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

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

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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…

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## TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES





ESSAYS

# 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).

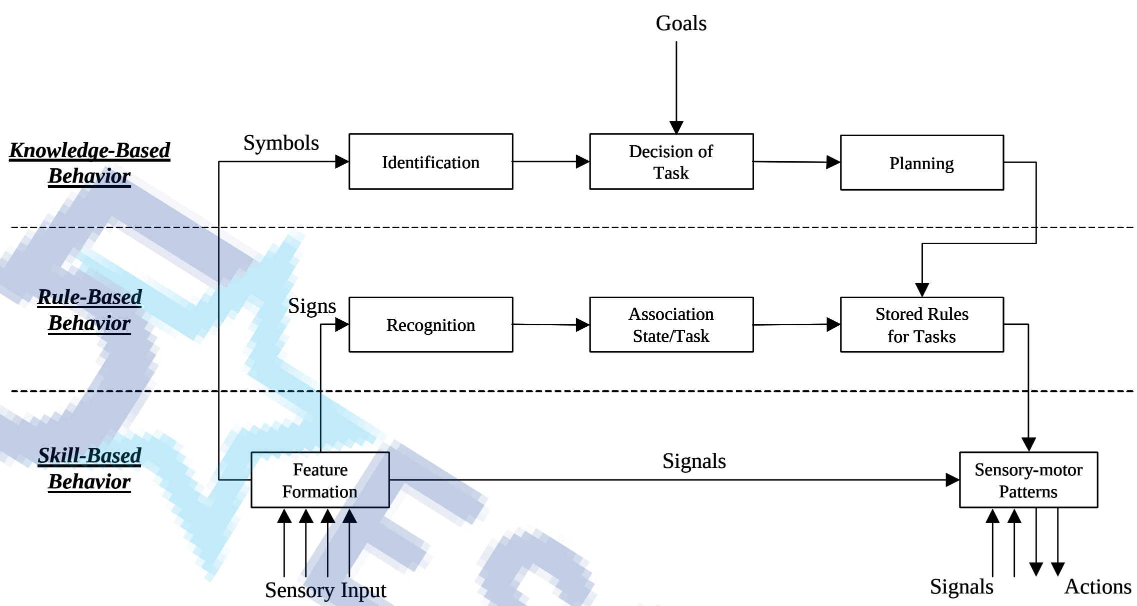


***Figure 1.1 Performance levels of the human operator (Rasmussen, 1983)***

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."

***<u>1.2.3 Mental Workload.</u>*** 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<br>* Multimode travel coordination and planning<br>* Predrive route and destination selection<br>* Dynamic route selection<br>* Route guidance<br>* Route navigation<br>* Automated toll collection<br>**** CVO-specific (route scheduling)*** | IVSAWS | * Immediate hazard warning<br>* Road condition information<br>* Automatic aid request<br>* Manual aid request<br>* Vehicle condition monitoring<br>**** CVO-specific (cargo and vehicle monitoring)*** |
| ISIS | * Roadway guidance sign information<br>* Roadway notification sign information<br>* Roadway regulatory sign information<br>**** CVO-specific (road restriction information)*** | IMSIS | * Broadcast services/attractions<br>* Services/attractions directory<br>* Destination coordination<br>* Message transfer |
| ***CVO-specific*** | | * Fleet resource management<br>* Dispatch<br>* Regulatory administration<br>* 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).

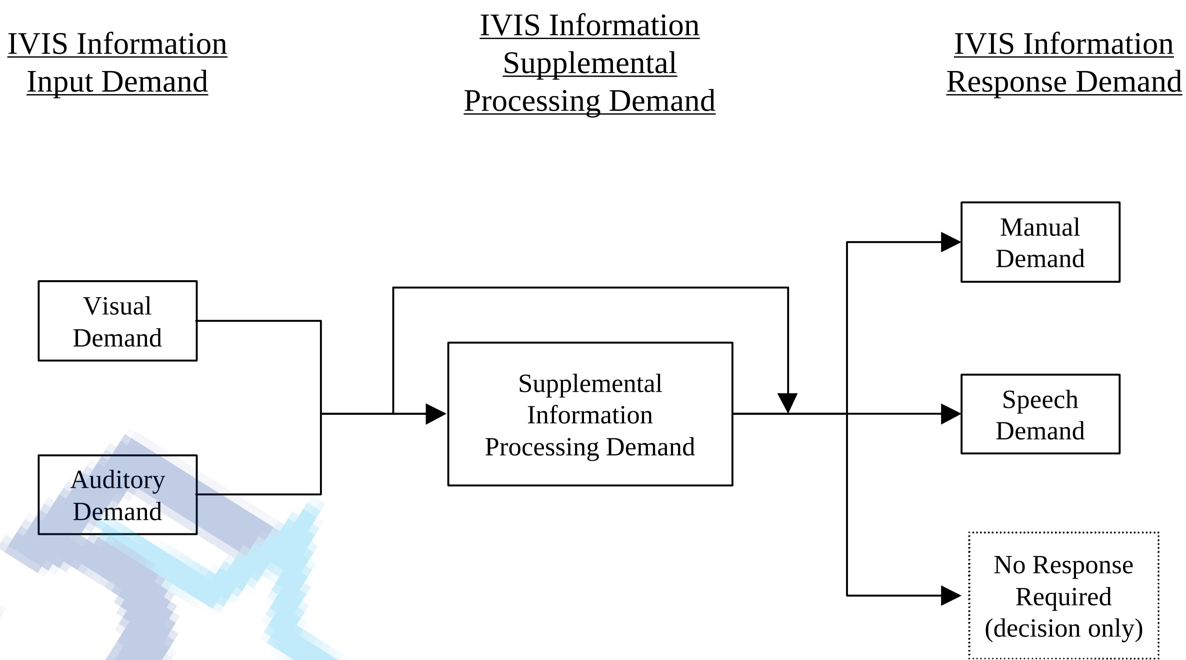


***Figure 2.1 In-Vehicle Information System attention demand model (Wierwille, Gellatly, Dingus, Gallagher, and Benel, 1997)***

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.

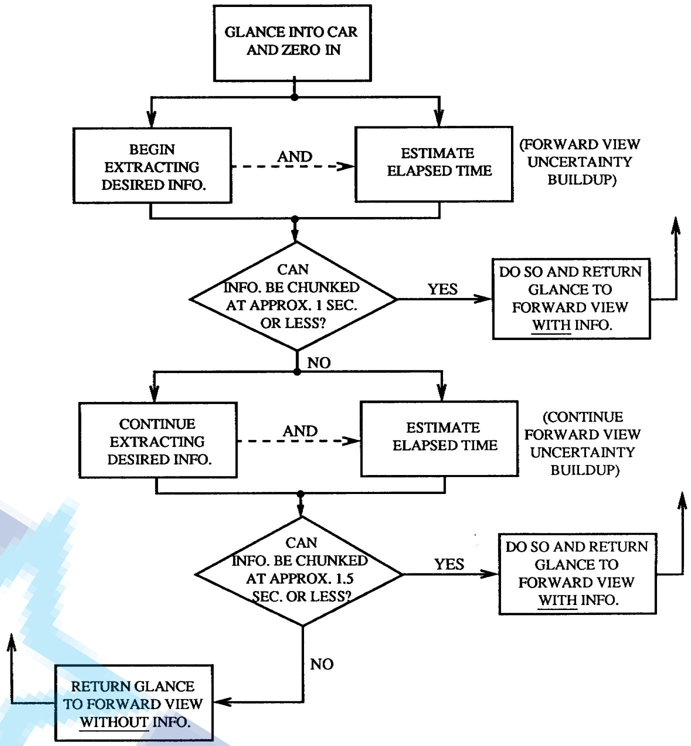


***Figure 2.2 A model of visual sampling for in-vehicle task performance (Wierwille, 1993)***

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 |

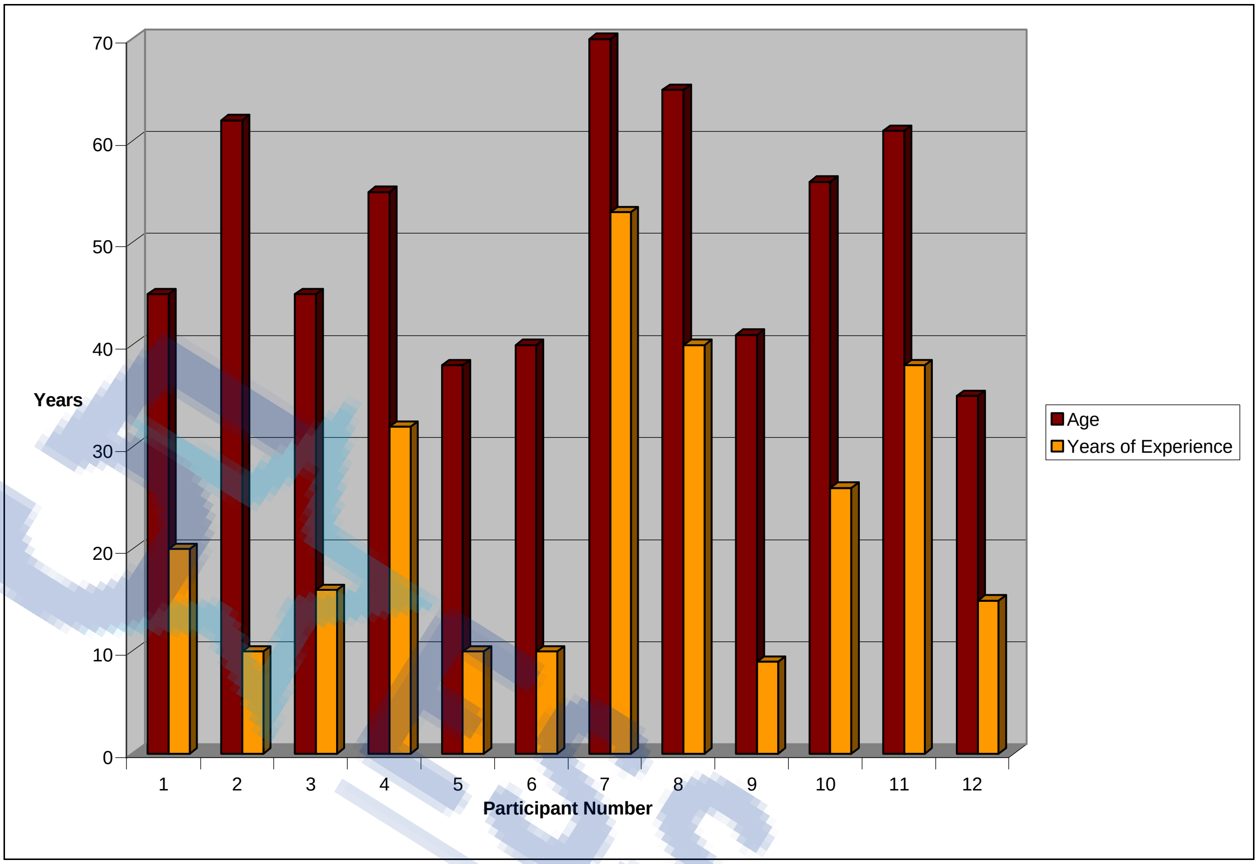


***Figure 3.1  Age and years of experience data for each participant***

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 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.

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***Table 3.2  Experimental design for IVIS/CVO***

| | | ELEMENT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | | Search | | | | | | | | | | | | Search-Compute | | | | | | | | | | | | Search-Plan | | | | | | | | | | | | Search-Plan-Compute | | | | | | | | | | | | Search-Plan-Interpret | | | | | | | | | | | | Search-Plan-Interpret-Compute | | | | | | | | | | | |
| | DISTYPE | 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<br>* Activate turn signal |
| Adjust vent | * Locate vent<br>* Adjust vent so that air flow is away |
| Adjust power mirror | * Check mirror adjustment<br>* Locate mirror control<br>* Switch control to proper mirror<br>* Adjust mirror until line-of-sight is correct |
| Monitoring fuel level | * Locate fuel gauge<br>* Read fuel gauge |
| Monitoring vehicle speed | * Locate speedometer<br>* 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).

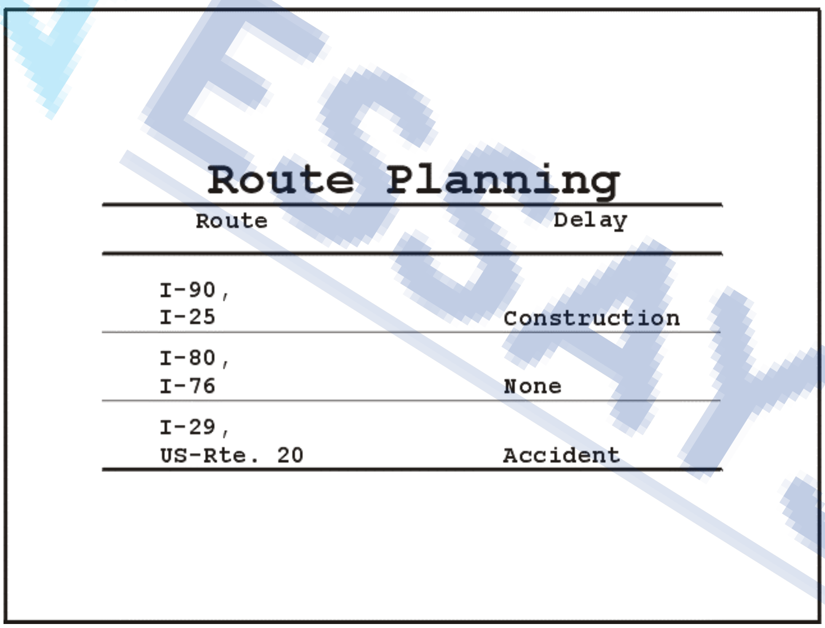
The information presented during the IVIS tasks followed one of four presentation formats: (1) tabular, (2) paragraph, (3) graphics with text, or (4) graphics with icons. These factors were included based on the following statement from Campbell, Kantowitz, and Hanowski (1995):

> 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,<br>I-25 | Construction |
| I-80,<br>I-76 | None |
| I-29,<br>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)***

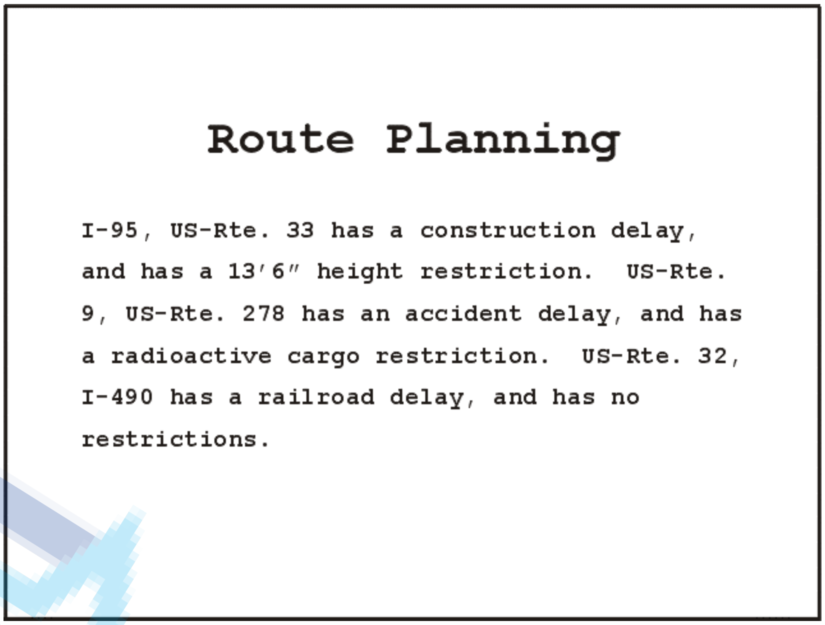



*Figure 3.3 Example of a screen of paragraph format with a medium level of information density (three categories of information and three alternatives)*

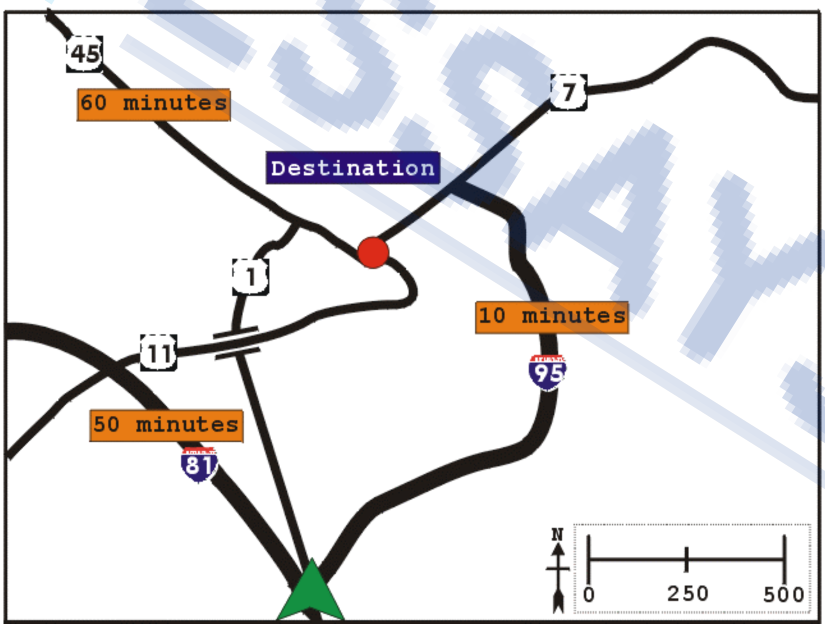



*Figure 3.4 Example of a screen of graphics with text format with a medium level of information density (three categories of information and three alternatives)*

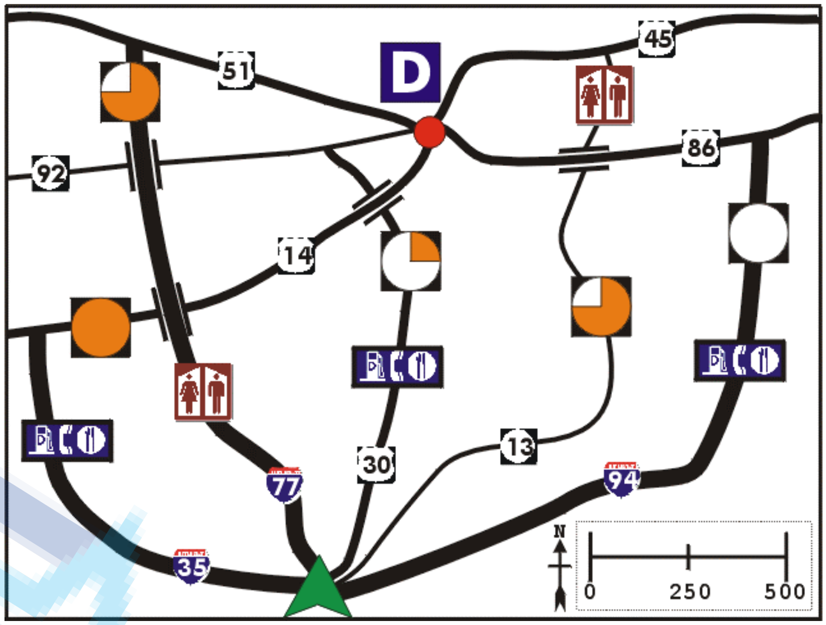



***Figure 3.5 Example of a screen in graphics with icons format with a high level of information density (four categories of information and five alternatives)***

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.

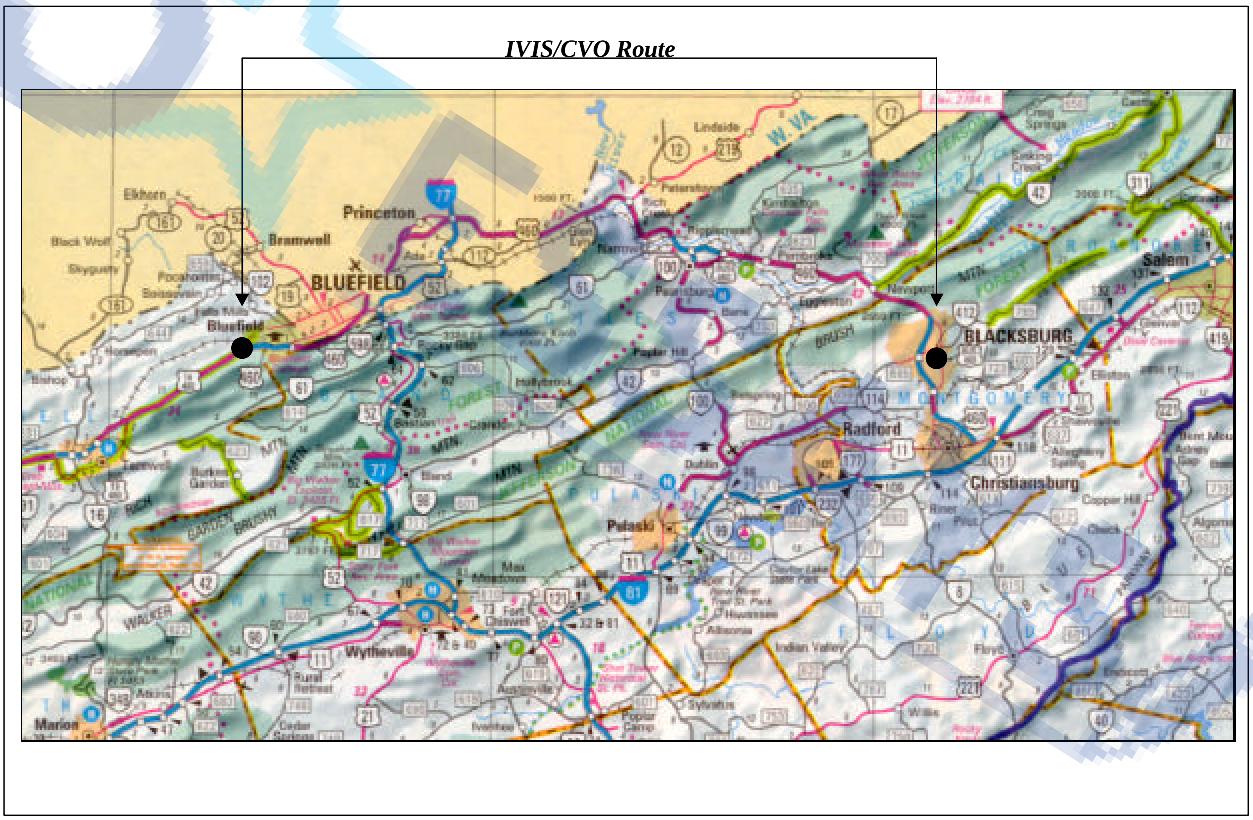



*Figure 3.6 Experimental route: U.S. Highway 460 between Blacksburg, VA and Bluefield, VA*

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?<br>Is there an Interstate 95 on the map?<br>Which route has a construction delay?<br>Which route has no restrictions?<br>Which roadway has a 10 min delay?<br>Which roadway has a 15 min delay?<br>Which route has a school crossing delay?<br>Which roadway has a 45 min delay?<br>Which roadway has no delay?<br>Which roadway has a speed limit of 60 mph?<br>Which roadway has a flammable material restriction?<br>Which roadway has a speed limit of 70 mph?<br>Which roadway has a hazardous cargo restriction?<br>Which roadway has a traffic signal delay?<br>Which roadway has a  construction delay?<br>Which roadway has a drawbridge delay?<br>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 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.

***<u>3.9.3 Truck and System Familiarization</u>***. 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.

***<u>3.9.4 Testing Hearing Abilities</u>***. 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).

***<u>3.9.5 Driving Instructions</u>***. 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.

***<u>3.9.6 Driving and Task Practice</u>***. 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.

***<u>3.9.7 Probe Questioning.</u>*** 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?<br>(2) Did you perform any calculation(s), and if so<br>(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?<br>(2) Did you perform any calculation(s), and if so<br>(3) Which categories of information were used to perform calculation(s)? |

***<u>3.9.8 General On-Road Procedure</u>***. 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***

***<u>3.10.2 Longitudinal Driving Performance.</u>*** 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 $(\text{degrees/sec})^2$, 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 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.

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***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 ≤ TGT < 2.5 sec |
| High Attentional Demand | 2.5 ≤ 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 ($[\text{degrees/sec}]^2$) | 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 | | | | | | | | | | | |
| | ***DISTYPE*** | 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 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**= SKIPPED** **= UNABLE TO PRESENT**

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

| | Variable | | | | |
|---|---|---|---|---|---|
| **Source** | **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*

| | Variable | | | | | |
|---|---|---|---|---|---|---|
| **Source** | **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 |
|---|---|---|
| A | 13.147 | Paragraph |
| B | 9.415 | Graph w/text |
| B | 8.649 | Table |
| C | 7.073 | Graph w/icon |

| SNK Grouping | Mean TGT | DISTYPE |
|---|---|---|
| A | 18.058 | Paragraph |
| B | 12.493 | Graph w/text |
| C B | 11.278 | Table |
| C | 9.501 | Graph w/icon |

*(a) Eye Glance Measures*

| SNK Grouping | Mean DECSPEED | DISTYPE |
|---|---|---|
| A | 3.140 | Paragraph |
| B | 2.218 | Graph w/text |
| B | 2.214 | Table |
| B | 1.720 | Graph w/icon |

| SNK Grouping | Mean STDSPEED | DISTYPE |
|---|---|---|
| A | 1.230 | Paragraph |
| B | 0.908 | Graph w/text |
| B | 0.901 | Table |
| B | 0.721 | Graph w/icon |

| 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 |

*(b) Longitudinal Driving Performance*

| SNK Grouping | Mean MAXSTVEL | DISTYPE |
|---|---|---|
| A | 93.129 | Paragraph |
| B | 85.835 | Graph w/text |
| B | 80.032 | Table |
| C | 71.263 | Graph w/icon |

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

*(c) Lateral Driving Performance*

| SNK Grouping | Mean TIME | DISTYPE |
|---|---|---|
| A | 27.199 | Paragraph |
| B | 18.997 | Graph w/text |
| C B | 16.610 | Table |
| C | 13.463 | Graph w/icon |

| SNK Grouping | Mean COMBMWK | DISTYPE |
|---|---|---|
| A | 23.877 | Paragraph |
| B | 17.235 | Graph w/text |
| C B | 14.813 | Table |
| C | 12.531 | Graph w/icon |

| SNK Grouping | Mean SITUAWAR | DISTYPE |
|---|---|---|
| A | 90.458 | Graph w/icon |
| B | 87.911 | Table |
| B | 87.424 | Graph w/text |
| 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.

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*

| | | Source | | | |
|---|---|---|---|---|---|
| | **Variable** | AGE | ELEMENT | DISTYPE | 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*

*Table 4.13 Post-Hoc results for the DISTYPE main effect*

| SNK Grouping | Mean DECSPEED | DISTYPE |
|---|---|---|
| A | 3.1403 | Paragraph |
| B | 2.2178 | Graph w/text |
| B | 2.2144 | Table |
| B | 1.7196 | Graph w/icon |
| B | 1.4101 | Baseline |

| SNK Grouping | Mean STDSPEED | DISTYPE |
|---|---|---|
| A | 1.2303 | Paragraph |
| B | 0.9083 | Graph w/text |
| B | 0.9009 | Table |
| B | 0.8539 | Baseline |
| B | 0.7214 | Graph w/icon |

| SNK Grouping | Mean MXLONDCL | DISTYPE |
|---|---|---|
| A | 0.0503 | Paragraph |
| B | 0.0350 | Table |
| B | 0.0334 | Baseline |
| B | 0.0312 | Graph w/text |
| B | 0.0294 | Graph w/icon |

*(a) Longitudinal Driving Performance*

| SNK Grouping | Mean VSTVEL | DISTYPE |
|---|---|---|
| A | 217.1500 | Paragraph |
| A | 198.7000 | Graph w/text |
| A | 189.6300 | Table |
| A | 174.3600 | Graph w/icon |
| B | 91.1300 | Baseline |

| SNK Grouping | Mean MAXSTVEL | DISTYPE |
|---|---|---|
| A | 93.1290 | Paragraph |
| B A | 85.8350 | Graph w/text |
| B | 80.0320 | Table |
| C | 71.2630 | Graph w/icon |
| D | 53.0200 | Baseline |

| SNK Grouping | Mean MSTVEL | DISTYPE |
|---|---|---|
| A | 12.0487 | Paragraph |
| B A | 11.5404 | Table |
| B A | 11.4622 | Graph w/text |
| B | 10.7483 | Graph w/icon |
| 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*

*Table 4.14 Post-Hoc results for the DENSITY main effect*

| BON Grouping | Mean MNSPEED | DENSITY |
|---|---|---|
| A | 47.68 | Med |
| B A | 47.41 | Baseline |
| B A | 46.98 | Low |
| B | 46.48 | High |

| SNK Grouping | Mean DECSPEED | DENSITY |
|---|---|---|
| A | 2.640 | High |
| A | 2.354 | Low |
| A | 2.118 | Med |
| B | 1.410 | Baseline |

| BON Grouping | Mean STDSPEED | DENSITY |
|---|---|---|
| A | 1.07 | High |
| B A | 0.92 | Low |
| B A | 0.85 | Baseline |
| B | 0.85 | Med |

*(a) Longitudinal Driving Performance*

| SNK Grouping | Mean NLANEDEV | DENSITY |
|---|---|---|
| A | 0.472 | High |
| B | 0.292 | Low |
| B | 0.274 | Med |
| B | 0.240 | Baseline |

| SNK Grouping | Mean MAXSTVEL | DENSITY |
|---|---|---|
| A | 90.02 | High |
| B | 81.83 | Med |
| C | 71.30 | Low |
| D | 53.02 | Baseline |

| SNK Grouping | Mean VSTVEL | DENSITY |
|---|---|---|
| A | 202.06 | High |
| A | 198.15 | Med |
| A | 180.37 | Low |
| B | 91.13 | Baseline |

| SNK Grouping | Mean MSTVEL | DENSITY |
|---|---|---|
| A | 11.754 | High |
| A | 11.453 | Med |
| A | 11.115 | Low |
| B | 7.546 | Baseline |

| SNK Grouping | Mean MXLACLMG | DENSITY |
|---|---|---|
| A | 0.1209 | High |
| B A | 0.1148 | Med |
| B | 0.1122 | 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 ($p < 0.05$)

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***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*

*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)

*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 | |
| Table | S | L | 401 | 3.60 | 0.76 | |
| Table | S | M | 404 | 4.29 | 1.35 | Very High |
| 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 | |
| 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.

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).

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

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

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: NEGDISP Mean | NEGDISP Red-Line | LEGDISP Mean | LEGDISP Red-Line | Secondary Task Performance: SKIPPED Total | SKIPPED Red-Line | TASK DIFFICULTY Measure | TASK DIFFICULTY Red-Line | TIME Mean | TIME 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.

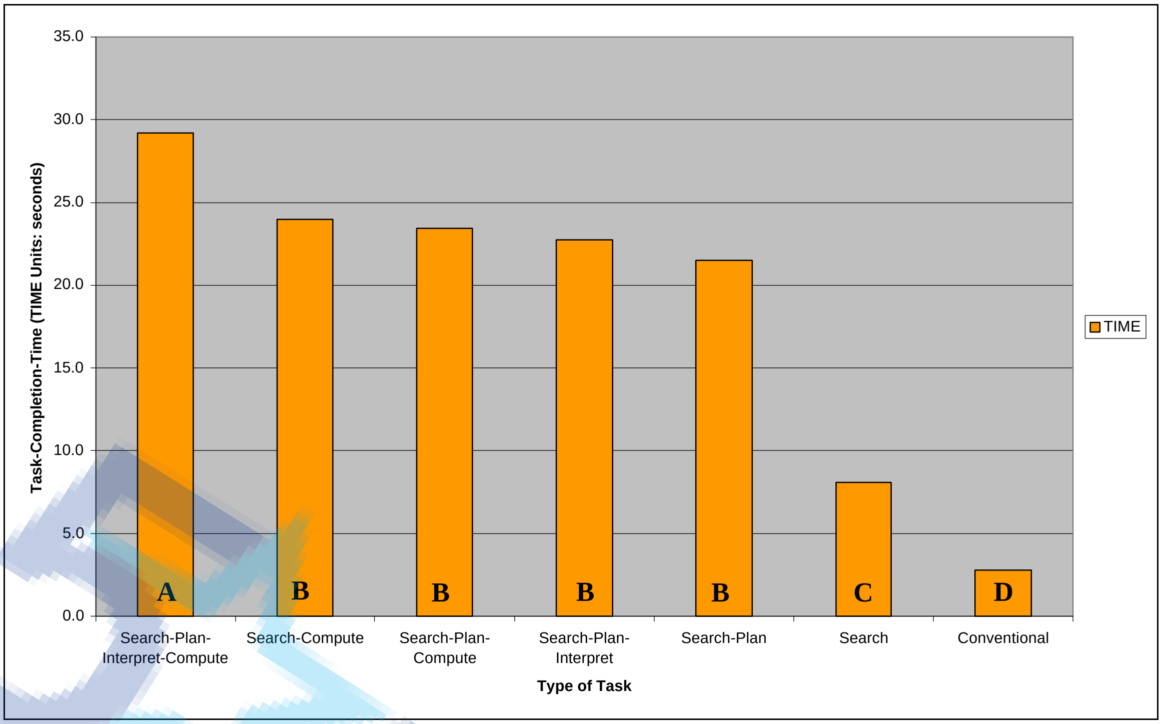


*Figure 5.1 Example of the grouping of the different types of tasks compared to the conventional tasks*

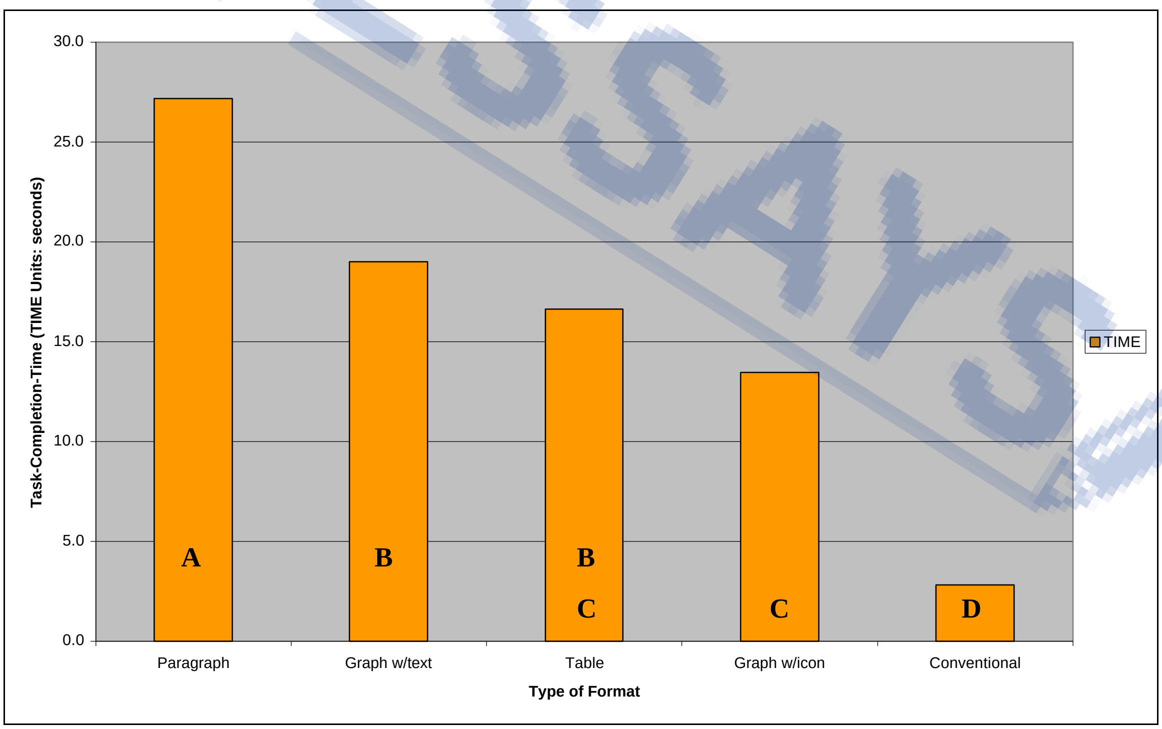


*Figure 5.2 Example of the grouping of the different types of format compared to the conventional tasks*

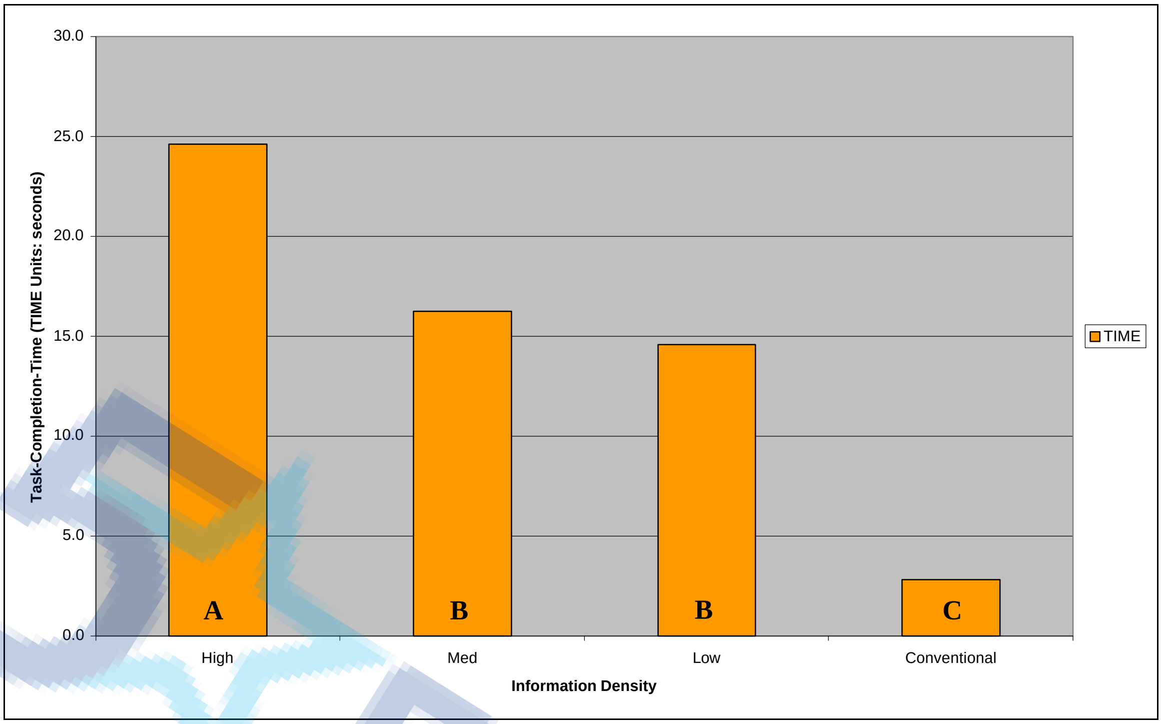


***Figure 5.3 Example of the grouping of the different information densities compared to the conventional tasks***

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.

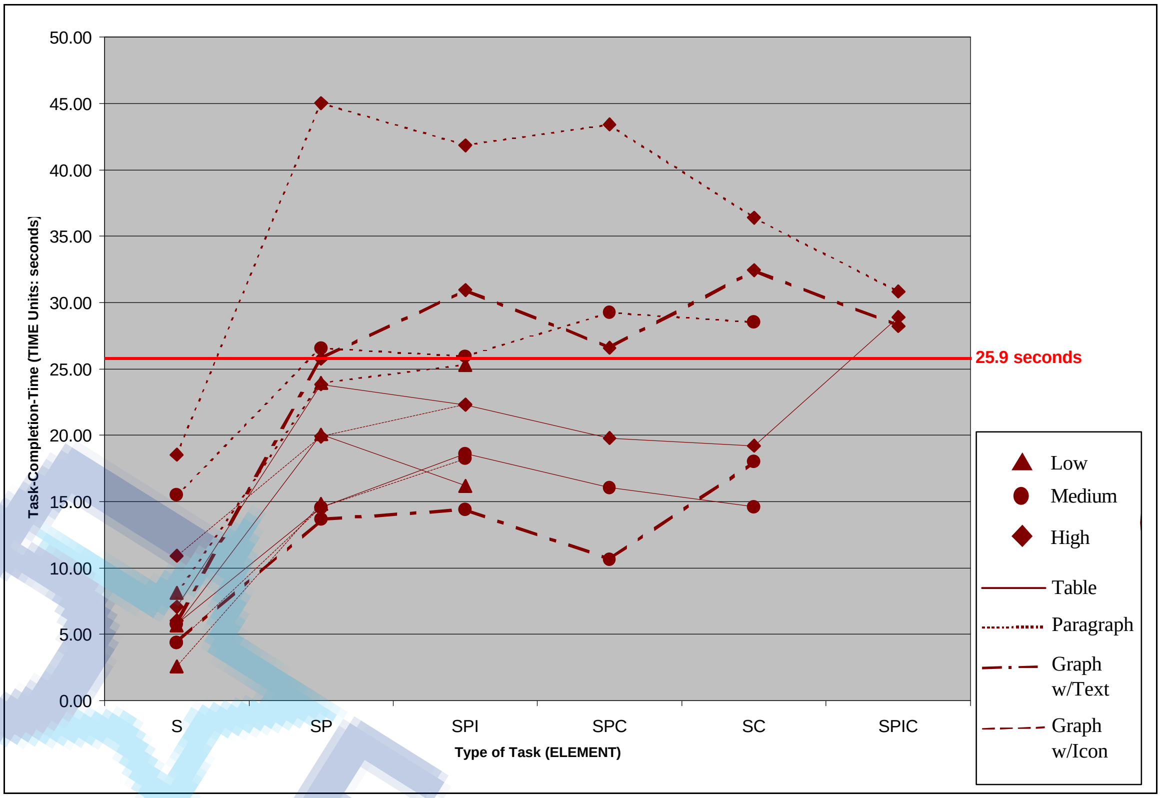


***Figure 5.4 Task-Completion-Time for the three-way interaction of type of task, type of format, and information density***

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.

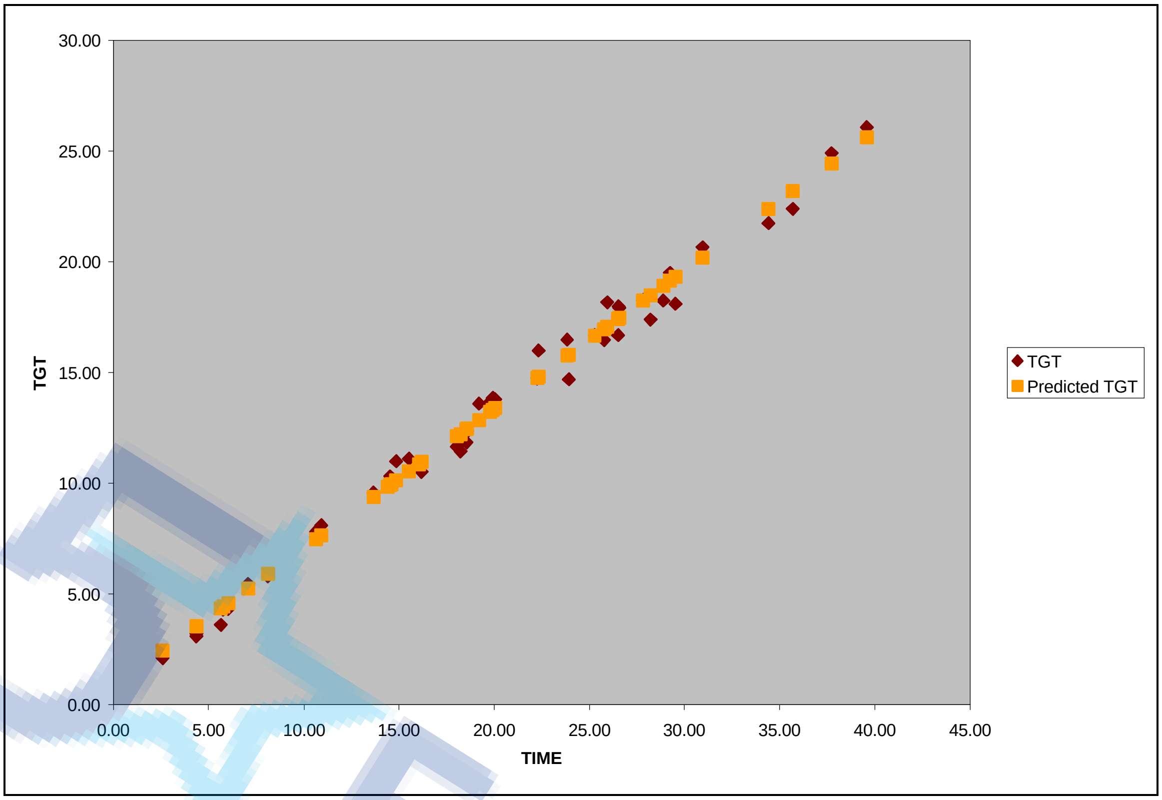


***Figure 5.5 Line fit plot for the regression performed for Equation 2***

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.

5ESSAYS

*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

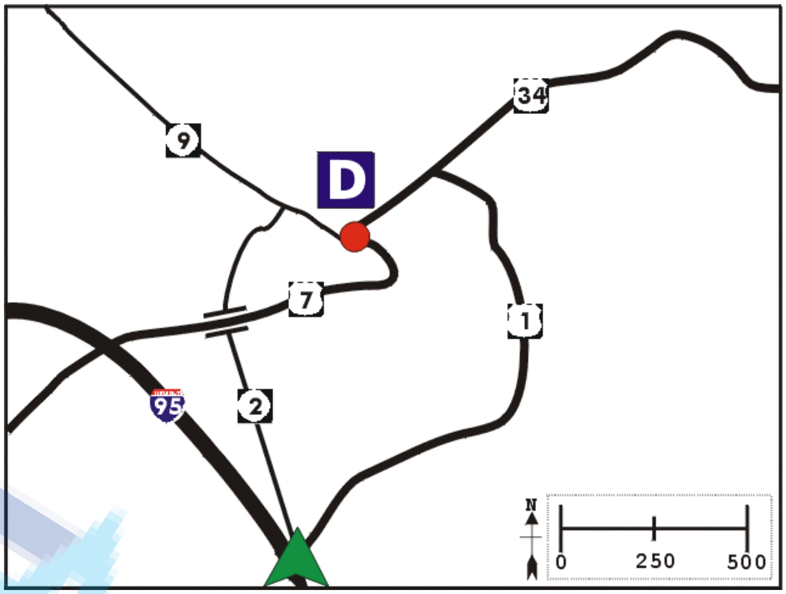
| Route | Delay |
|---|---|
| I-90, I-25 | Construction |
| I-80, I-76 | None |
| I-29, US-Rte. 20 | Accident |

- **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*

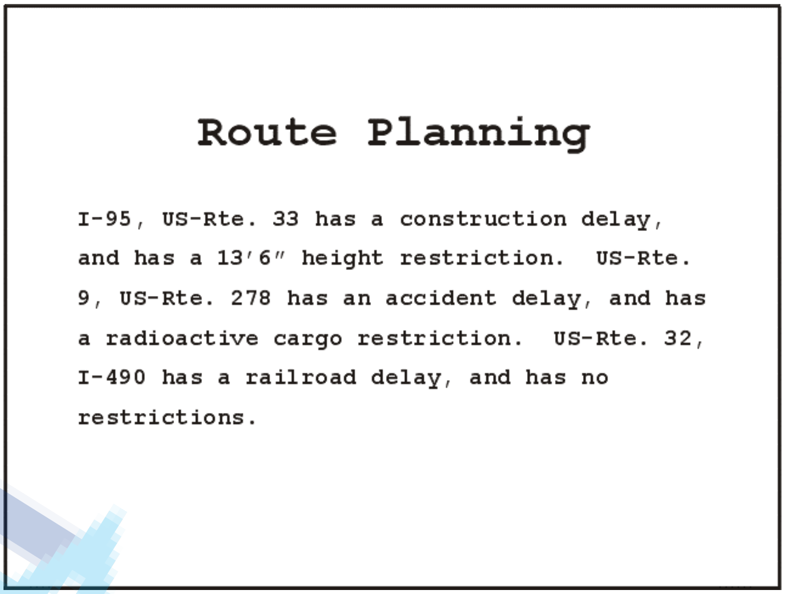



- **Instruction:** *Is there an Interstate 95 on the map?* [Task # 403]
  *Select a route to the delivery destination.* [Task # 429]
- **Format:** *Graphics with icons*
- **Information Density:** *Low* (2 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type*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

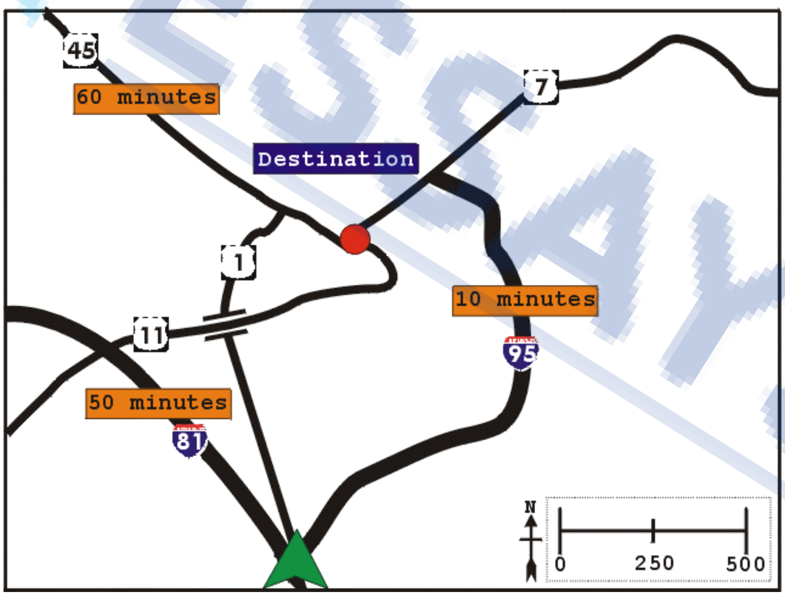
**Route Planning**

| 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 |

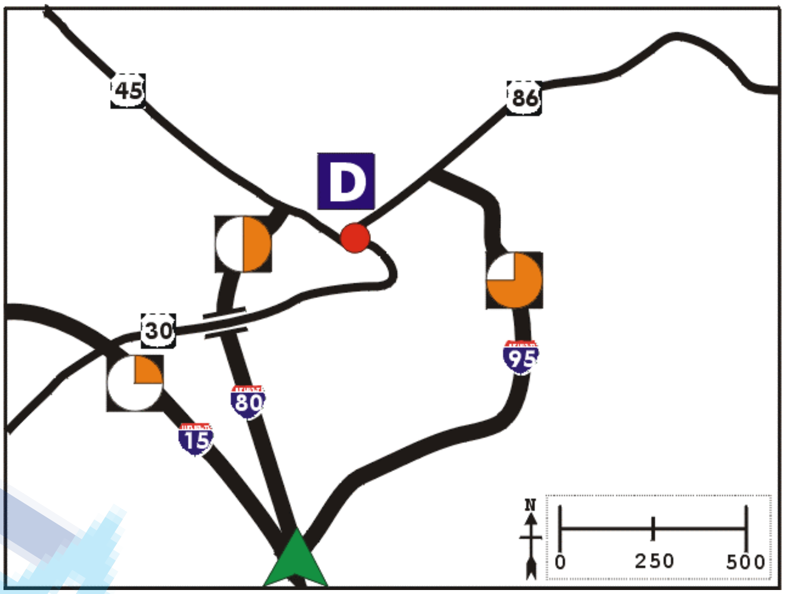
- **Instruction:** *Which route has a construction delay?* [Task # 404]
- **Format:** *Table*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type, Delay* and *Restriction*
- **Type of Task:** *Search*




- **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]

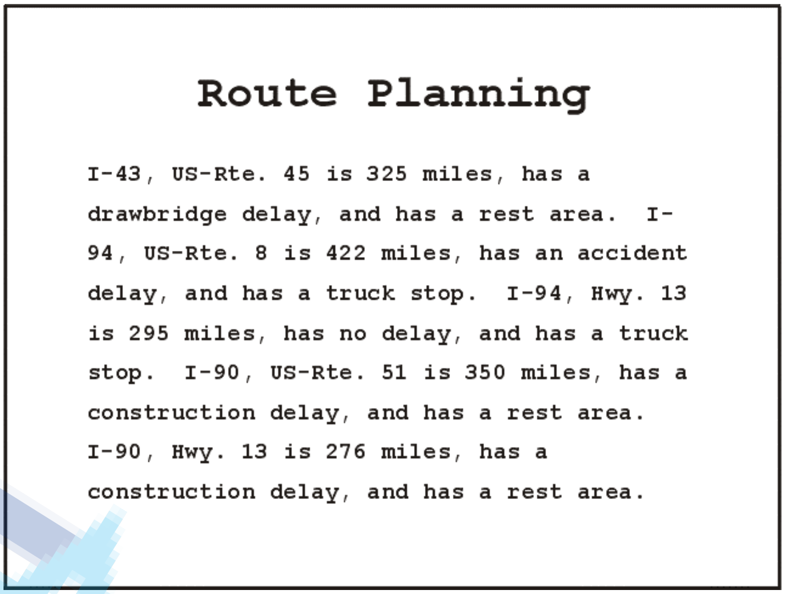



- **Instruction:** *Which roadway has a 15 min delay?* [Task # 407]
  *Select a route to the delivery destination.* [Task # 433]
- **Format:** *Graphics with icons*
- **Information Density:** *Medium* (3 categories of information x 3 alternatives)
  - **Categories of Information Used:** *Road Type*, *Distance* and *Delay*
- **Type of Task:** *Search* [Task # 407], *Search-Plan* [Task # 433]

**Route Planning**

| 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 |

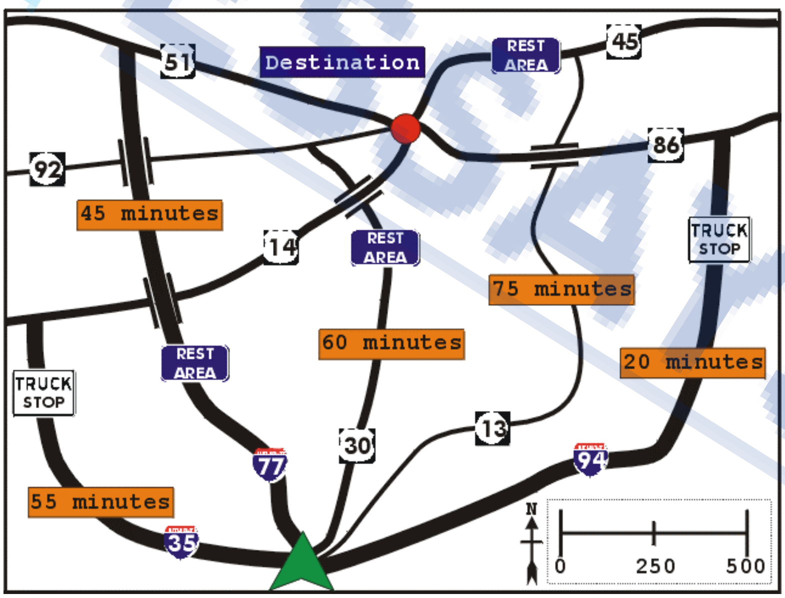
- **Instruction:** *Which route has a school crossing delay?* [Task # 408]
- **Format:** *Table*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type, Distance, Delay* and *Rest Areas/Truck Stops*
- **Type of Task:** *Search*



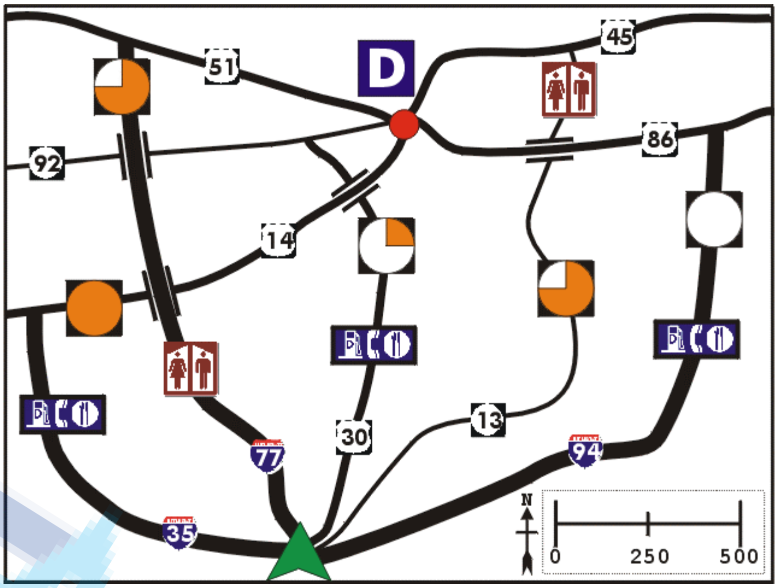
## Route Planning

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]

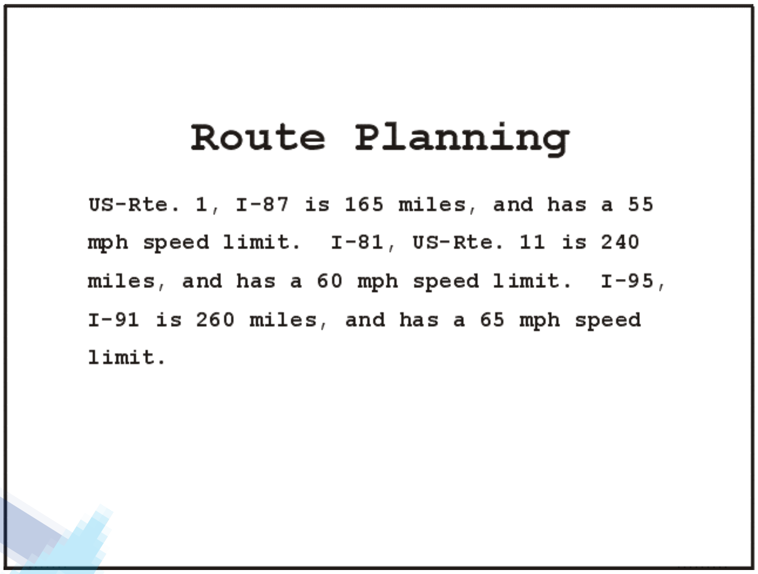



- **Instruction:** *Which roadway has no delay?* [Task # 411]
  *Select a route to the delivery destination.* [Task # 437]
- **Format:** *Graphics with icons*
- **Information Density:** *High* (4 categories of information x 5 alternatives)
  - **Categories of Information Used:** *Road Type*, *Distance*,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

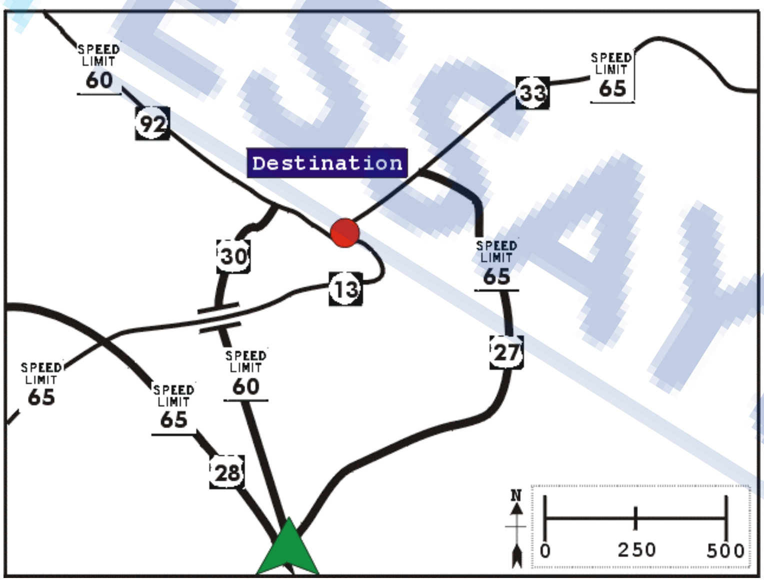
**Route Planning**

| Route | Distance | Speed Limit |
|---|---|---|
| US-Rte. 1, I-87 | 220 miles | 55 mph |
| I-81, US-Rte. 11 | 120 miles | 60 mph |
| I-95, I-91 | 195 miles | 65 mph |

- **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*




- **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

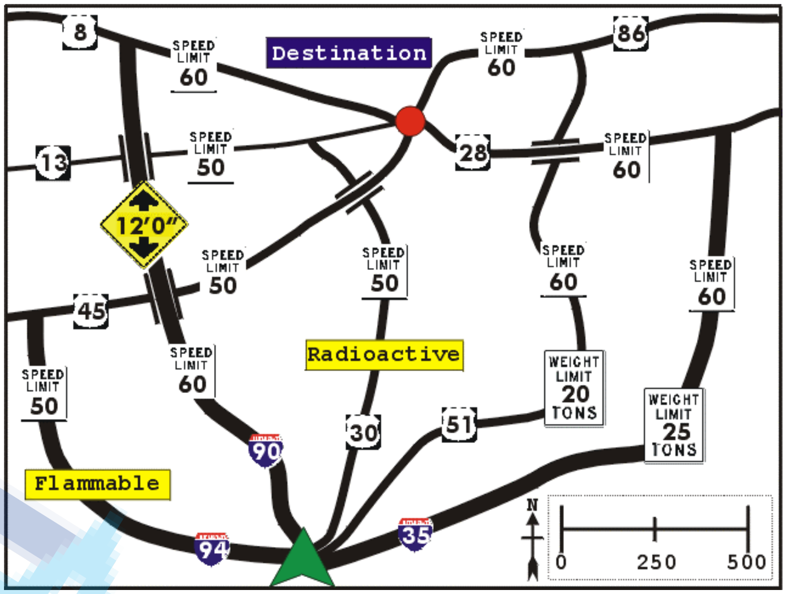
| Route | Distance | Restriction | Speed Limit |
|---|---|---|---|
| US-Rte. 1, I-87 | 220 miles | 16 TON | 55 mph |
| I-81, Hwy. 37 | 260 miles | Height-12′ | 65 mph |
| I-95, US-Rte. 7 | 210 miles | 25 TON | 70 mph |
| I-81, US-Rte. 11 | 240 miles | 20 TON | 60 mph |
| US-Rte. 1, US-Rte. 7 | 220 miles | 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*

**Route Planning**

| Route | Distance |
|---|---|
| US-Rte. 38, Hwy. 27 | 748 miles |
| Hwy. 92, US-Rte. 24 | 890 miles |
| Hwy. 33, US-Rte. 28 | 695 miles |

- **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

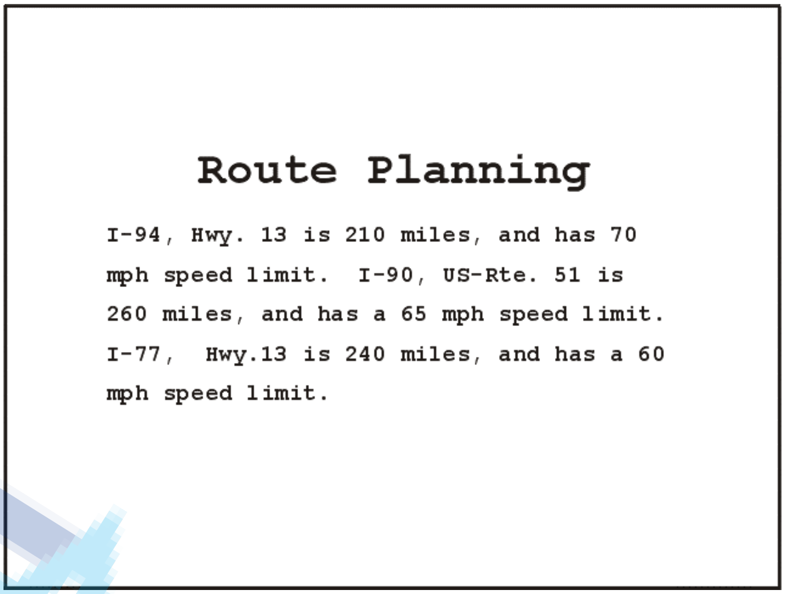
I-35, US-Rte. 14 is 770 miles, has a rest area, and has a 55 minute delay. I-29, US-Rte. 81 is 612 miles, has a truck stop, and has a 15 minute delay. US-Rte. 59, Hwy. 9 is 785 miles, has no rest areas or truck stops, and has a 10 minute delay. US-Rte. 77, US-Rte. 14 is 895 miles, has a rest areas, and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

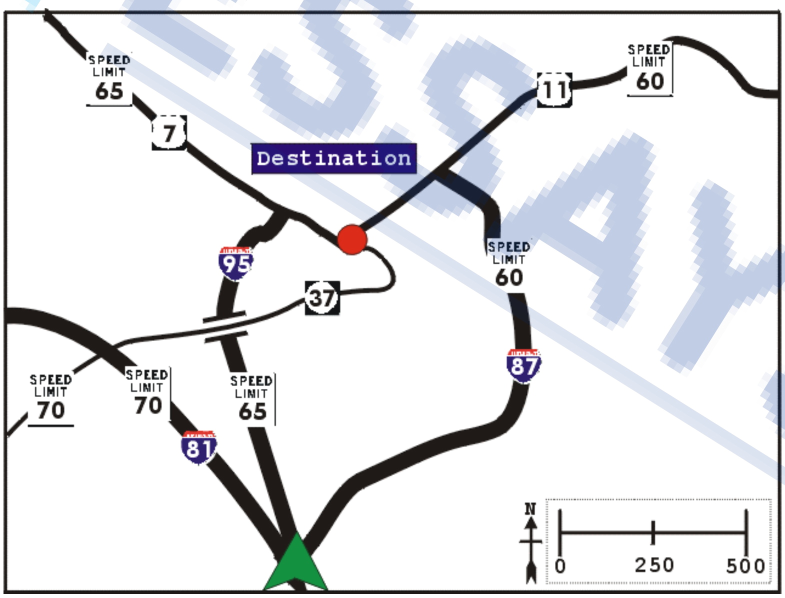
## Route Planning

| 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*




- **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

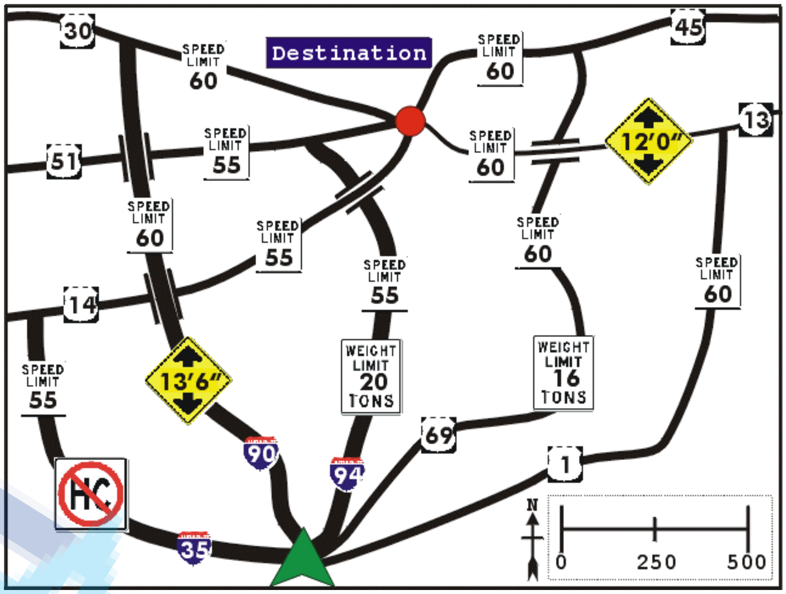
| Route | Distance | Restriction | Speed Limit |
|---|---|---|---|
| US-Rte. 1, I-87 | 165 miles | 16 TON | 55 mph |
| I-81, Hwy. 37 | 260 miles | 20 TON | 65 mph |
| I-95, US-Rte. 7 | 210 miles | Flammable | 70 mph |
| I-81, US-Rte. 11 | 240 miles | Radioactive | 60 mph |
| US-Rte. 1, US-Rte. 7 | 220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

| 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**

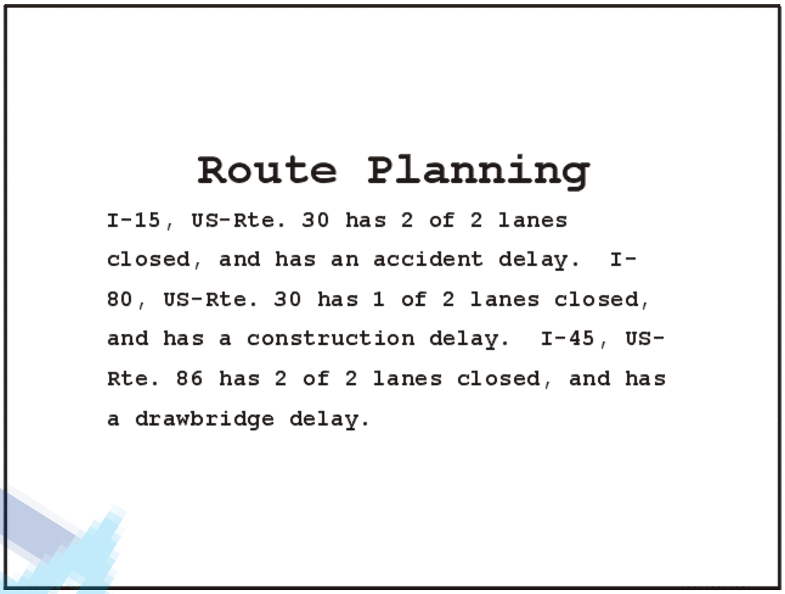
US-Rte. 38, Hwy. 27 has a railroad delay. Hwy. 92, US-Rte. 24 has a bike race delay. Hwy. 33, US-Rte. 28 has a school crossing delay.

- **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*

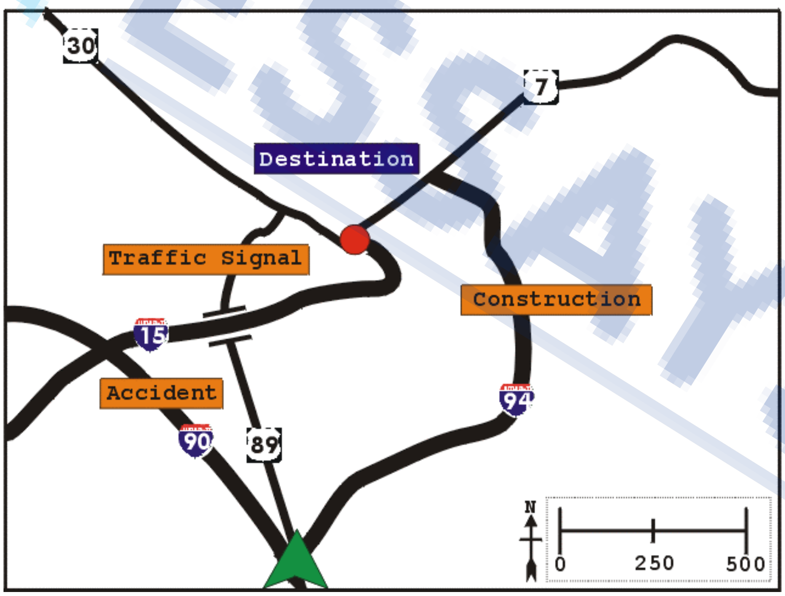
**Route Planning**

| Route | Lanes Closed | Delay |
|---|---|---|
| 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 |

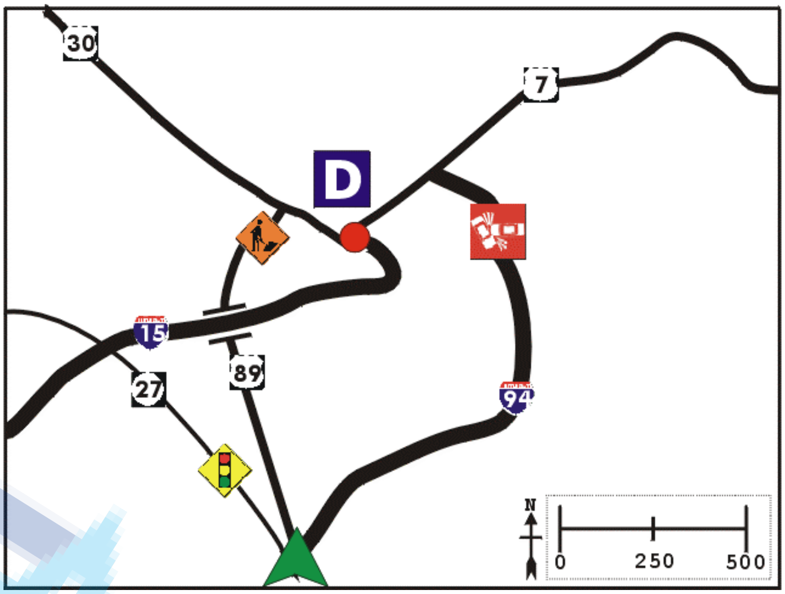
- **Instruction:** *Select a route to the delivery destination.* [Task # 446]
- **Format:** *Table*
- **Information Density:** Medium (3 categories of information x 3 alternatives)
    - **Categories of Information Used:** *Road Type, Lane Closed* and *Delay*
- **Type of Task:** *Search-Plan-Interpret*




- **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*

**Route Planning**

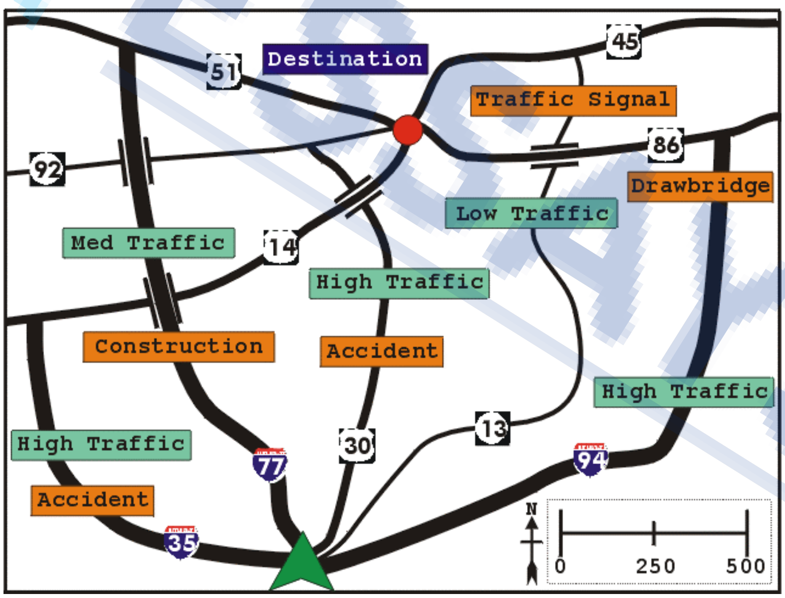
| Route | Lane Closed | Delay | Traffic Density |
|---|---|---|---|
| US-Rte. 70, I-5 | None | Traffic signal | Low |
| US-Rte. 20, Hwy. 49 | 1 of 2 | Funeral procession | Low |
| I-80, I-5 | 2 of 2 | Accident | High |
| Hwy. 16, Hwy. 33 | 1 of 2 | Bike race | Med |
| Hwy. 65, I-5 | 1 of 1 | School crossing | High |

- **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*

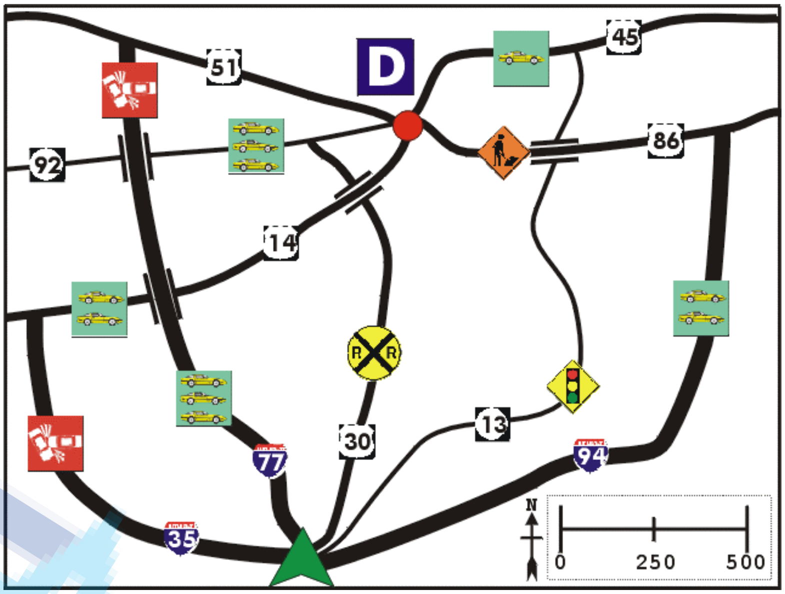
## Route Planning

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**

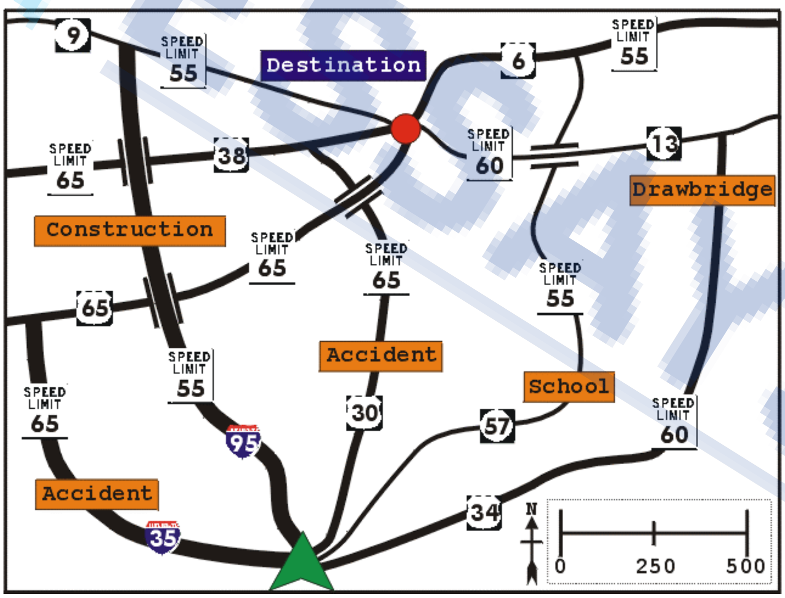
| Route | Distance | Speed Limit | Delay |
|---|---|---|---|
| US-Rte. 70, I-5 | 240 miles | 60 mph | Traffic signal |
| US-Rte. 20, Hwy. 49 | 180 miles | 60 mph | Funeral procession |
| I-80, I-5 | 280 miles | 70 mph | Accident |
| Hwy. 16, Hwy. 33 | 250 miles | 50 mph | Bike race |
| Hwy. 65, I-5 |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

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# In-Vehicle Information System (IVIS) / Commercial Vehicle Operations (CVO)


## Schedule and Training

***Experimenter:***

***Myra Blanco***

Virginia Tech

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# 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)

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## 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)

## 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

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# 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)

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# Lab Training


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# IVIS/CVO Display

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# Formats

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

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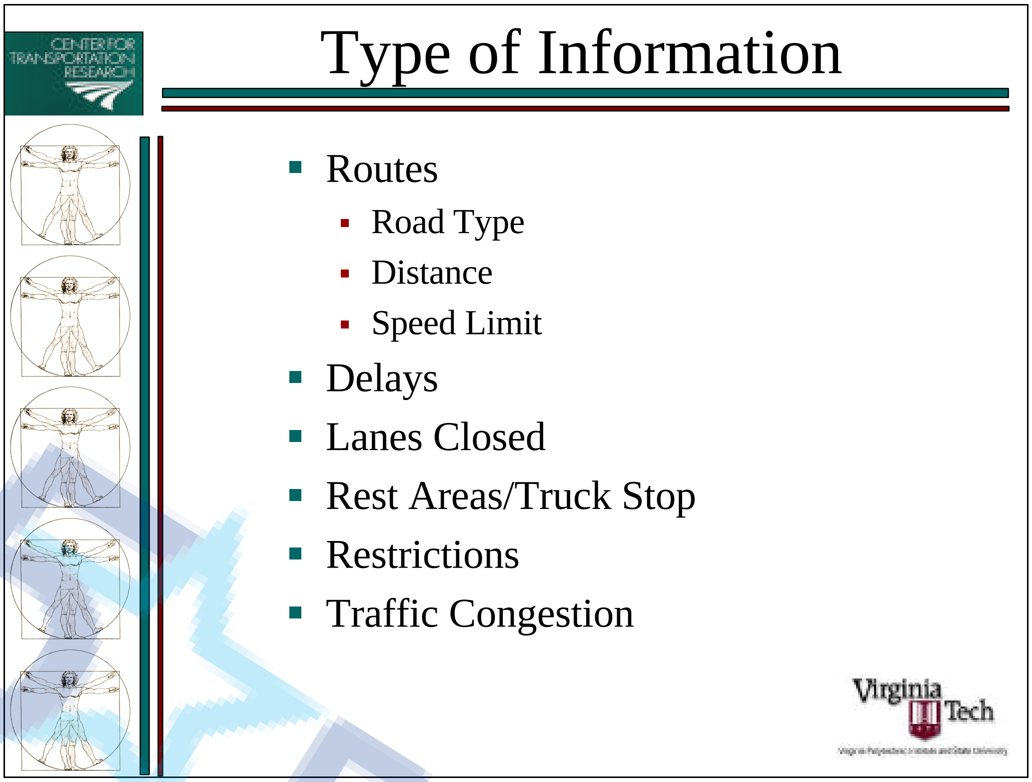
CENTER FOR TRANSPORTATION RESEARCH
Type of Information
Routes
Road Type
Distance
Speed Limit
Delays
Lanes Closed
Rest Areas/Truck Stop
Restrictions
Traffic Congestion
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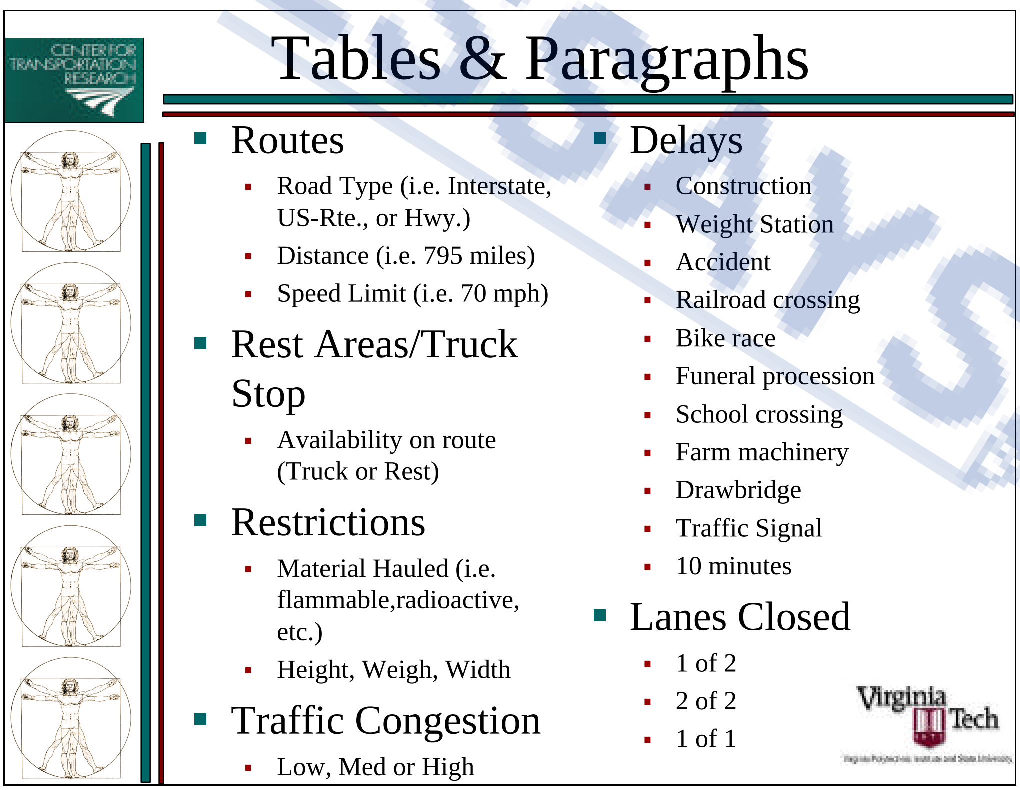
CENTER FOR TRANSPORTATION RESEARCH
Tables & Paragraphs
Routes
Road Type (i.e. Interstate, US-Rte., or Hwy.)
Distance (i.e. 795 miles)
Speed Limit (i.e. 70 mph)
Rest Areas/Truck Stop
Availability on route (Truck or Rest)
Restrictions
Material Hauled (i.e. flammable,radioactive, etc.)
Height, Weigh, Width
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
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# Table Example:

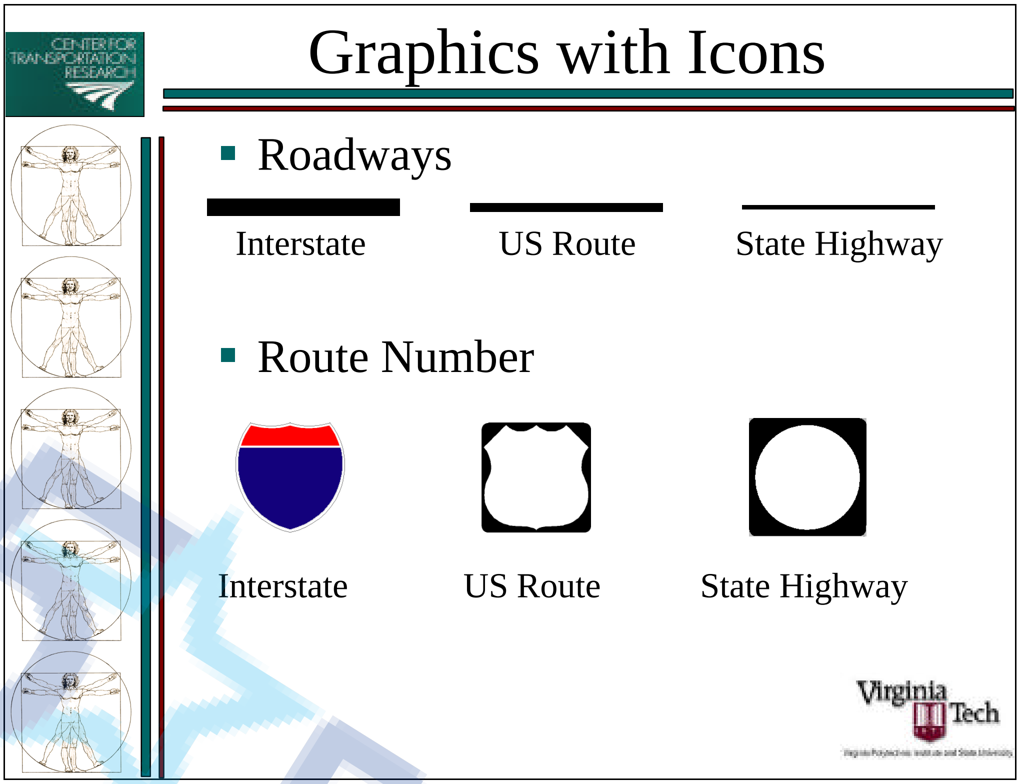
## Route Planning

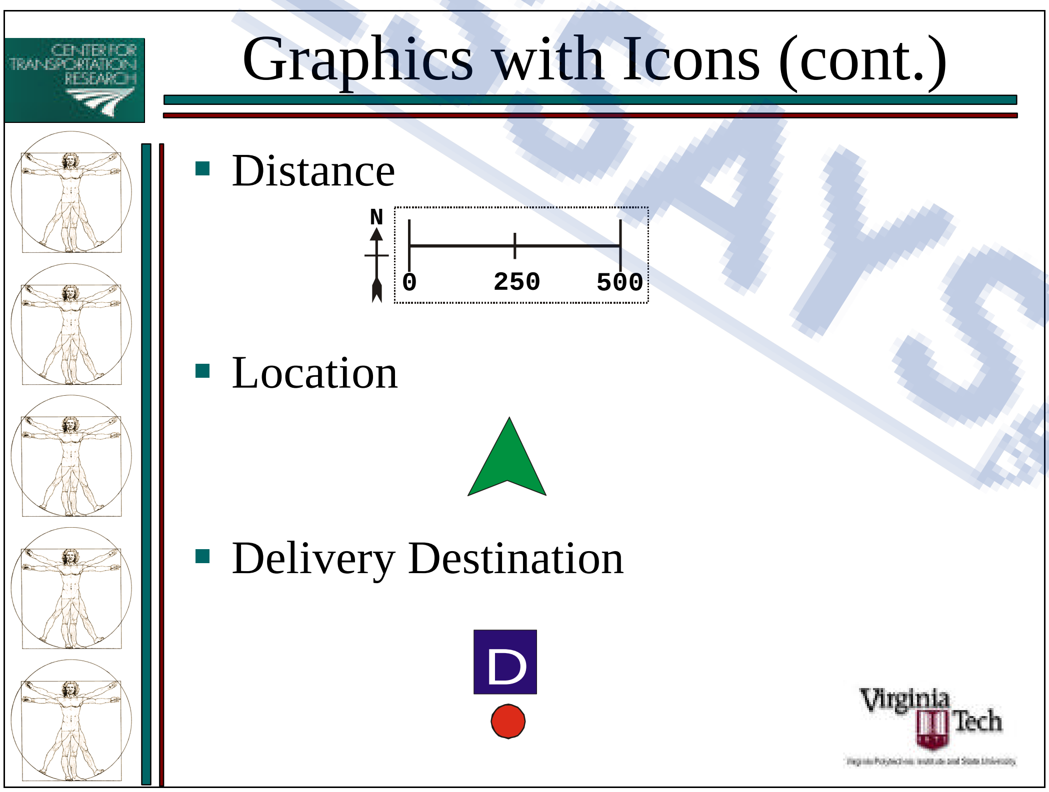
| Route | Distance | Restriction | Speed Limit |
|---|---|---|---|
| US-Rte. 1, I-87 | 165 miles | 16 TON | 55 mph |
| I-81, Hwy. 37 | 260 miles | 20 TON | 65 mph |
| I-95, US-Rte. 7 | 210 miles | Flammable | 70 mph |
| I-81, US-Rte. 11 | 240 miles | Radioactive | 60 mph |
| US-Rte. 1, US-Rte. 7 | 220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

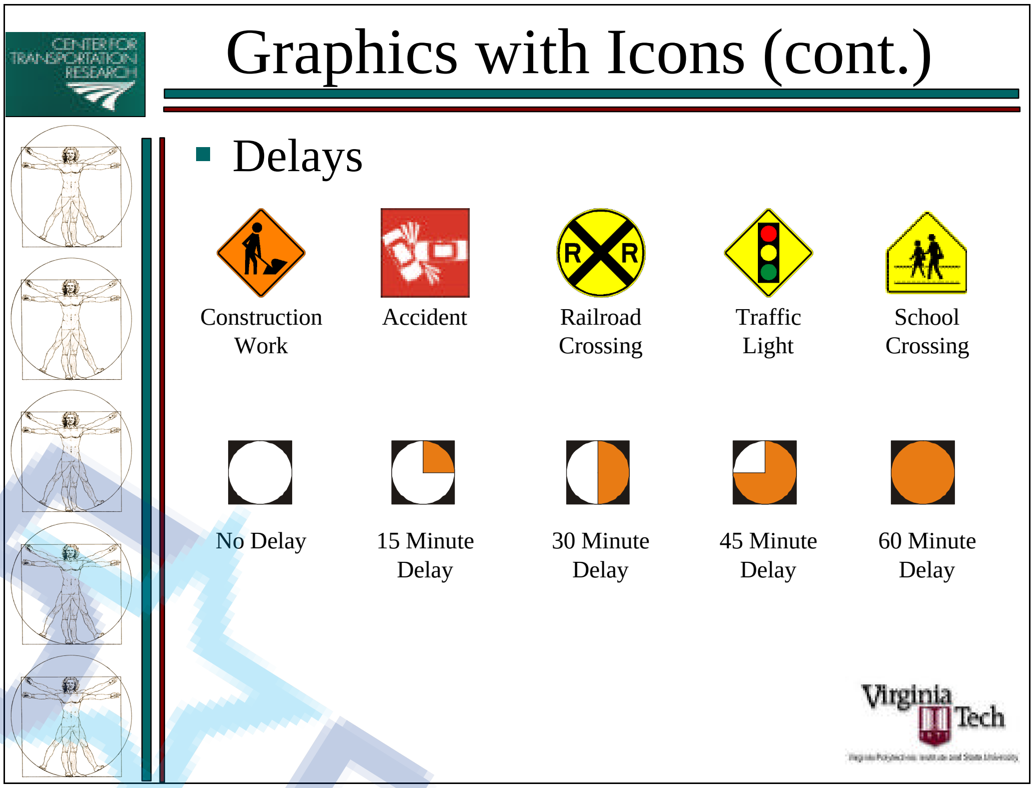
# Paragraph Example:

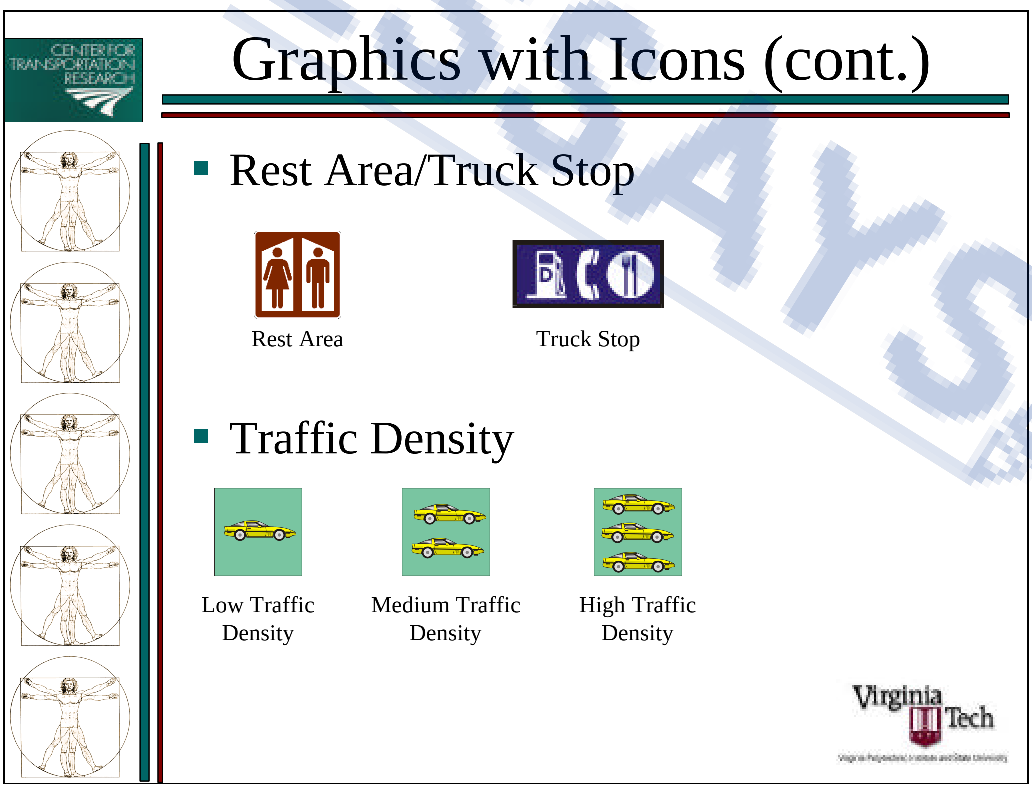
## Route Planning

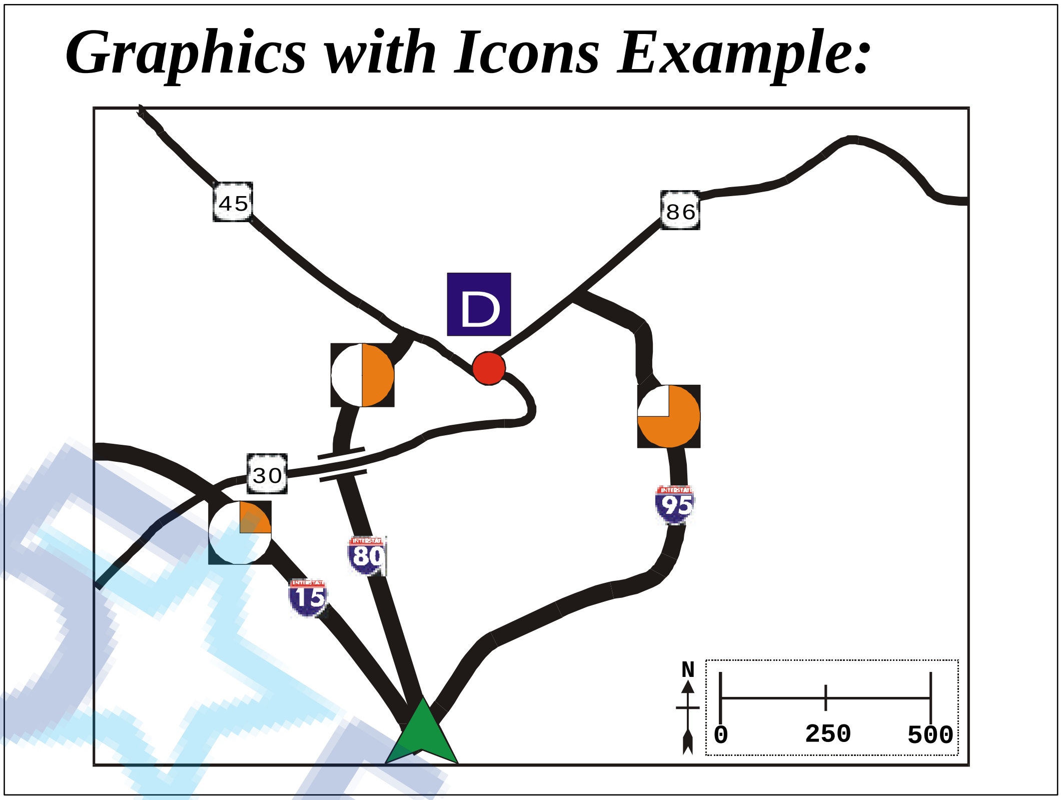
I-35, US-Rte. 14 is 770 miles, has a rest area, and has a 55 minute delay. I-29, US-Rte. 81 is 612 miles, has a truck stop, and has a 15 minute delay. US-Rte. 59, Hwy. 9 is 785 miles, has no rest areas or truck stops, and has a 10 minute delay. US-Rte. 77, US-Rte. 14 is 895 miles, has a rest areas, and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

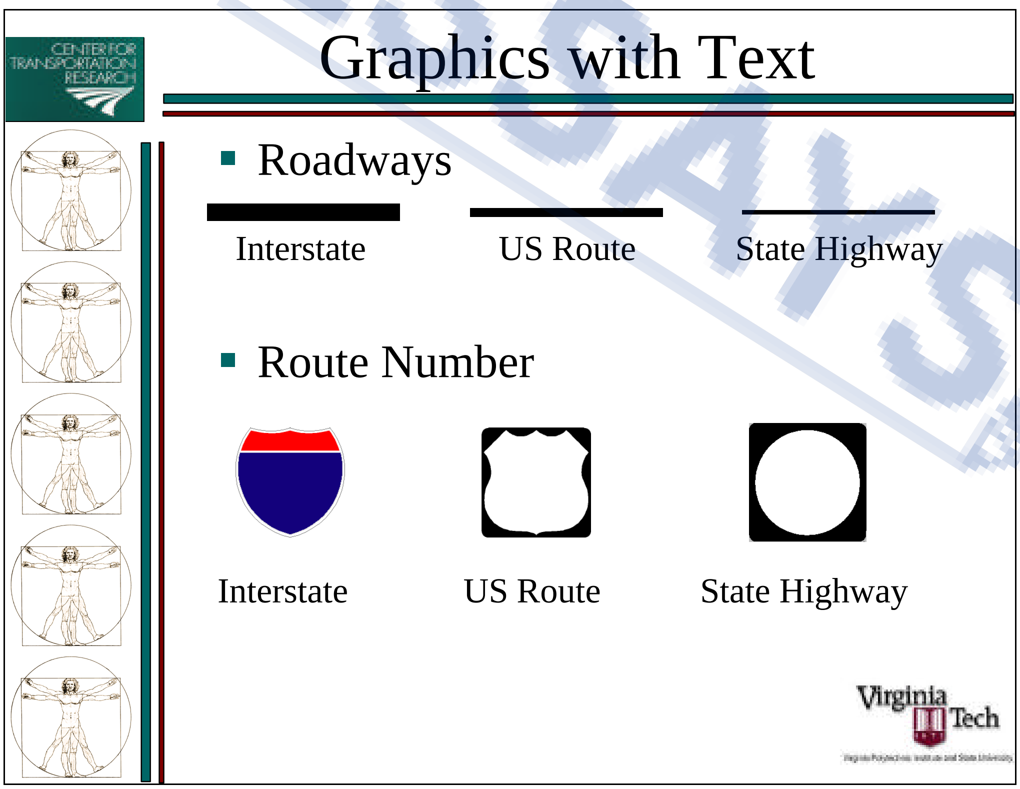

CENTER FOR TRANSPORTATION RESEARCH
Graphics with Icons
Roadways
Interstate
US Route
State Highway
Route Number
Interstate
US Route
State Highway
Virginia Tech

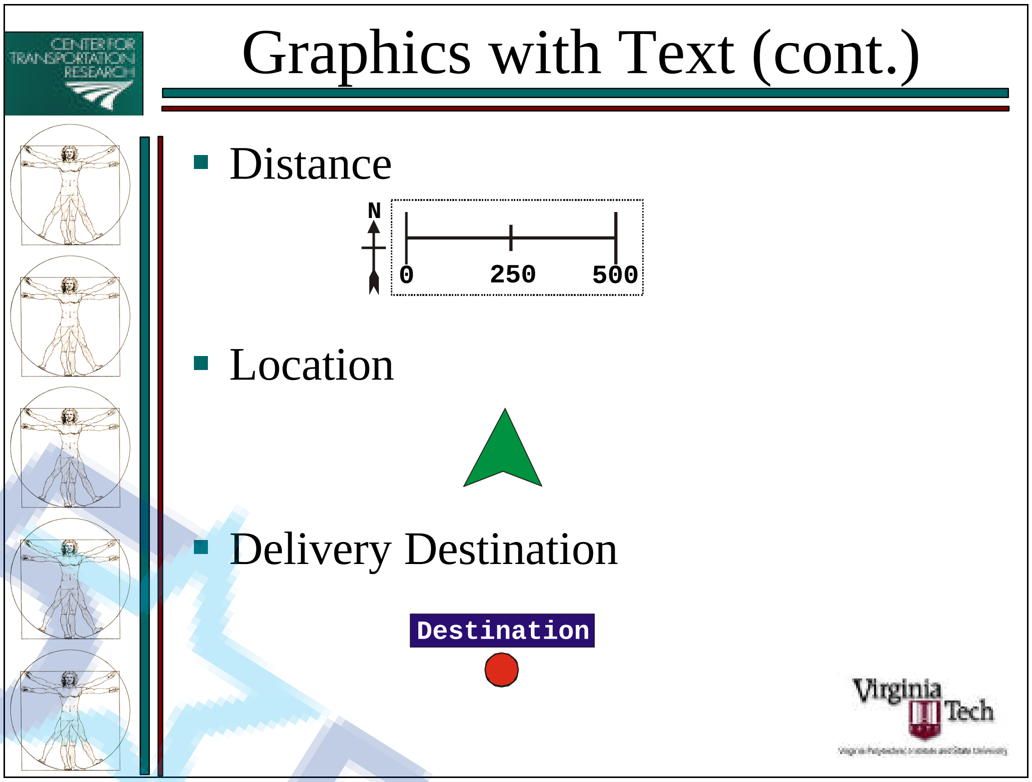

CENTER FOR TRANSPORTATION RESEARCH
Graphics with Icons (cont.)
Distance
N
0
250
500
Location
Delivery Destination
D
Virginia Tech

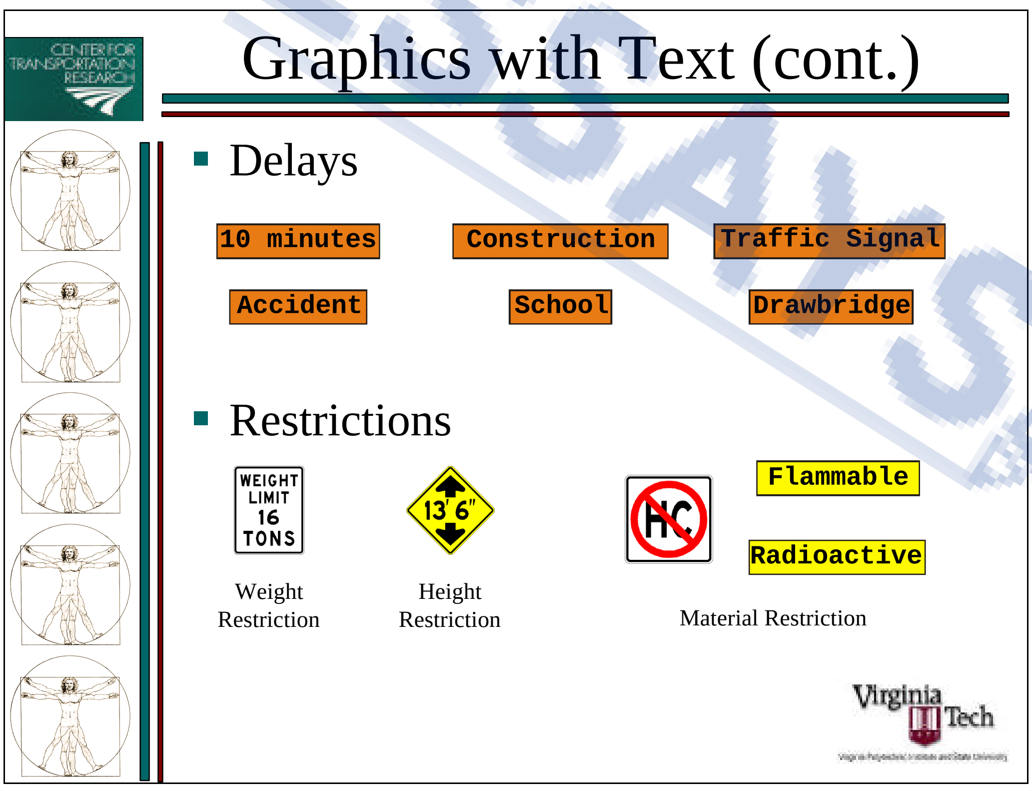

CENTER FOR TRANSPORTATION RESEARCH
Graphics with Icons (cont.)
Delays
Construction Work
Accident
Railroad Crossing
R R
Traffic Light
School Crossing
No Delay
15 Minute Delay
30 Minute Delay
45 Minute Delay
60 Minute Delay
Virginia Tech

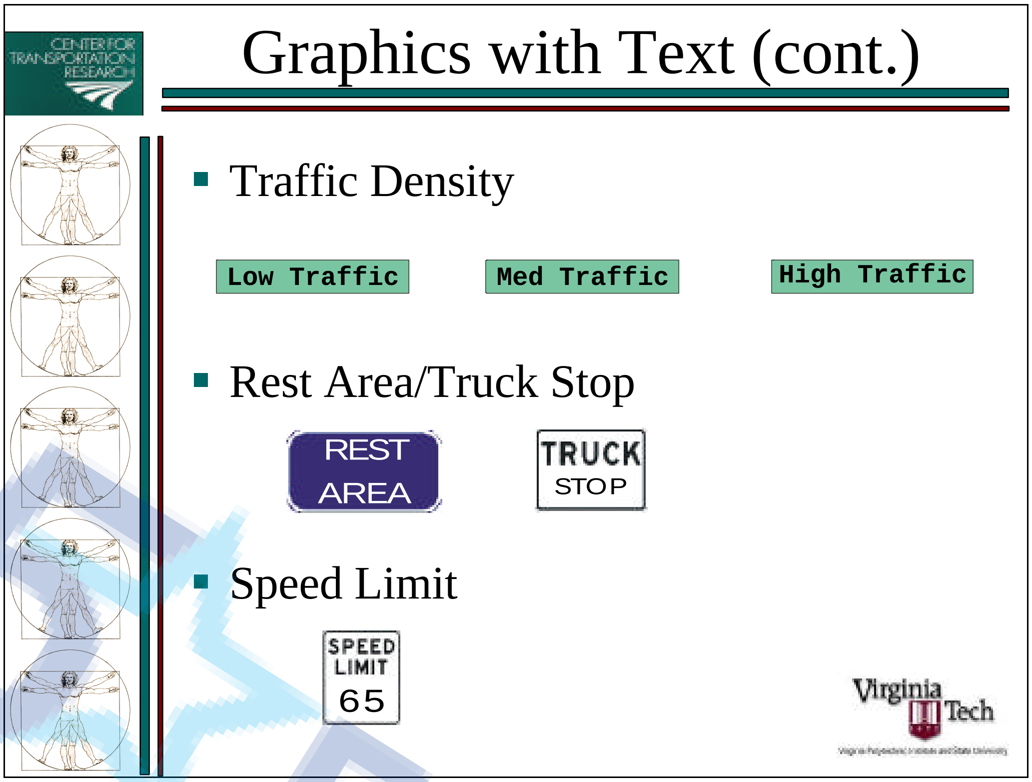

CENTER FOR TRANSPORTATION RESEARCH
Graphics with Icons (cont.)
Rest Area/Truck Stop
Rest Area
Truck Stop
Traffic Density
Low Traffic Density
Medium Traffic Density
High Traffic Density
Virginia Tech

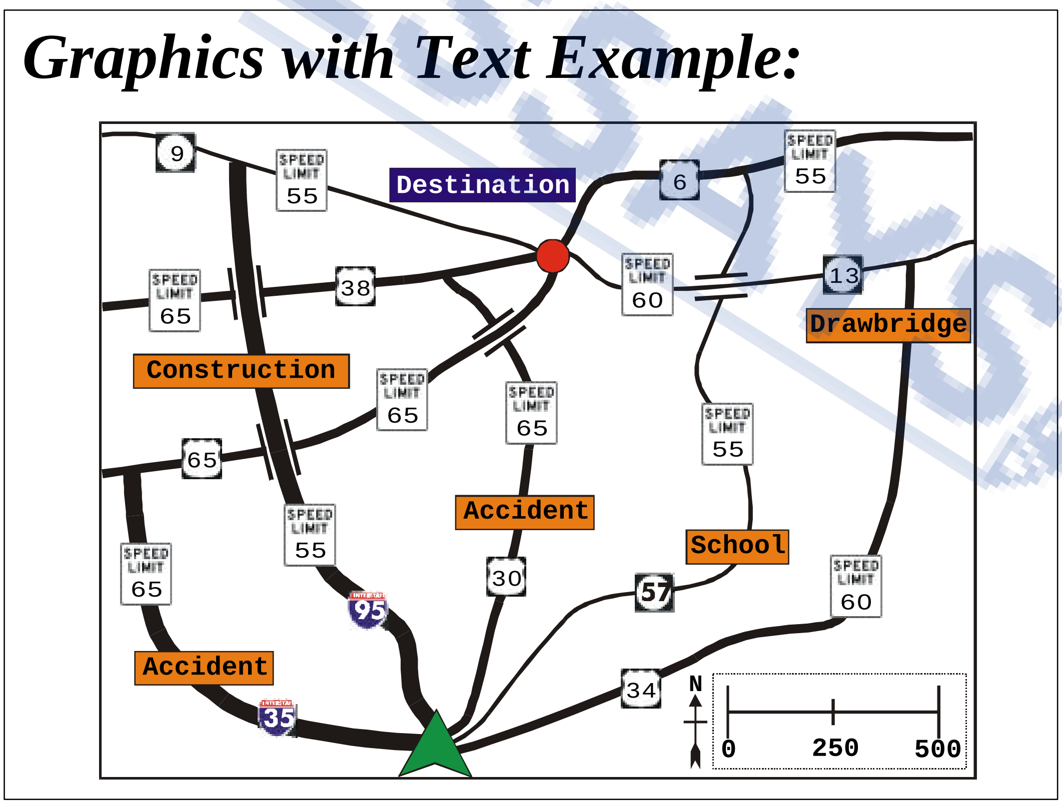

Graphics with Icons Example:
45
86
D
30
80
15
95
N
0
250
500


CENTER FOR TRANSPORTATION RESEARCH
Graphics with Text
Roadways
Interstate
US Route
State Highway
Route Number
Interstate
US Route
State Highway
Virginia Tech


Graphics with Text (cont.)
Distance
N
0
250
500
Location
Delivery Destination
Destination
Virginia Tech

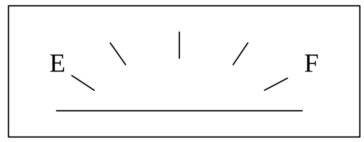

Graphics with Text (cont.)
Delays
10 minutes
Construction
Traffic Signal
Accident
School
Drawbridge
Restrictions
WEIGHT LIMIT 16 TONS
13' 6"
HC
Flammable
Radioactive
Weight Restriction
Height Restriction
Material Restriction
Virginia Tech


CENTER FOR TRANSPORTATION RESEARCH
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
Virginia Tech


Graphics with Text Example:
Destination
Construction
Drawbridge
Accident
School
Accident
SPEED LIMIT 55
SPEED LIMIT 65
SPEED LIMIT 60
9
38
6
13
65
30
57
34
95
35
N
0
250
500

# 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




- 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

# Tasks (cont.)

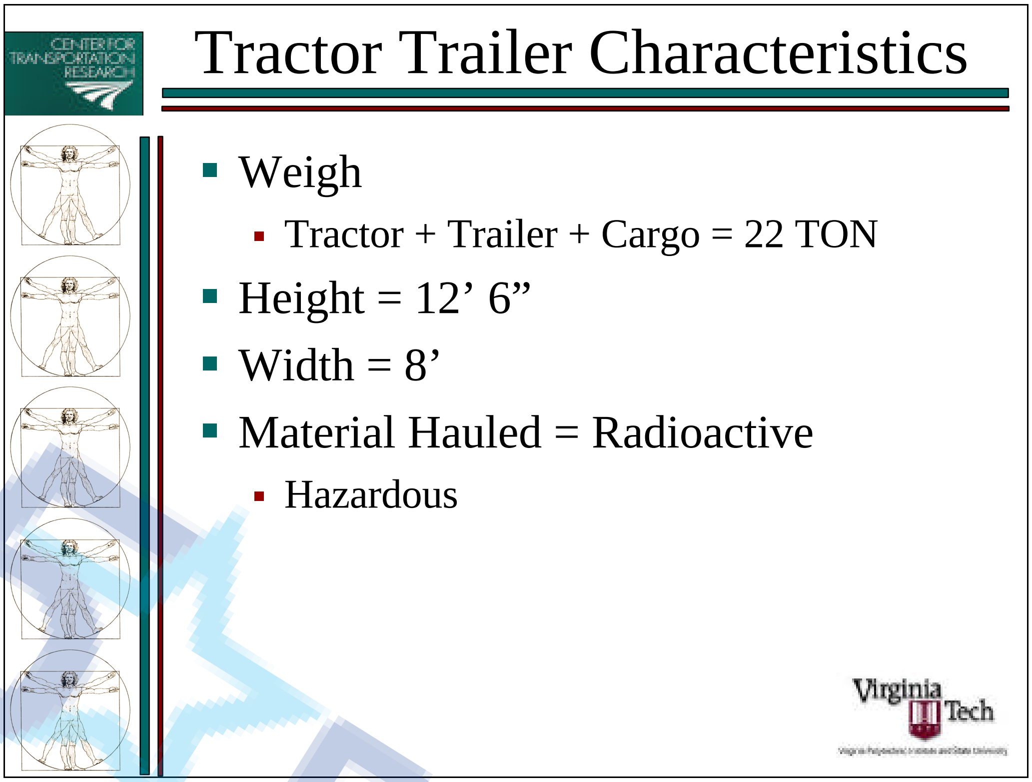
- Tasks

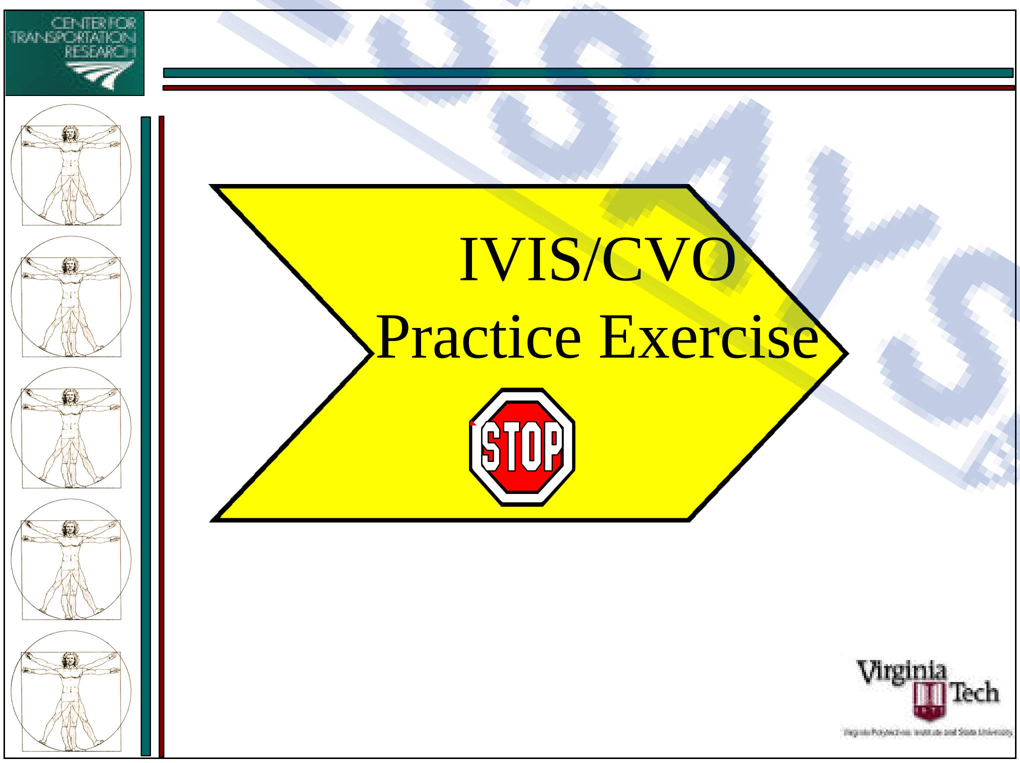
Questions & Survey

  - 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


CENTER FOR TRANSPORTATION RESEARCH
Tractor Trailer Characteristics
Weigh
Tractor + Trailer + Cargo = 22 TON
Height = 12' 6"
Width = 8'
Material Hauled = Radioactive
Hazardous
Virginia Tech

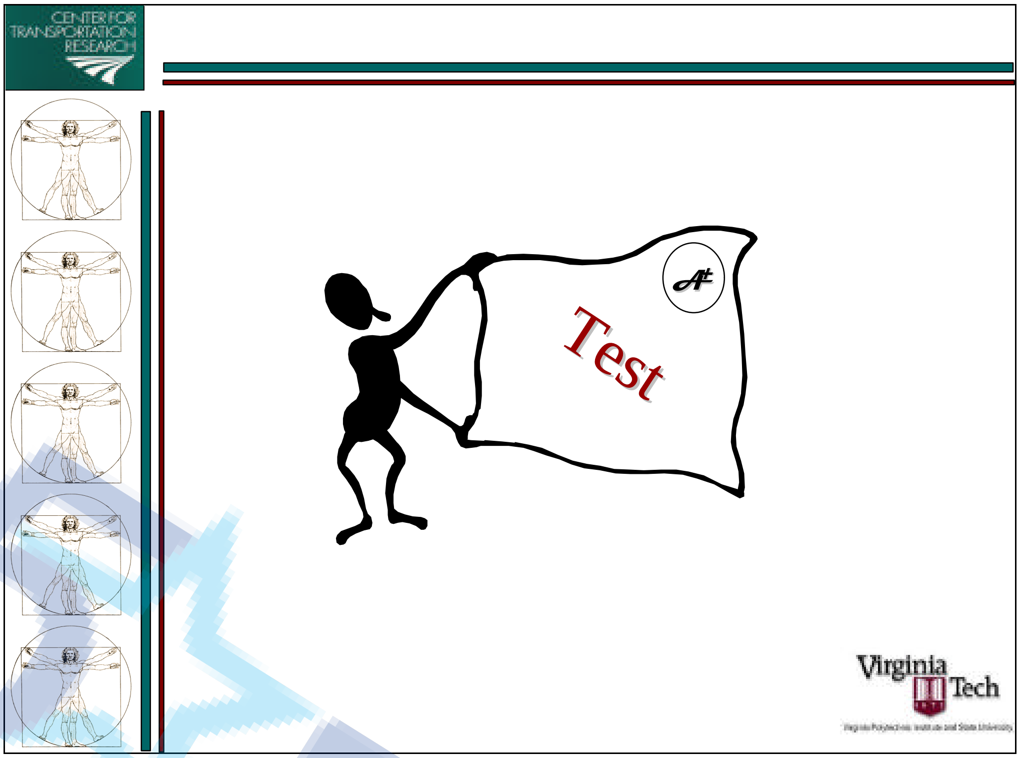

CENTER FOR TRANSPORTATION RESEARCH
IVIS/CVO
Practice Exercise
STOP
Virginia Tech

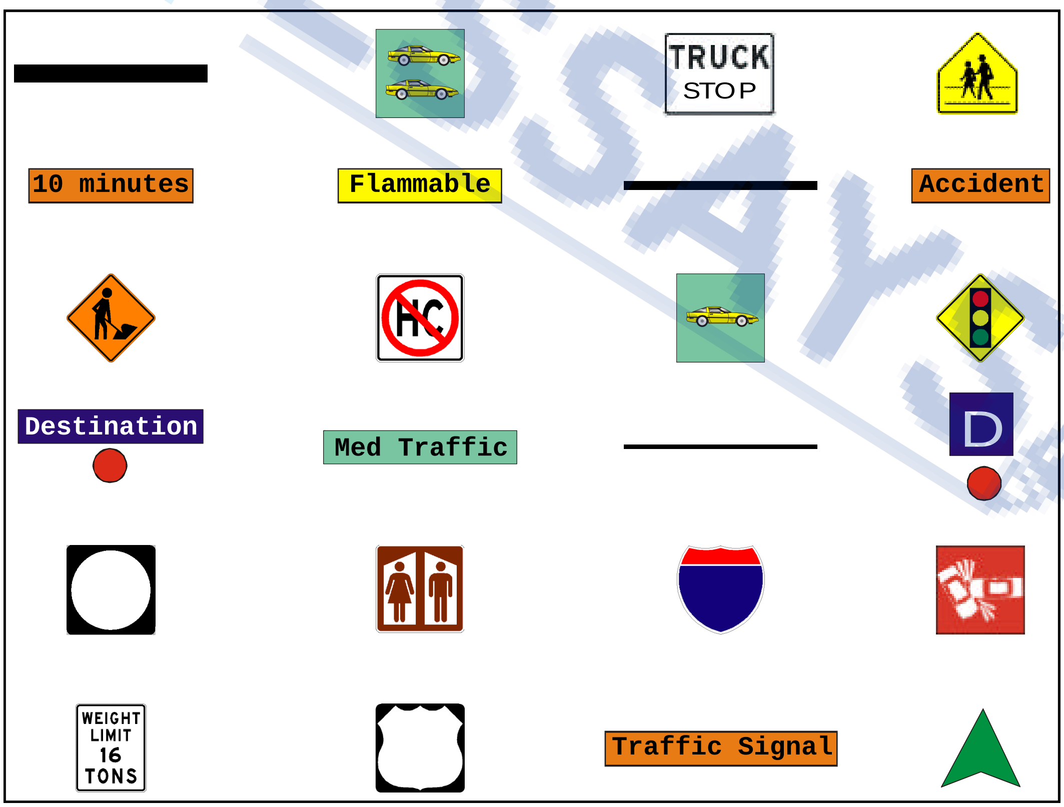
## Truck Training/Familiarization

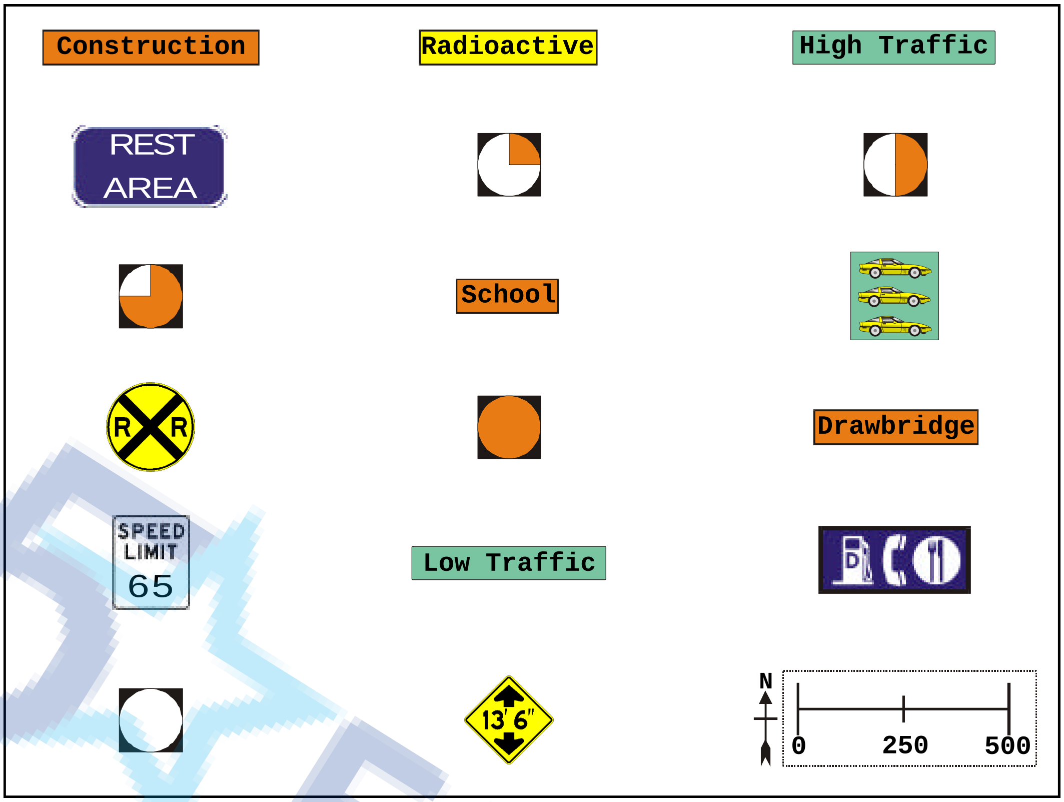
- Seat and Mirrors Adjustment
- Instrument Panel & Controls Familiarization
- Explain Conventional Tasks
- Hearing Test
- IVIS Task Practice
- Driving Familiarization
- Driving + IVIS Task Practice

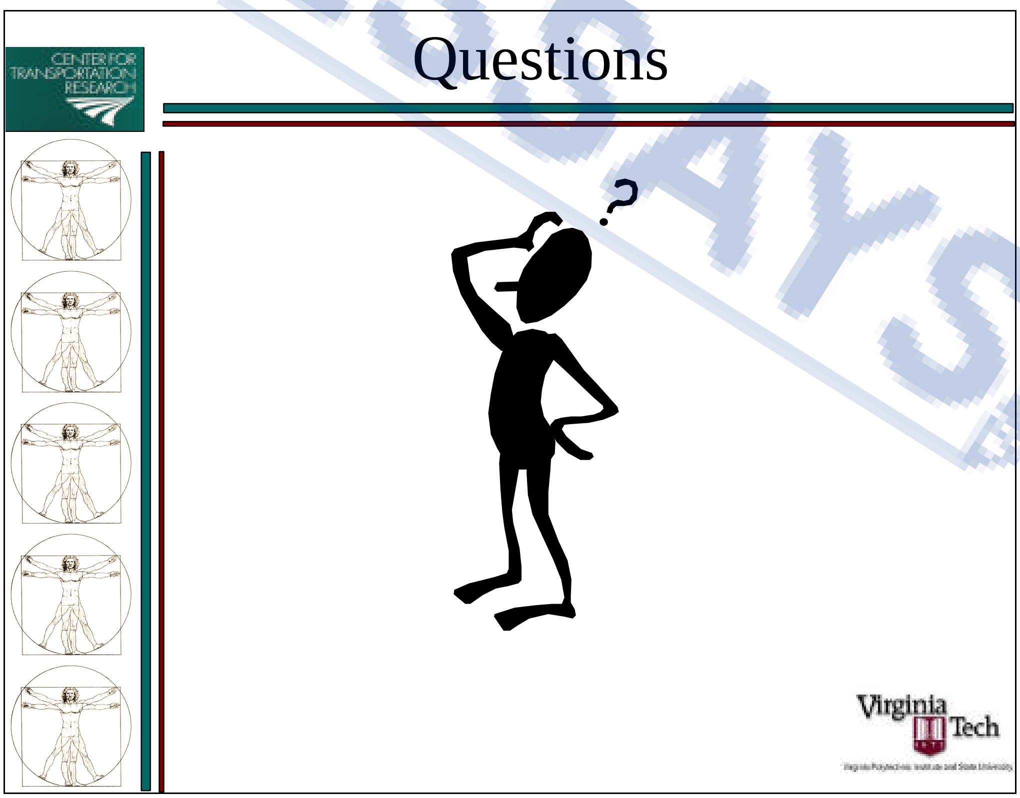
***Note: Sunglasses are not allow during the study***

## Questions


CENTER FOR TRANSPORTATION RESEARCH
Test
Virginia Tech


TRUCK STOP
10 minutes
Flammable
Accident
HC
Destination
Med Traffic
D
WEIGHT LIMIT 16 TONS
Traffic Signal


Construction
Radioactive
High Traffic
REST AREA
School
Drawbridge
SPEED LIMIT 65
Low Traffic
13' 6"
N
0
250
500


CENTER FOR TRANSPORTATION RESEARCH
Questions
Virginia Tech

Appendix 3 - Screening

***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 | | | | | (    )    - | | | | |

Appendix 4 – Informed Consent

**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<br>Principal Investigator | 552-5695 |
| Dr. Thomas A. Dingus<br>Faculty Advisor | 231-8831 |
| H.T. Hurd<br>Director, Sponsored Programs | 231-5281 |

5 ESSAYS

**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 1$^{st}$ 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

**Type of Task**

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

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

| | | Search Plan Interpret | | | | | | | | | | | | Search Plan Interpret Compute | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Format*** | Tabular | | | Paragraph | | | Graph w/Text | | | Graph w/Icon | | | Tabular | | | Paragraph | | | Graph w/Text | | |
| ***Age*** | *Info / Part.No.* | *L* | *M* | *H* | *L* | *M* | *H* | *L* | *M* | *H* | *L* | *M* | *H* | *L* | *M* | *H* | *L* | *M* | *H* | *L* | *M* | *H* |
| **Middle** | 1 | **38** | **44** | **53** | **35** | **22** | **55** | **58** | **28** | **6** | **57** | **37** | **1** | **31** | **7** | **25** | **60** | **56** | **46** | **27** | **18** | **30** |
| | 2 | **13** | **9** | **43** | **54** | **24** | **62** | **45** | **30** | **63** | **49** | **32** | **55** | **42** | **14** | **38** | **2** | **16** | **18** | **33** | **17** | **29** |
| | 3 | **49** | **42** | **18** | **47** | **43** | **22** | **15** | **12** | **26** | **56** | **50** | **35** | **28** | **41** | **39** | **62** | **54** | **2** | **48** | **51** | **30** |
| | 4 | **20** | **52** | **33** | **5** | **63** | **16** | **23** | **2** | **19** | **1** | **30** | **45** | **43** | **55** | **61** | **13** | **29** | **42** | **46** | **60** | **24** |
| | 5 | **26** | **22** | **7** | **5** | **58** | **18** | **31** | **50** | **48** | **12** | **34** | **51** | **39** | **13** | **2** | **49** | **29** | **63** | **32** | **9** | **57** |
| | 6 | **13** | **60** | **16** | **33** | **62** | **25** | **35** | **57** | **45** | **46** | **51** | **59** | **43** | **21** | **44** | **63** | **50** | **52** | **24** | **10** | **54** |
| **Older** | 7 | **39** | **55** | **2** | **63** | **60** | **46** | **43** | **57** | **47** | **54** | **42** | **62** | **7** | **58** | **16** | **22** | **35** | **53** | **6** | **20** | **33** |
| | 8 | **44** | **23** | **12** | **10** | **31** | **55** | **27** | **1** | **54** | **42** | **18** | **22** | **51** | **36** | **63** | **29** | **48** | **49** | **21** | **24** | **20** |
| | 9 | **47** | **41** | **30** | **1** | **57** | **53** | **59** | **12** | **19** | **35** | **13** | **49** | **7** | **56** | **9** | **40** | **28** | **63** | **15** | **46** | **11** |
| | 10 | **52** | **38** | **53** | **46** | **12** | **22** | **2** | **29** | **56** | **58** | **23** | **6** | **21** | **61** | **32** | **63** | **47** | **37** | **20** | **27** | **33** |
| | 11 | **54** | **28** | **25** | **16** | **58** | **19** | **11** | **50** | **35** | **18** | **36** | **23** | **7** | **57** | **40** | **12** | **41** | **61** | **63** | **33** | **30** |
| | 12 | **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 | \|--\|--\|--\|--\|--\|--\|--\|--\|--\|--\|<br>*1 20 40 60 80 100*<br>*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 | \|--\|--\|--\|--\|--\|--\|--\|--\|--\|--\|<br>*1 20 40 60 80 100*<br>*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 | \|--\|--\|--\|--\|--\|--\|--\|--\|--\|--\|<br>*1 20 40 60 80 100*<br>*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 | \|--\|--\|--\|--\|--\|--\|--\|--\|--\|--\|<br>*1 20 40 60 80 100*<br>*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.

## Appendix 9 – ANOVAs for Full Model for IVIS tasks

*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)

UK ESSAYS

*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)

UK ESSAYS

*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)



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*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)

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*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)

*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)

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*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)

*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)

*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)

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*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)

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*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)

*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)

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*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)

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*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)

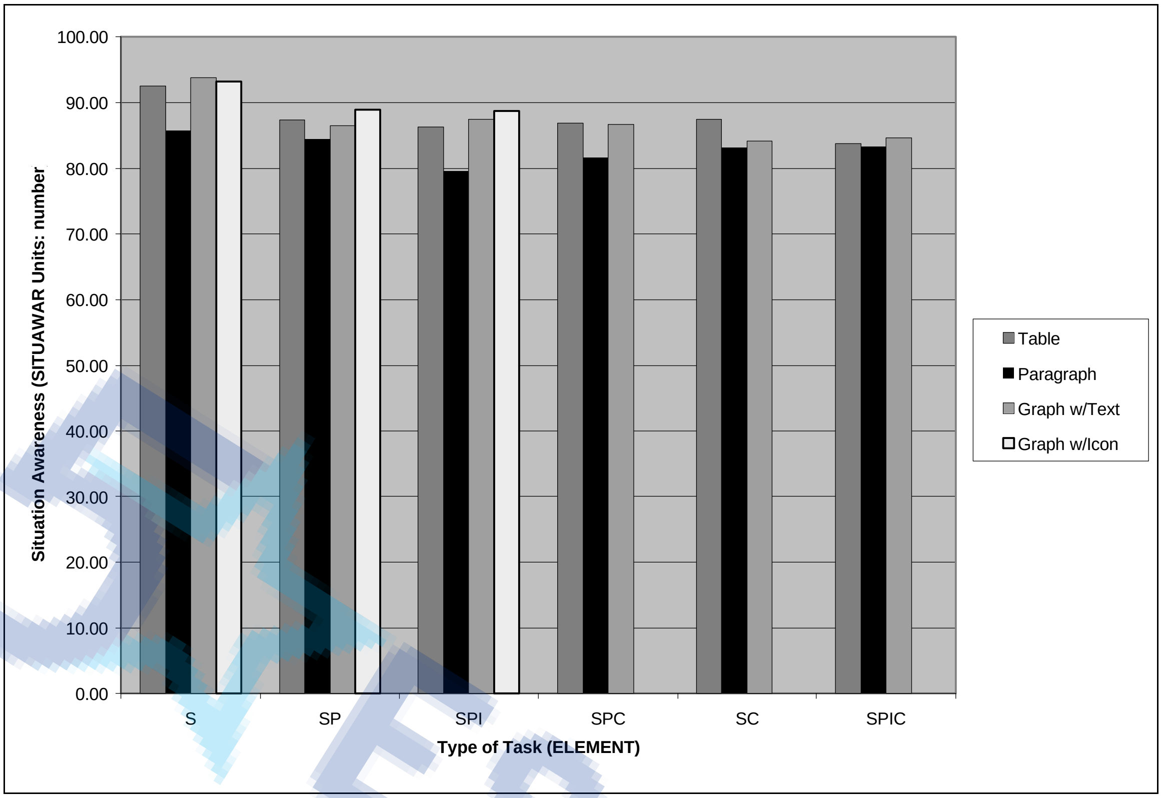
*Table A.9.19 Dependent Measure: Subjective Assessment of Situation Awareness*

| 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**



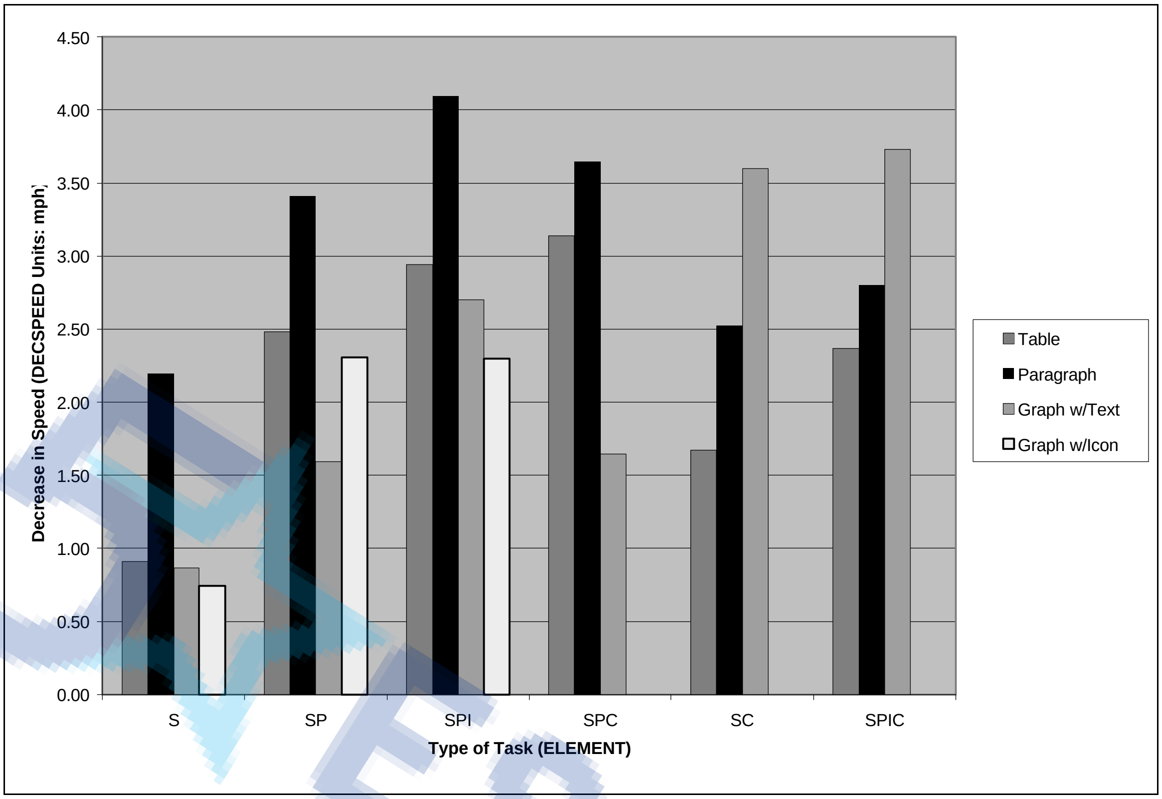

| DISTYPE | ELEMENT | SITUAWAR | N |
|---|---|---|---|
| Table | S | 92.50 | 36 |
| Table | SP | 87.36 | 36 |
| Table | SPI | 86.25 | 36 |
| Table | SPC | 86.88 | 24 |
| Table | SC | 87.46 | 24 |
| Table | SPIC | 83.75 | 12 |
| Paragraph | S | 85.69 | 36 |
| Paragraph | SP | 84.44 | 36 |
| Paragraph | 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.

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

## DISTYPE*ELEMENT



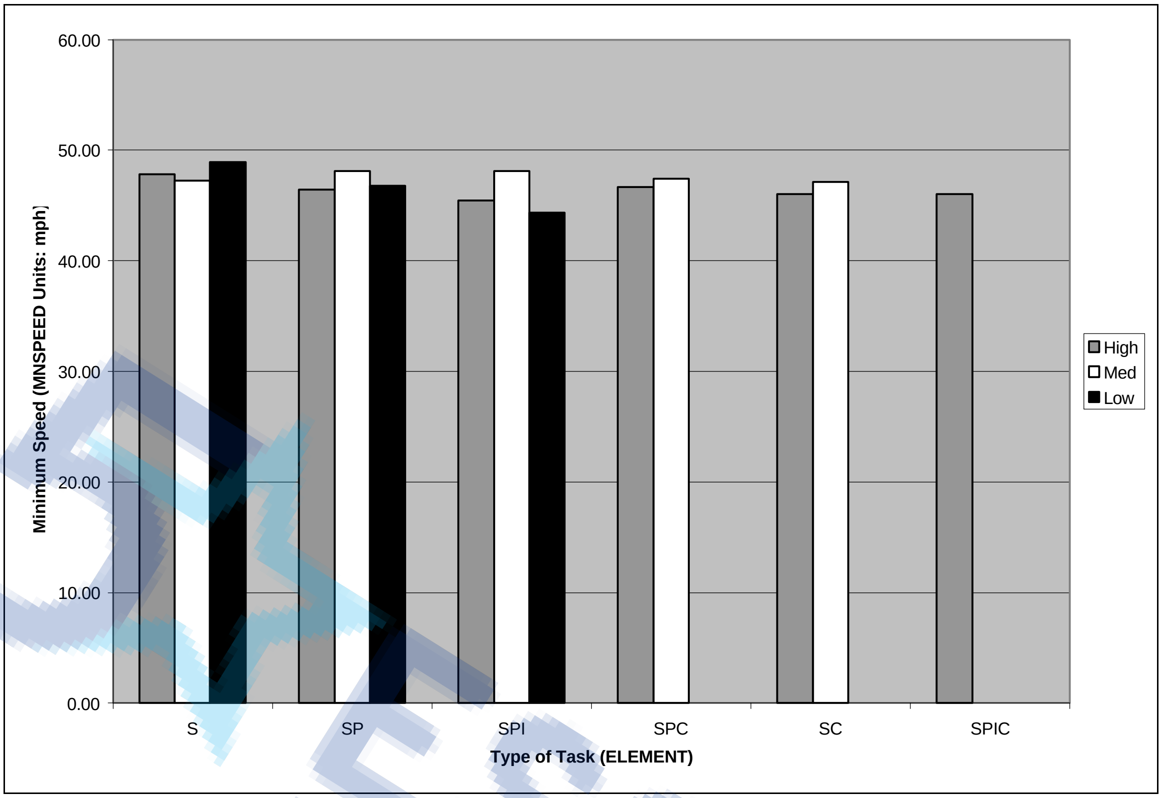

| DISTYPE | ELEMENT | DECSPEED | N |
|---|---|---|---|
| Table | S | 0.91 | 36 |
| Table | SP | 2.48 | 36 |
| Table | SPI | 2.95 | 36 |
| Table | SPC | 3.14 | 24 |
| Table | SC | 1.67 | 24 |
| Table | SPIC | 2.37 | 12 |
| Paragraph | S | 2.20 | 36 |
| Paragraph | SP | 3.41 | 36 |
| Paragraph | SPI | 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).

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

**DENSITY*ELEMENT**

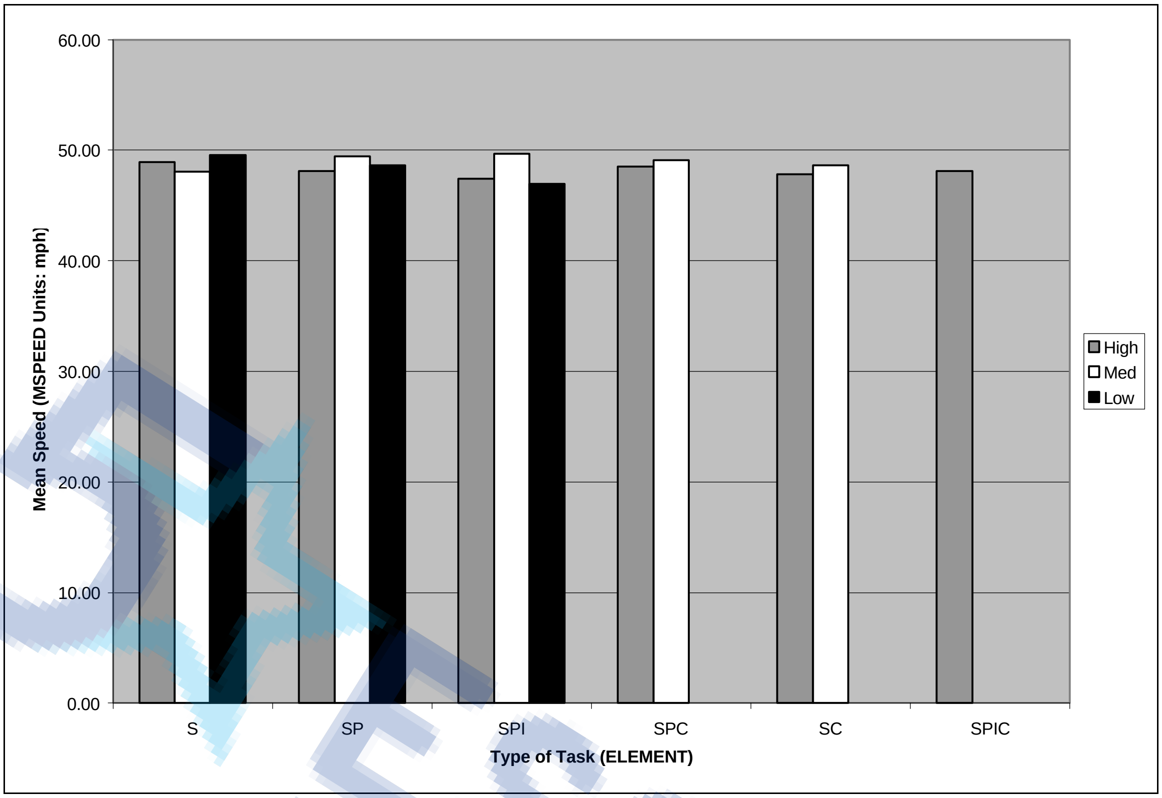



| DENSITY | ELEMENT | MNSPEED | N |
|---|---|---|---|
| Low | S | 48.93 | 36 |
| Low | SP | 46.81 | 36 |
| Low | SPI | 44.33 | 24 |
| Med | S | 47.29 | 48 |
| Med | SP | 48.15 | 48 |
| Med | SPI | 48.14 | 48 |
| Med | SPC | 47.40 | 36 |
| Med | SC | 47.12 | 36 |
| High | S | 47.83 | 48 |
| High | SP | 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.

**DENSITY*ELEMENT**

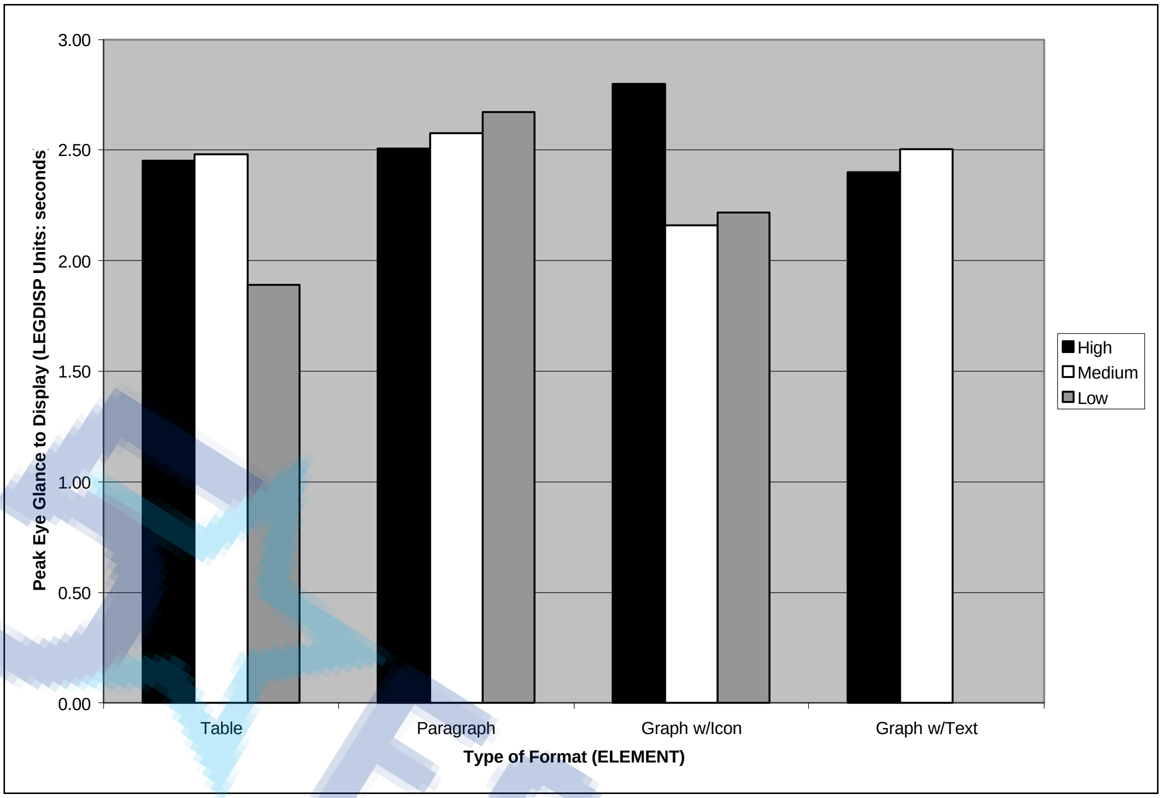



| DENSITY | ELEMENT | MSPEED | N |
|---|---|---|---|
| Low | S | 49.56 | 36 |
| Low | SP | 48.62 | 36 |
| Low | SPI | 46.95 | 24 |
| Med | S | 48.06 | 48 |
| Med | SP | 49.47 | 48 |
| Med | SPI | 49.67 | 48 |
| Med | SPC | 49.08 | 36 |
| Med | SC | 48.64 | 36 |
| High | S | 48.93 | 48 |
| High | SP | 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**



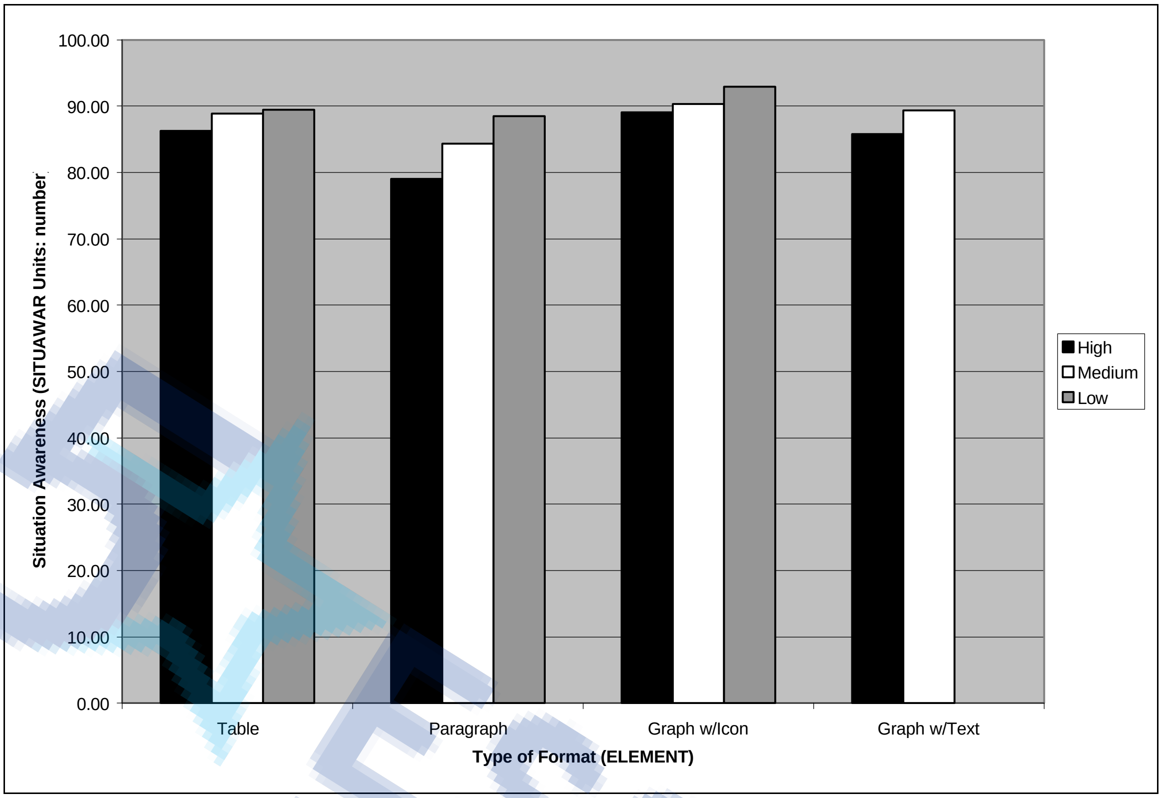

| DENSITY | DISTYPE | LEGDISP | N |
|---|---|---|---|
| Low | Table | 1.89 | 36 |
| Low | Paragraph | 2.67 | 36 |
| Low | Graph w/Icon | 2.22 | 24 |
| Med | Table | 2.48 | 60 |
| Med | Paragraph | 2.58 | 60 |
| Med | Graph w/Icon | 2.16 | 36 |
| Med | Graph w/Text | 2.50 | 60 |
| High | Table | 2.45 | 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.

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

## DENSITY*DISTYPE



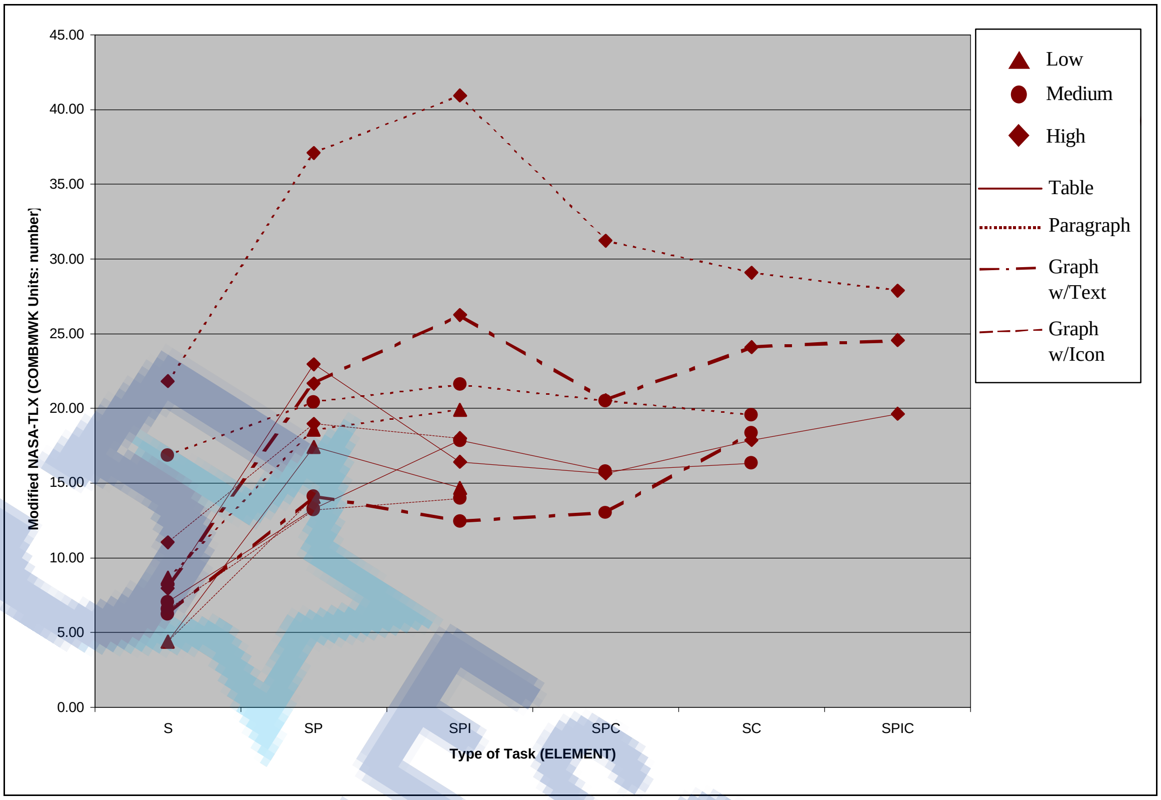

| DENSITY | DISTYPE | SITUAWAR | N |
|---|---|---|---|
| Low | Table | 89.44 | 36 |
| Low | Paragraph | 88.47 | 36 |
| Low | Graph w/Icon | 92.92 | 24 |
| Med | Table | 88.92 | 60 |
| Med | Paragraph | 84.42 | 60 |
| Med | Graph w/Icon | 90.28 | 36 |
| Med | Graph w/Text | 89.42 | 60 |
| High | Table | 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.

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

**DENSITY*DISTYPE*ELEMENT**



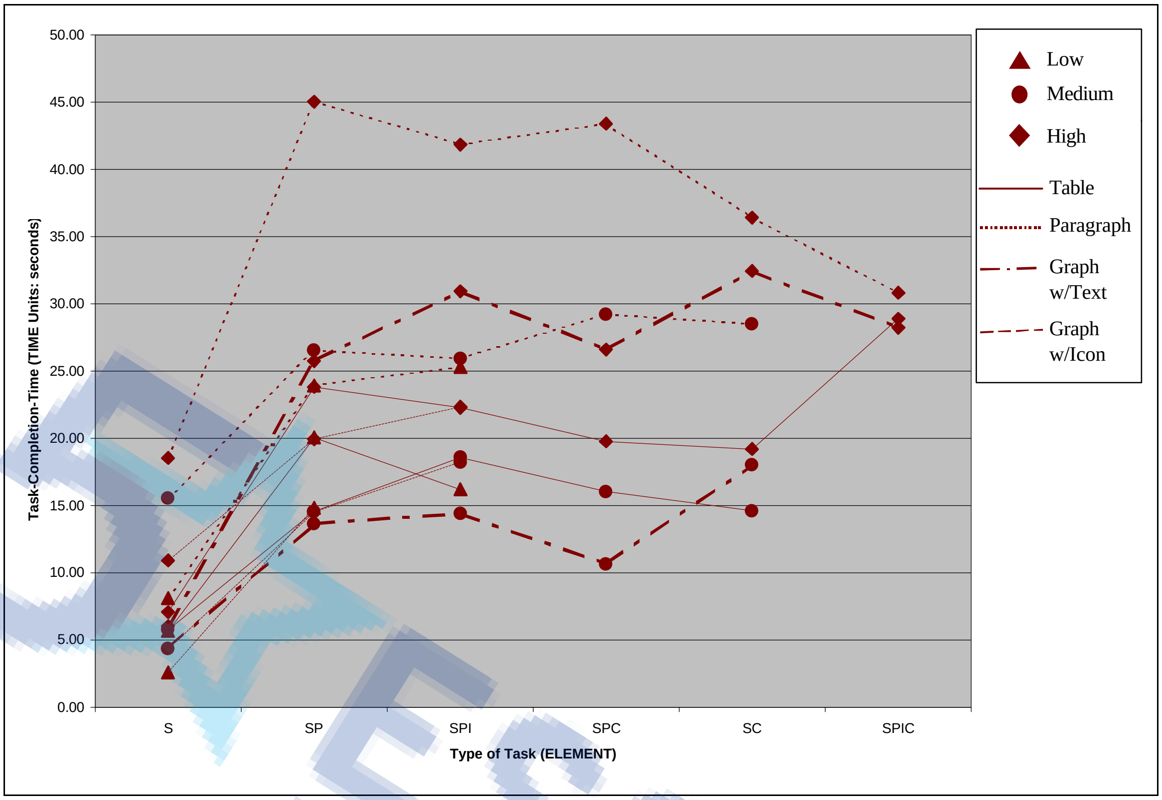

*Modified NASA-TLX (COMBMWK)*

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**



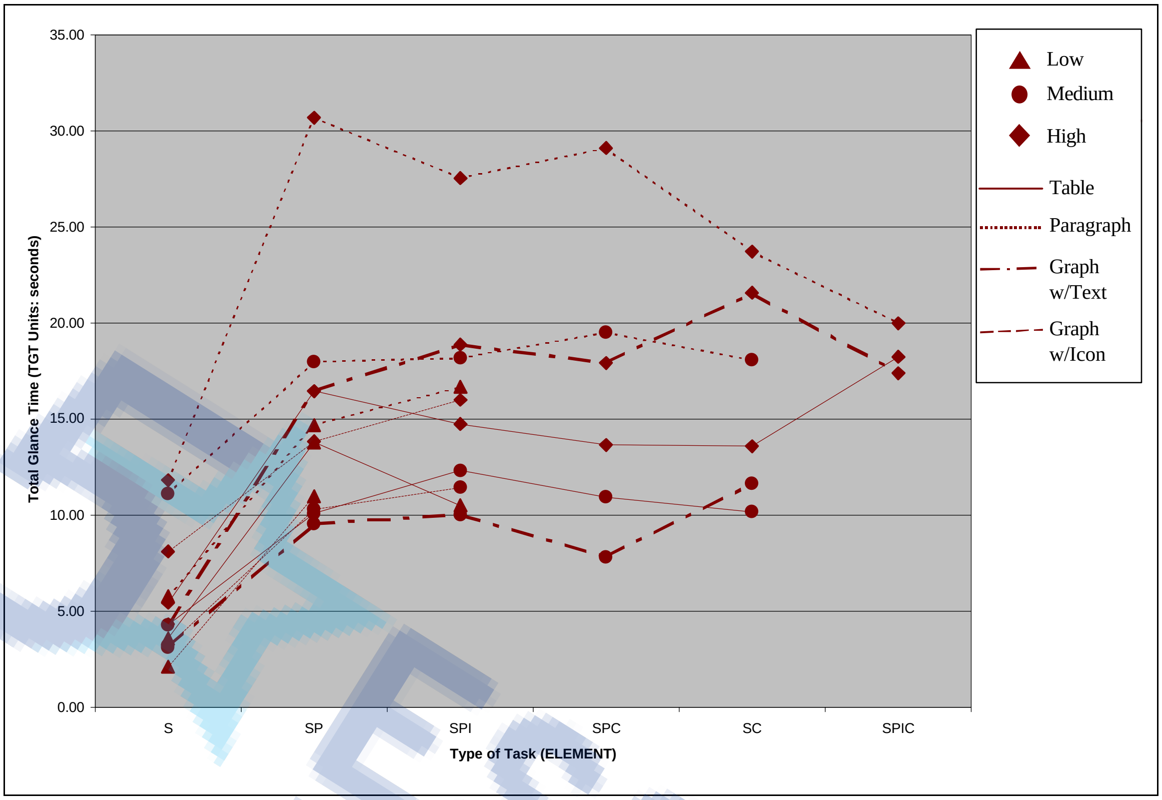

*Task-Completion-Time (TIME)*

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 |

**DENSITY*DISTYPE*ELEMENT**



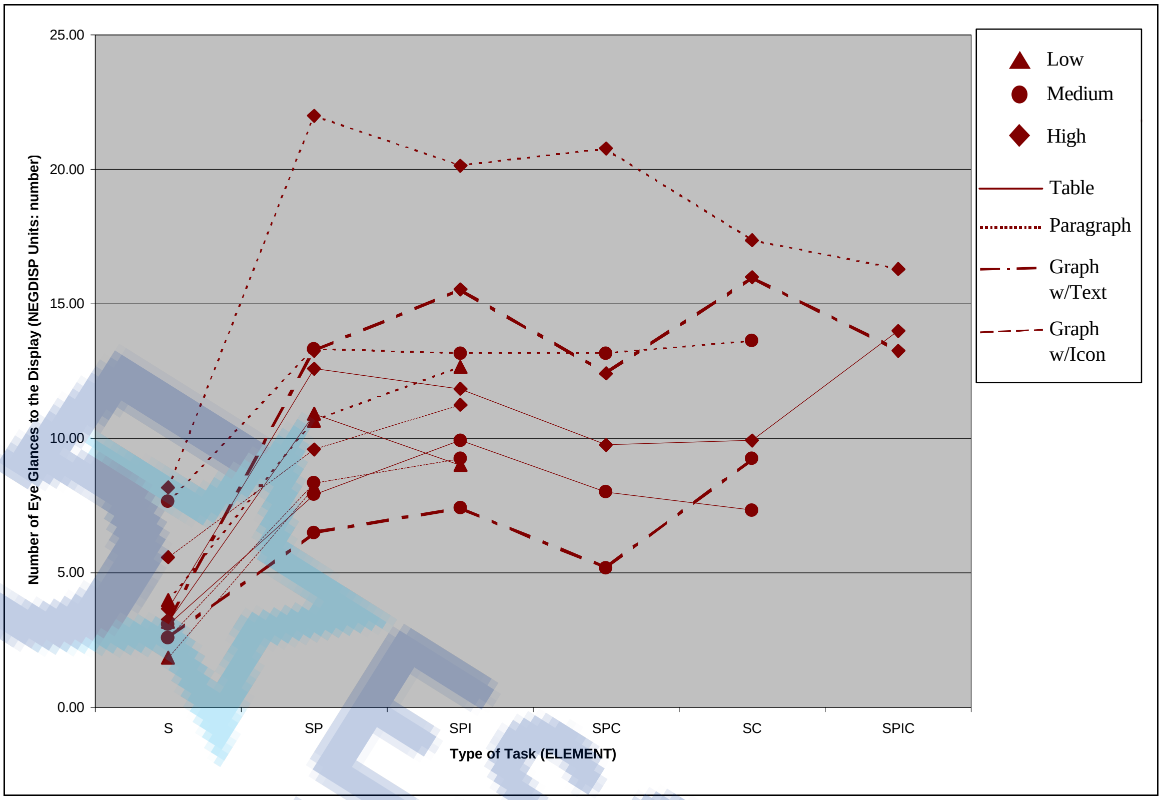

*Total Glance Time (TGT)*

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**



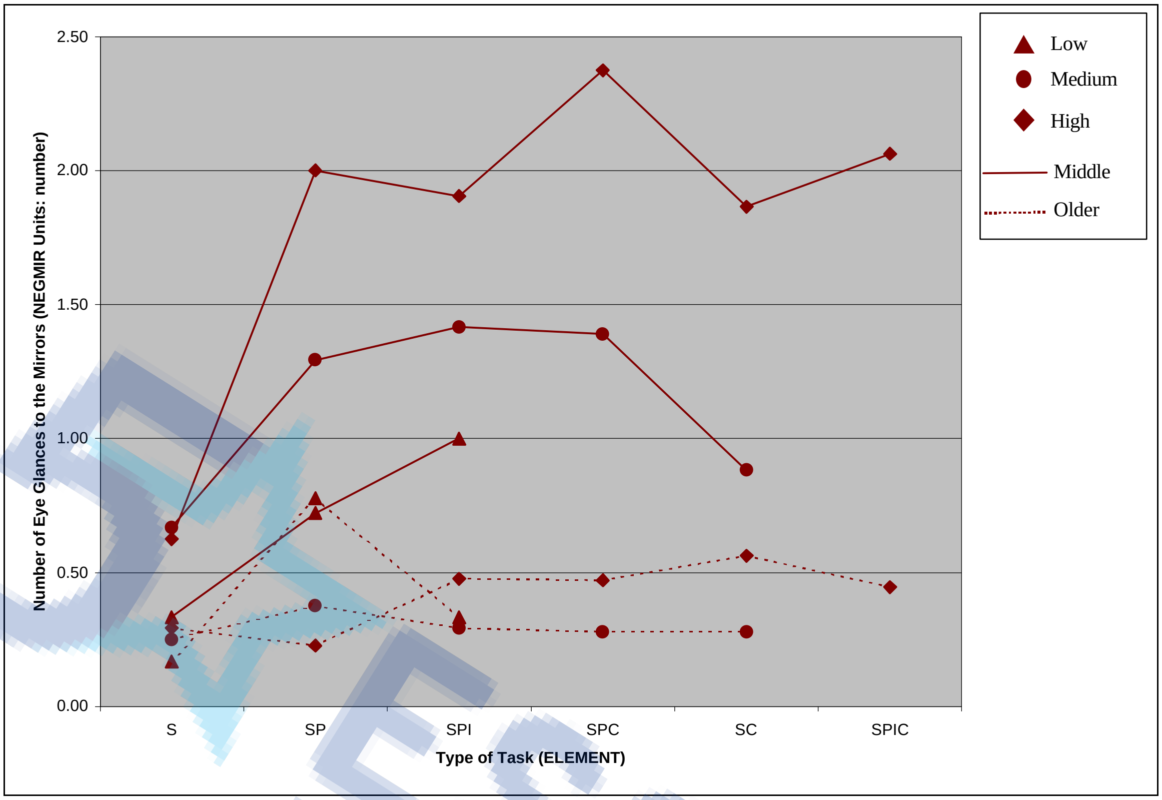

*Number of Eye Glances to the Display (NEGDISP)*

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)*

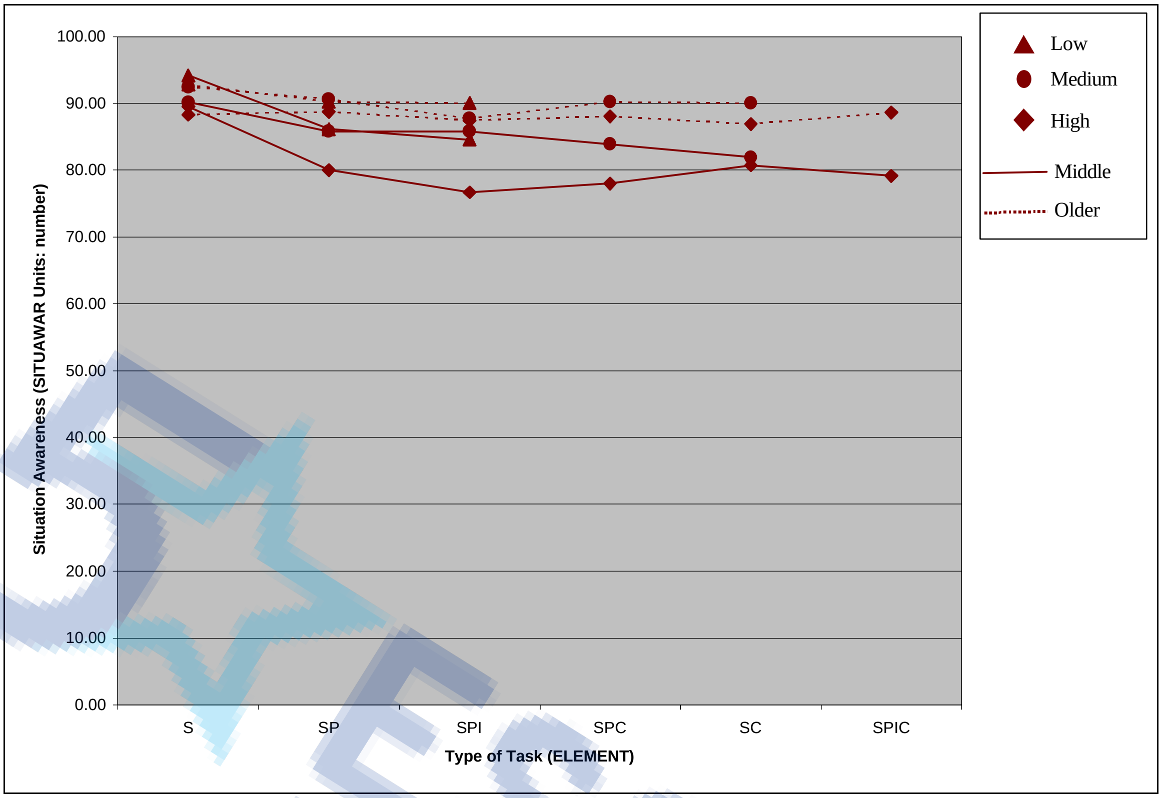
The number of eye glances to the mirrors for older drivers tend to be low compared to the middle age group, for all the six different types of tasks. It seems that older drivers tend to allocate less time scanning their surrounding environment (other than the front road) while a secondary task is in 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).

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

| 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 |

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

**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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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)

*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

| | | | | Longitudinal Driving Performance | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Display** | **Type of Task** | **Density** | **Task #** | 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 # | Lateral Driving Performance: 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 Mean | SITUAWAR SD | COMBMWK Mean | COMBMWK 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 |

**CURRICULUM VITAE**

***Myra Blanco***

---

## PERSONAL INFORMATION:

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## EDUCATION:

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

## POSITIONS HELD IN COLLEGE:

| | |
|---|---|
| *05/98-Present* | Virginia Polytechnic Institute and State University, Blacksburg, VA<br>**GRADUATE RESEARCH ASSISTANT**<br>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<br>**GRADUATE TEACHING ASSISTANT**<br>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<br>**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.

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