Running head: VIGILANCE

Differences Between Elderly and Young Drivers: Driving Vigilance in Two Tasks

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Abstract

According to statistics for 2003, 9 in 100,000 people in Canada died from driving accidents. A high percentage (30-40%) of these took place due to sleepiness on monotonous road conditions. Therefore, driver vigilance must be studied in order to attempt to decrease these fatal accidents. Thiffault and Bergeron (2003) have proposed a model for fatigue and vigilance which involves both endogenous and exogenous factors. In this framework, endogenous factors would include any fluctuation in alertness which originates from within the driver, such as circadian variations associated with the time of day, fatigue generated from the task itself, and sleep related problems that the individual may be suffering. Exogenous factors that influence driving vigilance are those which come from the task itself, such as road geometry and road-side environmental cues. The authors also suggest that mental under-load caused by such driving conditions could be as important as overload from urban expressway conditions. However, while data suggest that variations in vigilance may explain the occurrence of crashes in some situations there is a lack of data regarding age differences. Accordingly, this study was designed to compare the driving performance of younger and older drivers in monotonous and non-monotonous driving conditions. These conditions were created using the endogenous and exogenous factors mentioned earlier.

This study found reaction time differences between younger and mature drivers. Also, the heart rates of the drivers differed, depending upon the time of day, although that did not appear to have an effect on their reaction times, as there were no differences in reaction time over conditions. Also, there appear to be physiological differences in heart rates of young and mature drivers in their reactions to sudden stimuli while driving. Thus, although there are differences in performance between age groups, physiological differences in time of day did not appear to impact the performance of drivers.

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I would like to extend thanks to my family, in particular my parents, Ron and Carla, and my wife Paige, who have stood by me through this whole process, through my good times and bad, always encouraging me to keep up on the good work, and helping to keep me focused. Without their love and support, this would not have been possible.

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Table of Contents

APPENDICES

List of Tables

List of Figures

Differences Between Elderly and Young Drivers: Driving Vigilance in Two Tasks

Research Model

The purpose of the present study was to examine the sum of endogenous and exogenous factors in regards to vigilance. Vigilance is commonly defined as the act of paying close and continuous attention. Such a concept is important in driving, since the driver of a motor vehicle must constantly focus on the task of driving, watching carefully for potential threats to avoid fatal crashes. Researchers have worked to disentangle the various elements of vigilance, citing both endogenous and exogenous factors (Thiffault & Bergeron, 2003). Endogenous factors, those which originate from within the driver, include circadian variations due to time of day, fatigue generated from the task itself, and sleep related problems that the individual may be suffering. Exogenous factors are those which originate from the outside environment. Factors such as road geometry and road-side environmental cues appear to effect driver vigilance. This study was an attempt to bring all of the individual endogenous and exogenous factors together to study the overall influence of vigilance on driving, as such research has not been done previously. Also, due to a lack of research in the area, physiological data including heart rate, breathing rate, and blood pressure were recorded to help further understand the human system in terms of vigilance.

Vigilance Research

In classic vigilance studies, participants were required to stare at a single point, and respond when there was a change in the stimulus. Vigilance tasks tended to be long and monotonous, with people reporting changes in the onset of stimuli for nearly two hours (Adams, 1956).

In 1956, Adams reported that vigilance and attention research was important, as they related to several different types of important jobs. The first was military, for people needed to monitor radar for long periods of time, waiting for a change in stimulus to be detected, which may or may not occur. Another job where this was important was on any industrial line, where people had to watch for product defects. However, it is important to note the subtle difference in these two types of work. With radar tasks, the person fixates on a single point on a screen, watching for a change, whereas an industrial worker on a line is examining multiple objects as they move before them. Although the radar job is a classical example of vigilance, the line worker also has to be able to switch attention from item to item. For his own research, Adams used a five inch screen, varied the brightness of the stimulus, and duration of the stimulus. The stimulus always appeared in the same spot in the center of the screen, to avoid attentional problems where the participant may have missed the stimuli because they were searching in the wrong area. Rest periods were provided for the participants. Adams found that detection was improved by both brighter stimuli, and longer durations. Participants also did better after a rest period, although overall ability to detect correctly declined over time.

Vigilance and Driving Research

The idea of attention and vigilance being important to driving is not a new one. In 1938, Desilva and Robinson used reaction time tests in order to measure vigilance while driving. Vigilance was negatively affected by fatigue, intoxication, and distraction.

Following up on the fatigue research, Boring (1945) wrote about the effects of fatigue on driving performance. Although it focused mostly on the armed services, the information is valid in terms of all activities, including driving. One section, written about boredom, is of particular interest, as driving does not tend to cause typical deficits in energy, such as physically working hard, or using a great deal of mental capacity. Boring writes about the bored person's attention being interrupted while they are bored. The person's energy levels will remain high, and are easily accessed when there is a relief to the boredom.

Related to the attention research, Dobbins, Tiedemann, and Skordahl (1963) examined vigilance in army truck drivers. Although they predicted that long shifts on highly repetitive tasks with various other predictors would cause lowered vigilance levels, their own study did not reflect their hypothesis. They felt that the task may have been too complex, and acted as a stimulant itself, unlike more simple tasks.

Transport drivers were also the subject of early studies (Kovacs, 1965). It was discovered that fatigue was related to several factors, including distance traveled, duration of loading and unloading of the vehicle, rest times, and vehicle types. In particular, the author states that drivers should not be on the road longer than 500 minutes, and this finding is especially true for people who drive cars.

However, despite all of this research, there are researchers who believe that, unlike the classic vigilance task used by Adams (1956), driving vigilance studies cannot simply have a person paying attention to one thing only. While driving, drivers must be conscious of their position on the road, their speed, potential hazards on the drive (i.e., houses, trees, traffic), as well as keeping track of the vigilance task.

Modern Vigilance Model

Monotonous situations tend to be defined as those which involve unchanging stimuli, or stimuli which change in a predictable manner. Psychologically, people tend to react to monotony with feelings of boredom and drowsiness. It is common for people to lose interest in the task. According to the review done by Thiffault and Bergeron (2003), sleepiness on monotonous motorways was involved in 20-40% of all crashes. However, monotonous roads have anywhere from 30-40% of *fatal* crashes due to sleepiness (Thiffault & Bergeron, 2003).

To put this in perspective, Statistics Canada reported the following traffic-related death rates: 8.6 deaths per 100,000 in 2000, 8.3 deaths per 100,000 in 2001, 9.2 deaths per 100,000 in 2002, 9 deaths per 100,000 in 2003, and 8.7 deaths per 100,000 in 2004. Transport Canada's latest information for 2005 puts the death rate at 9.1 per 100,000. Thus, if the rate from 2005 was used, and the population was approximately 32 million, as stated on the Statistics Canada (2005) website, then 2912 people die per year in motor vehicle crashes, and anywhere from 874 to 1165 of those fatalities occur on monotonous roads due to sleepiness. Death rates were higher in the United States, at 15.5 people out of every 100,000 perishing in motor vehicle crashes in 2002 (Infoplease, 2005). As Campagne, Pebayle, and Muzet (2004) indicated, out of 50,000 fatal crashes in the United States, 15% were caused by the driver falling asleep during the drive. Thus, fatigue while driving is an important factor in motor vehicle accidents.

Thiffault and Bergeron (2003) and Campagne, Pebayle, and Muzet (2004) proposed a model for fatigue and vigilance which involved both endogenous and exogenous factors. In this framework, endogenous factors would include any fluctuation in alertness which originated from within the driver. Examples are circadian variations associated with time of day, fatigue generated from the task itself, and sleep related problems that the individual may be suffering. Exogenous factors that influence vigilance are those which come from the task itself, or outside of the driver. Thus, road geometry and road-side environmental cues could both influence the vigilance levels of the driver. The authors also suggest that mental under-load caused by monotonous driving conditions could be as important as overload from urban expressway conditions.

Studies of Endogenous Factors of Vigilance

There are several endogenous factors that could affect driving performance, including time of day, length of drive, traffic density, and age differences. Physiological differences may be related to endogenous factors, which have been related to fatigue due to the length of drives.

Smiley (1998), Thiffault and Bergeron (2003) as well as Campagne, Pebayle and Muzet (2004) mentioned that there are specific times of day during which people tend to become drowsy, and thus get into more motor vehicle crashes. These times are after lunch, between 1pm and 4pm, as well as early morning between 1am and 6am. Thus, a study on monotonous driving would be best run in the afternoon, shortly after lunch, in order to ensure minimal levels of vigilance. Also, Thiffault and Bergeron (2003) found that fatigue appeared in their drivers after only 20 to 25 minutes on task. Thus, it was hypothesized that after this point in time, tests of reaction time should indicate real differences in reaction time tests in monotonous and non-monotonous situations.

Fatigue was identified as a major cause of accidents by Phillip, Taillard, Klein, Sagaspe, Charles, Davies, Guilleminault, and Bioulac (2003). The authors found that a strong relationship existed between the duration of driving and fatigue. The longer the driver had been on the road, the more they departed from the ideal curve of the road in the simulated task afterwards. The finding reflected an age difference in long distance drivers. Younger drivers tended to stay closer to the ideal curve of the road while doing the simulated task. Therefore, it was hypothesized that there would be a difference in overall lane keeping behaviour between the mature and younger drivers in the present study.

Campagne, Pebayle, and Muzet (2004) also determined that the longer the drive, the more vigilance decayed by studying EEG readings. However, their findings in this regard did not reflect an age difference. Fatigue, coupled with monotony, would therefore likely combine to decrease vigilance levels in a way that could be measured physiologically. Another study which looked at physiological differences indicated that aggressive drivers react physiologically differently than normal drivers (Malta, Blanchard, Freidenberg, Galovski, Karl, & Holzapfel, 2001). They monitored heart rate, blood pressure, facial muscle activity and skin resistance while participants listened to vignettes of driving and fear-provoking scenarios. Aggressive drivers showed increased muscle tension and blood pressure during the vignettes, when compared to controls who showed increased heart rate and decreased skin resistance. They conclude that "physiological hyperarousal and differential responses to stressful stimuli may contribute to aggressive driving" (Malta et. al., 2001). Although Campagne, Pebayle, and Muzet (2004), and Malta and colleagues (2001) used physiological readings in their studies, most driving related studies simply infer vigilance in terms of reaction times, lane keeping, and speed variations.

Pandi-Perumal, Verster, Kayumov, Lowe, Santana, Pires, Tufik, and Mello (2006) conducted a review of sleepiness and its effects on driving. They stated that traffic density could have an effect on driver vigilance in both city driving and highway driving situations. Whereas high density traffic in city driving can cause fatigue, high density traffic on highways reduces it. The reason for this is that highway driving is a monotonous task, and thus giving the driver other cars to pay attention to break the monotony.

Another potential endogenous factor in a model of vigilance is age differences. Campagne, Pebayle, and Muzet (2004) reported that young drivers are more likely to be involved in accidents which involve low vigilance. In their own study, they confirmed this finding by showing that young drivers tended to have more running-off-the-road incidents (RORI's) than older drivers. However, older drivers were more likely to have large speed variations (LSV's) than younger drivers. Owsley, McGwin, and McNeal (2003) also state that there are differences in age groups. They found that mature drivers tended to have more accidents due to chronic medical conditions, and functional impairment, whereas young drivers were less experienced on the road, and had more risk-taking behaviours. Therefore, it would be likely that participants would show differences in their driving behaviours in the present study, showing speed differences, differences in number of speed exceedances above the posted speed limit, and ability to keep the car centered in the lane.

Furthermore, Stefano and Macdonald (2003) indicated that, although older drivers were reported as having more accidents, it was likely that the numbers are inflated, because elderly drivers were more likely to be injured and require treatment after an accident due to increased general frailty. The authors also stated that older drivers tend to spend more time in higher risk areas, such as urban and suburban areas, rather than freeways and rural areas. Bédard, Guyatt, Stones and Hirdes (2002) also concluded that older and younger drivers needed to be studied as separate groups after determining that age was a risk factor in fatal injuries in motor vehicle collisions. For their calculations, drivers 80+ were at 4.98 times greater risk of being in a fatal collision than drivers between the ages of 40-49. This finding was taken from data looking at single vehicle collisions with fixed objects. Another study done by de Waard, Steyvers, and Brookhuis (2004) indicated that elderly drivers were more easily confused by ambiguous cues. In their case, a single road split into two roads, and drivers were left to decide which to take on their own. One direction maintained the center line but did not have street lights, and the other continued on with the streetlights but had no center line. Thus, the idea that older and younger drivers vary in driving performance may be an important facet of driving safety to study, in order to make driving conditions safer for all age groups.

Another difference with aging is the ability to detect peripheral signals. Roge, Pebayle, Hannachi and Muzet (2003) had drivers follow a lead vehicle, and watch the back window of that vehicle for a dot of colour. Either the circle would be orange, and there was a second red dot in the periphery, or the central circle would become darker. Dots in the periphery were located in arcs at 4, 8, 12, and 16 degrees of retinal eccentricity. The task was done in two half hour intervals. They found an interaction between time and age, where older drivers had fewer correct responses to the central attention task overall, but even fewer in the second half hour trial, when compared to the younger drivers. For the peripheral responses, accuracy degraded with further distance from the central circle. Also, younger drivers detected more peripheral signals than the older drivers. In addition, there was an interaction where older drivers detected even fewer signals than the younger drivers as they were displayed at more distant locations. Thus, as age increased, the ability to detect peripheral signals deteriorated. This visual phenomenon, tunnel vision, appears with prolonged monotonous tasks.

Studies of Exogenous Factors of Vigilance

The other factors that may affect driving ability are exogenous factors, which include in-vehicle technology and automation, road environments, and meals.

With advanced technology, both in and out of vehicles, research has focused on these new risk factors for driving, as well, including, but not limited to, radios, cruise control, cell phones, laptops, and on-board movie DVD players. Some studies have found positive roles for some of these devices. For instance, Wiederhold, Wiederhold, Jang and Kim (2000) discovered that people who are fearful of driving are comforted by being able to call their therapist while driving. However, many researchers find that in-car devices cause dangerous distractions in normal driving situations. Strayer and Drews (2007) found that people talking on cell phones have to divide their attention between the phone and driving, which causes them to not focus their attention on objects which are relevant to their driving.

A study by Young and Stanton (2002) found that mental workload was decreased by the introduction and use of automation. Since lower mental workload is directly related to decreases in driving performance, the authors suggest that technology should be geared more towards driver support systems, rather than in automation to replace the driver. Their review indicated that participants were found to be slower to complete in-car tasks when stationary as opposed to when they were driving. Thus, participants were viewed as being less efficient without the extra mental and physical workload of actually driving the vehicle. They found that the more automation that was introduced into the driving task, the more the performance of the driver's deteriorated in terms of attention. This was explained by stating that the resources of the driver may decrease to accommodate the demand reductions due to automation.

Hoedemaeker and Brookhuis (1998) studied the effects of Adaptive Cruise Control Systems (ACCs) on driver behaviour. Adaptive cruise control is a system in which the vehicle’s onboard systems can maintain a fixed headway behind slower vehicles. Thus, ACC both adjusts speed of the vehicle to match the lead car’s speed, and is capable of keeping the driver at a safe and steady following distance at all times. However, ACC systems are incapable of performing emergency braking. With increasing automation, and decreasing mental workload, it is possible that the driver would pay less attention to the driving task, and use of ACC may lead to more accidents when vigilance is required in cases such as emergency braking. Hoedemaeker and Brookhuis (1998) found that the technology may not be useful, since the people who tend to drive fast and have short following distances tended to be the people who didn’t appreciate the system, and would not use it. Also, use of the ACC system tended to cause shorter following distances in general, which is positively correlated with crashes, and also forced people to hit the brakes harder. Additionally, Rudin-Brown and Parker (2004) found that, although there were positive gains in productivity for drivers using ACC, there were negative gains in safety. This means that participants performed better on a secondary number search task, but reacted more slowly to a safety task where they had to detect the brake lights of a lead vehicle and react appropriately by pressing their own brakes. This indicates that, although people can allocate more mental capacity to other tasks, their driving performance suffers, and they react more slowly, and outside of a safe time period to a lead vehicle’s brake lights activating. Also, while ACC was engaged, drivers tended to drift more, unable to maintain good lane keeping techniques. These findings are in line with the previous study by Hoedemaekar and Brookhuis (1998), thus bringing into question the safety of implementing ACC in particular, and other driver-replacing technologies in general.

Another exogenous factor was discussed by Thiffault and Bergeron (2003). They found that there was an effect of road environments on fatigue levels. They used three roads which were functionally identical, but differed in road side scenery. The first had only grass to the sides of the road, the second had pairings of pine trees, one on each side of the road, which passed the driver at a rate of one pair per second, and the third drive had randomly placed trees, and the typical surroundings of a rural drive, such as farms, houses, and people. The first drive was used as a baseline drive, the second as a monotonous, repetitive drive, and the third was designed to break the monotony. They found that people showed decreased vigilance in the monotonous drive, making more large steering corrections. Thus, road side environment was an important consideration in the development of the present study, when creating a difference in monotony.

Meals may also play a part in endogenous and exogenous factors that affect driving vigilance. Meals would be endogenous, as they alter the state of the body internally, but they originate outside the body and some choice can be made as to what sort of meal is consumed, which would be an exogenous factor. As Mahoney, Taylor, and Kanarek (2005) report, there is little information on the effects of meals in a short term situation. Fischer, Colombani, Langhans, and Wenk (2002) found that meals containing high protein levels and meals with balanced protein and carbohydrate levels can help to stimulate cognitive functioning. These meal types tended to improve attention and decision times one hour after consumption. Nabb and Benton (2006) found that higher levels of blood glucose were related to improved performance in vigilance and reaction time tasks. Thus, a meal with high protein and fats should make a driver less vigilant, since glucose is released more slowly by these nutrients.

Present Study

Due to the findings of previous research, an overall monotonous task, and non-monotonous task can be created taking into account several factors which weigh on vigilance and fatigue. To create a truly monotonous drive, it would have to contain the following aspects: it occurred in the early afternoon after lunch, there was no oncoming traffic (Pandi-Perumal, et. al., 2006), automation was used (i.e., cruise control) in order to take a measure of control out of the hands of the drivers, meals with high protein and fats were given for lunch before the drive and road conditions were straight, flat, and unchanging. The non-monotonous drive was essentially the opposite, occurring before lunch, with periodic oncoming traffic, no cruise control, no meal beforehand, and a curvy, and hilly road with a visually stimulating environment. It was reasonable to expect to find differences between mature and younger drivers, as differences have been illustrated in past research.

Physiological recordings were taken as well as the more conventional readings of reaction time in order to gauge participants' vigilance levels, in order to add to the small base of studies that have examined these measures before. It is expected that driver's heart rates, breathing rates, and blood pressure will all react to the stimuli in the drive, showing surprise and sudden alertness during an otherwise monotonous drive. It is also expected that there will be differences in these measures between the non-monotonous condition and monotonous condition, since vigilance should be lower in the monotonous condition, leading to larger differences in heart rate, breathing rate, and blood pressure in participants.

Outline of Hypotheses

The objective of the present study was to determine the combined effects of endogenous and exogenous factors on driving vigilance. We examined differences between younger and older drivers in their overall levels of vigilance in two separate tasks, and monitored their rates of alertness with physiological measurements, as well as the more traditional indicator of reaction time. We expected that the model proposed by

Thiffault and Bergeron (2003) involving endogenous and exogenous factors influencing vigilance levels would hold true. Our specific hypotheses were as follows: Hypothesis 1: Endogenous and exogenous conditions would combine to show a main effect difference between high and low vigilance conditions. The best driving performance would appear in the high vigilance condition. Hypothesis 2: There would be age differences, with mature drivers showing slower reaction times than young drivers. Hypothesis 3: There would be an interaction between Age x Monotony, where mature drivers will have magnified reaction times in the horn braking task in monotonous situations, as they may be more prone to developing tunnel vision in monotonous driving conditions (Roge, et. al., 2003). Hypothesis 4: Drivers will show physiological reactions to the reaction time cues, validating simulator research as comparable to real life situations which would elicit similar responses. Hypothesis 5: Physiological readings will indicate vigilance differences across monotonous and non-monotonous conditions, at the time of the reaction time cues. Hypothesis 6: Mature and younger drivers will indicate having similar levels of difficulty with the task on a self-report scale, as the task itself is simple, and similar to real driving.

Method

Participants

Eighty-four participants were recruited, and 79 completed the study. Forty-four were drawn from an introductory psychology pool ($n \approx 1000$) and summer students to create a "young drivers" group ($M = 22$ years, $SD = 3.55$), and the other 39 were recruited from public groups, such as 55+ centers, posters around the community, personal communications, and newspaper want advertisements to make up the "mature adult drivers" group ($M = 69$ years, $SD = 7.06$). The data from five mature participants could not be used, as they did not finish the drive. Three experienced simulator sickness, one drove far too slowly to complete the task in the allocated time frame, and another had health issues which would not allow completion of the task. All participants read and filled out a consent form (See Appendices A or B), as well as a short questionnaire (See Appendix C) to determine their demographic data, eligibility to participate, and to choose which choice of lunch they would prefer. All participants were offered a free lunch and the chance to win one of two draws per age group for one hundred dollars. All young drivers from the psychology pool were offered one bonus mark for taking part in the simulated drive.

Inclusion and Exclusion Criteria

The inclusion criteria for this study were the possession of a valid driver's license, as well as the participant being a regular driver. Regular driving has been previously indicated as driving from 11000 to 28000km per year (Taillard, et. al., 2003; Waard, Hulst, & Brookhuis, 1997; Waard, Steyvers, & Brookhuis, 2004), or more than 50km a week (Hoedemaeker, & Brookhuis, 1998). For the purposes of this study, 50km a week was used. An additional inclusion criterion was that participants had to belong to specific age groups (18-30, for young, and 60-80 for mature). Medical conditions which may have interfered with the study, including narcolepsy and poor vision were considered exclusion criteria. However, those who had corrected to normal vision were still allowed to participate. All inclusion and exclusion criteria were clearly stated in all forms of recruitment, and all of these facets were included in the initial screening package presented to the participants who wished to sign up for the study.

Procedure

The procedure was slightly different depending on the time of day during which the participants came in. Morning participants were immediately hooked up to the PowerLab equipment upon arrival to the driving simulator room, which recorded heart beats, respiration, and blood pressure. Heart beats were measured using three lead electrocardiogram (ECG) electrodes which were easily applied and removed without causing undo discomfort. Also, the PowerLab equipment had systems in place to ensure that there were no feedback signals, and thus no shocks given to participants, making it ideal for use with human subjects. Respiration was measured using a respiratory belt that wrapped snuggly around the participant's chest, which responded to expansion and contraction of the chest while breathing. Blood pressure was measured through an ear clip device, since arm cuffs, finger clips, and heel sensors allow too much noise in measurement with movement from the participant, making it impossible to get a clean signal during the driving event. Also, the idea of using groin catheters was discarded due to obvious discomfort concerns for participants, despite their greater accuracy. Short three minute baseline measurements were taken prior to taking part in the driving simulation. Physiological measurements were also taken at the beginning, in the middle, and at the end of the simulated drive. Afternoon participants were first given lunch, and then put through the same measurements as the morning drivers.

All participants completed a brief ten minute trial run in the simulator to acclimatize them to the apparatus. Part way into the study, the introductory simulation was changed. Initially a city driving style scenario was used, but when it was discovered that the sharp turns at intersections were causing people to feel uncomfortable, a second trial was used which was more akin to the test drive. The highway style of drive caused much less irritation with participants. Although the driving simulator closely simulated the driving experience, there were some obvious differences. For instance, in order to perform a shoulder check, the driver was required to press a button to have the screens rotate the environment, as the apparatus does not employ a full 360 degree screen, as seen in Figure 1, on the following page. Also, some drivers did not find the space the vehicle took up on the road to be intuitive, as the 'hood' of the car took up the screen directly in front of them, and part of the screen to their right. During this trial run no measures were recorded. Participants were informed that we were testing different driving habits in various driving conditions, and were given instructions for whichever driving condition they were participating in. In all cases, the driver was informed about reaction time

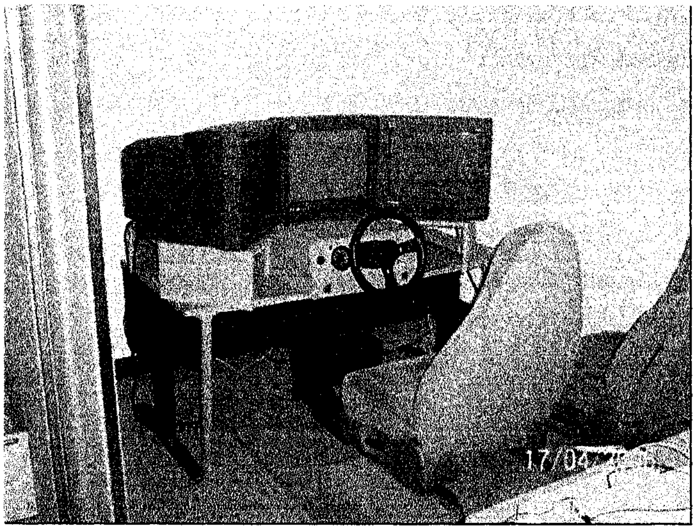


Figure 1: The STISIM simulated driving environment

tests involved during the drive, and told that they should try to remain in the center of their lane. Without this instruction, participants have been known to drive in different locations within the lane (Roge, et al, 2003) and this measure is being taken to attempt to standardize the lane tracking of the drivers.

In the high vigilance scenario, drivers began the simulation at 11am, before lunch, on a long curving highway with objects along the way to generate interest. The low vigilance scenario began at 1pm, after lunch, and involved the use of cruise control while driving down a straight, flat, featureless road. At present, adaptive cruise control (ACC) cannot be implemented, due to limitations in the STISIM software. Thus, regular cruise control was used for the purposes of this study. For each simulation, lunch was provided for the driver, although if participants indicated they were not interested in lunch, they were put in the morning condition. Because ACC could not be implemented, there was no lead car, and participants had to get up to speed and manually engage cruise control at approximately 55 mph in the monotonous condition. Half-way through the drive, a horn symbol appeared on the screen, indicating that the participant should press the horn as quickly as possible. At the end of forty-five minutes of driving, a stop sign appeared, indicating to the driver that they should apply their brakes as quickly as possible. Both of these conditions will reflect reaction time scores. After both the morning and afternoon drives, participants completed the Rating Scale Mental Effort (RSME) (See Appendix E) followed by a very brief questionnaire designed to determine self-reported areas of difficulty (See Appendix F). After drivers completed the forms, they received an information sheet which reminded participants of the rewards of participating, and informed them of the university policies of privacy and data storage (See Appendix D). Participants were free to leave their e-mail addresses, and/or home mailing addresses with the researchers to learn the outcome of the study.

Measures

The simulator itself recorded a host of measures, such as speed, number of speed exceedances (determined as five or more miles per hour above the posted speed limit), center line crossings, road edge crossings, position in the laneway, maximum distance they traveled to the right and left of the center position on the road, center line crossings, RORI's, and reaction times to both the horn and braking tasks.

Physiological measurements of heart rate, respiration, and blood pressure were the primary measurements taken during the simulation with the PowerLab system. The system used three electrodes, a respirator belt, and an ear clip, respectively, to measure those variables. Blood pressure before driving during the rest state was taken with an arm cuff. Particular attention was paid to the heart rate, both over time, and in relation to the planned reaction time events in the middle and at the end of the simulation. It was hoped that this measurement would accurately display the drivers' levels of vigilance during their driving performance. Due to the nature of the research, and the motions made by the participants while driving, clean data were not always available. Also, the ear clip failed to function as a reliable measure of blood pressure, so the analysis of physiological reactions in this regard to the reaction time stimuli was impossible.

The physiological data were examined heart beat by heart beat for two to three minute intervals, for the pre-drive, the beginning of the drive, before and after the reaction time test for the horn press, and before and after the reaction time test for the brake press. By utilizing macros to find the peaks of heart beats, both heart rate and breathing rate data had to be examined for errors. Errors occurred when the macro would pick up a false peak, or miss peaks in the heart rate data, or when peaks for breathing rate were erroneously picked up, or missed. Heart rate data were time consuming to correct, as the time frames between the incorrect readings could either be summed together to find one heart beat, or split apart when peaks were missed. Breathing rates that were incorrect were simply averaged across the times before and after the incorrect zone of data. This tended to be influenced by personal judgment. Whereas the heart rate corrections were using firm time frames where the heartbeats occurred in a difficult to read signal, the breathing rate had to be looked at while asking the question, "Does this rate look reasonable?" So, if a signal jumped from 15 breaths per minute to 100 breaths per minute, then back down to 14 breaths per minute, the error is obvious, and simple to fix. However, when rates went from 22 breaths per minute, and slowly up to 30, and lingering there for a while, before dropping to 25, the data from the rest of the dataset would have to be examined to make a decision as to whether or not that rate was all erroneous, or if the data were correct, as breathing rate differed from person to person.

The Rating Scale Mental Effort (RSME) was implemented in order to indicate how difficult the driving tasks were perceived to be. This rating scale has been used in previous driving studies, and was considered to be useful for overall demand ratings (Waard, et. al., 1999). In order to assess what particular facets made the task difficult, a secondary short questionnaire asked for self-report data on what made the simulated driving task more or less difficult. Included were endogenous (i.e., fatigue) and exogenous (i.e., road conditions) measures, rated on a 5-point Likert scale. As Waard, Hulst, and Brookhuis (1999) stated, self-reports on mental workload, such as those listed above, are popular due to easy application and low cost.

For each situation, measures of lane keeping, and reaction time (RT) for both the horn and brake tasks were analyzed. Lane tracking was defined as how closely the drivers maintained a center position through the course of their drive, which was automatically determined by the program. Positioning was measured in feet, and a value of 6, recorded by the equipment, was indicative of keeping the car perfectly centered in the right hand lane. Reaction time was a response by the driver to a symbol stimulus appearing on the simulator screen. After approximately half an hour, a horn symbol appeared in the upper right corner of the central screen, indicating that the driver should press on the horn as quickly as possible. After forty-five minutes, a stop sign appeared in the center of the middle screen, and the drivers were expected to brake as quickly as they could.

Apparatus

The PowerLab equipment included a base unit, capable of taking up to eight inputs at a time. For our purposes, three leads were used to measure heart rate, a respiratory belt measured breathing rate, and an ear clip measured blood pressure. The system directly connected to a laptop, which recorded the information during the drive, and was also directly connected to the driving simulator system, detailed below. Through this connection, the simulator was programmed to communicate with the PowerLab equipment, and sent a signal to begin and stop taking measurements, removing human error in manually recording events. Thus, if there were variations in speeds, the program would determine at what distance it should begin recording, rather than at time intervals determined by the researcher, which might have been inaccurate.

The particular simulator used for this study was a Systems Technology Incorporated Simulator (STISIM) system utilizing three computers for three monitors, which simultaneously give the driver a 135 degree view of the surroundings. The system includes a full-size steering wheel with torque motor for a true steering feel, turn indicator, horn, accelerator and brake pedals. Optical encoder sensors detect steering wheel, and pedals movements.

Table 1

Different Driving Conditions

Low Vigilance	**High Vigilance**
Time: 1pm – Post Lunch Monotonous Road Conditions – Straight, level, featureless roadway	Time: 11am – Pre-Lunch Interesting Road Conditions – curving, hilly, visually interesting roadway
CC Engaged	No CC

Conditions

The two simulator road conditions that were created were: A best case scenario for driving vigilance (See Appendix G for programming code), and a worst case scenario (See Appendix H for programming code). These scenarios are laid out in Table 1, above. We therefore expected a large main effect size in differences between the two conditions since previous research has pointed to each individual difference being a significant contributor to differences in vigilance levels.

It is important to note that there were only two conditions for two age groups in this study. It was not the purpose of this study to determine which individual factor was the most important in vigilance levels while driving, but rather to see if there were overall differences. Previous studies have looked at particular factors of vigilance, but have not studied whether they are all important together.

Lunch

The meals, as shown in Table 2, on the following page, were nutritionally balanced to the best of our abilities, with the menu options that we were given. The various components of the meals were given to a nutritionist to analyze, in order to create a meal that would help to make the driver slightly drowsy. Normal levels of proteins and fats were used, which are slow to release glucose into the blood.

Statistical Analysis

Our main interest was to examine the relationship between low vigilance and high

Table 2

Meal nutritional information

Selection (Soup, Salad, Sandwich)	Total Calories	Proteins (g)	Carbs (g)	Fats (g)
Tomato, Garden, Tuna	494	20	68	16
Tomato, Garden, BBQ Pork	489	37	50	18
Chk Noodle, Garden, Egg Salad	578	24	57	29
Borscht, Tomato, Roast Beef	568	28	57	28

vigilance conditions of driving, and to determine the extent of the difference between mature and younger drivers. As Thiffault and Bergeron (2003) noted, endogenous and exogenous factors coexist and constantly interact during the driving experience. Thus, teasing the effects of the two apart when adding both conditions together in this study may be impossible.

The method involved in the present study is a between subjects design. Because of the timing elements involved for the RT tests, particularly in the inability to randomly assign times for the horn pressing task, it was decided that a within subjects design would lend itself to too great of a practice effect. Two cohorts were used, involving young drivers and senior volunteers. Each subject participated in only one driving simulator road condition. Comparison of the four conditions was measured with a 2x2 ANOVA. The main effects looked at relationships between age and vigilance. We also examined potential interactions between the two main effects. Reports of significance were made using effect sizes and 95% confidence intervals (CIs) where possible. Confidence intervals give more information than significance levels. The use of CIs ensured that the data from this study will be maximally useful for other researchers in the future.

Taking into consideration that all of the measures used in this study were found to be significant aspects of previous research, we expected that the effect size due to combining all of the features listed in Table 1 would be large. Taking into account this assumption, the total number of participants required considering the analysis techniques used in this study was 96 (Cohen, 1988).

Ethical Issues

There was a slight (3-6%) risk of participants experiencing nausea during the driving task, possibly due to the discrepancy of sensory inputs. While the surroundings appeared to be moving, the seats of the simulator did not move to respond to the vehicle moving, as would have been the case in real driving. Our study confirmed this rate, with 3 out of 83 (3.6%) people experiencing simulator sickness. When participants experienced simulator sickness, they were excused from the study with no penalty. Other than the slight risk of nausea from simulator sickness, participants were at no risk of being harmed. Participants were given the contact information of Dr. Bédard, if they wished to have any questions answered.

Results

Data Screening and Examination of Assumptions

Before statistical analyses were conducted, data from the variables were examined for data entry errors, missing values, and outliers. Identification of outliers was performed visually and by creating z-scores. Outliers in all cases were reduced to +1 of the next highest value, in order to maintain their ordinal position, and to keep as much data as possible. In the case of the number of speed exceedances, there were several outliers, and they were all replaced with the next highest value (i.e., +1, +2, +3, etc.). Also, five people missed reacting to the horn reaction time test within 5 seconds, and their reaction times were reduced to slightly higher than the next highest value (2.30 seconds). When maintaining ordinal values of outliers was impossible (i.e., they were still outliers), the data were discarded.

Hypothesis 1

Hypothesis 1 stated that endogenous and exogenous conditions would combine to show a main effect difference between high and low vigilance conditions. The best driving performance would appear in the high vigilance condition.

Hypothesis one was not supported by the data. There were no differences for the reaction times for the horn task between monotonous (M = 1.46s, SD = 0.398, 95% Confidence Interval (CI) = 1.33-1.59) and non-monotonous (M = 1.42s, SD = 0.401, 95% CI = 1.28-1.55) conditions ($F(1,77) = 0.20, p = .655$). The braking task showed similar results for the monotonous (M = 0.99s, SD = 0.189, 95% CI = 0.92-1.05) and non-monotonous (M = 0.94s, SD = 0.126, 95% CI = 0.90-0.98) conditions ($F(1,68) = 0.91, p = .343$). Another way of measuring driving performance that was used was to examine the number of times drivers crossed the center line, or road edge. Again, there was no statistical difference between the monotonous (M = 0.56, SD = 1.343, 95% CI = 0.14-0.98) and non-monotonous (M = 0.95, SD = 2.837, 95% CI = 0.03-1.87) conditions in regards to the center line crossing ($F(1,78) = 0.62, p = .433$). Also, number of road edge crossings were not significantly different ($F(1,78) = 0.006, p = .937$) between the monotonous (M = 0.77, SD = 2.497, 95% CI = -0.04 -1.58) and non-monotonous (M = 0.80, SD = 1.436, 95% CI = 0.35-1.26) conditions.

Hypothesis 2

Hypothesis 2 stated that there would be age differences, with mature drivers showing slower reaction times than young drivers.

Hypothesis two was confirmed by the data. Young drivers (M = 1.27s, SD = 0.277, 95% CI = 1.18-1.35) had faster reaction times than mature drivers (M = 1.66s, SD

= 0.422, 95% CI = 1.51-1.81) for the horn task (*F*(1,77) = 24.52, $p < .001$). Also, the braking task (*F*(1,76) = 7.17, $p = .009$) indicated significant differences again where younger drivers (*M* = 0.92s, *SD* = 0.162, 95% CI = 0.87-0.97) had faster reaction times than mature drivers (*M* = 1.01s, *SD* = 0.147, 95% CI = 0.96-1.07). The differences may have been larger in the horn condition due to the fact that five of the mature drivers missed the horn symbol within the five second time frame they had to respond to it. The fact that mature drivers in both monotonous and non-monotonous conditions missed the horn symbol indicates an age difference which may reinforce the theory that mature drivers develop tunnel vision while driving, and they miss important cues in the periphery. There were some statistical differences and trends between those few mature drivers who missed the horn reaction time test, and the mature drivers who successfully reacted. The stop time in the braking task showed a weak trend towards being longer (*F*(1,31) = 2.58, $p = .118$) for the people who missed the horn task (*M* = 1.11, *SD* = 0.106, 95% CI = 0.98-1.24) over the people who reacted to the horn (*M* = 1.00, *SD* = 0.149, 95% CI = 0.94-1.06). Also, the people who missed the horn (*M* = 62.50, *SD* = 19.847, 95% CI = 41.67-83.33) rated the task more difficult (*F*(1,34) = 5.75, $p = .022$), in general, as measured by the RSME, than the drivers who successfully reacted to the task (*M* = 37.93, *SD* = 23.39, 95% CI = 29.20-46.47). Unexpectedly, the drivers who missed the horn task (*M* = 4.33, *SD* = 1.033, 95% CI = 3.25-5.42) rated the time of day as being more helpful to their driving (*F*(1,33) = 7.98, $p = .008$) than those drivers who reacted to the horn stimulus (*M* = 3.21, *SD* = 0.86, 95% CI = 2.88-3.53).

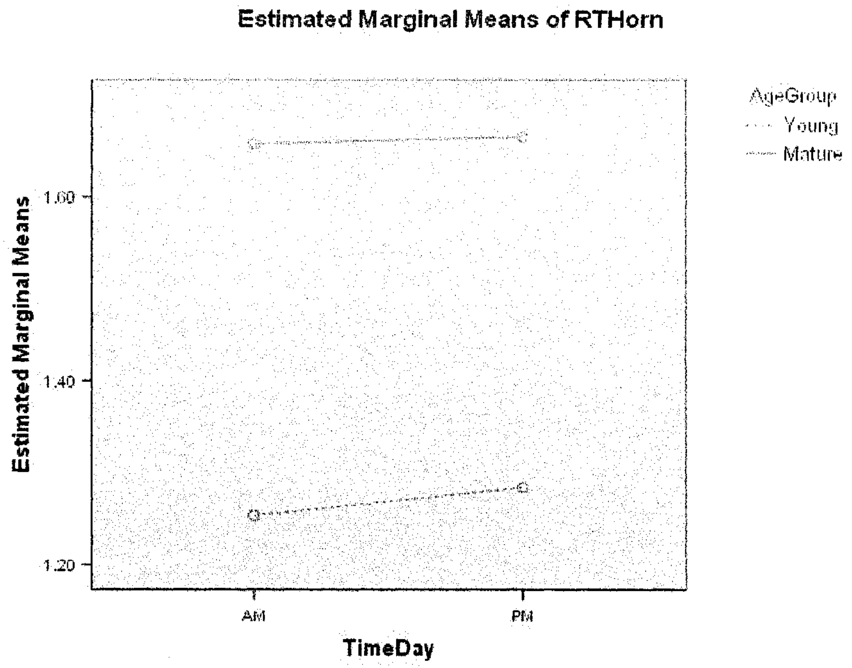


Figure 2: Reaction time to horn for young and mature drivers, during monotonous and non-monotonous conditions.

Hypothesis 3

Hypothesis 3 stated that there would be an interaction between Age x Monotony, where mature drivers would have a magnified reaction time in monotonous situations, as they were more prone to developing tunnel vision in monotonous driving conditions.

Hypothesis three was also not supported by the data. For the reaction time to the horn test, there was no interaction for Age x Monotony ($F(1,78) = 0.02, p = .887$), as shown in Figure 2, above. Also, the reaction time test for the braking condition did not show an interaction between Age x Monotony ($F(1,77) = 1.72, p = .194$), as illustrated in Figure 3, on the following page. Although the figure would seem to indicate an interaction, this relationship did not reach significance, which will be discussed later.

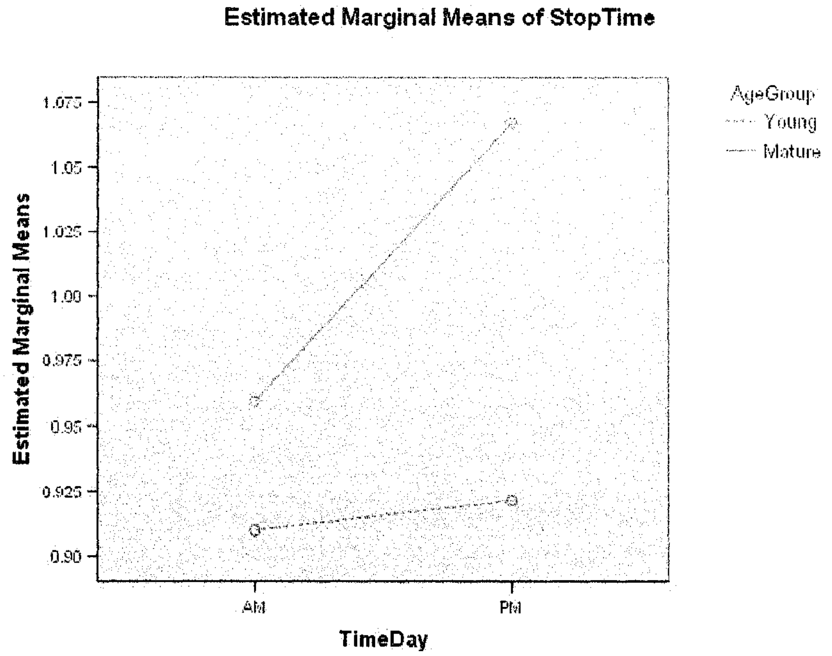


Figure 3: Reaction times to braking task for young and mature drivers, during monotonous and non-monotonous driving tasks.

Hypothesis 4

Hypothesis 4 stated that drivers would show physiological reactions to the reaction time cues, validating simulator research as comparable to real life situations which would elicit similar responses.

Hypothesis four was supported by the data. A Repeated Measures ANOVA was performed on the heart rates before, after, and one minute after the tasks. When looking at the first set for the horn reaction time data, the multivariate tests indicate that both the time (15 seconds before ($M = 82.28$, $SD = 11.77$), after ($M = 81.48$, $SD = 11.81$), and one minute after ($M = 79.31$, $SD = 12.00$)) ($F(2,41) = 4.82, p = .013$) and the interaction between time*age group ($F(2,41) = 5.12, p = .010$) were significant. Mauchly's test of sphericity was not significant, therefore the sphericity assumption is good, and the within-subjects effects were found to be significant for time before, after, and one minute after the horn test ($F(2,84) = 5.55, p = .005$), and for the interaction between the times*age group ($F(2,84) = 4.19, p = .018$). For this finding, we nearly had enough power

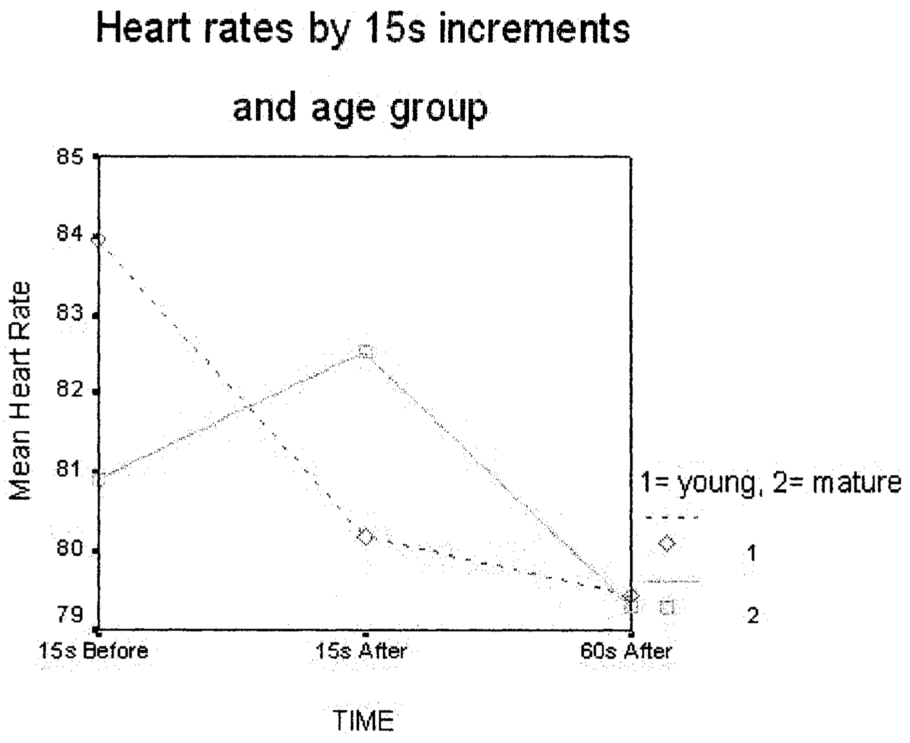


*Figure 4: Time*Age Group Interaction for Horn Reaction Time Test*

to confirm this finding, with an observed power of .730. The interaction was in the form of a quadratic ($F(1,42) = 6.52, p = .014$), as shown in Figure 4, above. These findings indicate that people reacted in a physiological way to the stimuli presented during the drive.

As before, a Repeated Measures ANOVA was conducted. This time it looked at the data fifteen seconds before ($M = 80.30, SD = 10.72$), after ($M = 83.07, SD = 12.08$), and one minute after ($M = 78.74, SD = 11.75$) the braking reaction time test. Again, the multivariate tests indicated that time ($F(2,41) = 28.90, p < .001$) and the interaction between time and age group ($F(2,41) = 4.24, p = .021$) were significant. However, this time Mauchly's test of sphericity was significant, so the Greenhouse-Geisser corrections were used. Again, time was a significant factor ($F(1.47,61.86) = 14.56, p < .001$), but the interaction between time and age group only indicated a trend ($F(1.47,61.86) = 2.68, p = .092$). This relationship may have become significant with increased power, as the observed power was only .439. In this case, the relationship for time fit a linear relationship ($F(1,42) = 5.47, p = .024$) and a quadratic ($F(1,42) = 21.08, p < .001$), although it fit the quadratic better. Figure 6 on page 35 illustrates this relationship. Different from the horn test, the interaction between time and age groups for the brake test was linear ($F(1,42) = 6.34, p = .016$).

Hypothesis 5

Hypothesis 5 stated that physiological readings would indicate vigilance differences across monotonous and non-monotonous conditions, at the time of the reaction time cues.

Hypothesis five was supported by the physiological readings. There were significant differences, or strong trends towards significance, in all time frames analyzed between morning and afternoon drives. For the time spans fifteen seconds before the horn task (Morning: $M = 79.63$, $SD = 12.70$; Afternoon: $M = 84.92$, $SD = 10.38$) ($F(1,46) = 3.27, p = .077$), fifteen seconds after the horn task (Morning: $M = 78.70$, $SD = 12.36$; Afternoon: $M = 84.25$, $SD = 10.79$) ($F(1,46) = 3.55, p = .066$), and before the brake task (Morning: $M = 77.95$, $SD = 11.04$; Afternoon: $M = 82.66$, $SD = 10.08$) ($F(1,46) = 3.19, p = .081$) all showed strong trends towards significant differences across times. One minute after the horn test (Morning: $M = 75.87$, $SD = 11.93$; Afternoon: $M = 82.75$, $SD = 11.29$) ($F(1,46) = 5.01, p = .030$), fifteen seconds after the brake test (Morning: $M = 79.31$, $SD = 11.84$; Afternoon: $M = 86.84$, $SD = 11.34$) ($F(1,46) = 5.77, p = .021$), and one minute after the brake test (Morning: $M = 75.44$, $SD = 11.54$; Afternoon: $M = 82.04$, $SD = 11.24$) ($F(1,46) = 4.89, p = .032$) all showed significant differences between heart rate in the morning and in the afternoon. In every case, the heart rate was increased in the afternoon, as illustrated by the mature group in Figures 5 and Figure 6, on the following page.

Hypothesis 6

Hypothesis 6 stated that mature and younger drivers will indicate having similar levels of difficulty with the task on a self-report scale, as the task itself is simple. Hypothesis six was supported by the RSME. There was no difference ($F(1,80) = 0.01, p=$

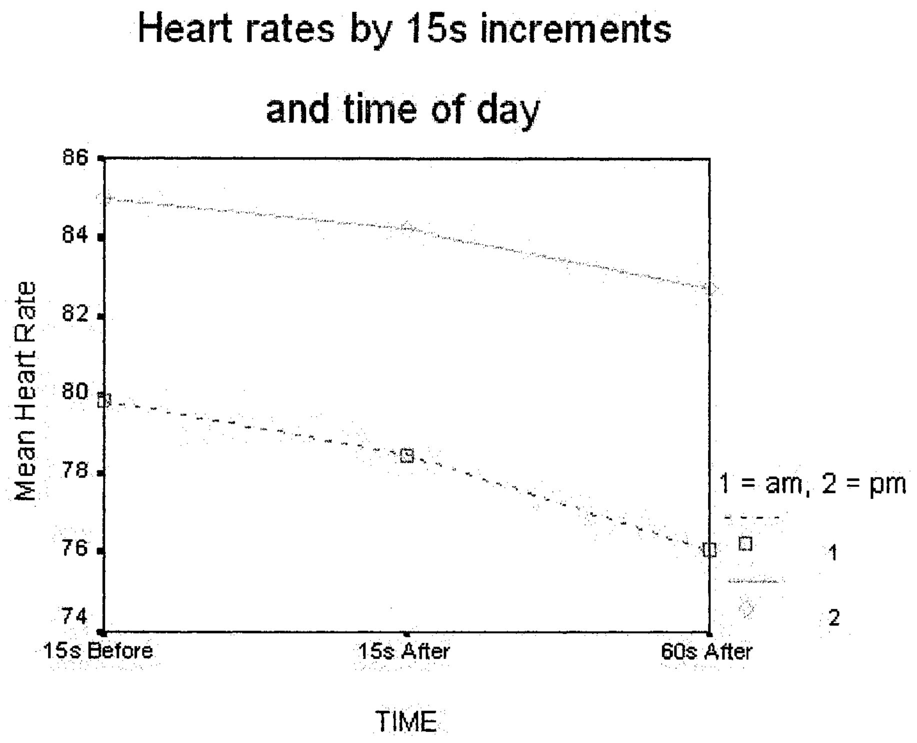


Figure 5: Heart rates were uniformly higher in the afternoon than in the morning for the Horn RT

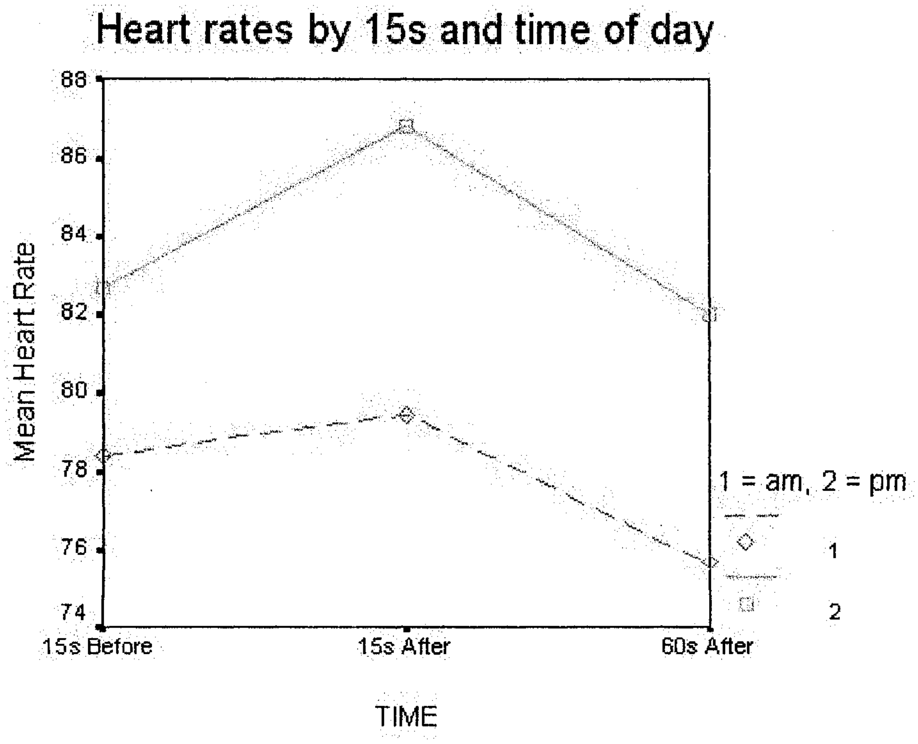


Figure 6: Heart rates were uniformly higher in the afternoon than in the morning for the Brake RT

.921) between younger and mature drivers in their self rating of the difficulty of the task, according to scores given on the RSME. Their scores (*M* = 42.6, *SD* = 22.18, 95% CI = 35.78-49.43 for younger, *M* = 43.1, *SD* = 25.69, 95% CI = 34.69-51.58 for mature) indicate that both groups, on average, found the driving task required some effort, with scores ranging from 10 (Almost No Effort) to 90 (Great Effort) for the younger drivers and 0 (Absolutely No Effort) to 100 (Very Great Effort) for the mature drivers.

When separated by time of day, there was no significant difference between the younger (*M* = 46.22, *SD* = 24.00, 95% CI = 35.84-56.60) and mature (*M* = 44.05, *SD* = 26.40, 95% CI = 31.69-56.41) in the morning (*F*(1,41) = 0.079, *p* = .779). Also, there was no significant difference between the younger (*M* = 38.45, *SD* = 19.65, 95% CI = 29.25-47.65) and mature (*M* = 42.11, *SD* = 25.60, 95% CI = 29.38-54.84) in the afternoon (*F*(1,36) = 0.247, *p* = .622).

The short questionnaire, however, did indicate that there were some differences between the young and mature groups of drivers. All scales were rated from 1 (Hindered) to 5 (Helped), with a score of 3 being neutral. All of the scales were analyzed using 2x2 ANOVAs. First, the time of day (*F*(1,80) = 6.80, *p* = .011) was found to have helped the mature drivers (*M* = 3.4, *SD* = 0.953, 95% CI = 3.06-3.70) more than the young drivers (*M* = 2.8, *SD* = 0.971, 95% CI = 2.52-3.11). When the sample was split into just the morning drivers, the relationship remained (*F*(1,41) = 5.34, *p* = .026), but when examining the afternoon drivers, the relationship became non-significant (*F*(1,38) = 2.00, *p* = .166). The length of the drive (*F*(1,81) = 11.23, *p* = .001) appeared to hinder younger drivers (*M* = 2.1, *SD* = 0.655, 95% CI = 1.91-2.31) more than the mature drivers (*M* = 2.8, *SD* = 1.076, 95% CI = 2.41-3.12). Although not significant, the cruise control indicated a trend towards significance (*F*(1,38) = 3.59, *p* = .062) with young people finding it to slightly helped their performance (*M* = 3.6, *SD* = 1.405, 95% CI = 2.92-4.17) whereas mature drivers found it more helpful to their driving performance (*M* = 4.2, *SD* = 1.015, 95% CI = 3.65-4.70). This finding likely would have reached significance with more people in the afternoon condition where cruise control was used. The road conditions ($F(1,79) = 0.19, p = .668$) and simulator ($F(1,79) = 0.004, p = .951$) had no difference in ratings from the young and mature groups. Both groups found the road conditions somewhat helpful ($M = 3.6$, $SD = 1.021$, 95% CI = 3.26-3.88 for younger, $M = 3.7$, $SD = 1.014$, 95% CI = 3.32-4.01 for mature), and the simulator to be only slightly hindering ($M = 2.7$, $SD = 0.983$, 95% CI = 2.38-2.98 for younger, $M = 2.7$, $SD = 1.195$, 95% CI = 2.26-3.07 for mature). Thus, although both groups found the task to be of approximately the same difficulty overall, there are some differences in how they viewed individual aspects of driving in a simulated driving environment.

Other Physiological Findings

Average heart rates over several different points in time were not significantly different when looking at age differences (ranging from $F(1,46) = 2.06, p = .158$ to $F(1,46) = 0.065, p = .801$), or gender differences (ranging from $F(1,46) = 2.19, p = .146$ to $F(1,46) = 0.531, p = .470$).

Unlike heart rates, the breathing rates did not show significant differences across any of the groups. The only significant difference was between genders fifteen seconds before the horn task ($F(1,29) = 4.61, p = .041$). Strong trends appeared fifteen seconds before the horn task across the morning ($M = 15.63$, $SD = 3.31$) and afternoon ($M = 17.95$, $SD = 3.04$) ($F(1,27) = 3.71, p = .065$) and between the age groups fifteen seconds after the brake task ($F(1,24) = 4.11, p = .055$). However, power rates were very low for this segment of data. After filtering out people with readable heart rate data (used to set the timing for each participant), only about half of those people had clean breathing data. Thus, we had only 12 sets of data for the morning, 16 for the afternoon, with 13 young and 15 mature drivers.

Apparatus

Because the simulated driving environment differed considerably from a real car, the participants were given the chance to make comments about their driving experience in the lab. Quite a few people commented that the experience could have been improved if there was sound. The speaker provided a low rumble to emulate the sound of the car's engine, but they would have liked to have heard other cars passing them. Related to sound, many people thought the experience would have been better if there was a radio or music to listen to. However, a radio was not introduced, because people's taste in music varies widely, and when trying to control for monotony, some people may have enjoyed what we played for that condition.

Physically, there were several complaints about the position of the seat, and the steering wheel. The seat itself could not move forward enough for some people to comfortably reach the pedals. Thus, some of the shorter participants had to sit more forward in the seat, rather than driving comfortably. Also, the steering wheel was not adjustable, so there were complaints that it was too high, or too far away, and difficult to use.

A difficulty with the simulated driving environment was that the further from the point of origin the drive went, the more the car would shake. That is, on the monitors, the car would slowly begin to move, and by the end of the drive, it appeared that the participants were driving on a gravel road with the amount of bumping and moving that occurred on the screens, despite no changes being made to the paved roadway. STISIM was aware of the problem, but could only suggest putting turns into the drive to bring people back towards the origin point. When the shake was weighed against the realism of feeling like you are traveling somewhere (i.e., not back to where you started in a big loop), not to mention that introducing 180 degrees in turns over the course of the monotonous drive may have made participants more alert, it was decided that the shaking would have to remain.

Another problem, which is common using simulators, is that people found it difficult to judge their acceleration, cruising speed, and braking speed. This is largely due to the fact that there are no gravitational forces on the driver, allowing them to feel how fast they are traveling.

Lastly, some people commented that there should have been road signs along the long highway drive. However, for the purposes of this study they were omitted, because for the non-monotonous drive, it forced people to pay more attention to the road, and in the monotonous drive we didn't want to give them anything to look at.

Miscellaneous Findings

As illustrated below in Figure 7, younger drivers (*M* = 56.36mph, *SD* = 2.60, 95% CI = 55.36-56.84) drove faster than mature drivers (*M* = 53.85, *SD* = 3.42, 95% CI = 53.88-55.58). This finding was statistically significant (*F*(1,78) = 13.86, *p* < .001).

Younger drivers (*M* = 5.82, *SD* = 0.52, 95% CI = 4.96-7.01) and mature drivers (*M* = 5.95, *SD* = 0.51, 95% CI = 5.05-7.02) did not differ significantly in their average center position in the lane (*F*(1,79) = 1.44, *p* = .234), with a value of 6 indicating perfectly center in the lane.

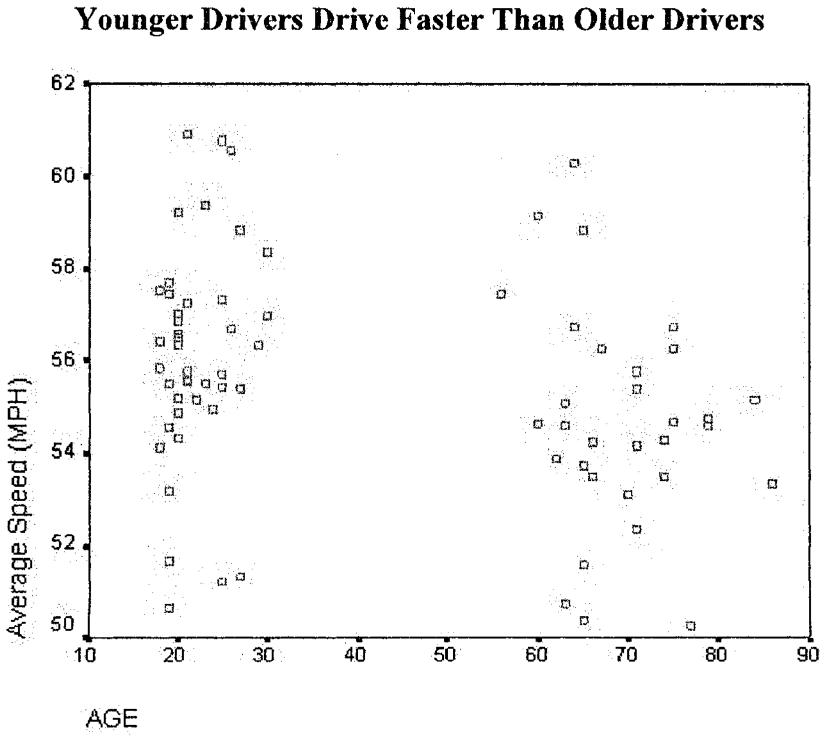


Figure 7: On average, younger drivers drive faster than older drivers.

Males (*M* = 9.35, *SD* = 10.64, 95% CI = 5.45-13.26) had more speed exceedances than females (*M* = 5.47, *SD* = 7.49, 95% CI = 3.32-7.62). This relationship showed a strong, near significant trend ($F(1,79) = 3.67, p = .059$).

There was only one RORI in the study, resulting in a collision which stopped the drive. One mature female experienced a micro-sleep in the non-monotonous driving condition, and drove off the road. She became alert immediately and explained the situation, as the simulator reset the vehicle into the center of the lane again. She stated that she often avoids long highway drives because she does experience sleepiness while driving.

The RSME indicated that there was a strong trend ($F(1,79) = 3.56, p = .063$) indicating that females (*M* = 46.61, *SD* = 23.80, 95% CI = 39.91-53.30) found the task more difficult, generally, than males (*M* = 36.47, *SD* = 22.61, 95% CI = 28.02-44.91).

However, when the sample of males and females were split up into younger and mature groups, the relationship disappears ($F(1,41) = 0.065, p = .801$) for the younger group, but becomes significant for the mature group ($F(1,36) = 6.00, p = .019$). Fatigue levels were found to be significantly different across the genders ($F(1,80) = 9.19$, $p = .003$) with females (*M* = 2.22, *SD* = 0.856, 95% CI = 1.97-2.46) feeling more fatigued during the task them males (*M* = 2.87, *SD* = 1.088, 95% CI = 2.47-3.27). These findings remain significant when looking at younger drivers ($F(1,42) = 4.73, p = .035$) and mature drivers ($F(1,36) = 6.07, p = .019$) separate from each other.

Exploratory Correlations

As shown on the following page in Figure 8, the younger the driver, the faster their reaction time in the horn task ($r = .464, p < .001$) and the braking task ($r = .292, p = .011$). As this correlation matches previous research findings for reaction times, it helps to validate the simulator as a source of driving related, experimental investigation. The older the driver was, the larger their difference in heart rate was before and after the horn test ($r = .517, p < .001$), before and one minute after the horn test ($r = .330, p = .028$), and

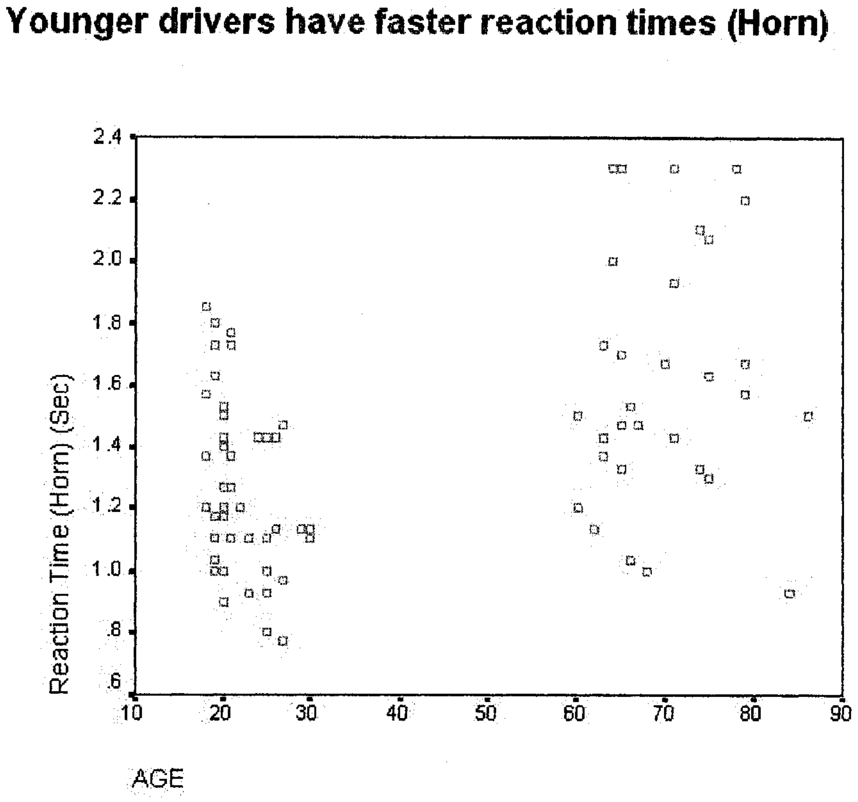


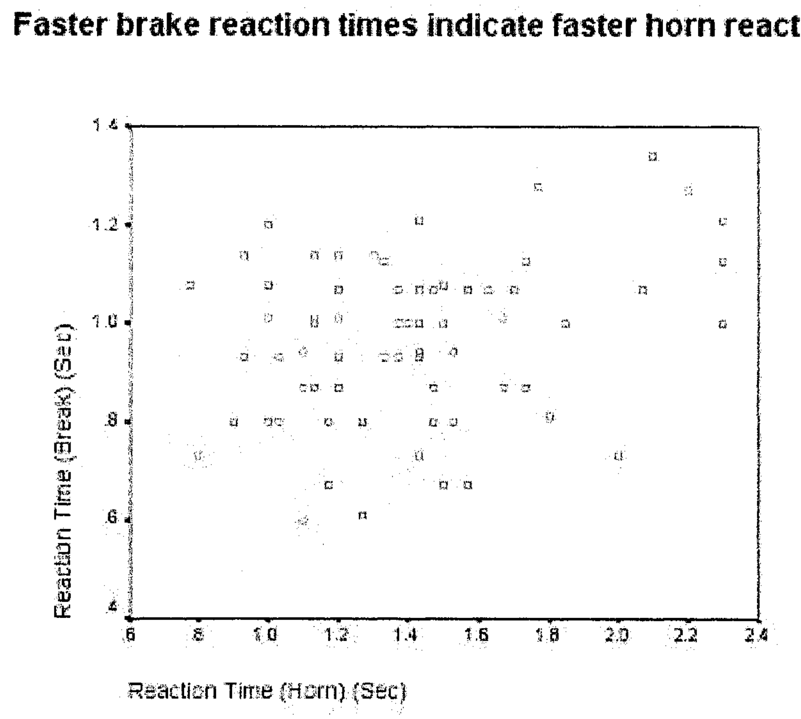
Figure 8: Younger drivers had faster reaction times to the horn pressing task than older drivers

before and one minute after the brake test ($r = .357, p = .019$).

Not surprisingly, the data indicated that the higher a person's average speed, the higher their number of speed exceedances ($r = .336, p = .003$).

A fast reaction time to the horn test was related to a fast reaction time on the brake task ($r = .314, p = .006$), as shown in Figure 9, on the following page. However, the correlation appears to be only of moderate size. When the reaction times are split by conditions, it was found that the correlation disappeared in the non-monotonous condition ($r = .139, p = .413$), but was stronger in the monotonous condition ($r = .424, p = .008$). Reasons for this difference are discussed later.

Differences in heart rates before and after tasks, and before and one minute after tasks, were all correlated (before and after horn, with before and one minute after horn: $r = .473, p = .001$) (before and after horn, with before and after brake: $r = .400, p = .009$) (before and after horn, with before and one minute after brake: $r = .411, p = .007$) (before



Faster brake reaction times indicate faster horn reaction times

Figure 9: Faster reactions times on the horn press task were related to also having a faster reaction time on the brake pressing task

and one minute after horn, with before and after brake: $r = .368, p = .017$) (before and one minute after horn, with before and one minute after brake: $r = .310, p = .052$) (before and after brake, with before and one minute after brake: $r = .566, p < .001$).

Also, the baseline heart rates before the horn and before the brake tests were positively correlated ($r = .849, p < .001$).

The RSME score was found to be unrelated to any of the driving parameters measured.

Discussion

Hypothesis 1: Differences in RT Between Conditions

There were no significant differences in reaction time to either the horn or the braking between the monotonous and non-monotonous conditions. The braking reaction time showed a weak trend, and perhaps if the required number of participants had been achieved, the relationship would have been stronger. However, that begs the question why would the braking task show a difference, and not the horn task? This may be best summed up by the fact that five people missed the horn symbol altogether (split between both conditions), whereas it was impossible to miss the stop sign, since it took up nearly the entire center screen when it appeared. The data for the people who missed the window of five seconds to respond to the horn stimulus were treated as outliers and decreased to being slightly higher than the next highest reaction time. Thus, the braking task may have been a better indicator of reaction times, since it was impossible to ignore, although the horn task may be a better indicator of tunnel vision or vigilance since it was missed only by the mature sample of drivers, supporting previous findings of tunnel vision with increasing age (Roge, Pebayle, Hannachi, & Muzet, 2003).

Also, the finding that drivers in both conditions were similar in terms of center line crossings and road edge excursions adds to the previous finding that there were no differences in driving skills based on vigilance and fatigue.

Hypothesis 2: Differences in RT Between Age Groups

Younger drivers had faster reaction times than mature drivers in both tasks. As numerous studies before have indicated this same phenomenon, it was not surprising that these findings mirror previous results. However, it is also important to note that the mature drivers drove slower than the younger drivers, on average. This may be a type of compensation for having slower reaction times in real world driving environments, giving them more time to react. On several occasions during the study, mature drivers stated when they started driving that they should drive slower, because they were unfamiliar with the road.

Because the reaction time differences appeared between younger and older drivers, there is an indication that the driving environment of the simulator works as other real world driving environments do. These findings would seem to validate the simulated driving experience as being similar to real world driving. It also then strengthens the conclusions of our other hypotheses, indicating whether or not differences really do exist.

Hypothesis 3: Interaction Between Age and Monotony

There was no interaction between Age and Monotony. This indicates that for both groups, their performance remained roughly the same within their own age groups, in the different conditions. However, as before, the braking task appeared as though an interaction may have occurred with stronger participant numbers. It may be worthwhile to attempt this research with stronger statistical power, as there was a weak trend with the power that was present in this study.

Hypothesis 4: Physiological Reactions to RT Cues

It is interesting that there was an interaction that appears between the times before, after and one minute after the reaction time tests, and the age groups. Although the interaction was not quite significant for the brake task, that may simply have been because of the low power issues discussed previously. These interactions point to the fact that older and younger drivers may react differently, on a physiological level, to surprising stimuli while driving. While the heart rates appear to rise immediately after each reaction time test, and fall back to normal a minute later for the mature drivers, this relationship was not found with the younger drivers. There are a few possible explanations for this finding. First, the mature drivers may have taken the simulated driving experience more seriously, and focused more on driving, so the appearance of the stimuli caught them off guard. The seriousness of the mature drivers was demonstrated in this study by their simple willingness to come to the study when they said they would. When mature drivers indicated they would come, they would. The younger participants however failed to show up for their appointments on several occasions. However, showing up to the study may indicate moral differences between younger and mature participants. Armon and Dawson (1997) found that moral reasoning changes over time. In their longitudinal study, it was found that people learned to be more moral, even into old age, where the effect began to flatten in a curvilinear fashion. Second, the younger drivers may have more experience with video games, and more thrilling sorts of events, and thus were not as easily stimulated by the appearance of the stimuli. Castel, Pratt and Drummond (2005) found that video game players were faster at responding to visual search tasks than non-players. Khoo and Cheok (2006) also indicated that there is a generational divide between youth and their elders, where younger people tend to prefer video games, and the older people tend to prefer traditional games such as chess. Putting the findings of these two studies together may indicate that the younger drivers are more prepared for the computer stimuli than the older drivers.

Hypothesis 5: Physiological Readings Indicate Vigilance Differences

The significant and near significant findings regarding differences between heart rates during the morning and afternoon drives is an interesting finding. Unlike breathing rate data, which did not show any consistent differences between time of day, age, or gender, this finding indicates that there is a real physiological difference in heart rate, depending on the time of day. In all cases, the heart rate was faster in the afternoon. This may indicate that the heart was beating faster to help digest the food that was offered for lunch prior to the drive. Krauchi, Cajochen, Werth and Wirz-Justice (2002) also found that the heart rates of their participants increased after a high carbohydrate meal. More generally, Kelbaek, Munck, Christensen and Godtfredsen (1989) found that heart rate increased by 17% after a standard meal (6900kJ). In the present study, the change was less, with only a 6-9% increase in heart rate after the meal. The differences may be due to differing overall calorie counts, time of administration, and/or meal composition, but the fact that heart rate increases after meals is what is truly important. However, since there were no reaction time differences across time of day conditions, it does not appear that these physiological differences influenced driving performance.

Hypothesis 6: Mature and younger drivers indicate similar levels of difficulty

Although the reaction time tasks were performed slower by the mature group of drivers, both groups appeared to have the same level of difficulty performing the driving task in general, according to their self-reports. Both groups rated the task at 42 to 43 out of 150, which was slightly higher than the description of "Some Effort." The differences in reaction times, which indicated that the mature group was slower overall than the young group, indicates that perhaps the self-reporting was not a true reflection of ability. Another possible explanation is that the drivers were rating the difficulty of the task on more than their performance on just the reaction time tests, and were looking more generally at how well they drove. If this was the case, then they would be correct, since both groups did remain steadily close to center in their driving lane, and drove close to the speed limit.

The differences found with the short questionnaire were interesting. For instance, the mature drivers indicated that the time of day of their drive was more helpful, overall, than the younger drivers. The fact that splitting the file indicated that younger drivers in the morning felt much worse about it than mature drivers in the morning may simply reflect the fact that the mature cohort naturally wakes up earlier than the younger cohort.

Unexpectedly, the younger drivers indicated that the length of the drive hindered them more than the mature drivers. One possible explanation for this may be that the mature sample has done more long drives in their lifetimes, and thus the 45 minutes required for this study was short in comparison to the road trips they have gone on in the past, whereas the younger drivers did not have as much experience with such travels. Also, it could be that the younger generation simply lacks the attention span and patience to relax and simply perform the task. Kovacs (1965) did find that the length of the drive influenced fatigue, in general, but these findings may indicate that it is subjective, depending on driving experience. Although the comments are in no way conclusive, many of the older drivers spoke of long road trips they had taken throughout their lives, whereas only a few of the younger drivers spoke of such trips. But those who did speak of long drives also tended to comment that they did not find the simulated driving task overly tiring, since they were used to longer drives.

Finally, and not surprisingly, the mature drivers found the cruise control much more helpful than the younger drivers. Indeed, two of the younger drivers disengaged cruise control part way through the drive, until they were told to reengage it. They wanted to feel more in control of their driving environment, to keep up their levels of alertness on the monotonous road, whereas the mature group viewed it as a helpful tool to maintain a constant safe speed. This is not surprising since, as mentioned previously, mature drivers tend to have more problems with large speed variations.

Exploratory Data

As was previously stated, a fast reaction time to the horn test was related to a fast reaction time on the brake task, but the correlation appears to be only of moderate size. When the reaction times were split by conditions, it was found that the correlation disappeared in the non-monotonous condition but was stronger in the monotonous condition. This may have to do with attentional versus vigilance research. For the non-monotonous drive, attention had to be split more between the tasks and the environment. Although the horn task appeared on a straight stretch, with no oncoming traffic or interesting environmental cues, participants were already used to shifting their attention around the screen. Thus, there may have been noise in the data, where some people were not looking in the correct area, or attending to the area where the horn symbol would appear. Conversely, in the monotonous condition there was extremely little for participants to attend to, and thus they would have been more likely to react to the vigilance tasks in a more reliable manner. Thus, the non-monotonous task may be a suitable attention task, while the monotonous task is more closely akin to a classical vigilance task.

Power

Unfortunately, it appears as though we did not have the power to detect significant differences for two out of three of our hypotheses. Even for our hypothesis about age differences in reaction times, the power we found was less than the .80 we would have liked. We had estimated that they might be large effect sizes, but the interactions may have actually been smaller than first thought. Although the number of younger drivers was relatively easy to achieve, the mature sample was quite difficult to recruit. Either Ryan Toxopeus or Marie Parkkari were at the local 55+ Centre for a week over the lunch hours which got one to four people per day. Posters were put up across the city, and newspaper articles were published in local papers, both with little response. It was stressed that driving licenses could not be revoked through the research, and that fact was also omitted on other recruiting attempts in case some people found the statement worrying (some people made comment about it while recruiting at the 55+ Centre), but people simply did not approach us to participate in the numbers required.

Study Limitations and Suggestions for Future Research

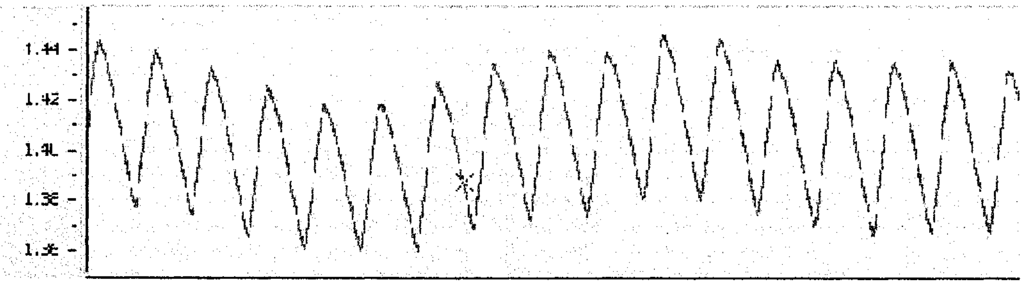
One limitation of this study is that we likely lacked the power required to find significant results for differences between monotonous and non-monotonous situations. A possible reason for this is that the tasks were not different enough. Future research may want to try making a monotonous task, and an *interesting* task, instead of simply making it non-monotonous. Perhaps the addition of more oncoming traffic, driving past small towns, adding live stock and wild animals (that feature was not available), and hazardous maneuvers by other traffic would have made the drive more interesting. However, such things could also have drawn their attention away from the reaction time tasks that they had to perform. Also, as Dobbins, Tiedemann, and Skordahl (1963) mentioned of their own research, the task itself may have been novel enough that it acted as a stimulant for participants, thus reducing the monotony of the tasks. If the monotonous and non-monotonous structure is maintained in future research, then more participants would be required to show any significant results, should they exist.

Breaking up the components of monotony may be a future step that may give interesting findings. Rather than making a "best case" and "worst case" scenario for vigilance, each aspect could be analyzed individually by randomizing whether people get a meal before or after the drive, what time of day they drive, what road conditions they drive on, and whether or not they use cruise control. In this way, it may be possible to see which aspects of vigilance are most important to driving. However, if the sum of all the parts is not important in determining differences, there is little point in looking at the smaller subsets.

There is a possibility that measuring vigilance while driving is not actually possible, with classic vigilance studies being conducted where the participants do nothing but pay attention for the onset of a stimulus - either visual or audio. Classic examples of these types of vigilance studies involve paying attention to a radar (Adams, 1956) or sonar (O'Hanlon, Schmidt, & Baker, 1965) for a target stimulus. With a driving study, there are other things happening, other than the attempt of the participants to remain vigilant for a stimulus presentation. They are driving, and even in a monotonous condition, the road is moving, which offers a basic level of change. Thus, such driving studies might better be classified as fatigue, or dual processing studies.

Making further adjustments to the simulator to make it more comfortable for participants would be a great improvement. Unfortunately, some participants were perched on the front of the seat in order to reach the pedals, which took away from the realism of the driving experience. Also increasing the stability and realism of the simulator may help participants feel that the driving experience is more realistic. Fixing the software glitch which causes the entire environment to rumble when the car drives too far away from the origin point of the drive would help with these problems, as well as adding typical driving sounds, such as other vehicles passing by.

After the study was completed, the makers of the ear clip, ADInstruments, were contacted by another researcher to learn more about it. As it turned out, the blood pressure monitor was light sensitive. Because the blood pressure ear clip was light sensitive, and was likely having light interact with it from the computer monitors, the data from it were useless. Whereas blood pressure usually stays somewhat stable over time, the blood pressure readings from the device moved like a roller coaster to values



Sample Blood Pressure Reading

Figure 10: A sample of the roller-coaster readings for blood pressure.

that are simply impossible. The data moved up and down so regularly that there were no parts of the data that could be analyzed, as can be viewed above in Figure 10. For instance, if the reading of the first wave was 120 over 80, the reading at the fifth peak would read as approximately 107 over 67. This sort of change in a matter of two seconds is clearly impossible, especially given how it fluctuates in this manner constantly, according to the readings.

Omitted from our study were personality variables. In 1956, Venables found neuroticism and extraversion-introversion to be negatively related to the ability of two groups of drivers (police driving instructors, less skilled drivers) to maintain a steady speed, while this finding was not replicated in a third group (skilled car club drivers). Despite these unexplained differences, Fine (1963) followed up by breaking male drivers into three groups: extraverted, intermediate and introverted. When separated in this way, it was found that extraverts had more traffic accidents and violations than introverts. However, despite this previous research on personality, Owsley, McGwin, and McNeal (2003) found in a recent study that a self-report personality questionnaire was not reflective of driving habits. Indeed, the personality traits they looked at were unrelated to objective data indicating how many accidents the drivers had been involved in. The authors stated that these findings could be related more to self-disclosure tendencies of the individuals, rather than self-reported errors and violations and accident involvement.

With the amount of time that would have been added to the already lengthy procedure for participants to complete a personality scale, and considering that the results may not be meaningful, personality scales were omitted from the present study.

Related to the self-disclosure problems of personality research may be the lack of results found with the RSME. The fact that the scale was unrelated to all types of driving data collected in the study indicates that how a person felt about the difficulty of the task did not reflect on their ability to perform the task. As it was unrelated to the variables, it is not recommended that the RSME be used in future research.

Summary and Conclusions

This study indicates that there are reaction time differences between younger and mature drivers. Also, the heart rates of the drivers differed, depending upon what time of day they were driving, although that did not appear to have an effect on their reaction times, as there were no differences in reaction time over conditions. Also, there appear to be physiological differences to how the heart rates of young and mature drivers react to sudden stimuli while driving. These findings definitely reinforce the structure that Thiffault and Bergeron (2003) proposed using endogenous and exogenous factors. Endogenous factors, such as age, seem to affect both reaction times and heart rates. Also, exogenous tests, such as our horn and brake pressing tasks, provided differing responses from drivers.

Thiffault and Bergeron (2003) as well as Campagne, Pebayle and Muzet (2004) appear to be correct that there are time of day effects on drowsiness. The change in heart rate between the morning and afternoon would certainly indicate that there are physiological differences. However, these differences may not be important when looking at driving, since there were no time of day differences found in any measures related to driving.

That there were differences in heart rates in the different times of day, but no reaction time differences in times of day indicates that the endogenous and exogenous systems may be separate, and not influence each other in all circumstances. It may be possible that the human system has adapted so that base heart rate is not a good indicator for actual vigilance, as the mind remains just as alert in potentially hazardous environments, no matter the time of day and conditions.

Although Phillip and colleagues (2003) found that fatigue was related to accidents, there was only one RORI resulting in a collision. This occurred when a mature driver experienced a very short micro-sleep during the more interesting morning drive. This finding also contradicts the findings of Campagne, Pebayle, and Muzet (2004), where younger drivers had increased accidents in low vigilance. Otherwise, the young and mature participants drove similarly.

Roge, Pebayle, Hannachi and Muzet's (2003) theory of mature drivers developing tunnel vision and missing peripheral cues was observed in this study. No younger driver missed the peripheral cue of the horn symbol for the first RT task, yet five mature drivers missed the appearance of the horn symbol entirely, with two noticing it as it disappeared. However, although we expected the tunnel vision to affect the monotonous condition, the tunnel vision appeared to affect the mature drivers equally in the monotonous and non-monotonous drives. This finding may also indicate that both driving conditions were monotonous.

The physiological readings were time consuming to record, and sort out into a useable format. Although the information was interesting, adding this much data to the analysis may be more appropriate for a PhD thesis, where they have more time to analyze it all in greater depth. As only the heart rate appeared to have any differences, and the blood pressure was difficult to measure, future research could focus solely on heart rate monitoring. Should researchers wish to invest in state-of-the-art blood pressure monitors, which would function correctly in a normal driving environment, there may be more useful information that could be gleaned.

There may be merit in further examining this line of research, but the numbers required to find statistically significant differences are quite large, and thus difficult to achieve. An easier way of finding differences may be to increase the effect size by making the tasks even more different, such as making one monotonous, and one interesting. However, if the effect sizes are small, as may be suggested by the fact that some results were not found in the present study, they may not be important enough to warrant further research, even if they are found to be statistically significant.

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Appendix A

Participant Number:__________

CONSENT FORM – Young Drivers

This study is being conducted by Ryan Toxopeus, under the supervision of Dr. M. Bédard of the Department of Psychology at Lakehead University. The purpose of the study is to examine differences in driving vigilance. After completing the application form, please return it to the box labeled "Driving Vigilance" in the main office in the Psychology Department. (Room SN 1042B).

The survey should take about 5 minutes to complete. The questionnaire includes personal questions about driving, and food choices for lunches provided by the researchers. If your name is randomly drawn to participate in the study, you will receive one bonus percentage point towards your Psychology 1100 mark upon completion of the driving condition. You will also be provided with a free lunch, and have your name put into two draws for $100 each. As well as automatically recorded information from the simulator, physiological data will be taken before, during, and after the simulated drive through non-invasive measurement instruments.

Participation in this experiment is voluntary and you may withdraw at any time without explanation and without penalty. All records of your participation will be kept in strict confidence and any reports of the study will not identify you as a participant. As per university requirements, all data will be stored for seven years by Dr. M. Bédard at Lakehead University and remain anonymous and confidential. This sheet will be removed from your application form and your information will remain both anonymous and confidential. There will be no way that your name can be connected to your responses. The only known physical or psychological risk associated with participating in this study is a small (3-6%) chance of becoming nauseas in the simulator due to the discrepancy between sensory inputs.

I have read and understand the consent form, and I agree to participate in this study under these conditions.

Name (Please Print): ________________________

Signed: ________________________

Contact Information- Tele # ________________________

E-Mail ________________________

Date: ________________________

Would you like to receive information concerning the results of this study?
[ ]Yes [ ]No
If yes, choose method: [ ] E-Mail [ ] Telephone

If you have any questions or concerns regarding this study, please contact Dr. M. Bédard (343-8630, or mbedard@lakeheadu.ca)

Appendix B

Participant Number:__________

CONSENT FORM – Mature Drivers

This study is being conducted by Ryan Toxopeus, under the supervision of Dr. M. Bédard of the Department of Psychology at Lakehead University. The purpose of the study is to examine differences in driving vigilance. After completing the application form, please either return it to the researcher who gave it to you, or to the box labeled "Driving Vigilance" in the main office in the Psychology Department at Lakehead University. (Room SN 1042B). As well as automatically recorded information from the simulator, physiological data will be taken before, during, and after the simulated drive through non-invasive measurement instruments.

The survey should take about 5 minutes to complete. The questionnaire includes personal questions about ability to drive, and food choices for lunches provided by the researchers. If your name is randomly drawn to participate in the study, you will be provided with a free lunch, and have your name put into two draws for $100 each.

Participation in this experiment is voluntary and you may withdraw at any time without explanation and without penalty. All records of your participation will be kept in strict confidence and any reports of the study will not identify you as a participant. As per university requirements, all data will be stored for seven years by Dr. M. Bédard at Lakehead University and remain anonymous and confidential. This sheet will be removed from your application form and your information will remain both anonymous and confidential. There will be no way that your name can be connected to your responses. The only known physical or psychological risk associated with participating in this study is a small (3-6%) chance of becoming nauseas in the simulator due to the discrepancy between sensory inputs.

I have read and understand the consent form, and I agree to participate in this study under these conditions.

Name (Please Print): ______________________

Signed: ______________________

Contact Information: Tele #: ______________________

E-Mail: ______________________

Date: ______________________

Would you like to receive information concerning the results of this study?
[ ]Yes [ ]No
If yes, choose method: [ ] E-Mail [ ] Telephone

If you have any questions or concerns regarding this study, please contact Dr. M. Bédard (343-8630, or mbedard@lakeheadu.ca)

Appendix C

Application Form

Thank you for showing interest in the study, and taking the time to fill out this form. Please do not put any personal information on the application form, as it will be separated from the consent form to ensure your anonymity. If you decide you do not wish to participate, and have not filled in the forms, please return them to the researcher.

Date of birth: _______________

[ ] Male [ ] Female

Do you currently hold a valid driver's license? [ ] Yes [ ] No

Do you drive at least 50km/31mi per week? [ ] Yes [ ] No

Do you naturally have good vision? [ ] Yes [ ] No

-If not, is your vision corrected to normal? [ ] Yes [ ] No

Do you have narcolepsy? [ ] Yes [ ] No

Menu Options

Please choose one of the following meal packages that you would like us to provide for you if you are chosen to participate:

Soup, Salad, Sandwich/Wrap:

[ ] Tomato, Garden, Tuna Melt
[ ] Tomato, Garden, Pulled BBQ Pork Wrap
[ ] Chicken Noodle, Garden, Egg Salad Sandwich
[ ] Tomato, Homestyle Borscht, Roast Beef Sandwich

Drink:

[ ] Milk
[ ] Juice

Notes (Allergies, preferences, etc):

Appendix D

INFORMATION SHEET

Please detach and keep this form

Thank you for your interest in participating in this driving simulator study. Portions of the data that you have provided will be used for a Master's level thesis to examine group differences in driver's vigilance levels. You will receive one bonus percentage point towards your mark for Psychology 1100 if you are chosen to take part in, and complete the driving simulation. Also, if chosen, you will receive a free lunch. Finally, your name will be put into a draw for two chances to win $100. As well as automatically recorded information from the simulator, physiological data will be taken before, during, and after the simulated drive through non-invasive measurement instruments.

Once they are handed in, the consent forms will be removed from the information form in order to ensure total anonymity. Thus there will be no way to connect a person's name to their responses. Participation in this experiment is voluntary, and you may withdraw at any time without explanation and without penalty. The university requires that all data collected be stored for seven years by Dr. M. Bédard. The only known psychological risk associated with participation is a slight (3-6%) chance of becoming nauseated in the simulator due to the discrepancy between sensory inputs. All participants who write their e-mail address on the consent form will receive a brief summary of the research findings upon completion of the data analysis. Please do not give Hotmail addresses, as they tend to refuse mass mail of this kind. If you have any questions or concerns about the study, please contact Dr. M. Bédard.

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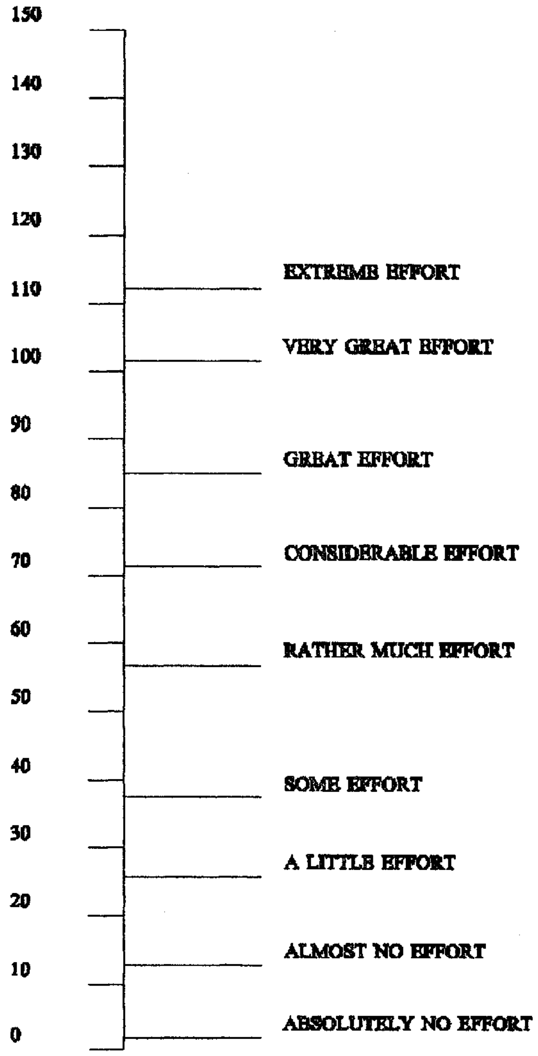
Appendix E

Rating Scale Mental Effort

Please indicate, by marking the vertical axis below, how much effort it took for you to complete the task you've just finished



Appendix F

Questionnaire

Please rate the importance of the following items with regards to how well you feel that you performed in the driving task.

	Hindered		No Effect		Helped
Time of day:	1	2	3	4	5
Road conditions:	1	2	3	4	5
Length of drive:	1	2	3	4	5
Fatigue levels:	1	2	3	4	5
Cruise Control:	1	2	3	4	5
Simulator:	1	2	3	4	5

Comments:

Appendix G

Code for Morning Drive

```
-1 ==============================================================================
-1        File name: p004_drive_am.evt
-1        Written by:        Ryan Toxopeus, rtoxopeu@rogers.com
-1        Date:              09-Mar-2006
-1        Notes:             Non-monotonous driving task
-1 ==============================================================================


-1  Use BSAV to save data for the entire run .
-1        Comment for BSAV -- Begin Block Save
-1        P        Val              Notes
-1        1        0                Save data option (0=distance, 1=time).
-1        2        50               Save increment.
-1        3        C1               Data block title.
-1        4        1,2,3            Up to 44 comma-separated numbers (1-44) that represent the data variables you wish to
                                    save.

0,    BSAV, 0, 50, B1, 1,2,3,4,5,6,7,15,18,23
215000, BSAV, 0, 50, B2, 1,2,3,4,5,6,7,15,18,23

-1 Digital Output for times/distances of interest
-1 At distance = 10 feet, set bit 1 high (i.e., set it to 1).
10, DO, 1
10000, DO, 0

-1 Signal around the first reaction time test for pressing the horn.
135000, DO, 1
145000, DO, 0
145100, DO, 1
155000, DO, 0

-1 Signal around the second reaction time test for pressing the brake.
202500, DO, 1
212500, DO, 0
212600, DO, 1
222500, DO, 0


-1  Use 2-lane road with light brown pebble shoulder, and dry grass ground.
0, ROAD, 12, 2,      1, 2, 0.333, 10, 10, 0.333, 0.333, @1, -1, -1, 0, 6, 0, 6, 0, 5, 0, 5, 0, 0, 0, C:\STISIM\Data\Textures\Dirt09.Jpg,
25, C:\STISIM\Data\Textures\Grass10.Jpg, 12, C:\STISIM\Data\Textures\Grass06.Jpg, 25

-1        Place a 35 mph speed limit sign 250 feet from the start of the course .
-1        The sign appears when the driver is at distance = 0, but is 250 feet away.
-1        Comment for SIGN -- Display roadway sign
-1        P        Val              Notes
-1        1        100              Type of sign that will be displayed (1-16, or 100 for own sign).
-1        2        250              Distance (ft) that the sign is away from the driver when the sign initially appears.

-1        3        C:\STISIM\Data\Signs\SP30MPH.3ds
-1                                  Specialty parameters for any signs that require them.
-1        4        0                Sign source: 0=USA, 1=Europe.
-1        5                         Sign location:  0=Driver's side of road; 1=other side of road.
-1        6                         Sign heading rotation value, in degrees.

0, SIGN, 100, 250, C:\STISIM\Data\Signs\SP55MPH.3DS, 0

-1        Set speed limit at 32.5 MPH (allow 2.5 MPH over posted limit).
-1        Comment for LS -- Limit Speed
-1        P        Val              Notes
-1        1        32.5             The maximum speed, in miles/hour, that the driver may legally drive.
-1        2        350              The distance (ft)that the event is away from the driver when the event initially occurs.
```

```
0, LS, 60, 350

-1      Comment for TREE -- Roadside Trees
-1      P       Val             Notes
-1      1       10              Maximum number of trees that will be displayed at any one time.
-1      2       0               No longer used but has been left for backward compatibility.
-1      3       *7~12;17;18             Type of tree that will be displayed (1-18).
-1      4       35              Minimum lateral distance from the roadway dividing line to the trees (ft).
-1      5       200             Maximum lateral distance from the roadway dividing line to the tree.
-1      6       0               Side of road: 0=both, 1=Left, 2=Right.

500, TREE, 10, 0, 2;3;5;*8~12;17;18, 35, 200, 0
5000, TREE, 30, 0, 2;3;5;*8~12;17;18, 25, 200, 0
6000, TREE, 100, 0, 2;3;5;*8~12;17;18, 25, 200, 0
9000, TREE, 30, 0, 2;3;5;*8~12;17;18, 25, 200, 0
11000, TREE, 0, 0, 2;3;5;*8~12;17;18, 35, 200, 0
12500, TREE, 10, 0, 2;3;5;*8~12;17;18, 35, 200, 0
24500, TREE, 0, 0, 2;3;5;*8~12;17;18, 25, 200, 0
25500, TREE, 20, 0, 2;3;5;*8~12;17;18, 25, 200, 0
30000, TREE, 100, 0, 2;3;5;*8~12;17;18, 25, 200, 0
40000, TREE, 10, 0, 2;3;5;*8~12;17;18, 25, 200, 0
41500, TREE, 0, 0, 2;3;5;*8~12;17;18, 25, 200, 0
45500, TREE, 10, 0, 2;3;5;*8~12;17;18, 25, 200, 0
50000, TREE, 50, 0, 2;3;5;*8~12;17;18, 25, 200, 0
51500, TREE, 0, 0, 2;3;5;*8~12;17;18, 25, 200, 0
59000, TREE, 10, 0, 2;3;5;*8~12;17;18, 25, 200, 0
68000, TREE, 30, 0, 2;3;5;*8~12;17;18, 25, 200, 0
75000, TREE, 100, 0, 2;3;5;*8~12;17;18, 25, 200, 0
80000, TREE, 0, 0, 2;3;5;*8~12;17;18, 100, 200, 0
81000, TREE, 100, 0, 2;3;5;*8~12;17;18, 25, 200, 0
90000, TREE, 30, 0, 2;3;5;*8~12;17;18, 25, 200, 0
92500, TREE, 0, 0, 2;3;5;*8~12;17;18, 35, 200, 0
100000, TREE, 15, 0, 2;3;5;*8~12;17;18, 25, 200, 0
106000, TREE, 100, 0, 2;3;5;*8~12;17;18, 25, 200, 0
109000, TREE, 30, 0, 2;3;5;*8~12;17;18, 25, 200, 0
111000, TREE, 0, 0, 2;3;5;*8~12;17;18, 35, 200, 0
112500, TREE, 10, 0, 2;3;5;*8~12;17;18, 35, 200, 0
124500, TREE, 0, 0, 2;3;5;*8~12;17;18, 25, 200, 0
125500, TREE, 20, 0, 2;3;5;*8~12;17;18, 25, 200, 0
130000, TREE, 100, 0, 2;3;5;*8~12;17;18, 25, 200, 0
135000, TREE, 10, 0, 2;3;5;*8~12;17;18, 25, 200, 0
138500, TREE, 0, 0, 2;3;5;*8~12;17;18, 25, 200, 0
142500, TREE, 10, 0, 2;3;5;*8~12;17;18, 25, 200, 0
150000, TREE, 25, 0, 2;3;5;*8~12;17;18, 25, 200, 0
159000, TREE, 0, 0, 2;3;5;*8~12;17;18, 25, 200, 0
168000, TREE, 30, 0, 2;3;5;*8~12;17;18, 25, 200, 0
175000, TREE, 100, 0, 2;3;5;*8~12;17;18, 25, 200, 0
190000, TREE, 30, 0, 2;3;5;*8~12;17;18, 25, 200, 0
192500, TREE, 0, 0, 2;3;5;*8~12;17;18, 35, 200, 0
200000, TREE, 50, 0, 2;3;5;*8~12;17;18, 25, 200, 0
210000, TREE, 150, 0, 2;3;5;*8~12;17;18, 25, 200, 0

-1      Parameters for BUILDING.PDE file:
-1      @1 = distance building is away when it becomes visible
-1      @2 = lateral distance from centre of road. E.g., *40~60
-1      @3 = building model number. E.g., H*2;4~7;9;13
-1      @4 = Heading angle (counter clockwise rotation, in degrees). Set it to 0 for no rotation.

0, PDE, C:\Projects\common\pde\building.pde, 500, -175, U1, 0
0, PDE, C:\Projects\common\pde\building.pde, 450, -90, U3, 0
0, PDE, C:\Projects\common\pde\building.pde, 600, -50, H1, 0
1850, PDE, C:\Projects\common\pde\building.pde, 2500, -60, H10, 0
12000, PDE, C:\Projects\common\pde\building.pde, 2500, 175, U1, 0
25000, PDE, C:\Projects\common\pde\building.pde, 2500, -175, H11, 0
42000, PDE, C:\Projects\common\pde\building.pde, 2500, 175, H9, 0
80400, PDE, C:\Projects\common\pde\building.pde, 2500, 65, H1, 0
80100, PDE, C:\Projects\common\pde\building.pde, 2500, 75, U3, 0
80750, PDE, C:\Projects\common\pde\building.pde, 2500, -60, H10, 0
112000, PDE, C:\Projects\common\pde\building.pde, 2500, 75, H11, 0
141700, PDE, C:\Projects\common\pde\building.pde, 2500, -90, H10, 0
```

```
165000, PDE, C:\Projects\common\pde\building.pde, 2500, -75, H9, 0

-1 Comment for VC --- Verticle Curvature of the road
-1  P   Val     Notes
-1  1   500     Length of the verticle curvature
-1  2   .01    percent grade/feet

1000, VC, 500, .01
1500, VC, 1000, -.005
3000, VC, 500, -.01
3500, VC, 1000, .005
5000, VC, 500, -.01
5500, VC, 500, .01
9500, VC, 500, .01
10000, VC, 500, -.01
15500, VC, 500, -.01
16500, VC, 1000, .005
20500, VC, 1000, .005
21500, VC, 500, -.01
34500, VC, 1000, -.01
36000, VC, 1000, .01
37000, VC, 500, .01
37500, VC, 500, -.01
42000, VC, 1000, -.005
43000, VC, 500, .01
50000, VC, 2000, .005
52000, VC, 1000, -.01
53000, VC, 500, -.01
53500, VC, 500, .01
56000, VC, 500, .005
56500, VC, 1000, -.0025
64000, VC, 500, -.01
64500, VC, 1000, .005
79000, VC, 500, .01
79500, VC, 500, -.01
85000, VC, 500, -.01
85500, VC, 500, .01
100500, VC, 1000, .01
101500, VC, 1000, -.01
109500, VC, 1000, -.005
110500, VC, 500, .01
118000, VC, 500, .01
118500, VC, 1000, -.005
124000, VC, 500, -.01
124500, VC, 1000, .005
129500, VC, 500, .01
130000, VC, 500, -.01
140000, VC, 500, -.01
140500, VC, 500, .01
154000, VC, 500, -.01
154500, VC, 1000, .005
179500, VC, 500, .01
180000, VC, 500, -.01
185000, VC, 500, -.01
185500, VC, 500, .01
189000, VC, 500, .01
189500, VC, 500, -.01
196000, VC, 2000, -.0025
198000, VC, 500, .01
206000, VC, 1000, -.005
207000, VC, 500, .01
218000, VC, 500, .01
223000, VC, 500, -.01

-1 Comment for C --- Curvature of the road
-1  P   Val          Notes
-1  1   2000         Distance at which the curve appears to the driver
-1  2   50           Entry spiral into curved road section. Must be in whole numbers of feet
-1  3   500          Length of curved section
-1  4   20           Exit spiral. Must be in whole numbers of feet
```

```
-1  5   .0025      Constant roadway curvature. (1/foot: +ve is right turn, -ve is left turn)
-1  6   1          Either 1 or 0. Indicates whether you want supercurvature to the turn
-1  7   .0025      Grade of supercurvature

2000, C, 2000, 50, 500, 50, -.0010
4000, C, 2000, 100, 500, 100, .0010, 1, -.0025
6000, C, 2000, 100, 500, 100, -.0010, 1, .0025
10000, C, 2000, 100, 500, 100, .0010, 1, -.0025
13000, C, 2000, 100, 500, 100, -.0010, 1, .0025
17000, C, 2000, 100, 500, 100, .0010, 1, -.0025
22000, C, 2000, 100, 250, 100, -.0010, 1, .0025
25000, C, 2000, 100, 500, 100, .0010, 1, -.0025
30000, C, 2000, 100, 500, 100, .0010, 1, -.0025
38000, C, 2000, 100, 500, 100, -.0010, 1, .0025
40000, C, 2000, 100, 250, 100, .0010, 1, -.0025
46000, C, 2000, 100, 500, 100, .0010, 1, -.0025
49000, C, 2000, 100, 500, 100, -.0010, 1, .0025
50000, C, 2000, 100, 500, 100, .0010, 1, -.0025
53000, C, 2000, 100, 500, 100, -.0010, 1, .0025
8000, C, 2000, 100, 500, 100, .0010, 1, -.0025
62000, C, 2000, 100, 500, 100, .0010, 1, -.0025
67000, C, 2000, 100, 500, 100, -.0010, 1, .0025
70000, C, 2000, 100, 500, 100, .0010, 1, -.0025
74000, C, 2000, 100, 250, 100, -.0010, 1, .0025
75000, C, 2000, 100, 500, 100, .0010, 1, -.0025
79000, C, 2000, 100, 500, 100, -.0010, 1, .0025
82000, C, 2000, 100, 250, 100, .0010, 1, -.0025
83000, C, 2000, 100, 500, 100, -.0010, 1, .0025
88000, C, 2000, 100, 500, 100, .0010, 1, -.0025
94000, C, 2000, 100, 500, 100, -.0010, 1, .0025
99000, C, 2000, 100, 250, 100, -.0010, 1, .0025
100000, C, 2000, 100, 500, 100, .0010, 1, -.0025
104000, C, 2000, 100, 500, 100, .0010, 1, -.0025
106000, C, 2000, 100, 500, 100, -.0010, 1, .0025
110000, C, 2000, 100, 500, 100, .0010, 1, -.0025
113000, C, 2000, 100, 500, 100, -.0010, 1, .0025
117000, C, 2000, 100, 500, 100, .0010, 1, -.0025
123000, C, 2000, 100, 500, 100, -.0010, 1, .0025
125000, C, 2000, 100, 500, 100, .0010, 1, -.0025
134000, C, 2000, 100, 500, 100, -.0010, 1, .0025
138000, C, 2000, 100, 500, 100, -.0010, 1, .0025
140000, C, 2000, 100, 250, 100, .0010, 1, -.0025
141000, C, 2000, 100, 500, 100, -.0010, 1, .0025
149000, C, 2000, 100, 500, 100, -.0010, 1, .0025
150000, C, 2000, 100, 500, 100, .0010, 1, -.0025
157000, C, 2000, 100, 500, 100, -.0010, 1, .0025
162000, C, 2000, 100, 500, 100, .0010, 1, -.0025
167000, C, 2000, 100, 500, 100, -.0010, 1, .0025
170000, C, 2000, 100, 500, 100, .0010, 1, -.0025
174000, C, 2000, 100, 250, 100, -.0010, 1, .0025
175000, C, 2000, 100, 500, 100, .0010, 1, -.0025
179000, C, 2000, 100, 500, 100, -.0010, 1, .0025
182000, C, 2000, 100, 250, 100, .0010, 1, -.0025
183000, C, 2000, 100, 500, 100, -.0010, 1, .0025
188000, C, 2000, 100, 500, 100, .0010, 1, -.0025
194000, C, 2000, 100, 500, 100, -.0010, 1, .0025
199000, C, 2000, 100, 250, 100, -.0010, 1, .0025
200000, C, 2000, 100, 500, 100, .0010, 1, -.0025
202000, C, 2000, 100, 500, 100, -.0010, 1, .0025
208000, C, 2000, 100, 500, 100, .0010, 1, -.0025
214000, C, 2000, 100, 500, 100, -.0010, 1, .0025

-1 Comment for A --- Oncoming traffic
-1  P    Val       Notes
-1  1    80        Speed of the oncoming car in feet/second
-1  2    1000      Distance at which car appears to driver
-1  3    -6        Lateral position of car in its lane
-1  4    *1-8      Vehicle model number
-1  5-24 X         Parameters to control car movement. X denotes that this is not used here
```

```
100, A, 80, 2000, -6, *1~35; 37~57
2000, A, 80, 2000, -6, *1~35; 37~57
5000, A, 80, 2000, -6, *1~35; 37~57
20000, A, 80, 2000, -6, *1~35; 37~57
24000, A, 80, 2000, -6, *1~35; 37~57
30000, A, 80, 2000, -6, *1~35; 37~57
39000, A, 80, 2000, -6, *1~35; 37~57
50000, A, 80, 2000, -6, *1~35; 37~57
55000, A, 80, 2000, -6, *1~35; 37~57
70000, A, 80, 2000, -6, *1~35; 37~57
78000, A, 80, 2000, -6, *1~35; 37~57
82000, A, 80, 2000, -6, *1~35; 37~57
82100, A, 80, 2000, -6, *1~35; 37~57
90000, A, 80, 2000, -6, *1~35; 37~57
100000, A, 80, 2000, -6, *1~35; 37~57
104000, A, 80, 2000, -6, *1~35; 37~57
110000, A, 80, 2000, -6, *1~35; 37~57
116000, A, 80, 2000, -6, *1~35; 37~57
122000, A, 80, 2000, -6, *1~35; 37~57
150000, A, 80, 2000, -6, *1~35; 37~57
153000, A, 80, 2000, -6, *1~35; 37~57
158000, A, 80, 2000, -6, *1~35; 37~57
162000, A, 80, 2000, -6, *1~35; 37~57
168000, A, 80, 2000, -6, *1~35; 37~57
174000, A, 80, 2000, -6, *1~35; 37~57
175000, A, 80, 2000, -6, *1~35; 37~57
190000, A, 80, 2000, -6, *1~35; 37~57
205000, A, 80, 2000, -6, *1~35; 37~57

-1 Reaction time test (horn press)
145000, DA, 4, 0

-1 Reaction time test (brake press)
212500, PDE, C:\STISIM\PDEs\ReactionTime.PDE, 1

222000, ESAV

-1 End Simulation
223000, ES
```

Appendix H

Code for Afternoon Drive

```
-1 ======================================================================
-1        File name: p004_drive_pm.evt
-1        Written by:        Ryan Toxopeus, rtoxopeu@rogers.com
-1        Date:              09-Mar-2006
-1        Notes:             Monotonous driving task
-1 ======================================================================

-1  Use BSAV to save data for the entire run .
-1        Comment for BSAV -- Begin Block Save
-1        P       Val              Notes
-1        1       0                Save data option (0=distance, 1=time).
-1        2       50               Save increment.
-1        3       C1               Data block title.
-1        4       1,2,3            Up to 44 comma-separated numbers (1-44) that represent the data
                                   variables you wish to save.
0,   BSAV, 0, 50, B1, 1,2,3,4,5,6,7,15,18,23
215000, BSAV, 0, 50, B2, 1,2,3,4,5,6,7,15,18,23

-1 Digital Output for times/distances of interest
-1 At distance = 10 feet, set bit 1 high (i.e., set it to 1).
10, DO, 1

-1 Turn off bit 1 at distance = 10000 feet .

10000, DO, 0

-1 Signal around the first reaction time test for pressing the horn.
135000, DO, 1
145000, DO, 0
145100, DO, 1
155000, DO, 0

-1 Signal around the second reaction time test for pressing the brake.
202500, DO, 1
212500, DO, 0
212600, DO, 1
222500, DO, 0

-1  Use 2-lane road with light brown pebble shoulder, and dry grass ground.

0, ROAD, 12, 2,      1, 2, 0.333, 10, 10, 0.333, 0.333, @1, -1, -1, 0, 6, 0, 6, 0, 5, 0, 5, 0, 0, 0, C:\STISIM\Data\Textures\Dirt03.Jpg,
25, C:\STISIM\Data\Textures\Grass01.Jpg, 12, C:\STISIM\Data\Textures\Grass01.Jpg, 25

-1        Place a 35 mph speed limit sign 250 feet from the start of the course .
-1        The sign appears when the driver is at distance = 0, but is 250 feet away.
-1        Comment for SIGN -- Display roadway sign
-1        P       Val              Notes
-1        1       100              Type of sign that will be displayed (1-16, or 100 for own sign).
-1        2       250              Distance (ft) that the sign is away from the driver when the sign initially appears.
-1        3       C:\STISIM\Data\Signs\SP30MPH.3ds
                                   Specialty parameters for any signs that require them.
-1        4       0                Sign source: 0=USA, 1=Europe.
-1        5                        Sign location: 0=Driver's side of road; 1=other side of road.
-1        6                        Sign heading rotation value, in degrees.

0, SIGN, 100, 250, C:\STISIM\Data\Signs\SP55MPH.3DS, 0

-1        Set speed limit at 32.5 MPH (allow 2.5 MPH over posted limit).
-1        Comment for LS -- Limit Speed
-1        P       Val              Notes
-1        1       32.5             The maximum speed, in miles/hour, that the driver may legally drive.
-1        2       350              The distance (ft)that the event is away from the driver when the event initially occurs.

0, LS, 60, 350
```

```
-1      Comment for TREE -- Roadside Trees
-1      P       Val             Notes
-1      1       2               Maximum number of trees that will be displayed at any one time.
-1      2       0               No longer used but has been left for backward compatibility.
-1      3       *7~12;17;18             Type of tree that will be displayed (1-18).
-1      4       35              Minimum lateral distance from the roadway dividing line to the trees (ft).
-1      5       200             Maximum lateral distance from the roadway dividing line to the tree.
-1      6       0               Side of road: 0=both, 1=Left, 2=Right.

500, TREE, 2, 0, 2;3;5;*8~12;17;18, 35, 200, 0

-1      Parameters for BUILDING.PDE file:
-1      @1 = distance building is away when it becomes visible
-1      @2 = lateral distance from centre of road.  E.g., *40~60
-1      @3 = building model number.  E.g., H*2;4~7;9;13
-1      @4 = Heading angle (counter clockwise rotation, in degrees). Set it to 0 for no rotation.

0, PDE, C:\Projects\common\pde\building.pde, 500, -175, U1, 0
0, PDE, C:\Projects\common\pde\building.pde, 450, -90, U3, 0
0, PDE, C:\Projects\common\pde\building.pde, 600, -50, H1, 0

-1 Comment for C --- Curvature of the road
-1  P  Val      Notes
-1  1  2000     Distance at which the curve appears to the driver
-1  2  5        Entry spiral into curved road section. Must be in whole numbers of feet
-1  3  20       Length of curved section
-1  4  5        Exit spiral. Must be in whole numbers of feet
-1  5  .0015    Constant roadway curvature. (1/foot: +ve is right turn, -ve is left turn)
-1  6  0        Either 1 or 0. Indicates whether you want supercurvature to the turn
-1  7  0        Grade of supercurvature

1000, C, 2000, 5, 20, 5, .0010, 0
1200, C, 2000, 5, 20, 5, -.0010, 0
50000, C, 2000, 5, 20, 5, .0010, 0
50200, C, 2000, 5, 20, 5, -.0010, 0
100000, C, 2000, 5, 20, 5, .0010, 0
100200, C, 2000, 5, 20, 5, -.0010, 0
150000, C, 2000, 5, 20, 5, .0010, 0
150200, C, 2000, 5, 20, 5, -.0010, 0
200000, C, 2000, 5, 20, 5, .0010, 0
200200, C, 2000, 5, 20, 5, -.0010, 0

-1 Reaction time test (horn press)
145000, DA, 4, 0

-1 Reaction time test (brake press)
212500, PDE, C:\STISIM\PDEs\ReactionTime.PDE, 1

222000,  ESAV

-1 End Simulation
223000, ES
```