
Table	S	H	408	46.67	6.09	1.31	1.72	0.50	0.84	47.44	5.73	0.51	0.51	0.02	0.02
Paragraph	S	H	409	46.94	5.32	2.49	2.80	1.63	2.02	48.73	4.75	1.10	0.67	0.03	0.04
Graph w/text	S	H	410	50.14	4.81	1.09	1.25	0.37	0.75	50.81	4.72	0.44	0.43	0.02	0.04
Graph w/icon	S	H	411	47.58	6.22	1.19	1.73	1.19	2.49	48.72	6.45	0.79	0.79	0.03	0.05
Table	SC	M	421	47.93	6.61	1.96	1.66	1.11	1.49	49.40	6.00	0.88	0.60	0.04	0.04
Paragraph	SC	M	422	45.61	6.54	3.27	2.08	1.68	1.51	47.35	6.70	1.19	0.55	0.05	0.05
Graph w/text	SC	M	423	47.70	5.12	2.52	2.22	1.09	1.38	49.08	4.81	0.89	0.58	0.03	0.04
Table	SC	H	424	46.05	6.04	1.38	1.18	1.44	3.18	47.38	5.45	0.88	0.86	0.04	0.03
Paragraph	SC	H	425	46.06	6.37	0.73	0.88	1.17	1.64	47.71	5.83	0.89	0.66	0.06	0.05
Graph w/text	SC	H	426	45.95	6.37	4.38	3.37	3.63	4.63	48.48	5.60	1.65	1.00	0.03	0.03
Table	SP	L	427	45.23	5.52	2.89	2.73	1.61	2.59	46.81	4.90	1.01	0.81	0.06	0.05
Paragraph	SP	L	428	45.61	7.02	4.15	5.10	3.29	5.46	47.88	6.60	1.44	1.15	0.05	0.05
Graph w/icon	SP	L	429	49.57	7.44	2.10	2.09	0.95	0.84	51.17	6.94	0.88	0.44	0.03	0.03
Table	SP	M	430	47.24	5.11	2.39	2.40	1.22	2.12	48.48	5.43	0.86	0.73	0.03	0.06
Paragraph	SP	M	431	47.04	6.05	2.36	2.90	1.39	2.43	48.63	5.22	0.90	0.79	0.07	0.06
Graph w/text	SP	M	432	49.26	5.67	1.30	0.93	0.64	0.73	50.31	5.32	0.69	0.43	0.03	0.03
Graph w/icon	SP	M	433	49.07	4.83	2.25	1.92	1.08	1.24	50.46	5.12	0.86	0.62	0.05	0.08
Table	SP	H	434	46.99	6.36	2.16	2.33	1.33	1.91	48.31	6.26	0.96	0.68	0.03	0.03
Paragraph	SP	H	435	44.00	4.94	2.87	2.42	2.58	2.10	46.53	4.98	1.44	0.75	0.05	0.04
Graph w/text	SP	H	436	47.71	4.22	1.88	1.81	0.80	0.82	49.28	4.48	0.79	0.43	0.04	0.03
Graph w/icon	SP	H	437	46.41	7.19	2.58	2.87	1.83	2.49	47.90	7.03	1.05	0.89	0.05	0.05
Table	SPC	M	438	45.39	8.04	3.90	4.88	4.52	10.78	47.71	5.25	1.45	1.63	0.05	0.05
Paragraph	SPC	M	439	48.48	5.67	3.11	3.15	2.40	3.40	50.46	5.26	1.28	0.91	0.06	0.04
Graph w/text	SPC	M	440	48.34	4.68	1.13	1.35	0.42	0.56	49.07	4.52	0.52	0.40	0.02	0.02
Table	SPC	H	441	48.13	4.45	2.38	2.04	1.10	1.48	49.64	4.42	0.85	0.64	0.05	0.04
Paragraph	SPC	H	442	45.41	6.36	3.28	3.19	2.54	2.23	47.72	6.44	1.41	0.79	0.06	0.04
Graph w/text	SPC	H	443	46.15	3.42	2.17	2.43	1.84	1.85	48.10	3.70	1.19	0.67	0.04	0.03
Table	SPI	L	444	44.87	5.73	1.70	1.95	1.01	1.38	46.40	5.23	0.81	0.62	0.03	0.03
Paragraph	SPI	L	445	43.79	10.08	5.56	9.07	12.10	35.57	47.49	5.84	2.09	2.91	0.05	0.05
Table	SPI	M	446	47.00	4.76	3.09	3.21	2.44	4.36	48.72	4.83	1.22	1.02	0.04	0.04
Paragraph	SPI	M	447	46.89	4.69	2.77	2.17	1.93	2.09	48.93	4.97	1.24	0.65	0.04	0.04
Graph w/text	SPI	M	448	49.33	5.98	1.43	1.43	0.57	0.61	50.58	6.25	0.66	0.39	0.04	0.04
Graph w/icon	SPI	M	449	49.33	5.32	1.71	1.62	0.87	1.10	50.43	5.49	0.76	0.56	0.03	0.03
Table	SPI	H	450	46.47	5.40	4.05	2.03	2.09	1.73	48.33	5.33	1.31	0.63	0.03	0.03
Paragraph	SPI	H	451	45.89	7.11	2.24	2.27	1.64	1.46	47.58	6.81	1.18	0.52	0.06	0.05
Graph w/text	SPI	H	452	44.57	6.25	3.76	3.34	3.11	2.96	46.83	5.66	1.56	0.86	0.04	0.03
Graph w/icon	SPI	H	453	44.95	4.75	2.89	2.40	1.27	1.51	47.00	4.78	0.91	0.69	0.03	0.04
Table	SPIC	H	454	47.34	5.79	2.37	2.30	2.00	3.34	49.24	5.85	1.16	0.84	0.05	0.05
Paragraph	SPIC	H	455	45.32	5.88	2.34	2.08	2.62	2.76	47.47	5.52	1.42	0.82	0.06	0.06
Graph w/text	SPIC	H	456	45.42	5.24	3.73	3.11	2.67	2.76	47.52	5.33	1.43	0.82	0.05	0.04
Activate turn signal			501	48.49	3.97	0.27	0.37	0.03	0.03	48.70	3.96	0.16	0.08	0.00	0.00
Adjust A/C vent			502	45.62	5.98	0.25	0.54	0.09	0.15	45.97	5.98	0.22	0.21	0.01	0.03
Adjust power mirror			503	45.27	4.84	0.05	0.10	0.21	0.42	45.81	4.90	0.30	0.36	0.02	0.03
Monitoring fuel level			504	46.28	5.33	0.50	0.65	0.11	0.15	46.69	5.41	0.26	0.21	0.01	0.02
Monitoring vehicle speed			505	47.79	3.98	0.29	0.52	0.05	0.11	48.01	4.02	0.16	0.15	0.01	0.02

Appendix 13 – Means and Standard Deviations for IVIS Tasks, Conventional Tasks, and Baselines

Type of Display	Type of Task	Density	Task #	NLANEDEV Mean	NLANEDEV SD	MAXSTVEL Mean	MAXSTVEL SD	VSTVEL Mean	VSTVEL SD	MSTVEL Mean	MSTVEL SD	MXLACLMG Mean	MXLACLMG SD
Baseline 5 seconds			205	0.10	0.37	40.14	18.40	88.05	66.76	7.49	2.95	0.09	0.03
Baseline 10 seconds			210	0.19	0.45	46.22	21.74	92.09	94.67	7.43	2.94	0.11	0.03
Baseline 20 seconds			220	0.29	0.65	62.15	26.56	95.01	58.04	7.54	2.16	0.12	0.04
Baseline 30 seconds			230	0.38	0.76	63.58	23.86	89.39	46.32	7.73	2.04	0.13	0.05
Table	S	L	401	0.08	0.29	71.70	24.40	223.78	123.23	12.36	4.07	0.12	0.03
Paragraph	S	L	402	0.25	0.62	66.04	50.48	221.96	299.65	11.63	5.88	0.09	0.03
Graph w/icon	S	L	403	0.17	0.39	37.45	23.13	98.14	86.87	7.82	2.40	0.08	0.05
Table	S	M	404	0.17	0.39	58.61	24.76	165.85	100.65	10.44	3.08	0.10	0.04
Paragraph	S	M	405	0.33	0.49	86.92	32.40	218.77	124.51	12.15	3.62	0.10	0.04
Graph w/text	S	M	406	0.00	0.00	57.08	35.83	170.01	170.50	10.60	4.14	0.09	0.03
Graph w/icon	S	M	407	0.17	0.39	61.48	34.01	219.46	219.62	12.18	5.44	0.08	0.03
Table	S	H	408	0.17	0.39	69.97	25.65	211.38	139.98	12.07	4.10	0.11	0.02
Paragraph	S	H	409	0.50	0.67	104.53	53.27	270.98	190.36	13.14	3.91	0.12	0.04
Graph w/text	S	H	410	0.08	0.29	68.75	43.62	192.45	167.19	10.68	4.09	0.09	0.04
Graph w/icon	S	H	411	0.50	0.52	71.70	34.97	172.60	115.42	11.21	4.43	0.11	0.03
Table	SC	M	421	0.08	0.29	82.19	43.62	201.69	162.24	11.48	3.29	0.10	0.02
Paragraph	SC	M	422	0.67	0.98	122.29	43.83	283.56	184.43	13.26	4.18	0.12	0.04
Graph w/text	SC	M	423	0.25	0.45	98.91	36.73	209.32	93.27	12.03	2.57	0.12	0.03
Table	SC	H	424	0.25	0.62	102.87	26.14	238.02	123.29	12.56	3.67	0.12	0.04
Paragraph	SC	H	425	0.33	0.65	83.49	19.51	175.50	57.85	11.69	2.29	0.13	0.06
Graph w/text	SC	H	426	0.83	1.03	103.22	41.62	193.65	90.99	11.17	3.83	0.13	0.05
Table	SP	L	427	0.25	0.62	71.84	26.11	173.23	117.04	11.35	4.06	0.11	0.02
Paragraph	SP	L	428	0.67	0.98	89.65	31.08	203.19	127.15	12.04	4.02	0.14	0.05
Graph w/icon	SP	L	429	0.25	0.45	68.44	34.53	161.99	112.35	10.62	4.05	0.11	0.04
Table	SP	M	430	0.50	0.67	75.99	19.95	172.20	72.33	11.55	3.32	0.12	0.04
Paragraph	SP	M	431	0.42	0.67	92.12	18.47	192.85	86.54	11.46	3.52	0.14	0.05
Graph w/text	SP	M	432	0.17	0.39	84.71	34.97	205.43	117.60	11.76	2.53	0.13	0.04
Graph w/icon	SP	M	433	0.17	0.39	82.26	36.41	201.10	143.70	10.74	3.76	0.11	0.03
Table	SP	H	434	0.42	0.67	84.30	27.36	176.00	70.70	11.46	2.78	0.12	0.03
Paragraph	SP	H	435	0.67	0.78	87.88	21.67	187.02	94.92	11.43	3.66	0.13	0.04
Graph w/text	SP	H	436	0.42	0.67	106.13	36.11	245.50	110.41	12.84	2.55	0.13	0.03
Graph w/icon	SP	H	437	0.50	0.52	86.18	18.33	195.45	110.47	11.69	2.93	0.13	0.05
Table	SPC	M	438	0.08	0.29	75.46	30.63	167.91	118.68	10.62	3.63	0.12	0.04
Paragraph	SPC	M	439	0.33	0.49	89.24	31.00	180.99	79.87	10.82	2.49	0.13	0.04
Graph w/text	SPC	M	440	0.33	0.49	81.31	28.32	221.27	106.77	12.44	3.22	0.11	0.05
Table	SPC	H	441	0.67	0.78	76.77	18.26	160.68	56.18	10.77	2.10	0.11	0.02
Paragraph	SPC	H	442	0.58	0.79	92.91	24.20	188.29	84.66	11.07	2.52	0.12	0.05
Graph w/text	SPC	H	443	0.42	0.67	93.61	24.51	192.30	67.04	12.00	2.69	0.12	0.04
Table	SPI	L	444	0.50	0.90	85.02	14.89	193.96	75.28	12.49	3.78	0.12	0.03
Paragraph	SPI	L	445	0.17	0.39	80.29	25.17	166.73	63.49	10.61	2.32	0.11	0.02
Table	SPI	M	446	0.17	0.39	82.93	39.89	181.85	105.81	10.87	2.60	0.12	0.03
Paragraph	SPI	M	447	0.50	0.67	94.29	36.69	253.32	236.72	12.89	5.87	0.14	0.04
Graph w/text	SPI	M	448	0.25	0.45	74.19	28.77	160.19	98.04	10.11	3.31	0.11	0.03
Graph w/icon	SPI	M	449	0.33	0.78	76.40	27.67	168.12	92.71	10.91	3.01	0.11	0.03
Table	SPI	H	450	0.58	1.00	88.82	23.95	189.70	71.05	11.79	2.31	0.12	0.02
Paragraph	SPI	H	451	0.67	0.89	127.71	43.35	256.87	120.44	13.46	3.25	0.12	0.02
Graph w/text	SPI	H	452	0.50	0.80	90.81	36.51	177.55	87.43	11.10	3.01	0.12	0.04
Graph w/icon	SPI	H	453	0.25	0.87	86.21	34.18	178.02	159.55	10.81	4.14	0.12	0.02
Table	SPIC	H	454	0.58	0.79	93.98	32.10	198.51	109.47	11.76	4.08	0.13	0.04
Paragraph	SPIC	H	455	0.67	1.15	99.83	35.62	236.82	88.22	13.45	2.61	0.14	0.03
Graph w/text	SPIC	H	456	0.50	0.80	87.33	40.26	215.87	243.49	11.30	5.41	0.12	0.03
Activate turn signal			501	0.00	0.00	29.89	13.12	85.02	55.67	9.81	4.25	0.06	0.02
Adjust A/C vent			502	0.00	0.00	31.66	14.82	80.04	60.89	8.17	3.65	0.10	0.03
Adjust power mirror			503	0.00	0.00	47.96	27.12	135.91	124.09	8.62	4.68	0.11	0.03
Monitoring fuel level			504	0.17	0.39	45.20	33.25	146.08	191.38	10.29	3.98	0.08	0.01
Monitoring vehicle speed			505	0.25	0.45	31.43	16.91	112.69	103.50	9.60	4.56	0.08	0.03

Appendix 13 – Means and Standard Deviations for IVIS Tasks, Conventional Tasks, and Baselines

Type of Display	Type of Task	Density	Task #	Secondary Task Performance					
				SKIPPED	ERRORS	WRONGTSK	TASK DIFFICULTY	TIME	
				Total	Total	Total		Mean	SD
Baseline 5 seconds			205	*	*	*	*	*	*
Baseline 10 seconds			210	*	*	*	*	*	*
Baseline 20 seconds			220	*	*	*	*	*	*
Baseline 30 seconds			230	*	*	*	*	*	*
Table	S	L	401	0	0	0	1	5.66	1.05
Paragraph	S	L	402	0	0	0	1	8.13	2.38
Graph w/icon	S	L	403	0	0	0	1	2.60	0.64
Table	S	M	404	0	0	0	1	5.77	2.21
Paragraph	S	M	405	0	0	0	1	15.53	4.18
Graph w/text	S	M	406	0	0	0	1	4.36	2.11
Graph w/icon	S	M	407	0	0	0	1	4.35	0.83
Table	S	H	408	0	0	0	1	7.09	2.59
Paragraph	S	H	409	0	1	0	1	18.55	5.91
Graph w/text	S	H	410	0	0	0	1	6.04	2.09
Graph w/icon	S	H	411	0	1	0	1	10.91	7.30
Table	SC	M	421	0	2	0	1	14.59	7.83
Paragraph	SC	M	422	1	2	0	0.92	26.51	20.01
Graph w/text	SC	M	423	0	1	0	1	18.03	8.18
Table	SC	H	424	0	2	0	1	19.21	7.02
Paragraph	SC	H	425	4	0	0	0.67	27.82	17.55
Graph w/text	SC	H	426	1	3	0	0.92	30.95	13.37
Table	SP	L	427	0	3	0	1	20.06	9.14
Paragraph	SP	L	428	0	2	0	1	23.93	17.11
Graph w/icon	SP	L	429	0	9	0	1	14.84	5.34
Table	SP	M	430	0	0	0	1	14.55	3.82
Paragraph	SP	M	431	0	1	0	1	26.54	10.17
Graph w/text	SP	M	432	0	1	0	1	13.66	4.70
Graph w/icon	SP	M	433	0	2	0	1	14.53	6.42
Table	SP	H	434	0	1	0	1	23.84	9.09
Paragraph	SP	H	435	3	4	0	0.75	39.58	26.08
Graph w/text	SP	H	436	0	11	0	1	25.77	17.31
Graph w/icon	SP	H	437	0	4	0	1	19.92	8.43
Table	SPC	M	438	0	2	0	1	16.05	5.81
Paragraph	SPC	M	439	0	2	0	1	29.23	10.82
Graph w/text	SPC	M	440	0	0	0	1	10.64	2.98
Table	SPC	H	441	0	2	0	1	19.77	10.47
Paragraph	SPC	H	442	3	0	0	0.75	37.72	24.14
Graph w/text	SPC	H	443	0	1	0	1	26.58	12.91
Table	SPI	L	444	0	8	0	1	16.19	8.07
Paragraph	SPI	L	445	0	7	0	1	25.29	9.48
Table	SPI	M	446	0	3	0	1	18.58	8.65
Paragraph	SPI	M	447	0	2	0	1	25.94	7.59
Graph w/text	SPI	M	448	0	0	0	1	14.40	5.03
Graph w/icon	SPI	M	449	0	4	0	1	18.22	7.06
Table	SPI	H	450	0	1	0	1	22.27	5.58
Paragraph	SPI	H	451	5	4	0	0.58	35.68	24.41
Graph w/text	SPI	H	452	1	9	0	0.92	29.54	18.24
Graph w/icon	SPI	H	453	0	3	0	1	22.33	10.51
Table	SPIC	H	454	0	2	7	0.42	28.90	16.86
Paragraph	SPIC	H	455	2	0	6	0.33	34.43	22.54
Graph w/text	SPIC	H	456	0	1	9	0.25	28.22	14.67
Activate turn signal			501	0	0	0	1	1.26	0.75
Adjust A/C vent			502	0	0	0	1	2.27	0.96
Adjust power mirror			503	0	0	0	1	4.79	2.18
Monitoring fuel level			504	0	0	0	1	3.70	2.03
Monitoring vehicle speed			505	0	0	0	1	2.09	1.56

Appendix 13 – Means and Standard Deviations for IVIS Tasks, Conventional Tasks, and Baselines

Type of Display	Type of Task	Density	Task #	Subjective Measures			
				SITUAWAR		COMBMWK	
				Mean	SD	Mean	SD
Baseline 5 seconds			205	*	*	*	*
Baseline 10 seconds			210	*	*	*	*
Baseline 20 seconds			220	*	*	*	*
Baseline 30 seconds			230	*	*	*	*
Table	S	L	401	92.92	3.37	4.39	4.98
Paragraph	S	L	402	91.25	6.26	8.69	7.11
Graph w/icon	S	L	403	96.25	4.04	4.39	3.77
Table	S	M	404	92.92	5.39	7.06	4.98
Paragraph	S	M	405	85.42	11.31	16.86	11.17
Graph w/text	S	M	406	94.17	5.20	6.22	5.15
Graph w/icon	S	M	407	92.92	5.77	6.56	4.50
Table	S	H	408	91.67	5.47	7.94	7.49
Paragraph	S	H	409	80.42	14.14	21.83	13.89
Graph w/text	S	H	410	93.33	9.34	8.19	7.18
Graph w/icon	S	H	411	90.33	9.31	11.06	8.81
Table	SC	M	421	87.50	10.96	16.33	10.34
Paragraph	SC	M	422	86.25	11.93	19.56	8.29
Graph w/text	SC	M	423	84.17	11.78	18.36	10.19
Table	SC	H	424	87.42	11.82	17.89	7.81
Paragraph	SC	H	425	80.00	20.55	29.08	12.61
Graph w/text	SC	H	426	84.17	15.70	24.11	11.84
Table	SP	L	427	87.08	14.57	17.42	10.33
Paragraph	SP	L	428	87.92	13.98	18.56	9.16
Graph w/icon	SP	L	429	89.58	10.84	14.06	7.53
Table	SP	M	430	90.42	7.12	13.31	5.42
Paragraph	SP	M	431	85.83	14.23	20.44	9.73
Graph w/text	SP	M	432	88.75	11.36	14.14	9.32
Graph w/icon	SP	M	433	87.92	8.49	13.22	8.91
Table	SP	H	434	84.58	18.65	22.97	9.88
Paragraph	SP	H	435	79.58	26.66	37.11	13.05
Graph w/text	SP	H	436	84.17	16.34	21.69	11.84
Graph w/icon	SP	H	437	89.17	15.85	18.97	10.41
Table	SPC	M	438	86.67	11.92	15.81	10.73
Paragraph	SPC	M	439	84.58	14.25	20.53	12.52
Graph w/text	SPC	M	440	90.00	8.66	13.03	7.39
Table	SPC	H	441	87.08	10.23	15.67	9.40
Paragraph	SPC	H	442	78.75	21.85	31.25	19.32
Graph w/text	SPC	H	443	83.33	13.35	20.56	12.85
Table	SPI	L	444	88.33	10.15	14.69	8.88
Paragraph	SPI	L	445	86.25	11.86	19.92	10.03
Table	SPI	M	446	87.08	13.61	17.86	9.64
Paragraph	SPI	M	447	80.00	17.58	21.61	15.81
Graph w/text	SPI	M	448	90.00	8.90	12.44	7.39
Graph w/icon	SPI	M	449	90.00	9.72	13.97	10.66
Table	SPI	H	450	83.33	10.19	16.42	9.85
Paragraph	SPI	H	451	72.50	27.57	40.94	20.06
Graph w/text	SPI	H	452	85.00	20.99	26.28	9.29
Graph w/icon	SPI	H	453	87.50	11.24	18.03	8.92
Table	SPIC	H	454	83.75	13.25	19.64	14.48
Paragraph	SPIC	H	455	83.33	20.59	27.89	14.82
Graph w/text	SPIC	H	456	84.58	16.80	24.56	10.54
Activate turn signal			501	98.75	1.51	1.92	3.11
Adjust A/C vent			502	96.67	5.05	3.97	6.51
Adjust power mirror			503	95.83	7.63	6.39	4.17
Monitoring fuel level			504	96.25	3.51	3.78	4.33
Monitoring vehicle speed			505	94.58	4.29	4.03	6.89

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CURRICULUM VITAE

Myra Blanco

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PERSONAL INFORMATION:

1105 Lora Lane
Blacksburg, VA 24060
(540) 552-5695, mblanco@vt.edu

EDUCATION:

08/97 - Present	Virginia Polytechnic Institute and State University, Blacksburg, VA **Ph.D., HUMAN FACTORS ENGINEERING** **Degree:** *Expected 05/2002* **MS, HUMAN FACTORS ENGINEERING** **Degree:** *Expected 12/1999* **GPA: 4.00**
08/91 – 12/96	University of Puerto Rico - Mayaguez campus, Mayaguez, PR **BS, INDUSTRIAL ENGINEERING** **Degree:** *December 1996* **GPA: 3.81**

POSITIONS HELD IN COLLEGE:

05/98-Present	Virginia Polytechnic Institute and State University, Blacksburg, VA **GRADUATE RESEARCH ASSISTANT** Conduct applied research on human factors issues in transportation, specifically dealing with the human information processing aspects of different types of in-vehicle information systems. Present research results to varied audiences, including the general public, sponsors, and academia.
08/97 – 05/98	Virginia Polytechnic Institute and State University, Blacksburg, VA **GRADUATE TEACHING ASSISTANT** Responsible for all grades assigned to the work turned in by nearly 40 sophomore undergraduate students, including homework and exams. Tutored students requesting help on class problems or general course material.

12/94 - 06/95	U. of Puerto Rico - Mayaguez campus: Solar Car Project, Mayaguez, PR **RESEARCH ASSISTANT - COMPOSITE MATERIALS** Undertook, with a team of other students, the design and construction of a body shell for a solar car. Accomplished goals, which included: low weight, modularity and high strength. Gained experience with the several composite materials used in the body shell, including fiberglass, carbon fiber and Kevlar. Analyzed all aspects of manufacturing, including economics, and suggested appropriate material usage considering all goals and restrictions. The team exceeded overall expectations, improving its position by more than 50 percent, compared to past races.

PROFESSIONAL EXPERIENCE:

05/99 – 08/99	Scientific Research Lab - Ford Motor Company, Dearborn, MI **SUMMER INTERN – VEHICLE SAFETY RESEARCH** Justify, design, execute, and analyze a research experiment related to vehicle safety using navigation systems. The experiment was performed in Ford's driving simulator and included 31 participants. The goals of the experiment were to find a surrogate measure of visual demand while driving, develop a relationship between eyes-off-the-road time and total task time, and provide a basis for evaluation/refinement of SAE-2364.
07/96 – 7/97	Techno Plastics Industries, Añasco, PR **SAFETY AND HEALTH ENGINEER** Evaluate company compliance with OSHA regulations. Develop comprehensive plans to document compliance with these regulations. Evaluate Personal Protection Equipment for a variety of work environments. Develop monitoring procedures for several chemicals. Serve as a liaison between employees and management in matters related to Industrial Safety and Health.
08/95 - 12/95	Techno Plastics Industries, Añasco, PR **UNDERGRADUATE ENGINEERING RESEARCH** Researched the ergonomic difficulties presented by a repetitive manual operation to various workers. Suggested economically feasible improvements to the operation. Considerably reduced cycle times for the operation. Greatly reduced operator's complains concerning the operation.

MEMBERSHIPS:

08/98 – Present	Phi Kappa Phi, *Virginia Tech Chapter,* Blacksburg, VA
12/97 – Present	American Industrial Hygienists Association
08/97 – Present	Human Factors and Ergonomics Society, Blacksburg, VA
05/95 – Present	Alpha Pi Mu, *Puerto Rico Alpha Chapter*, Mayaguez, PR
	Vice-president: *05/95 – 12/96*
08/95 - Present	Tau Beta Pi, *Puerto Rico Alpha Chapter*, Mayaguez, PR
05/95 – Present	Institute of Industrial Engineers, Blacksburg, VA
05/96 – Present	Golden Key National Honor Society, *PR Chapter,* Mayaguez, PR

HONORS:

08/99 - Present	IIE - E.J. Sierleja Memorial Transportation Fellowship
08/97 - 05/98	Graduate Dean's Assistantship Recipient
05/96, 05/97, and 05/99	Hispanic Scholarship Fund Scholar
08/97 - 05/98	Outstanding Graduate Teaching Assistant Award - Alpha Pi Mu

PUBLICATIONS:

Farber, E., Blanco, M., Curry, R., Greenberg, J.A., Foley, J.P., and Serafin, C.P. (1999). Surrogate measures of driving performance (Technical Report SRL-99). Dearborn, MI: Ford Motor Company-Scientific Research Laboratory.