IMPROVED AUTOMOTIVE SAFETY THROUGH INSTRUCTIONAL MODULES AND AUTOMOTIVE DRIVING SIMULATOR BASED SKILLS TRAINING WITH ASSESSMENT

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IMPROVED AUTOMOTIVE SAFETY THROUGH INSTRUCTIONAL MODULES AND AUTOMOTIVE DRIVING SIMULATOR BASED SKILLS TRAINING WITH ASSESSMENT

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
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Master of Science
Mechanical Engineering

by
Dionne M. Norfleet
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Accepted by
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ABSTRACT

Motor vehicle crashes involving novice drivers are significantly higher than matured drivers’ incidents as reported by the National Highway Traffic Safety Administration Fatality Analysis Reporting System (NHTSA-FARS). There is ongoing research on how to decrease the number of crashes for this driver demographic group in the United States and Europe. Novice drivers usually complete driver education classes as a pre-requisite for full licensure to improve overall knowledge and safety. However, compiled statistics still indicate a need for more in-depth training after full licensure.

This thesis introduces classroom and virtual training modules to improve the driving skills, attitudes, knowledge, and behavior of “high-risk” young adult participants. The approach was to design two training modules for classroom instruction and establish a framework for a Public Service Announcement (PSA) seminar. In addition, a case study was performed using three automotive simulators exploring their potential use as a driver training resource. One of the driving simulators was subsequently used to complete a feasibility study examining the use of simulators as a driver training tool.

The instructional modules covered vehicle maintenance, vehicle safety systems, and general automotive operations. The vehicle maintenance material included topics such as operating fluids, tires, brakes, windshield wipers, light bulbs, batteries, and warning lights. The second module focused on the basic operation of the vehicle and several key safety features (e.g., anti-lock braking system, electronic
stability control, traction control system, seatbelts, and airbags). The PSA seminar introduced driving strategies such as avoiding driver distractions, seatbelt usage, and speed management using video campaigns produced by national and international organizations. Three simulators (DriveSafety Simulator, STISIM Drive Simulator, CU-Steering Simulator) were evaluated at North Carolina A&T University and Clemson University for their possible use in driver education programs. The overall performance was considered in nine general areas: ease of use, user-interface, motion/vision agreement, vehicle dynamics, haptic feedback, traffic scenarios, realism, mobility, and programmability. The DriveSafety simulator was determined the best option, since it provided the greatest number of characteristics ideally required for a training simulator. Based on the favorable results of this study, the opportunity to improve the driving skills of novice drivers using a DriveSafety automotive simulator was examined. Training test scripts for “Following Etiquette” and “Situational Awareness” were developed to introduce these key driving techniques. The training modules were administered in a pilot study using Clemson University students (ages 18-25). Students received little verbal instruction from the examiner; the majority of information was delivered by custom training videos and embedded driving simulator instructions. The “Following Etiquette” module taught a basic timing method that allowed drivers to maintain a recommended following distance: 58% passed and 42% failed. The “Situational Awareness” module allowed students to practice obstacle avoidance techniques and emergency maneuvers: 25% passed out right, 58% conditionally passed, and 17% failed.
The classroom and virtual training modules were developed for possible implementation in a safe driving program. The automotive driving simulator proved to be a feasible option for facilitating automotive safety lessons, followed immediately by driving exercises to practice and reinforce the educational concept. Recommendations for additional classroom modules and virtual training modules are put forth for future study.
DEDICATION

I would like to dedicate this thesis to the late Thomas Elmore Norfleet, Sr of Waterbury, CT who passed away while I was writing this thesis. He is my paternal grandfather and a true patriarch. He stressed the importance of family and prayer, for he wholeheartedly believed in the saying, “A family that prays together, stays together.”
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CHAPTER ONE

INTRODUCTION

Driver training for young adults has become an increasingly popular topic in the literature (Berg, 2004, Keating, 2007, Underwood, 2007). This current focus may be due to the re-occurring high number of fatalities associated with traffic crashes in the 16-20 age bracket. According to the National Center for Injury Prevention and Control (2009), traffic crashes are the leading cause of death for this age group. In 2007, persons between the ages of 16 and 20 were involved in more than 400,000 injury-related motor vehicle crashes and nearly 6,500 fatal crashes (NHTSA, 2009).

In an effort to increase the number of young “good drivers” and decrease the number of young driver related fatalities and injuries, many states have implemented driver’s education courses, Graduated Drivers License (GDL) programs, and/or insurance incentives (Senserrick, 2007). In driver education courses, novice drivers usually learn basic skills and techniques for driving in both classroom and behind-the-wheel training sessions. However, some states have reluctantly discontinued driver education classes due to budget cuts (Stokes, 2009). As a result, parents have had to seek out privately funded driver education programs provided by independent organizations. For GDL programs, young drivers are restricted from certain unsupervised “high risk” situations, such as nighttime driving, driving with passengers, and operating large vehicles, for a specified amount of time (age based).

The GDL programs rely heavily on parents to enforce the rules. Accordingly, parents have a substantial opportunity to impact their teen and encourage safe driving
behaviors from the beginning (Hartos et al., 2004). Most states now require parents to certify that their child has driven a logged amount of hours with their learners permit, and some states even require parents to attend public driver’s education (two hours) programs with their child (State Legislature, 2008). A variety of commercial programs, such as the Richard Petty Driving Experience (RPDE, 2009) and the Skip Barber Driving School (Skip Baber, 2009) have been developed to address driver safety and to educate young drivers. These safe driving programs typically teach critical driving techniques and then allow the novice drivers to practice the skills on closed road courses.

Research investigations has focused on various factors that may influence teen drivers, including overconfidence (Katila, 2004), under developed driving skills (Renge, 2000), ignored accepted protocol (Williams, 2003), and parental involvement (Williams, 2006). Driver education alone has not been successful mainly because of unidentified educational outcomes, the easily obtainable driver’s license (i.e., written test and parking lot driving skill assessment), and little research on the best practices to improve basic driver behavior (Hartos and Huff, 2007). Malik and Rakotonirainy (2008) concluded that driver training may be improved with a more in-depth analysis of the driving task and traffic situations. Specifically, the authors suggested consideration of cognitive skill aspects of driver training such as hazard and risk perception, decision making, self-monitoring processes, learning styles, and risky attitudes.

Ivancic and Hesketh (2000) examined the effects of driving skills on self-confidence and concluded that lowering a driver’s self-confidence increased his/her
skills. The authors also noted that it is important to teach adaptable driving skills such as obstacle avoidance, rather than a specific driving skill such as skid recovery. Thus, a driver will then be able to apply learned driving skills to a variety of situations rather than to a specific scenario. It is interesting to note that an international study (Mynttinen et al., 2009) supported the theory of teaching adaptable skills, but concluded that overconfidence and driving skills have no correlation. The Mynttinen investigation determined that improving the overall competence of the driver improved his/her driving skills. While both studies concur on the need to teach adaptable driving skills, the former may be most popular with the issue of confidence. Finally, Runyan and Yonas, (2008) suggested a need to have a multi-disciplinary team to address driver education and safety for novice drivers because of the diversity of circumstances surrounding motor vehicle crashes.

**Research Objective and Goals**

The overall research objective was to improve ground vehicle driver skills, attitudes, knowledge, and behavior of “high-risk” young adult participants. The proposed approach was to systematically develop training modules for novice drivers using both classroom and virtual reality simulation strategies, to target the acquisition of safe driving skills, knowledge, attitudes, and behaviors. There were three main goals to fulfill the research objective as shown in Figure 1.1.

The first goal was to design two instructional modules to address vehicle maintenance and vehicle safety and operations, and to identify safe driving public service announcements (PSA). The Vehicle Maintenance module introduced the basic
skills for the up-keep of the vehicle. Topics included, but were not limited to, operating fluids, tires, and brakes. The Vehicle Safety and Operations module focused on how the vehicle operates and on some of its safety features, such as the traction control system (TCS) and the anti-lock braking system (ABS). Driving strategies were reviewed within a public service announcement (PSA) framework which focused on key driving techniques that should ensure safe everyday driving. The PSA’s focused on topics such as avoiding driver distractions, seatbelt usage, and speed management. Some of the developed materials were supplied to the Clemson University Automotive Safety Research Institute (CU-ASRI) for use in the Richard Petty Driving Experience (RPDE) program of Concord, NC.

The second goal was to study the implementation and use of real-time automotive driving simulators frequently located at government agencies, universities, and corporations. Some of the specific users include vehicle manufacturers, automotive component suppliers, game developers, research universities, government agencies, and companies with fleet vehicles. The applications include, but are not limited to, research, development, education, and training. The driving simulator can be a cost effective and safe research tool that offers a controlled environment for its applications. In this study, the driving simulator was used for education and training of novice drivers.

The third goal was to design unique training exercises on an automotive driving simulator to address critical road hazards and risky behaviors. Two virtual training modules were created: one to teach the proper vehicle following distance (“Following Etiquette”) and another to strategies for obstacle avoidance (“Situational
Awareness”). After the simulator modules were designed, a pilot study with human test subjects was performed to evaluate their feasibility. The study was approved by the Clemson University Institutional Review Board (IRB), and the study results revealed that the use of driving simulators for education and training provides a viable tool.

Figure 1.1: Research Objective and Goals for the Education and Training of Novice Drivers
**Thesis Organization**

This thesis presents a series of instructional and virtual driving training modules developed for the education of novice drivers. Chapter 2 offers a detailed description of the training modules used for classroom instruction. Chapter 3 provides an introduction to and a literature review of automotive driving simulators. Chapter 4 describes the development and initial application of the virtual automotive driving simulator training modules. Concluding remarks are presented in Chapter 5. The Appendices contain the IRB approval paperwork (Appendix A), the virtual driving simulator modules’ test scripts (Appendix B and Appendix C), the driving simulator training questionnaire results (Appendix D), the “Following Etiquette” graphical results (Appendix E), the “Situational Awareness graphical results (Appendix F), and the training videos (Appendix G).
CHAPTER TWO

INSTRUCTIONAL TRAINING MODULES FOCUSED ON AUTOMOTIVE SAFETY

Novice drivers typically complete a driver education class as a pre-requisite for full licensure. However, statistics from the nationwide Fatality Analysis Reporting System (FARS) database for these drivers show that there is a need for more in depth training after full licensure to reduce crashes (NHTSA, 2009). In some instances, driver education programs may not offer detailed information on basic vehicle maintenance, how the vehicle operates, or key strategies on how to remain safe behind the wheel. The U.S. Department of Transportation (2009) suggests that one of ten steps to improve safety and minimize crash risk is to keep a motor vehicle in a well maintained state and periodically inspected. The understanding of how a motor vehicle operates may in turn help the novice driver to realize vehicle limits. Implementing a set of key driving strategies may also increase greater safety which is especially critical for young drivers. After completing the two proposed classroom modules and reviewing the suggested public service announcements (PSA), the student should be able to properly maintain and inspect a vehicle, discuss basic vehicle operations, and improve his/her safety behavior behind the wheel.

A series of two self-contained training modules were designed for a classroom type learning environment: “Vehicle Maintenance” and “Vehicle Operations”. A third module, “Driving Strategies”, has been suggested using PSA material available on the Internet. The two classroom modules provide the theory and examples on how to
properly maintain a vehicle for safe driving and how the vehicle operates. The third module offers a skeleton framework to introduce PSA material to novice drivers. The thirty PSA’s address dangerous practices from a global perspective.

The first module, “Vehicle Maintenance”, examines the maintenance of vehicles to ensure optimal performance. The second module, “Vehicle Safety and Operations”, focuses on the basic operation of the vehicle and some of its key safety features. The third module, “Driving Strategies”, presents a list of both national and international PSA’s that address driver distractions, seatbelts, and speeding. The information in the two classroom modules can be found on a variety of credible websites including Edmunds (www.edmunds.com), How Stuff Works (www.howstuffworks.com), National Highway Traffic Safety Administration (www.nhtsa.dot.gov), and The Center for Autosafety (www.autosafety.org), as well as Automotive Encyclopedia (Toboldt et al., 1989). The vast majority of the “how to” information came from the automotive manual of a 2007 Honda Civic EX (Honda, 2006).

**Module 1 - Vehicle Maintenance**

The basic care and maintenance of a vehicle is important in terms of reliability, cost, and safety. A reliable car usually offers a sense of security for the driver to provide transportation. Financially, it is typically better to regularly maintain vehicle components before they negatively affect the major systems (engine, transmission), which may be costly to repair. Safety issues come into play when the vehicle malfunctions due to negligent maintenance or fails to perform properly in
traffic. Simply put, drivers should have a good understanding of general maintenance procedures and periodically monitor routine items. The learning objectives of this module include locating and checking the vehicle’s operating fluids, maintaining the proper tire pressure, checking the tire tread, discovering the signs of brake wear, knowing when to change the wiper blades and light bulbs, keeping the battery terminals clean, checking the battery state, and understanding the meaning of a number of dashboard warning lights.

Operating Fluids

The vehicle’s operating fluids include the engine oil, automatic transmission fluid, engine coolant, brake fluid, power steering fluid, and windshield washer fluid. Figure 2.1 shows the location of these fluids under-the-hood of a 2007 Honda Civic EX. The locations may vary by individual vehicle type. The engine oil lubricates and cools the engine by coating moving parts and carrying heat away from these internal components. It also removes contaminants through the oil filter and inhibits corrosion (Toboldt et al., 1989, pp. 148). Like the oil, the automatic transmission fluid lubricates and cools the transmission through the fluid filled torque converter. It also aids in transmitting the power from the engine to the transmission. The engine coolant keeps the engine block from freezing in the winter and overheating in the summer. The brake fluid is a non-compressible fluid that transfers force through hydraulic lines to the braking mechanisms (friction elements) near the wheels (Jordan, 1995, pp. 43) from the driver depressed brake pedal via the master cylinder. The power steering fluid transmits the power in the vehicle’s steering system and makes the
steering wheel easier to turn via the hydraulic assisted steering gear box. Finally, the windshield washer fluid helps keep the windshield clean.

![Location of Operating Fluids for a 2007 Honda Civic EX](image)

Figure 2.1: Location of Operating Fluids for a 2007 Honda Civic EX

The specific steps to check the vehicle’s fluids are as follows:

- To check the oil, make sure the vehicle is parked on level ground and the engine is cool. Pull out the oil dipstick and wipe it off with a clean rag or paper towel. Reinsert the clean dipstick, pull out dipstick again, and if the oil that remains on the dipstick is below the line marked "full," then add more oil while ensuring not to overfill.

- The transmission fluid level may be checked by first, letting the engine idle until the radiator fan comes on once then turn off engine. After one minute, pull out transmission dipstick and wipe off with a clean rag or paper towel, then reinser. Pull out again and check the fluid level. The fluid level should be between the upper and lower marks. (Note: not all vehicles have electric fans; some vehicles require the engine to be
running to check the level.) The Automotive Encyclopedia (Toboldt et al., 1989, pp. 502) suggest driving the car until the engine is at normal operating temperature, then putting the car in neutral and activate the parking brake before checking the transmission fluid. However, the former was suggested for safety.

- To check the radiator coolant level, when both the engine and radiator are cool, relieve any pressure in the cooling system by very slowly turning the radiator cap counter-clockwise (CCW) without pressing down. Next, remove the radiator cap by pressing down and turning CCW. The coolant level should be up to the base of the filler neck. For the coolant reservoir, the coolant level should be between the "LOW" and "FULL" marks. Remember to never open the radiator while the engine is hot due to scolding concerns. If fluid is required, add directly to the coolant reservoir.

- The brake fluid level should read between the “MAX” and “MIN” marks on the side of the opaque plastic master cylinder brake reservoir. If the fluid level reads below “MIN,” then have your brake system inspected immediately for leaks or worn brake pads.
- Check the power steering fluid when the engine is cold. The fluid level should read between the “MAX” and “MIN” marks on the side of the reservoir or on the small dipstick. If the fluid level reads below “MIN”, add more fluid.
- To check the washer fluid level, remove the cap and look at the level gauge, which may vary depending on the vehicle design. Remember to use a mixture that will not freeze in cold weather.

The vehicle manual is the best reference for when these fluids need to be replaced and in terms of type and quality. It is important to note that when replacing these items, the fluids should be properly disposed at a local auto parts store.

**Tire Pressure and Tire Depth**

Proper tire pressure and tread are important to maintain on a frequent basis, because underinflated tires can lead to skidding, hydroplaning, and blowouts (NHTSA, 2004). Recommended tire pressures are located on the inside of the driver’s door jam. A placard displays the tire’s cold pressure (32 psi or 221 kPa for 2007 Honda Civic EX) in pounds per square inch (psi) or kilopascals (kPa); therefore, it is important to check the pressure when the tires are cold. The spare tire’s pressure should also be checked at least once a month. The pressure gauge used to check the tire pressure is shown in Figure 2.2, along with an example of how to check the tire pressure. First, unscrew the valve cap and set it to the side, then press the tire gauge onto the valve stem. Next, read the tire pressure gauge and make sure it matches the value on the door jam. Finally, add more air to the tire if needed.
Figure 2.2: Illustration for Checking Tire Pressure and Pressure Gauge

The tire tread allows a tire to grip the road and prevent the vehicle from slipping and/or sliding. A minimum tire tread depth of 2/32” (0.0625 inches or 1.5875 mm) is recommended so that water can be channeled away from the tire (Michelin, 2009). The tire tread can be quickly checked using the “Penny Technique” (refer to Figure 2.3). This is done by inserting a U.S. penny into the shallowest tread groove with President Lincoln’s face showing, but his head upside down. If part of President Lincoln’s head is covered by the tread, then the minimum tread-depth requirements have been met, otherwise the tire tread is insufficient, and the tire shall be replaced immediately. Tires also have tread-wear indicators molded into them by their manufacturer. At the minimum tire depth, bars in the tread grooves become visible and it is time to replace the tire.
Knowledge of common signs of brake wear may help to avoid brake failure. One indicator of brake failure is if the pedal “sinks” toward the floor, which may mean there is a leak in the brake system. Another sign is if the vehicle “pulls” to one side while braking, which may be an indication that the brake linings are wearing disproportionately or there is a blockage in the fluid lines. Ideally, all wheels will be bonded in a manner to allow straight line stopping. Noise indicators for brake wear include a high pitched screeching sound and grinding or growling caused by two pieces of metal (disc and caliper) rubbing together when the brake is applied. This may signify the brake pads have worn completely resulting in the warning noise. The most common type of brakes are disc brakes (refer to Figure 2.4), which have brake
pads attached to a caliper that squeeze the sides of the disc (rotor) to slow down the wheels. Another type is drum brakes, which has a piston that pushes the drum “shoes” against the drum to slow the wheels down.

Figure 2.4: Disc and Caliper Brakes (How Stuff Works, 2009)

**Wiper Blades, Light Bulbs and Batteries**

Wiper blades and light bulbs have a finite life span and are crucial for safe driving. In the event of inclement weather, these two items are heavily relied on for visibility. To replace these items, it is important to refer to the vehicle’s operation manual. It is also critical to keep the battery terminals free from corrosion, so that proper amounts of current flow from the battery to the vehicle. The status of the battery can be checked by looking at the test indicator window located on the battery. A label (Figure 2.5) on the battery explains the test indicator’s colors. The battery may also be taken to the local auto parts store to check the charge.
Warning Lights

The on board vehicle controllers will often alert the driver that there is a problem, in particular with the engine, tailpipe emissions, and safety systems, by using certain warning lights (Figure 2.6). Though the check engine light could indicate a variety of problems, it mainly relates to the emissions. The oil light comes on when the oil level is low. In the event that the battery light does not turn off a few seconds after the vehicle is started, there may be a problem with the alternator or starter cables. The brake light will illuminate if the emergency brake is activated or the brake fluid is low. The anti-lock brake system light and the airbag light come on if these items are not ready to operate. In the event of a warning light illuminating, it is best to drive to a safe place to investigate the problem and seek expert advice.
Module 2 - Vehicle Safety and Operations

This module details the overall electrical and mechanical power flow of the vehicle, as well as how different systems of the vehicle interact with each other. The learning objectives in this module consist of gaining knowledge on vehicle operation and the purpose of key vehicle safety features provided by the manufacturer. Topics include how the vehicle starts, propulsion created by the powertrain (engine and transmission), and available safety systems such as the anti-lock brake system (ABS), electronic stability control (ESC), traction control system (TCS), seat belts, and airbags. The students are also taught how to jump start a vehicle due to a dead battery. The overall objective is to increase the students’ awareness of these vehicular
components for improved safety and general knowledge to better utilize an expensive asset.

**Vehicle Power Flow**

The power flow of the vehicle, from starting the ignition by turning the key to the rotation of the tires, is illustrated in Figure 2.7. When the ignition key is turned, current flows from the battery to energize the starter motor. The starter motor causes the crankshaft to turn, which temporarily moves the pistons. Once ignition has occurred by the spark plugs (gasoline engine) or auto compression (diesel engines), the starter motor disengages. When the gear select is placed in “drive”, pressing the gas pedal allows the throttle valve to supply air to the intake manifold where it mixes with injected fuel. A computerized fuel system matches that amount of air to create an air/fuel mixture for the engine’s cylinder to combust. This chemical reaction causes the pistons to move, which rotates the crankshaft connected to the transmission. The output shaft of the transmission rotates the differential which turns the front and/or rear wheels. The direction of the car is determined by the driver’s input angle to the steering wheel. A rack and pinion steering system (most common) translates the rotational motion from the steering wheel into linear motion at the tires about the pivot axis (Jordan, 1995, pp. 282).
Vehicle Powertrain (Engine and Transmission)

The main components of the vehicle’s powertrain are the engine and transmission. The engine is essentially a “power plant” that produces kinetic energy from a fuel or energy source. The transmission transmits this energy to the wheels for motion. There are two types of engines: gasoline and diesel. The gasoline engine uses a spark plug to ignite its fuel, whereas a diesel engine uses the heat produced by compression to ignite its fuel. Figure 2.8 explains how both of these engines ignite their fuel. Engine are characterized by the number of cylinders (4, 6, 8, etc.) and the alignment of the cylinders (inline, V, and flat). Hybrid vehicles may use a
A combination of different types of engines (electric, gasoline, diesel, flex-fuel, fuel cell, etc.).

<table>
<thead>
<tr>
<th>Gasoline Engines</th>
<th>Diesel Engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gasoline engines compress a mixture of air and fuel inside a cylinder using a piston.</td>
<td>1. Diesel engines compress the air inside the engine. Fuel is then injected into the engine.</td>
</tr>
<tr>
<td>2. A spark plug at the top of the cylinder ignites the mixture to create a small explosion sending the piston back to the bottom of the cylinder.</td>
<td>2. The mixture ignites, as a result of fuel being added to the hot air, forcing the piston back down.</td>
</tr>
<tr>
<td>3. These small explosions create a rotary motion which is transmitted to the wheels making the vehicle move.</td>
<td>3. These small explosions create a rotary motion which is transmitted to the wheels making the vehicle move.</td>
</tr>
</tbody>
</table>

Figure 2.8 Explanation of How Gasoline and Diesel Engines Ignite Fuel

There are three types of automotive transmissions: automatic, manual, and continuously variable transmissions (CVT). Automatic and manual transmission have a finite set of gear ratios (relationship between the number of teeth on two gears that are meshed) that allow the car to go a certain speed, whereas the CVT has an infinite set. Manual transmission gear ratios are set by the driver, but the automatic transmission chooses the appropriate gear ratio by design. The CVT consist of two pulleys connected by a V-belt that change radii relative to each other. Images of an automatic transmission and a CVT in “low gear” are shown in Figure 2.9. The CVT image is from the How Stuff Works (2009) website and the automatic transmission image is from the website of marine and industrial transmission specialist company, Pacific Driveline Ltd. (2009).
Safety Systems

The vehicle has safety systems in place in the event of an emergency. These safety systems include the anti-lock braking system (ABS), the electronic stability control system (ESC), the traction control system (TCS), seat belts, and air bags. The ABS prevents the wheels from locking up under extreme braking, prevents skidding and loss of control, and allows the driver to stop faster. If the ABS sensor detects a sudden deceleration of the wheel, the system prevents any further increase in braking pressure at the respective wheel. The braking distance may be reduced by 10% or several times amount depending on the road conditions (Bosch, 2007, pp. 841). The TCS was designed to prevent loss of traction between the wheels and road surface, maintain steering capability, and prevent wheel spin in a variety of μ-conditions such as ice, snow, wet, and gravel (Bosch, 2007, pp. 849). The TCS blocks fuel-injection pulses in the engine and acts as secondary system to the ABS by holding drive slip inside acceptable levels.
The ESC is a computerized system designed to improve a vehicle’s handling by detecting and preventing skids. It uses the vehicle’s braking system as a tool for steering the vehicle back on track. Hence, the ABS prevents the wheels from locking, the TCS stops the wheels from spinning, and the ESC prevents the wheels from spinning out (Bosch, 2007, pp. 852). Figure 2.10 illustrates how the ESC works during a rear-wheel skid and a front wheel skid. With a rear-wheel skid (oversteer), the back tires lose traction and cause the vehicle to turn more than the driver intended (B'). The ESC engages the right front brake (A) of the vehicle to keep the driver on track (B). During a front-wheel skid (understeer), the front tires lose traction and cause the vehicle to turn less than the driver expected (D'). The ESC engages the left rear brake (C) of the car to keep the driver on track (D).
Jump-Starting a Vehicle

When a vehicle does not start after several attempts, there is always a possibility that the battery needs a boost from another vehicle’s charged battery. First, make sure both vehicles are turned off and their emergency brakes are engaged. The second step is to connect the cables in the manner and order shown in Figure 2.11. After the cables are connected, start the vehicle with the booster battery and rev the engine. Let it run for a few minutes before starting the vehicle with the dead battery. Once the vehicle with the dead battery is running, the cables can be disconnected in the prescribed order.
Figure 2.11: Steps for Connecting and Disconnecting Battery Cables While Jump-Starting a Disabled Vehicle Engine
Module 3 – Driving Strategies

A public service announcement (PSA) is a form of antecedent intervention that attempts to present the negative, or naturally occurring, consequence of an undesirable action (Whittam et al., 2006). This module presents a framework for a teen safe driving PSA seminar. The seminar will focus on three safe driving strategies: distraction avoidance, adhering to seatbelt laws, and speed management. A list of thirty, ten for each strategy, public service announcements available via the Internet have been presented in Tables 2.1 through 2.3. The Tables contain the title, length, publisher (name, location, and website), and a brief summary of each PSA. The announcements are from both national and international organizations that campaign for safe driving habits.

Distraction takes place when a trigger event motivates an attention shift from the task of driving. Drivers should not do anything that requires them to take either their hands off the steering wheel, eyes off the roadway, and/or breaks their concentration. An external task that removes attention from driving should be considered a distraction (e.g., cell phones, eating, grooming, passengers, etc.). Table 2.1 contains PSA’s campaigning for drivers to avoid distractions. For example, in PSA #6 ("Regenerate PSA: LA DOT"), a narrator sarcastically describes three types of drivers: the texter, the one who talks on the phone, and the one who tries to eat, change a CD, and talk on the phone all at once. Each driver ends up crashing. The majority of the PSA’s in the Table focus on distractions caused by cell phones, which are probably one of the biggest distractions for drivers today.
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Publisher</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Texting While Driving PSA&quot; 4:15</td>
<td>Gwent Police Department Wales, United Kingdom</td>
<td>Three teenage girls are involved in a head-on collision while the driver of the car is text messaging. Only one of the girls survives in this extremely graphic video, while another little girl survives in the other car involved in the crash. However, the little girl's parents and infant sibling do not survive.</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Quit Clowning Around&quot; 0:35</td>
<td>Erie Insurance Group and Christian Brothers Academy Erie, PA <a href="http://www.erieinsurance.com/lookinout">www.erieinsurance.com/lookinout</a></td>
<td>A teenage male is trying to talk on his cell phone, eat a doughnut, and read a newspaper while driving. Three clowns are also in his car trying to distract him. The driver ultimately ends up driving off the road.</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Youth Reckless Driving Prevention - Eyes&quot; 0:30</td>
<td>Ad Council Washington, DC <a href="http://www.adcouncil.org">www.adcouncil.org</a></td>
<td>A teenage passenger realizes the driver is trying to change a CD while driving. She then goes on to say who she's going to donate her eyes too if they get into a car crash and die. The message for the PSA was that if a person is not paying attention to the road while driving, say something.</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Youth Reckless Driving - Haunting&quot; 0:30</td>
<td>Ad Council Washington, DC <a href="http://www.adcouncil.org">www.adcouncil.org</a></td>
<td>A teenage passenger realizes the driver is trying to send a text message while driving. He then goes on to tell the driver that if he dies, he will come back to haunt him. The message for the PSA was that if a person is not paying attention to the road, say something.</td>
</tr>
<tr>
<td>5</td>
<td>&quot;On the Road, Off the Phone&quot; 0:30</td>
<td>National Safety Council and CTIA: The Wireless Association Washington, DC <a href="http://www.teendriver.nsc.org">www.teendriver.nsc.org</a>.</td>
<td>A teen is texting his friend while driving and is involved in a head on collision.</td>
</tr>
</tbody>
</table>

<p>| Table 2.1: Public Service Announcements (PSA) Focused on Driver Distraction |</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Publisher</th>
<th>Content</th>
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<tbody>
<tr>
<td>6</td>
<td>&quot;Regenerate PSA: LA DOT&quot; 0:30</td>
<td>Los Angeles Department of Transportation&lt;br&gt;Los Angeles, CA&lt;br&gt;www.watchtheroad.org</td>
<td>The PSA sarcastically narrates three types of driver: the texter, the one who talks on the phone, and the one who tries to eat, change a CD, and talk on the phone all at once. Each driver ends up crashing.</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Live to Drive Another Day - Teen Distraction&quot; 0:30</td>
<td>American Automobile Association (AAA) and Minnesota Safety Council&lt;br&gt;Saint Paul, MN&lt;br&gt;www.minnesotasafetycouncil.org</td>
<td>The PSA's message is to eliminate distractions so &quot;you and your best friend can live to text each other another day&quot;.</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Teen Driving and Distractions&quot; 0:30</td>
<td>All State Foundation and Florida Sheriff's Association&lt;br&gt;Orlando, FL&lt;br&gt;www.fsateendriverchallenge.com/</td>
<td>A sheriff talks about the different types of distractions that teens come across. They include music, cell phones, and friends.</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Texting While Driving is Deadly!&quot; 0:40</td>
<td>Prince William County&lt;br&gt;Woodbridge, VA&lt;br&gt;www.pwcgov.org</td>
<td>A little girl talks about how her best friend's sister was great at texting but died in a car crash as a result of it.</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Bye Bye Syndrome&quot; 0:30</td>
<td>Kids and Cars&lt;br&gt;Leawood, KS&lt;br&gt;www.kidsandcars.org</td>
<td>After saying goodbye to his family, a man gets into his car and starts drinking his coffee and talking on his cell phone. He was too distracted to know his little girl had run behind the car.</td>
</tr>
</tbody>
</table>

Table 2.1: Public Service Announcements (PSA) Focused on Driver Distraction (continued)
A major cause of teen fatalities and serious injuries when involved in a traffic crash is the lack of seatbelt use (NHTSA, 2005). Some excuses for not wearing them include discomfort, driving short trips, and fear of being trapped inside a car after a crash. To counter the discomfort issue, today’s seatbelt design gives you the ability to move freely until abrupt braking occurs. Also, during short trips, there is no guarantee that a crash will not take place as a result of another driver. Finally, if a car catches on fire or is submerged, the seatbelt may keep the driver from being knocked unconscious and, in turn, increase the driver’s chances of escaping without major injuries. Table 2.2 lists PSA’s which advocate seatbelt usage. A particular PSA, “Heaven Can Wait: Buckle Up” (#4), sends a powerful message using religion and seatbelt safety. Three teens are involved in a car crash, but only one has on a seatbelt. The souls of the two without seatbelts, left their bodies, but the soul of the restrained teen was held in by the seatbelt. PSA #9 ("Out of Nowhere-Seatbelt") approaches the consequence of not wearing a seatbelt from a different perspective. Namely, this is a "Click It or Ticket” PSA that emphasize the monetary effect of not wearing a seatbelt.
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Publisher</th>
<th>Content</th>
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<tbody>
<tr>
<td>1</td>
<td>&quot;No Seatbelt, No Excuse!!&quot; 1:32</td>
<td>Department of the Environment and AXA Insurance Ireland <a href="http://www.doeni.gov.uk">www.doeni.gov.uk</a></td>
<td>A group of four teens are involved in a head-on collision. Only three of the teens have on their seatbelts when a crash occurs. The passenger without a seatbelt ends up doing more damage to the other passengers than the impact of the crash. He ends up giving one the passenger’s brain damage from slamming into them.</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Belt Up Before You Kill Someone.&quot; 0:31</td>
<td>Government of South Australia and the Motor Accident Commission South Australia <a href="http://www.mac.sa.gov.au">www.mac.sa.gov.au</a></td>
<td>A mom is killed by the impact between herself and her son during a car crash. Her son was not wearing a seatbelt.</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Governor Jon Corzine's Seatbelt PSA&quot; 0:30</td>
<td>U.S. Department of Transportation Washington, DC <a href="http://www.dot.gov">www.dot.gov</a></td>
<td>Governor Jon Corzine discusses how his injuries as a result of a car crash could have been lessened had he been wearing a seatbelt.</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Heaven Can Wait, Buckle Up&quot; 0:44</td>
<td>Naval Safety Center Norfolk, VA <a href="http://www.safetycenter.navy.mil">www.safetycenter.navy.mil</a></td>
<td>Three teens are involved in a car crash, but only one has on a seatbelt. The souls of the two passengers with no seatbelt on left their bodies. However the soul of the teen with a seatbelt could not escape his body because of the restraint, so he survived the crash.</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Always Wear Safety Belts&quot; 0:30</td>
<td>Armed Forces Network Alexandria, VA <a href="http://www.afrts.dodmedia.osd.mil">www.afrts.dodmedia.osd.mil</a></td>
<td>A marine sergeant talks about wearing safety belts to protect valued assets: yourself.</td>
</tr>
</tbody>
</table>

Table 2.2: Public Service Announcements (PSA) Focused on Seatbelt Usage
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Publisher</th>
<th>Content</th>
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</thead>
<tbody>
<tr>
<td>6</td>
<td>&quot;Think! Three Strikes&quot;</td>
<td>Department for Transport United Kingdom</td>
<td>The government PSA shows graphic images of the fatal damage car crashes can cause to internal organs.</td>
</tr>
<tr>
<td></td>
<td>0:45</td>
<td><a href="http://www.dft.gov.uk/think">www.dft.gov.uk/think</a></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>&quot;Wear Your Seatbelt: &quot;Catapult&quot; PSA&quot;</td>
<td>Tennessee Governor's Highway Safety Office</td>
<td>The PSA indicates that catapulting on a seesaw is just as stupid as not wearing a seatbelt.</td>
</tr>
<tr>
<td></td>
<td>0:30</td>
<td>Nashville, TN</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.tdot.state.tn.us/ghso">www.tdot.state.tn.us/ghso</a></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>&quot;Think! - Backwards (Seatbelt)&quot;</td>
<td>Department for Transport United Kingdom</td>
<td>Three teens get a second chance to put on their seatbelts when they first enter the car. The first chance results were fatal because they did not buckle up.</td>
</tr>
<tr>
<td></td>
<td>0:40</td>
<td><a href="http://www.dft.gov.uk/think">www.dft.gov.uk/think</a></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>&quot;Out of Nowhere-Seatbelt&quot;</td>
<td>National Highway Traffic Safety Administration</td>
<td>This is a &quot;Click It or Ticket” PSA</td>
</tr>
<tr>
<td></td>
<td>0:30</td>
<td>Washington, DC</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.nhtsa.gov">www.nhtsa.gov</a></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>&quot;WTSC-Seatbelt Safety Ad&quot;</td>
<td>Washington Traffic Safety Commission Olympia, WA</td>
<td>This ad shows a real-life traffic crash that could have had a different result if the victims would have been wearing a seatbelt.</td>
</tr>
<tr>
<td></td>
<td>0:30</td>
<td><a href="http://www.wtsc.wa.gov">www.wtsc.wa.gov</a></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.2: Public Service Announcements (PSA) Focused on Seatbelt Usage (continued)
Speed management entails driving the appropriate speed for roadway and traffic conditions, such as construction zones, school zones, and inclement weather. Drivers should also adhere to speed limits and decrease speed when driving in potentially hazardous situations. Speeding usually occurs when the driver is in a rush. Therefore, patience and trip planning play a crucial role in speed management. The vehicle’s speed affects not only the severity of a crash, but also the risk of participating in a crash (Aarts and Schagen, 2006). Table 2.3 provides a list of PSA’s that campaign for drivers to obey the posted speed limit. PSA #2 ("The Faster the Speed, the Bigger the Mess") specifically focuses on the aforementioned point on how speed affects the severity of the crash. In this video campaign, a driver is speeding excessively and attempts to pass another driver. However, at this same instant, the other driver swerves in front of the speeding driver to avoid hitting a dog. The PSA emphasizes the consequences and suffering not only to the driver, but to innocent third parties when speeding.
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Publisher</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Stop Creeping&quot;</td>
<td>Government of South Australia and the Motor Accident Commission South Australia <a href="http://www.mac.sa.gov.au">www.mac.sa.gov.au</a></td>
<td>The PSA shows the consequences of creeping over the speed limit by emphasizing possible outcomes such as hitting pedestrians and car crash pile-ups.</td>
</tr>
<tr>
<td>2</td>
<td>&quot;The Faster the Speed, the Bigger the Mess&quot;</td>
<td>Department of the Environment in Northern Ireland and Republic of Ireland's Road Safety Authority Ireland <a href="http://www.doeni.gov.uk">www.doeni.gov.uk</a></td>
<td>A driver is speeding excessively and attempts to pass another driver. However, at this same instant, the other driver swerves in front of the speeding driver to avoid hitting a dog. The PSA emphasizes the risks of consequences and suffering not only to the driver, but to innocent third parties.</td>
</tr>
<tr>
<td>4</td>
<td>&quot;A 5 km/h Difference&quot;</td>
<td>Monash University Accident Research Centre Victoria, Australia <a href="http://www.monash.edu.au/muarc">www.monash.edu.au/muarc</a></td>
<td>Professor Ian Johnston of Monash University demonstrates the difference in stopping distances for two cars traveling at 65 and 60 km/h.</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Youth Reckless Driving Prevention - Horse&quot;</td>
<td>Ad Council Washington, DC <a href="http://www.adcouncil.org">www.adcouncil.org</a></td>
<td>A teen's cousin warns him that if he does not slow down, he will bite into his head like an apple. The message for this PSA was that if a person is speeding, say something.</td>
</tr>
</tbody>
</table>

Table 2.3: Public Service Announcements (PSA) Focused on Speed Management
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Publisher</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>&quot;Remember…It's Cheaper to Drive the Limit.&quot;</td>
<td>Georgia Office of Highway Safety and Georgia Safety Patrol Atlanta, GA <a href="http://www.drivesafegeorgia.org">www.drivesafegeorgia.org</a></td>
<td>The PSA shows a state patrol officer using a radar gun to catch speeders. A message, &quot;You Can't Out Run The Radar Gun&quot;, appears during the PSA.</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Live to Drive Another Day - Teen Speeding&quot;</td>
<td>American Automobile Association (AAA) and Minnesota Safety Council Saint Paul, MN <a href="http://www.minnesotasafetycouncil.org">www.minnesotasafetycouncil.org</a></td>
<td>The PSA tries to convey the difference between driving a video race car game and a real car. The message is that a real car does not have a reset button.</td>
</tr>
<tr>
<td>8</td>
<td>&quot;RTA Youth Speeding Advertisement&quot;</td>
<td>Roads and Traffic Authority Wales, United Kingdom <a href="http://www.rta.nsw.gov.au/roadsafety/speedandspeedcameras/campaigns">www.rta.nsw.gov.au/roadsafety/speedandspeedcameras/campaigns</a></td>
<td>A teen believes that everyone thinks he is cool for speeding, but he then realizes that everyone is making fun of him.</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Think!-Slow Down&quot;</td>
<td>Department for Transport United Kingdom <a href="http://www.think.dft.gov.uk/think">www.think.dft.gov.uk/think</a></td>
<td>The PSA emphasizes how much longer it takes to stop at just 5 mph over the speed limit.</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Stop Neighborhood Speeding&quot;</td>
<td>Atlanta Pedestrian Advocacy Organization Atlanta, GA <a href="http://www.peds.org">www.peds.org</a></td>
<td>A little girl poses the question &quot;What will it take for you to slow down in her neighborhood?&quot; She answers the question by getting hit by a car.</td>
</tr>
</tbody>
</table>

Table 2.3: Public Service Announcements (PSA) Focused on Speed Management (continued)
CHAPTER THREE

DRIVING SIMULATORS

An automotive driving simulator is a virtual reality device in which the operator feels as if they are actually driving a ground vehicle (Park et al., 2001). The degree of operator immersion is dependent on the integrated hardware and software which create the simulator system. It should be noted that the aviation and railroad industries have successfully used flight (Hosman et al., 2005) and railroad (Sandbald et al., 2000) simulators for training purposes and engineering design evaluations. Inspired by these specialized transportation simulators, the use of ground vehicle driving simulators for research and other purposes has increased (Lee et al., 1998, Green, 1998). In particular, vehicle manufacturers, automotive component suppliers, game developers, research universities, government agencies, and companies with fleet vehicles have embraced automotive simulators for a variety of reasons including occupant safety, vehicle performance, system validation, operator training, education, entertainment, and legislative efforts.

During the past few decades, automotive simulators have provided safe opportunities to recreate environments for various types of driver research, education, and training. These systems offer controlled experimental conditions, testing repeatability, ease of experimental changes through parameters or scenarios, cost efficiencies compared to in-vehicle experiments, and safety to drivers (Shiiba and Suda, 2007). Academic institutions use driving simulators for research and
development in areas such as engineering design and human factors, whereas companies with fleet vehicles often focus on education and training to improve overall driver competence. Organizations such as the U.S. Department of Transportation (USDOT), the National Highway Traffic Safety Administration (NHTSA), and the French National Centre for Scientific Research (CNRS), as well as automotive companies including Ford, Toyota, Honda, and General Motors have teamed with universities in collaborative simulator research activities. For example, NHTSA developed a sophisticated driving simulator, located at the University of Iowa, which caters to many interdisciplinary research issues (NADS, 2008). Other available driving simulators include the Ford’s VIRTTEX driving simulator (Ford, 2008), the Toyota Driving Simulator (Motor Trend, 2008), as well as the DriveSafetyTM and STISIMTM Drive simulators. In some instances, custom vehicle simulators have been developed in university laboratories to satisfy specific research needs (Mandhata et al., 2004, Gupta et al., 2001).

**Simulator Technology**

The complexity of driving increases the challenge of evaluating in-vehicle events. A driving simulator normally consist of five subsystems: a real-time vehicle simulation system executing the vehicle dynamics; motion, visual, and audio systems reproducing vehicle behavior, driving environment scenes, and noise sensed by a driver; a control force loading system which acts as an interface between the driver and the simulator; an operator console for monitoring system operation; and an information management system which coordinates data transfer among subsystems.
and synchronization (Lee et al., 1998). Each of these subsystems is contained in either the hardware and/or software of the driving simulator.

**Hardware**

The driving simulator hardware typically consists of the driver controls (e.g., pedals, steering wheel, gear select, etc.), computing systems, and components that aid in reproducing vehicle motion. These components comprise the physical characteristics of the simulator which allows the user to “feel” as if they are in a real car. Figure 3.1 illustrates an overview of the typical driving simulator technology. The operator (driver) selects inputs through the simulator hardware, which are in turn supplied to the digital I/O (DIO) or the analog-to-digital converter (ADC) channels for computer processing. After the inputs are processed, the output signals are sent through the digital-to-analog converter (DAC) or the DIO channels to the operator (driver).
Driving simulators can feature either a fixed-based or motion-based platform. A fixed-based driving simulator has no platform movement and subsequently, lower levels of required technical support which make them suitable for use in many training and entertainment venues. In contrast, motion-based driving simulators can range from one to six degrees of freedom (longitudinal, lateral, bounce, roll, pitch, yaw) with electric, hydraulic, and/or pneumatic actuators. The most common type of field application is research and development within industry, education, and government agencies due to their complexity and engineering support requirements.

**Software**

Real-time executing software that provides the vehicle dynamics, projected environment scenarios, and data acquisition are essential to an effective driving
simulator (refer to computer block in Figure 3.1). Accurate vehicle dynamics and user-defined test scripts with traffic and specific automotive platforms assist in the creation of believable, immersive environments. The driving simulator algorithms are also responsible for feedback and motion cueing in concert with the simulator hardware. Finally, the software must have integrated safety features (especially in motion-based driving simulators) to ensure occupant safety.

**Driving Simulator Applications**

Automotive simulators have been applied in research, development, education, training, assessment, licensing, certification, and entertainment (Allen et al., 1999). Industries use driving simulators for training; whereas, most colleges and universities apply simulators for research. Some of the automotive research involving driving simulators consists of vehicle system development, safety improvement, and human factors engineering studies (Lee et al., 1998). The complexity of the driving simulator and its interaction with research studies is shown in Figure 3.2. For example, a complex motion-based driving simulator may be needed for vehicle development in comparison to driver education and training (Figure 3.2a). However, human immersion (i.e., human-interface interaction) with the driving simulator is important for driver education and training since it must replicate a vehicle to the operator. The inverted pyramid (Figure 3.2b) displays the research that may be typically performed using an actual vehicle. The use of automobiles is more likely for vehicle development activities than human factors engineering research due to safety and cost concerns in the latter.
Vehicle Development

Driving simulators are often used for developing and improving vehicle subsystems. Shiiba and Suda (2007) developed a multibody-based driving simulator for vehicle analysis. The effects of suspension geometry and the mechanical characteristics of the vehicle’s components can be evaluated before any prototyping using multi-body analysis. The driving simulator had a six-axis motion-based platform which emulated the lateral acceleration of an automobile in cornering, and longitudinal acceleration in braking and accelerating. The vehicle dynamics calculation was performed by two PCs – real time multi-body dynamics calculation; and engine, transmission, brake, and tire/road forces calculations. Three computers were used to create the graphics, control the motion system, and generate the steering
reactive force. Chen and Ulsoy (2006) evaluated the use of a steering assistant controller to reduce vehicle road departure crashes. A desktop computer based driving simulator was applied in the research. The steering wheel featured a commercially available force feedback game pad from Microsoft.

**In-Vehicle System Design**

A number of in-vehicle systems provide drivers with information and services to assist in the operation of their automobile. Vashitz _et al._ (2008) used a driving simulator to evaluate the safety benefits and risks of in-vehicle displays for driving in long tunnels. The variables measured in the experiment included driving performance, distraction, mental workload, and physiological characteristics. Fifteen participants experienced three driving sessions: high-information display, low-information display, and no display. The authors concluded that in-vehicle systems improve safety and their benefits offset their distraction. This study was completed using a Systems Technology, Inc. (STI) STISIM fixed-based simulator featuring a 1995 Rover sedan. The virtual simulation tunnel was presented on a wide screen in front of the vehicle. A number of loud speakers were placed around the vehicle to create the necessary audio experience. Takayama and Nass (2008) investigated in-car vehicle services (traffic and road conditions, navigation assistance, weather) and concluded that they were highly favored among drivers. A STI driving simulator was again used which featured a rear projection screen, a gas pedal, a brake pedal, a forced feedback steering wheel, and a driver’s seat.
A study by Hatfield and Chamberlain (2008) examined the effect of radio and audio sounds from an audio visual entertainment system on drivers. The authors concluded that these in-vehicle systems do not pose a serious risk on driver safety. Using a driving simulator, twenty-seven participants completed vehicle drives under three different conditions: without audio materials, with audio materials from a movie, and with audio materials from a radio. The driving simulator consisted of a car body with a steering wheel, an automatic transmission, and accelerator and brake pedals. Visual scenes were projected on three screens, providing a 135º field of view. Engine noise, tire screeches, and collision sounds were provided by the STI simulator software.

**Psychology and Human Factors Research**

One popular research topic utilizing driving simulators is the examination of the behavior of drivers in various age brackets. Young *et al.* (2008) used a driving simulator to measure the effects of eating and drinking while driving. In this study, a driving simulator was fixed-based with a Ford Mondeo as the chassis. The vehicle’s original controls were connected to a computer, running STISIM Drive software version 2.06.04. A haptic feedback steering wheel was integrated into the steering column, and audio was produced in Dolby Pro Logic with a low frequency subwoofer placed under the car for vibration. The computer was equipped with a 1.2 GHz processor, CreativeT 3D video and audio cards, and NVIDIA GEForce2GTST hardware. The visual scene was projected onto a large forward screen at 1024x768
pixel resolution. The field of view was at the driver’s eye point of approximately 60º horizontal and 40º vertically.

Boyle et al. (2008) examined whether individuals with obstructive sleep apnea syndrome (OSAS) had impairments in driving performance. A STI selected simulator offered a fixed-based with a 150º forward view and a 50º rear view. The components were a game controller steering wheel, accelerator pedal, brake pedal, and a LCD monitor to display the roadway scenes. The authors noted the effects of distraction and experience on situational awareness.

**Education and Training**

The use of automotive driving simulators for education and training assessment is becoming more common for novice, as well as older drivers. Driving simulators offer a safe and controlled environment for driver education and training. Further, actual driving is often harder to measure than simulated driving. Allen et al. (2003) developed an assessment and training platform using a low cost driving simulator. Their PC-based simulator allowed training sessions to be executed outside the laboratory. For example, fleet drivers were subject to driver simulator training.

**Traffic Control Improvements**

Improvements in traffic control may help reduce crashes due to poor traffic flow designs. Research completed by Harb et al. (2007a), using the driving simulator acquired by the Center for Advanced Traffic and Transportation System Simulation at the University of Central Florida, concluded that a traffic signal pole on the right side
of the road would reduce the incidence of red light running. The premise of this experiment was based on the assumption that larger sized vehicles blocked the vertical visibility of smaller passenger cars.

A second study was completed by Harb et al. (2007b) that examined the contribution of light truck vehicles to rear-end collisions. The simulator car (Saturn sedan) was mounted on a motion-based platform with six degrees of freedom, and included five channels of image generation: one forward, two side views, and two mirror views. It also consisted of steering wheel feedback and an audio (vibration) system. The simulated environment was projected at 180º field of view with a 1280x1024 resolution. Using the same driving simulator, Yan et al. (2007) undertook a study on the effects of traffic speed, driver age, and driver gender on major road left-turn traffic gap acceptance. It was concluded that all three of these factors have significant effects on gap acceptance. However, when only considering age, older drivers appeared to have to have a more conservative gap acceptance level.

**Entertainment**

The use of driving simulators for entertainment creates a more realistic visual user environment. Traditional arcade entertainment, such as the SEGA Daytona 2 USA driving arcade game, offer a driver interface composed of pedals, steering wheel, and a video screen in a small vehicle cab (Sega, 1998) In contrast, “at home” games usually contain hand held input mechanisms with scenes rendered on a television. In each instance, user feedback is often limited or nonexistent and rarely contains real world variables. Furthermore, these simulators typically provide
excellent graphics and sounds for motorsports racing without accompanying true vehicle dynamics. Nevertheless, young adults are aware of the possible realism and may demand it in other vehicle simulators. A relatively new type of racing called “sim racing” has replaced the arcade objective to provide a sense of speed with greater realism. Companies such as EA SPORTS attempt to accurately simulate auto racing complete with variables such as fuel usage, damage, tire wear, tire grip, and suspension settings in their NASCAR SimRacing product. Overall, most driving simulators used for entertainment are fixed-based platforms.

**Case Study: Three Driving Simulators**

The overall performance of three driving simulators was investigated for the following nine characteristics: ease of use, user-interface, motion/vision agreement, vehicle dynamics, haptic feedback, traffic scenarios, realism, mobility, and programmability. Each simulator was driven and evaluated for similar driving patterns by the research team.

The DriveSafety simulator (refer to Figure 3.3) was a fixed-based driving simulator built around a four-door sedan. The simulator may be used to explore three aspects in human behavior: perception, cognitive processing, and judgment and decision making. The simulator has six visual channels (five forward and one rear) that each offer a 50º field of view and automatic transmission controls (Broughton *et al.*, 2007). The DriveSafety simulator was easy to operate, and offered a realistic user interface (actual vehicle cabin). However, motion sickness may be an issue when driving this simulator for some operators. Further, the vehicle dynamics on this
simulator are adequate but not particularly strong. The driving simulator software did not appear to be open to customization, but the traffic conditions and surrounding scenery were sufficient for its use in most scenarios.

Figure 3.3: DriveSafety Simulator Psychology Department, Clemson University

The STISIM Drive simulator (refer to Figure 3.4) is a fixed-based desktop driving simulator. It is primarily used for human factors and automotive engineering research but offers additional research and education opportunities. The system was ready for custom programming and offered a relatively easy to operate computer interface. The vehicle dynamics for the simulator were quite strong; however, the haptic feedback was minimal. The simulator has three screens which offer a 135° field of view to the operator. The driver controls consisted of a steering wheel, brake
pedal, and throttle pedal located on a table and the floor (as tested). Motion sickness was minimized with this simulator due to good visual cues.

Figure 3.4: STISIM Drive Simulator Industrial & Systems Engineering Department, North Carolina A&T University

The real-time reconfigurable steering simulator, shown in Figure 3.5, was a fixed-based (recently upgraded to one degree of motion) driving simulator that emulates the behavior of automotive steering simulators and supports system design studies (Iyasere et al., 2007). The simulator features the front half of a 2002 Honda CRV with a high fidelity haptic feedback steering system to emulate hydraulic, electric, and steer-by-wire components. A feedback electric motor was located under the steering wheel and an electronic power steering rack and pinion system may be placed under the hood. The steering simulator was user friendly, and contains a
realistic user interface. Motion sickness was not a common issue but has occurred for some test subjects. The vehicle dynamics (CarSim) on this simulator were excellent and a requirement for its automotive engineering design use. The driving simulator was customized and therefore programmable, however, the traffic scenarios were poorly designed and must be created by the user.

Figure 3.5: Steering Simulator with Motion Platform Located in the Mechanical Engineering Department, Clemson University

Table 3.1 summarizes the evaluations for these three driving simulators. As stated previously, a series of nine features, placed into three different categories, were considered. The hardware capabilities (e.g., ease of use, user interface, motion and vision agreement) determine how well the driving simulator looks and feels like an actual vehicle. The software characteristics (e.g., vehicle dynamics, haptic feedback,
traffic scenarios) combined to create the virtual environment. Finally, the general features (e.g., realism, mobility, programmability) depend on the development and envisioned purpose of the simulator. The driving simulators were scored based on their intended uses by the research team. Overall, the three simulators offer acceptable driving environments targeted to different audiences. However, it is not clear whether one can provide a complete solution to the diverse automotive community.

<table>
<thead>
<tr>
<th>Category</th>
<th>Feature</th>
<th>DriveSafety</th>
<th>STISIM</th>
<th>Steering SIM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardware</strong></td>
<td>Ease of Use</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>User Interface</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Motion/Vision Sync.</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td><strong>Software</strong></td>
<td>Vehicle Dynamics</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Haptic Feedback</td>
<td>5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Traffic/Scenario</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td>Realism</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Programmability</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mobility (Relocation)</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3.1: Driving Simulator Comparison As Evaluated by the Research Team (1 - Fair, 3 - Good, 5 - Excellent)

Automotive simulator technology is improving each year. Although a global solution for driving simulators does not yet exist, there are customizable simulators available. The opportunity to develop a standard driving simulator for driver training remains an open issue. The minimum tools needed to accomplish tasks in the general areas of human factors research, vehicle development, and driver education and training are illustrated in Figure 3.6. The equipment requirement for human factors engineering research can typically be performed using a driving simulator, whereas vehicle development may require a driving simulator and an actual in-vehicle
assessment. In contrast, driver education and training typically requires classroom reinforcement prior to, and in-vehicle exposure after the simulation lesson to ensure adequate learning. A desirable goal would be to develop a driving simulator that mimics in-vehicle driving and allows classroom reinforcement through education scripts. It can be used as a tool for practice and training of basic driving skills, which is illustrated in Chapter 4. It is the most effective driving training tool that not only improves driver’s skill level, but it can also be cost effective (Yang et. al, 2007).

![Diagram](image)

Figure 3.6: Desired Simulator Capabilities for Human Factors, Vehicle Development, and Driver Learning

The suggested basic simulator functionality includes three fundamental ingredients:

- **Inputs (4 channels):** Brake, throttle, steering, and gear select
- **Outputs (3 channels):** Haptic steering wheel, single video screen, and vehicle speed instrument panel display
- **Cab of vehicle with seat belt (not motion-based)**
It is very plausible to have the simulation technology facilitate lessons, followed immediately by driving exercises to practice the given educational concept. An actual in-vehicle activity may also take place with a driving instructor to strengthen the learning experience. In summary, driving simulators offer a safe and controlled environment, yet require a standardized curriculum to accompany its training capabilities for driver education needs.
CHAPTER FOUR

AUTOMOTIVE SIMULATOR BASED NOVICE DRIVER TRAINING WITH ASSESSMENT

Automotive driving simulators are widely used research tools for universities, automotive manufactures, and government agencies, as previously discussed in Chapter Three. Using them for driver training activities is another viable option, given their ability to provide standardization and safe data collection (Hoffmann and Buld, 2006). For instance, Brandness and Sealy (2004) introduced a driving program that delivered training to novice drivers using a portable computerized driving simulator. The feasibility of using custom virtual hardware-in-the-loop training modules, based on the DriveSafety driving simulator’s limitations and evaluation of gathered driver databases, for a safe driving program will be investigated in this chapter.

The two virtual driving training modules, “Following Etiquette” and “Situational Awareness”, were designed to reinforce and practice driving methods in support of an advanced driver training curriculum. According to the National Highway Traffic Safety Administration (2009), rear-end collisions account for 23% of all traffic crashes. The “Following Etiquette” module teaches a basic timing method that allows a driver to maintain the proper following distance behind a lead vehicle. The purpose of this training exercise was to instruct students how to implement the “three second rule”, which states that a safe distance in time (assuming
uniform speeds) between two vehicles is three seconds (Nationwide, 2009). Implementing this rule requires knowledge of the “timing method”. This concept consists of the student counting the number of seconds required before passing a fixed object (i.e., tree, pole, etc.) on the side of the road after the vehicle in front of him/her has already passed that same object. In the “Following Etiquette” module, the recommended fixed object was a highway marker on the side of the road.

The “Situational Awareness” module allows the student to practice obstacle avoidance techniques and emergency maneuvers. According to the American Automobile Association (2009), novice drivers typically have not developed the ability to identify hazards and foresee likely events on the roadway. Drivers may encounter a wide range of road obstacles during routine driving adventures. One strategy is to look in the distance for select cues that allow him/her to prepare in advance to identify and avoid an obstacle in a safe manner (Garay-Vega et al., 2007). The purpose of this training module was to teach novice drivers to practice recognizing hazardous situations by using select roadway environmental cues and complete avoidance steering maneuvers (i.e., steer around a roadway hazard). For instance, a “deer crossing” sign or tree thicket (forest area) enables drivers to anticipate the possibility of a deer (or other animal) crossing in front of their cars. A surrounding environmental cue would be a child playing with a ball in a front yard or a dog standing on a side walk. There is always a potential for the ball, dog, or child to enter the roadway, so the driver should be on high alert in these instances. In summary, the obstacles presented in the “Situational Awareness” module, were
chosen to represent common driving situations and available within the simulator library.

**Virtual Driving Module Development**

The driving simulator (refer to Figure 4.1) applied in this study is located in the Psychology Department at Clemson University (Brackett Hall). The DriveSafety partial cab research simulator (DS-250c) features five front and side projection screens, two side mirrors with displays, and a rear view mirror with a display. The main driver inputs include the steering wheel, brake pedal, throttle pedal, and gear select. As mentioned in Chapter 3, these driver controls are essential for an effective and realistic training experience. The simulator features two programs to create and execute driving scenarios. First, the scenario software offers a broad selection of roads, vehicles, and landscapes (DriveSafety, 2009). Developing a scenario involves selecting the road types (e.g., urban, rural, highway), autonomous vehicle types (e.g., sedan, SUV, motorcycle) and other objects (e.g., animals, pedestrians, signs), and then placing them into a creation palette. Second, the surrounding vehicles and roadway/environmental objects can be scripted to complete desired actions using the Tool Command Language (TCL). A typical driving scenario may often be created within a single day by an experienced DriveSafety user.
“Following Etiquette”

The “Following Etiquette” module applies a five step learning process that each student must complete. First, a student watches a 30 second video that introduces the training module. This video instructs the driver to follow a lead car and maintain what he/she believes to be a safe distance. Second, the driver uses the simulator to follow a lone yellow sedan scripted to achieve a speed of 70 mph (112.65 kph) on a four-lane highway (two lanes per direction) with a concrete barrier. Third, the student then watches another 75 seconds video explaining the “Timing Method”. Fourth, the driving simulator was then used to administer a training session on implementing the “Timing Method”. Help messages (refer to Figure 4.2) were embedded in the exercise to guide the student. If the driver is following behind the lead vehicle at an integral greater than three seconds, then “too far” displays on the center simulator screen. If the driver is less than three seconds away from the lead
vehicle, then “too close” appears on the center simulator screen. Fifth, after the training session, the student drives the simulator one more time to capture his/her understanding of the method.

Figure 4.2: Help Messages (“Too Far”/“Too Close”) for Driving Simulator Study Student in “Following Etiquette”

The key data collection variables (refer to Table 4.1) include the student’s headway time and velocity, the lead car’s velocity, and the driving simulator’s run time. The first run and the last run were statistically compared to determine if the training session was effective.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headway Time</td>
<td>h</td>
<td>Time (sec) from lead vehicle</td>
</tr>
<tr>
<td>Subject Velocity</td>
<td>v_S</td>
<td>Driver’s velocity (m/s)</td>
</tr>
<tr>
<td>Lead Car Velocity</td>
<td>v_L</td>
<td>Lead vehicle’s velocity (m/s)</td>
</tr>
<tr>
<td>Time</td>
<td>t</td>
<td>Time (sec) it takes to complete exercise</td>
</tr>
</tbody>
</table>

Table 4.1: Table of the Key Data Collection Variables Used to Assess the “Following Etiquette” Virtual Module

“Situational Awareness”

The “Situational Awareness” training module entailed two identical simulator driving scenarios that were accompanied by training videos that highlighted different
learning concepts within a four step process. First, the student watched a video (15 seconds) that was somewhat ambiguous with an expert simply instructing the student to react to certain driving scenarios (described below) which they may encounter during the module. Second, the student drove the driving scenario described in the first video using the DriveSafety simulator. Third, the student watched a 60 second video informing them to look for certain environmental cues to better prepare them for the hazardous scenarios encountered during the first run. Fourth, the student then drove the previous driving scenario again while implementing the suggestions from the second video.

The three virtual driving environment scenarios within this training module require the student to avoid a deer, a dump truck entering the roadway, and a dog. Each scenario contains a cue to alert the driver. The student starts on a two lane rural road with a posted speed limit of 55 mph (88.51 kph). The first cue for the driver is a “deer crossing” sign. A deer is scripted to run across the road from the right side (refer to Figure 4.3) when the driver is approximately four seconds away.
The second scenario takes place in a construction zone (warning sign cue) with a speed limit of 45 mph (72.42 kph). A dump truck enters the roadway from the construction site (refer to Figure 4.4) and cuts the driver off by making a left turn from the right lane to travel to the other side of the road. Ideally, the driver must perform a quick maneuver to avoid hitting this dump truck.
The third and final scenario occurs in a residential area with a 25 mph (40.23 kph) speed limit. The student should avoid hitting a dog that runs across the street from the left side (refer to Figure 4.5). The scenario features pedestrians on the sidewalk which serve as an environmental cue for the driver to slow down. The simulation program does not allow pedestrians to enter the roadway to avoid the emotional consequence of striking a virtual person.
The key data collection variables (refer to Table 4.2) included the subject vehicle’s velocity, acceleration, lane position offset, steering angle offset, the percent braking, and the driving simulator’s run time.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject Velocity</td>
<td>v</td>
<td>Driver velocity (m/s)</td>
</tr>
<tr>
<td>Subject Acceleration</td>
<td>a</td>
<td>Driver acceleration (m/s²)</td>
</tr>
<tr>
<td>Subject Lane Position</td>
<td>y</td>
<td>Lane offset (m)</td>
</tr>
<tr>
<td>Subject Steer Angle</td>
<td>δ</td>
<td>Steering Input in degrees</td>
</tr>
<tr>
<td>Subject Brake</td>
<td>b</td>
<td>Normalized braking percentage</td>
</tr>
<tr>
<td>Time</td>
<td>t</td>
<td>Time (sec) it takes to complete exercise</td>
</tr>
</tbody>
</table>

Table 4.2: Table of the Key Data Collection Variables Used to Assess the “Situational Awareness” Virtual Module

**Pilot Study and Results**

A pilot study was performed to test the feasibility of the developed virtual training modules; the participants were Clemson University students (ages 18-25). According to the National Highway Traffic Safety Administration (2009), this age group has the highest number of fatalities and injuries as a result of traffic crashes. The Clemson University Institutional Review Board (IRB) approved documents for this study are located in Appendix A. The students were given a pre- and post-questionnaire which asked specific questions pertaining to the items taught in the training modules. The questionnaires provided a baseline of the content administered. Students received no verbal instruction from the examiner other than to watch the videos and drive the simulator; the majority of information was delivered by the training videos (Appendix G) and instructions from the driving simulator (i.e., help messages for “Following Etiquette”).
Four students were asked to participate in a preliminary study prior to the pilot study to make sure useful data could be gathered and analyzed from the developed training modules. As a result, the “Following Etiquette” module was slightly altered by eliminating all autonomous vehicles. The other vehicles had forced the lead car to change lanes, causing a glitch in data collection. The “Situational Awareness” module was drastically changed. Instead of two completely different training scenarios, identical scenarios were used throughout the study. A practice run was also added to let the test subjects become familiar with the driving simulator and to serve as a base run for the second module. The questionnaires and the students’ results have been placed in Appendix B. One of the original twelve subjects experienced a computer data collection malfunction, so an additional person had to be tested.

“Following Etiquette” Results

The “Following Etiquette” module was analyzed using each student’s headway time, $h$. It was expected that the student’s performance for the second run would improve from the first run. The results for this module are presented in Table 4.3. The relationships to calculate the student’s average headway time, $\mu_h$, and the standard deviation, $\sigma_h$, were

$$\mu = \frac{1}{n} \sum_{i=1}^{n} h_i$$  \hspace{1cm} (4.1)

$$\sigma = \sqrt{\frac{1}{n} \sum_{i=1}^{n}(h_i - \mu)^2}$$  \hspace{1cm} (4.2)
where \( n \) represents the number of total headway times acquired during data collection and \( i = 1, 2, \ldots, n \). In other words, the \( \mu_h \) for a 90 second run with a sampling rate of \( \Delta t = 0.0167 \text{s} \) results in \( n \approx 5390 \) data points. The subjects’ \( \mu_h \) for Runs 1 and 2 are presented in Columns 2 and 3 of Table 4.3, and the subjects’ \( \sigma_h \) have been listed in Columns 4 and 5.

The student’s headway error time, \( e \), and peak error, \( e_{peak} \), may be calculated as

\[
e_i = 3.0 - t_i \quad (i = 1, 2, \ldots, n)
\]

(4.3)

\[
e_{peak} = \max |e_i| \quad (i = 1, 2, \ldots, n)
\]

(4.4)

where the desired headway time is 3.0 seconds as previously discussed. Therefore, any time above or below 3.0 seconds provided an error value. The subjects’ peak errors, \( e_{peak} \), are listed in Columns 6 and 7 for both runs. Finally, the integral error (refer to Columns 8 and 9) has been calculated as \( \int e \, dt \) which reflects the total elapsed error for a simulator run. The smaller the integral, the better the driver performed.

The percentage of improvement, \( \% \text{ IMP} \), was also calculated as

\[
\% \text{ IMP} = \left( \frac{e_{\text{peak}_1} - e_{\text{peak}_2}}{e_{\text{peak}_1}} \right) \times 100
\]

(4.5)

to measure the student’s performance between Runs 1 and 2. This metric has been presented in Column 10 of Table 4.3.
The student was assigned a *fail* (F), *pass* (P), or *conditional pass* (CP) (refer to Column 12) based on how well he/she did on the second run. The mathematical foundation of these classifications are

\[
\begin{align*}
&\text{If } \mu < 2.5; \quad \text{Fail (F)} \\
&\text{If } 2.5 \leq \mu \leq 3.5; \quad \text{Pass (P)} \\
&\text{If } \mu > 3.5; \quad \text{Conditional Pass (CP)} \\
\end{align*}
\]

(4.6)

The threshold values 2.5s and 3.5s correspond to 256.82 ft (78.28 m) and 359.42 ft (109.55 m) at 70 mph (112.7 kph) respectively, which are the distances away from a lead car. If the stopping distance, \(d\), is given by expression

\[
d = \frac{v^2}{2\mu g}
\]

(4.7)

where \(\mu_k = 0.8\) and \(g = 32.2 \text{ ft/s}^2 (9.81 \text{ m/s}^2)\), at 70 mph (112.7 kph), then it will require a driver approximately 206.69 ft (63 m) to stop (not including the reaction time).
### Simulator Data

| Subject  | $\mu_h$ | $\mu_h$ | $\sigma_h$ | $\sigma_h$ | $e_{\text{peak}}$ | $e_{\text{peak}}$ | $\int |e| \ dt$ | $\int |e| \ dt$ | % IMP | Rule Knowledge | P/CP/F |
|----------|---------|---------|-----------|-----------|-------------------|-------------------|----------------|----------------|-------|----------------|--------|
| PS5      | 2.91    | 2.11    | 1.82      | 0.51      | 2.73              | 1.79              | 139            | 74             | 34    | No             | F      |
| PS6      | 1.32    | 1.54    | 0.45      | 0.25      | 2.19              | 1.90              | 138            | 120            | 13    | No             | F      |
| PS8      | 2.78    | 1.93    | 1.15      | 0.25      | 1.93              | 1.83              | 86             | 84             | 5     | No             | F      |
| PS9      | 2.35    | 2.52    | 0.71      | 0.38      | 1.71              | 1.35              | 68             | 41.83          | 21    | No             | P      |
| PS10     | 2.90    | 2.80    | 0.83      | 1.28      | 1.53              | 2.42              | 60             | 95             | -58   | Yes            | P      |
| PS11     | 6.68    | 3.18    | 1.75      | 0.40      | 5.26              | 0.99              | 307            | 28             | 81    | No             | P      |
| PS12     | 5.37    | 2.90    | 1.10      | 0.60      | 4.00              | 1.28              | 195            | 41             | 68    | No             | P      |
| PS13     | 2.33    | 2.86    | 0.43      | 0.83      | 1.51              | 1.63              | 59             | 61             | -8    | Yes            | P      |
| PS14     | 1.45    | 3.30    | 0.31      | 0.67      | 2.13              | 1.58              | 127            | 49             | 26    | No             | P      |
| PS15     | 1.09    | 2.17    | 0.35      | 0.31      | 2.43              | 1.78              | 157            | 68             | 27    | No             | F      |
| PS16     | 3.47    | 3.40    | 0.66      | 0.73      | 1.35              | 1.76              | 58             | 57             | -30   | Yes            | P      |
| PS17     | 0.70    | 2.78    | 0.24      | 0.86      | 2.52              | 2.11              | 188            | 83             | 16    | No             | P      |

Table 4.3: Human Subject Test Results for “Following Etiquette” Module reflects the Percentage Improvement for Peak Headway Error between Run 1 and Run 2 While the Fail/Pass/Conditional Pass Reflects Run 2 Average Headway Time
Previous knowledge of the “3 Second Rule” was indicated on the Pre-Questionnaire (Questions 8: “Please explain how you determine a safe following distance.”) and presented in Column 11 of Table 4.3. If the student indicated that he/she used the “3 Second Rule” then that driver was noted for having knowledge of the rule. As expected, 100% of the students (PS10, PS13, and PS16) that had previous knowledge of this rule passed the training exercise. A little over half (56%) of the students (PS9, PS11, PS12, PS14, and PS17) that had no knowledge of the rule, also passed the simulator exercise. However, the rest (33%) of the students (PS5, PS6, PS8, and PS15) continued to follow too closely even after the training and failed.

Data for three representative students (PS6, PS14, and PS16) are highlighted in Table 4.3. Pilot study subject 6 (PS6) was a student with no knowledge of the three second rule and who dangerously followed too closely to the lead car both before and after the training session ($\mu_h = 1.32$ and 1.54s). PS14 was a student with no knowledge of the rule and who followed too closely ($\mu_h = 1.45$s) before knowledge of the rule but maintained a safe distance ($\mu_h = 3.30$s) after knowledge of the rule. PS16 was a student with previous knowledge of the rule and maintained a safe distance both before and after the training session ($\mu_h = 3.47$ and 3.40s). The three subject’s graphical results are represented in Figures 4.6 through 4.8. The rest of the participating students’ graphical results are listed in Appendix E.

The subject velocity, $v_S$, lead car velocity, $v_L$, and subject headway time, $t_H$, for PS6 is represented in Figure 4.6. As illustrated in the Table 4.3, the student maintained a headway time that was well below the desired magnitude in both runs.
The student maintained a headway time of approximately 1.50 seconds from \( t=30s – 60s \). This largely contributes to the average headway time of \( \mu_h = 1.32 \) and 1.54s for each run and explains why he/she acquired a failing score. Finally, the student’s speed patterns were similar for both runs which may explain why the average headway time for Run 1 and Run 2 were consistent.

Subject PS14 was an ideal candidate for this training program. The student had no prior knowledge of the rule and it was demonstrated in the first run (i.e., \( \mu_h = 1.45s \)). However, in the second run, the student maintained a headway time that was very close to the desired headway time (i.e., \( \mu_h = 3.30s \)) and acquired a passing score.
For example, at $t = 40s$, the headway time was approximately $h = 1.10s$ and $h = 3.20s$ for Run 1 and Run 2, respectively. Also, unlike in Run 1, the student decreased his/her velocity between $t = 40$ to $50s$ in Run 2 to maintain a safe following distance. This result clearly demonstrates that the virtual reality training program fulfilled its purpose for subject PS14.

![Figure 4.7: Subject PS14 Following Etiquette Results for Run 1 and Run 2](image)

Subject PS16 indicated knowledge of the “three second rule” (Rule Knowledge = Yes) and effectively applied that knowledge for both runs (i.e., $\mu_h = 3.47s$ and 3.40s). The average headway times, as well as the velocity curves, are very similar between the two runs. The student effectively implemented the rule for both runs and acquired a passing score. At $t = 30$ to $80s$, the student speeds up after
noticing he/she is falling behind and slows up as he/she approaches the recommended distance. The student has actually reached the target 3 seconds a little before $t = 16$s.

![Graph showing headway time and velocity](image)

Figure 4.8: Subject PS16 Following Etiquette Results for Run 1 and Run 2

“Situational Awareness” Results

The “Situational Awareness” module was evaluated using the students’ peak acceleration, $a_{peak}$, and peak steering angle, $\delta_{peak}$, for Run 2. The results for this module are presented in Tables 4.4 and 4.5. The deceleration, $-a_{peak}$, value determined whether the student eased off the brake or made a “panic” or hard stop (Columns 4, 7, and 10 in Table 4.5). The steering angle, $\delta$, pertained to how smoothly the driver turned the steering wheel during the module. This factor also indicatively informed the evaluator whether or not the student looked and planned ahead while driving.
Specifically, a long view should result in small steering angles, while a short perspective causes the driver to not see the hazards in advance and shall require large steering angles to avoid them.

The performance for each student was evaluated via Run 2 using the criteria

\[
\{ \begin{array}{c}
< \theta < \theta' \\
\end{array} \} \tag{4.8}
\]

where \( g = 32.2 \text{ ft/s}^2 (9.81 \text{ m/s}^2) \) and \( g_{\text{peak}} = \frac{a_{\text{peak}}}{g} \). The level for acceptable \( g \)'s was set by the evaluation team based on the panic stopping expressions

\[
a_{\text{peak}} = \mu_k g, \quad F = \mu_k N \tag{4.9}
\]

where \( \mu_k \) is the road force coefficient of friction. For a dry road surface with \( \mu_k = 0.75 \), then \(|g_{\text{peak}}| = 0.75\) represents a stopping distance scenario that does not require the full friction available and gives the driver an additional margin of safety.

| Subject | Run 1 Deer | y T/B | DT | T/B | Dog | y T/B | y T/B | Run 2 Deer | Dog | | | | Pre-Questionnaire Self Rating |
|---------|------------|--------|-----|-----|-----|--------|--------|------------|-----|-----|-----|-----|-------------------------------|-----|
| PS5     | 0.37       | T 1.72 B 0.11 | B | 0.05 | B | 0.54 | 0.54 | 0.79 | 0.87 B | Above Average | Outstanding |
| PS6     | 0.91       | B 1.80 | -0.18 | B | 0.34 | B | 0.64 | 0.64 | Average | Above Average |
| PS8     | -0.26      | B -0.65 | 0.39 | B | -0.90 | B | 0.44 | 0.44 | Average | Above Average |
| PS9     | 0.58       | B -0.65 | 0.39 | B | 0.37 | B | 0.37 | 0.37 | Average | Above Average |
| PS10    | 0.81       | B -0.59 | 0.61 | B | 0.44 | B | 0.44 | 0.44 | Average | Above Average |
| PS11    | -0.34      | B -1.77 | -0.19 | B | 0.22 | B | 0.22 | 0.22 | Average | Above Average |
| PS12    | -0.44      | B -0.59 | 0.46 | B | 0.46 | B | 0.46 | 0.46 | Average | Above Average |
| PS13    | 0.08       | B -0.87 | 0.27 | B | 0.87 | B | 0.87 | 0.87 | Average | Above Average |
| PS14    | -0.16      | B -0.22 | 0.48 | B | 0.48 | B | 0.48 | 0.48 | Average | Above Average |
| PS15    | -0.32      | B -0.35 | 1.60 | B | 0.77 | B | 0.77 | 0.77 | Average | Above Average |
| PS16    | -0.28      | B -2.70 | 0.34 | B | 0.49 | B | 0.49 | 0.49 | Average | Above Average |
| PS17    | -0.44      | T -0.54 | 1.66 | T | 0.79 | T | 0.79 | 0.79 | Above Average | Above Average |

Table 4.4: Run 1 and Run 2 Lane Offset for Each Object, Throttle/Brake Results, and Self Rating from Pre-Questionnaire
### Table 4.5: Base Run, Run 1, and Run 2 Steering Smoothness, Peak Steering Angle, Peak Acceleration, and Percentage Improvement for Steering Smoothness, Peak Steering Angle, and Peak Acceleration (Run1 and Run 2)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Base Run</th>
<th></th>
<th></th>
<th>Run 1</th>
<th></th>
<th></th>
<th>Run 2</th>
<th></th>
<th></th>
<th>% IMP</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\int</td>
<td>\delta</td>
<td>, dt$</td>
<td>$\delta_{\text{peak}}$</td>
<td>$a_{\text{peak}}$</td>
<td>$\int</td>
<td>\delta</td>
<td>, dt$</td>
<td>$\delta_{\text{peak}}$</td>
<td>$a_{\text{peak}}$</td>
<td>$\int</td>
</tr>
<tr>
<td>PS5</td>
<td>29</td>
<td>-322</td>
<td>-12.72</td>
<td>80</td>
<td>363</td>
<td>-28.45</td>
<td>11</td>
<td>-91</td>
<td>-9.00</td>
<td>-0.92</td>
<td>86%</td>
</tr>
<tr>
<td>PS6</td>
<td>12</td>
<td>-119</td>
<td>-7.08</td>
<td>13</td>
<td>-67</td>
<td>-9.48</td>
<td>12</td>
<td>-64</td>
<td>-9.12</td>
<td>-0.93</td>
<td>8%</td>
</tr>
<tr>
<td>PS8</td>
<td>12</td>
<td>-65</td>
<td>-6.17</td>
<td>13</td>
<td>-63</td>
<td>-6.60</td>
<td>44</td>
<td>293</td>
<td>-9.18</td>
<td>-0.94</td>
<td>-238%</td>
</tr>
<tr>
<td>PS9</td>
<td>11</td>
<td>-81</td>
<td>-5.76</td>
<td>13</td>
<td>-62</td>
<td>-6.60</td>
<td>12</td>
<td>-71</td>
<td>-8.94</td>
<td>-0.91</td>
<td>8%</td>
</tr>
<tr>
<td>PS10</td>
<td>23</td>
<td>-294</td>
<td>-22.86</td>
<td>12</td>
<td>-81</td>
<td>-9.36</td>
<td>12</td>
<td>-97</td>
<td>-5.88</td>
<td>-0.60</td>
<td>0%</td>
</tr>
<tr>
<td>PS11</td>
<td>12</td>
<td>-70</td>
<td>-5.16</td>
<td>14</td>
<td>-72</td>
<td>-9.34</td>
<td>13</td>
<td>-70</td>
<td>-9.18</td>
<td>-0.94</td>
<td>7%</td>
</tr>
<tr>
<td>PS12</td>
<td>11</td>
<td>-73</td>
<td>-4.62</td>
<td>15</td>
<td>-76</td>
<td>-8.70</td>
<td>13</td>
<td>-69</td>
<td>-5.16</td>
<td>-0.53</td>
<td>13%</td>
</tr>
<tr>
<td>PS13</td>
<td>12</td>
<td>-73</td>
<td>-9.06</td>
<td>12</td>
<td>-105</td>
<td>-9.18</td>
<td>12</td>
<td>-66</td>
<td>-7.14</td>
<td>-0.73</td>
<td>0%</td>
</tr>
<tr>
<td>PS14</td>
<td>12</td>
<td>-82</td>
<td>-5.70</td>
<td>15</td>
<td>-99</td>
<td>-9.18</td>
<td>14</td>
<td>-65</td>
<td>-8.16</td>
<td>-0.83</td>
<td>7%</td>
</tr>
<tr>
<td>PS15</td>
<td>12</td>
<td>-87</td>
<td>-5.28</td>
<td>17</td>
<td>-166</td>
<td>-7.14</td>
<td>13</td>
<td>-90</td>
<td>-9.18</td>
<td>-0.94</td>
<td>24%</td>
</tr>
<tr>
<td>PS16</td>
<td>12</td>
<td>-62</td>
<td>-5.52</td>
<td>13</td>
<td>-68</td>
<td>-9.90</td>
<td>13</td>
<td>-53</td>
<td>-9.12</td>
<td>-0.93</td>
<td>0%</td>
</tr>
<tr>
<td>PS17</td>
<td>12</td>
<td>-85</td>
<td>-5.16</td>
<td>15</td>
<td>-97</td>
<td>-4.02</td>
<td>12</td>
<td>-82</td>
<td>-3.30</td>
<td>-0.34</td>
<td>20%</td>
</tr>
</tbody>
</table>
Table 4.4 presents the results for the max lane offset, $y$, and whether or not the student chose to brake, $B$, or let off the throttle, $T$, while encountering the obstacle. However, the usefulness of throttle/brake information was minimal. The Table shows that the favored option for the subjects was to “brake” during the encounter. The Table also presents the students self-rating from the pre-questionnaire; note that 7 of 12 students gave themselves the self-rating response “Above Average”. Table 4.5 presents the results for the overall driving smoothness, $\int |\delta| \, dt$, the peak steering angle, $\delta_{peak}$, and the peak acceleration, $a_{peak}$. The percentage improvement, $\%IMP$, values were calculated using Runs 1 and 2. For this module, 58% of the students were given a conditional pass (CP), while 3 or 35% passed (P) based on equation (4.8). Only two students failed (F) to attain the minimum requirements for the driving scenario.

Data for three subjects (PS5, PS11, and PS17) were highlighted in both tables and will be discussed. One subject passed (P), one conditionally passed (CP), and the last subject failed (F) to meet the minimum requirements for this module. The graphical results for the remaining subjects are presented in Appendix F. The simulator data for the three subjects are presented in Figures 4.9 through 4.26. The first set of graphs (refer to Figures 4.9, 4.15, and 4.21) show the subject’s normalized brake angle during the obstacle encounter for all of the runs. The second set of graphs (refer to Figures 4.10, 4.11, 4.16, 4.17, 4.22, and 4.23) represent the subject velocity and acceleration patterns for all three runs. The third set of graphs (refer to Figures 4.12, 4.13, 4.18, 4.19, 4.24, and 4.25) illustrate the subject lane position and steering
angle throughout the runs. The last graphs (refer to Figures 4.14, 4.20, and 4.26) for each subject correspond to the position during each obstacle and the course path from a top view. All of the graphs contain the time at which the obstacle occurred per a dashed vertical line.

Pilot study subject 5 (PS5) was $1^\circ$ removed for the steering angle requirements of $90^\circ$. The hard braking event in Figure 4.9 produced while trying to avoid hitting the dog in Run 2 also contributed to his failing grade. This deceleration is illustrated at $t = 53s$ to $55s$ in Figures 4.10 and 4.11 for Run 2. The peak acceleration during this time ($t = 53.9s$) was $-9.0 \text{ m/s}^2$. According to Figures 4.12 and 4.13, the student did a minute amount of steering during the dog scenario resulting in the $y = 0.05m$ which is reported in Table 4.4. Even though the subject improved in all areas between Runs 1 and 2, the improvement was not sufficient for a passing score. Although, PS5 indicated that he/she was an outstanding driver, he/she failed the module which may indicate the subject is an overconfident driver.
Figure 4.9: PS5 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)

Figure 4.10: PS5 Velocity Versus Time (Base Run, Run 1, and Run 2)
Figure 4.11: PS5 Acceleration Versus Time (Base Run, Run 1, and Run 2)

Figure 4.12: PS5 Lane Position Versus Time (Base Run, Run 1, and Run 2)
Figure 4.13: PS5 Steering Offset Versus Time (Base Run, Run 1, and Run 2)
Figure 4.14: PS5 Subject Position Versus Entity Position and Entity Positioning on Road Course
Pilot Study Subject 11 (PS11) satisfied only one (of the two) criterion to conditionally pass this module and that was the steering angle requirement ($\delta_{peak} = -70^\circ$). Figure 4.19 shows similar steering patterns for all three runs which confirm why the peak steering angles are relatively close between the runs and that the $\%\, IMP$ in Table 4.4 is only 3%. The subject executed hard braking during the dump truck scenario (refer to Figure 4.15) and failed to meet the deceleration requirement per equation (4.8). The subject should have eased off the throttle upon first seeing the construction zone which could have reduced the peak acceleration value of $a_{peak} = -9.18\, \text{m/s}^2$. Even though the subject changed lanes to avoid the dump truck in Run 1, he/she did not completely change lanes in Run 2 as shown in Figure 4.15. PS11 stated that he/she was an average driver and was given a conditional pass for this module, which indicates a fairly accurate self rating.

![Figure 4.15: PS11 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)
Figure 4.16: PS11 Velocity Versus Time (Base Run, Run 1, and Run 2)

Figure 4.17: PS11 Acceleration Versus Time (Base Run, Run 1, and Run 2)
Figure 4.18: PS11 Lane Position Versus Time (Base Run, Run 1, and Run 2)

Figure 4.19: PS11 Steering Offset Versus Time (Base Run, Run 1, and Run 2)
Figure 4.20: PS11 Subject Position Versus Entity Position and Entity Positioning on Road Course
Pilot Study Subject 17 met both the minimum requirements to pass (P) this training module. Figure 4.23 and 4.26 provide no evidence of hard braking for Run 2 which coincides with the $a_{peak}$ value of -0.34 m/s$^2$ in Table 4.5. This driver was one of the few test subjects that avoided the deer in Run 2 by steering around it with $y = -0.47m$ (refer to Table 4.4). Figure 4.26 actually shows that the driver entered the lane of oncoming traffic to avoid the dog. However, this factor did not affect the subject’s score. Finally, PS17 indicated that he/she was an above average driver; he/she passed this module which reflects accurate driver capability self-rating.

Figure 4.21: PS17 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)
Figure 4.22: PS17 Velocity Versus Time (Base Run, Run 1, and Run 2)

Figure 4.23: PS17 Acceleration Versus Time (Base Run, Run 1, and Run 2)
Figure 4.24: PS17 Lane Position Versus Time (Base Run, Run 1, and Run 2)

Figure 4.25: PS17 Steering Offset Versus Time (Base Run, Run 1, and Run 2)
Figure 4.26: PS17 Subject Position Versus Entity Position and Entity Positioning on Road Course
Summary

The training modules proved to be very successful at carrying out their intended purposes. For the twelve subjects, 58% passed the first module and 42% failed. For the second module, 25% passed, 58% conditionally passed, and 17% failed. For both modules, the difference in passing rate may be attributed to more lenient threshold for driver awareness. If a maximum $g_p = 0.60$ instead of 0.75, then the pass rate for the second module would have decreased. The driver classification (Age/DL) in Table 6 was obtained from the Pre-Questionnaire (preliminary questions), where the age denotes the subject’s physical age and the DL years is the number of years licensed. The results for the two modules are summarized in Table 7.

<table>
<thead>
<tr>
<th>Age</th>
<th>Classification</th>
<th>Driver License Years</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-18</td>
<td>Teen (T)</td>
<td>0-4</td>
<td>Novice (N)</td>
</tr>
<tr>
<td>19-23</td>
<td>Young Adult (YA)</td>
<td>5-8</td>
<td>Experienced (E)</td>
</tr>
<tr>
<td>24+</td>
<td>Adult (A)</td>
<td>9+</td>
<td>More Experienced (ME)</td>
</tr>
</tbody>
</table>

Table 4.6: Age and Driver License Classification

The two subjects (PS5, PS8) that failed both modules were classified as young adult drivers and illustrated overconfidence in that they gave themselves high self ratings (Column 3). None of the adult drivers (PS11, PS13, PS16, PS17) failed either module and only one of the three novice drivers (PS12, PS14, PS15) did not pass both modules. The young adult drivers’ scores were across the board which illustrates the variability in automotive skill and knowledge.
<table>
<thead>
<tr>
<th>Subject</th>
<th>Classification (Age/DL)</th>
<th>Self - Rating</th>
<th>Module 1</th>
<th>Module 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS5</td>
<td>YA E</td>
<td>O</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>PS6</td>
<td>YA E</td>
<td>AA</td>
<td>F</td>
<td>CP</td>
</tr>
<tr>
<td>PS8</td>
<td>YA E</td>
<td>AA</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>PS9</td>
<td>YA E</td>
<td>A</td>
<td>P</td>
<td>CP</td>
</tr>
<tr>
<td>PS10</td>
<td>A E</td>
<td>AA</td>
<td>P</td>
<td>CP</td>
</tr>
<tr>
<td>PS11</td>
<td>A E</td>
<td>A</td>
<td>P</td>
<td>CP</td>
</tr>
<tr>
<td>PS12</td>
<td>YA N</td>
<td>A</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>PS13</td>
<td>A ME</td>
<td>AA</td>
<td>P</td>
<td>P</td>
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<tr>
<td>PS14</td>
<td>T N</td>
<td>AA</td>
<td>P</td>
<td>CP</td>
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<tr>
<td>PS15</td>
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<td>CP</td>
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<tr>
<td>PS16</td>
<td>A ME</td>
<td>AA</td>
<td>P</td>
<td>CP</td>
</tr>
<tr>
<td>PS17</td>
<td>A ME</td>
<td>AA</td>
<td>P</td>
<td>P</td>
</tr>
</tbody>
</table>

Table 4.7: Summarized Results for the “Following Etiquette and Situational Awareness” Training Modules (Outstanding, O, Above Average, AA, Average, A)
CHAPTER FIVE
CONCLUSION AND DISCUSSION

The continued high number of occurrences of injuries and fatalities among novice drivers represents a critical situation meriting immediate action by researchers, government agencies, and parents. In this thesis, a series of training modules were introduced to increase driver knowledge and enhance their driving skills. The training modules may be carried-out using a classroom style format and an automotive driving simulator. The training modules also helped bridge the gap between knowledge learned in driver education courses and “behind-the-wheel” experience. Three goals were accomplished in this thesis to achieve the research objective of improving driver attitudes, knowledge, and behavior of “high-risk” adolescent and adult students. Specifically, two training modules were designed for classroom instruction, an investigation of automotive driving simulators was carried out, and a pilot study was performed for virtual reality driving simulator training modules. The classroom and virtual training modules were developed for possible implementation in a safe driving program.

The training courses developed are but one part of the solution to the goal of making young drivers safer. The students need to practice the information contained in these training modules and implement it into their daily driving habits. In the case, such as of emergency situations, the program materials hopefully instill permanent cues for memory retrieval. The driving simulator proved to be an effective tool for driver education and training. The safe and controlled environment of a simulator
made it possible to produce unique curricula which cater to specific driver education needs. The virtual training modules conveyed their intended lessons in a cost effective (no funds were required) and efficient manner (available rain or shine). The students’ performances increased between runs in the “Following Etiquette” module with a 58% passing rate (42% failed). The “Situational Awareness” module showed that the students can react to obstacles in a safe manner; 25% passed, 58% conditionally passed, and 17% failed. This proves the practicality that the driving simulator has to offer.

**Recommendations for Future Work**

The following recommendations should aid in further meeting the research objective discussed in this thesis. First, a classroom module for parents might be added to the proposed curriculum, since parents play a key role in enforcing safety with novice drivers. The module would include tips for parents to enforce safe driving behaviors, offer preventative methods to reduce in-car distractions for their teens, and offer a recap on safe driving laws pertaining to teens. A module presenting a series of mental and visual tasks (e.g., visual scanning, hazard perception, risk perception) that drivers should perform regularly when operating their vehicles might also be included. The safe operation of a motor vehicle on various roadways (e.g., wet, dry, icy) requires the recognition, practice, and continual execution of driving strategies such as visual scanning, distraction avoidance, speed management, and hazard recognition. Finally, there should also be a classroom module on the severe dangers
of driving under the influence of alcohol and drugs. A high percentage of traffic crashes result due to the driver being intoxicated.

The DriveSafety driving simulator applied in this research study had some restrictions and limited capabilities. For example, the simulator offered no steering wheel or roadway feedback which could have been crucial in the “Situational Awareness” virtual module. Also, the driving simulator only allowed vehicles and two types of animals (deer, dog) to enter the roadway. Therefore, big city and neighborhood scenarios were not overly realistic. In the future, a driving simulator should offer more realistic haptic feedback and a more diverse scenario programming capacity.

A driving simulator should be used in future driving programs for novice drivers. It should be used as reinforcement for learning material being taught, and it can be used to practice scenarios too dangerous to perform with an actual vehicle on the roadway. One example would be to practice the techniques to recover from running off the road. Drivers usually make the mistake of overcorrecting their vehicle which may bring about a detrimental outcome. In a sense, the training courses offered via driving simulator will be very effective if properly structured and administered.
REFERENCES


APPENDICES
Appendix A: International Review Board (IRB) Approval Documents

The materials in Chapter 4 reference the acquisition of Institutional Review Board (IRB) approval for the human subject testing performed in this thesis. The following documents were presented to the Board for their approval.
Office use only
Protocol Number: 
Approved  [ ] Full Board  [ ] Expedited  Expiration date: ____________
Signature of IRB Chair/Designee  Date

**Level of Review** (Questions 12 & 13 determine if the protocol can be expedited): 
- [ ] Expedited  [ ] Full

1. **Developmental Approval:** If you already have developmental approval for this research study, please give the IRB protocol number assigned to the study. More information available [here](#).

2. **Research Title:** Virtual Driving Instruction Using an Automotive Driving Simulator
   - If different, title used on consent document(s)
   - If class project, include course number and title

3. **Principal Investigator (PI):** The PI must be a member of the Clemson faculty or staff. You cannot be the PI if this is your thesis or dissertation. The PI must have completed IRB-approved human research protections training. Training will be verified by IRB staff before approval is granted. Training instructions available [here](#). CITI training site available [here](#).

<table>
<thead>
<tr>
<th>Name: Dr. John Wagner</th>
<th>Faculty  [ ]  Staff  [ ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department: Mechanical Engineering</td>
<td>E-mail: <a href="mailto:jwagner@clemson.edu">jwagner@clemson.edu</a></td>
</tr>
<tr>
<td>Campus address: 212 Fluor Daniel Engineering Innovation Building Clemson, South Carolina 29634-0921</td>
<td>Phone: 864-656-7376</td>
</tr>
<tr>
<td></td>
<td>Fax: 864-656-4435</td>
</tr>
</tbody>
</table>

4. **Co-Investigator(s):** Co-Investigators must have completed IRB-approved human research protections training. Training will be verified by IRB staff before approval is granted. Training instructions available [here](#). CITI training site available [here](#).

<table>
<thead>
<tr>
<th>Name: Dionne Norfleet</th>
<th>E-mail: <a href="mailto:dnorfle@clemson.edu">dnorfle@clemson.edu</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Department: Mechanical Engineering</td>
<td>Phone: 706-566-1753</td>
</tr>
</tbody>
</table>
5. **Additional Research Team Members**: All research team members must have completed IRB-approved human research protections training. Training will be verified by IRB staff before approval is granted. Training instructions available [here](#). CITI training site available [here](#).

   - List of additional research team members included. Form available [here](#).

6. **Research Team Roles**: Describe the role of each member of the research team (everyone included in Items 3, 4 and 5), indicating which research activities will be carried out by each particular member. Team members may be grouped into categories.

   **Description**: Dr. John Wagner and Dionne Norfleet have developed two virtual driving modules on the DriveSafety automotive driving simulator located in the Department of Psychology (Brackett Hall). Dionne Norfleet and Matthew Jensen will administer the test and collect the data. Data Analysis and review will be done by Dionne Norfleet, Dr. John Wagner, Dr. Kim Alexander, Dr. Philip Pidgeon, and Matthew Jensen. In the future, these modules may be modified and/or expanded to incorporate other driving scenarios.

7. **Study Purpose**: In non-technical terms, provide a brief description of the purpose of the study. Upon conclusion of the study, how will you share your results (e.g., academic publication, evaluation report to funder, conference presentation)?

   **Description**: The purpose of this research is to determine the effectiveness of using an automotive driving simulator to improve driver safety through driver education and training. Two virtual driving training modules have been designed for reinforcement and practice purposes in support of a safe teenage driving program. The first module teaches a simple timing method that allows the driver to maintain the proper following distance behind a lead vehicle. The second module allows the individual to practice obstacle avoidance techniques and emergency maneuvers to
avoid hitting objects (e.g., animals, other vehicles, etc.) on the roadway. As needed, other modules will be proposed that instruct students on driving methods for high risk vehicle scenarios within the safe confines of a driving simulator. The results of this study will be integrated into a research program for safe automotive driving and presented in academic publications.

8. **Anticipated Dates of Research:**

Anticipated start date (may not be prior to IRB approval; may be “upon IRB approval”): **upon IRB approval**

Anticipated completion date (Please include time needed for analysis of individually identifiable data): **July 1, 2010**

9. **Funding Source:** Please check all that apply.

- [ ] Submitted for internal funding
- [x] Internally funded
- [ ] Submitted for external funding
- [ ] Externally funded

  Funding source, if applicable (Do not use initials): ____

  Proposal number (PPN) for the Office of Sponsored Programs: ____

  Name of PI on Funding Proposal: ____

- [ ] Intend to seek funding  From whom? ____
- [ ] Not funded

10. **Support provided by Creative Inquiry Initiative:**  [ ] Yes  [x] No

11. **Other IRB Approvals:**

Has this research study been presented to any other IRB?  [ ] Yes  [x] No

Where? ____  When? ____

If yes, what was their decision?  [ ] Approved  [ ] Disapproved  [ ] Pending

Please attach a copy of any submissions, approvals, or disapprovals from other IRBs.

12. **Level of Risk:** Does this project include any procedures that present more than minimal risk to the participants? (A project is considered to present minimal risk if the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations.)

- [ ] Yes  [x] No
If your study presents no more than minimal risk to participants, your study may be eligible for expedited review.

13. The Federal Code [45 CFR 46.110] permits research activities in the following seven categories to undergo expedited review. Please check the relevant expedited category / categories.

<table>
<thead>
<tr>
<th>Categories of Research that May Be Reviewed by the Institutional Review Board (IRB) through an Expedited Review Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ 1. Clinical studies of drugs and medical devices only when condition (a) or (b) is met:</td>
</tr>
<tr>
<td>□ a. Research on drugs for which an investigational new drug application is not required. (Note: Research on marketed drugs that significantly increase the risks or decrease the acceptability of the risks associated with the use of the product is not eligible for expedited review.)</td>
</tr>
<tr>
<td>□ b. Research on medical devices for which 1) an investigational device exemption application is not required or 2) the medical device is cleared or approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.</td>
</tr>
<tr>
<td>□ 2. Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows:</td>
</tr>
<tr>
<td>□ a. From healthy, non-pregnant adults, who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml. in an eight week period and collection may not occur more than two times per week; OR</td>
</tr>
<tr>
<td>□ b. From other adults and children, considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount may not exceed the lesser of 50 ml. or 3 ml. per kg. in an eight-week period, and collection may not occur more than two times per week.</td>
</tr>
<tr>
<td>□ 3. Prospective collection of biological specimens for research purposes by non-invasive means.</td>
</tr>
<tr>
<td>Examples:</td>
</tr>
<tr>
<td>□ a. hair and nail clippings in a non-disfiguring manner;</td>
</tr>
<tr>
<td>□ b. deciduous teeth at time of exfoliation or if routine patient care indicates need for extraction;</td>
</tr>
<tr>
<td>□ c. permanent teeth if routine patient care indicates need for extraction;</td>
</tr>
<tr>
<td>□ d. excreta and external secretions (including sweat);</td>
</tr>
<tr>
<td>□ e. uncannulated saliva collected either in an unstimulated fashion or stimulated by chewing gum base or wax or by applying a dilute citric solution to the tongue;</td>
</tr>
</tbody>
</table>
f. placenta removed at delivery;
g. amniotic fluid obtained at the time of rupture of the membrane prior to or during labor;
h. supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques;
i. mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings;
j. sputum collected after saline mist nebulization.

4. Collection of data through non-invasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)

Examples:

a. physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject’s privacy;
b. weighing or testing sensory acuity;
c. magnetic resonance imaging;
d. electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, Doppler blood flow and echocardiography,
e. moderate exercise, muscular strength testing, body composition assessment, and flexibility testing when appropriate given the age, weight, and health of the individual.

5. Research involving materials (data, documents, records, or specimens) that have been collected or will be collected solely for non-research purposes (such as medical treatment or diagnoses).

6. Collection of data from voice, video, digital, or image recordings made for research purposes.

7. Research on individual or group characteristics, behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior), or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.
14. **Study Sample:** (Groups specifically targeted for study)

Describe the participants you plan to recruit and the criteria used in the selection process. Indicate if there are any special inclusion or exclusion criteria.

**Description:** The participants in this study will be Clemson University students/employees initially between ages 18-25, but may be expanded to other age groups. According to the National Highway Traffic Safety Administration (NHTSA), this age group is among those with the highest number of fatalities and injuries as a result of traffic crashes.

Age range of participants: **18-25**  
Projected number of participants: **50**

- [X] Employees  
- [X] Students  
- [ ] Minors (under 18) *
- [ ] Pregnant women *  
- [ ] Prisoners *  
- [ ] Educationally / economically disadvantaged *
- [ ] Minors who are wards of the state, or any other agency, institution, or entity *  
- [ ] Fetuses / neonates *  
- [ ] Persons incompetent to give valid consent *  
- [ ] Other – specify: _____  
- [ ] military personnel

*State necessity for using this type of participant: **Target demographic**

15. **Study Locations:**

- [X] Clemson University  
- [ ] Other University / College __________
- [ ] School System / Individual Schools __________  
- [ ] Other – specify _____

You may need to obtain permission if participants will be recruited or data will be obtained through schools, employers, or community organizations. Are you required to obtain permission to gain access to people or to access data that are not publicly available? If yes, provide a research site letter from a person authorized to give you access to the participants or to the data. Guidance regarding Research Site Letters is available [here](#).

- [X] Research Site Letter(s) not required.  
- [ ] Research Site Letter(s) attached.  
- [ ] Research Site Letter(s) pending and will be provided when obtained.

16. **Recruitment Method:**

Describe how research participants will be recruited in the study. How will you contact them? **Attach a copy of any material you will use to recruit participants (e.g.,**
advancements, flyers, telephone scripts, verbal recruitment, cover letters, or follow-up reminders).

Description: The participants will be recruited verbally by research team members; scheduling arrangements will be made by phone and/or email.

17. Participant Incentives:

a. Will you pay participants? □ Yes  ☒ No
   Amount: $_____   When will money be paid?: ______

b. Will you give participants incentives / gifts/reimbursements? □ Yes  ☒ No
   Describe incentives / gifts/reimbursements: ______
   Value of incentives / gifts/reimbursements: $_____
   When will incentives / gifts/reimbursements be given?: ______

c. Will participants receive course credit or extra credit? □ Yes  ☒ No
   If course credit or extra credit is offered to participants, is an equivalent alternative to research participation provided? □ Yes  □ No

18. Informed Consent:

a. Do you plan to obtain informed consent from your research subjects?  ☒ Yes  □ No
   If no, you will need to request a waiver of informed consent. See chart below.
   For what groups will you need this waiver of informed consent?
   □ for all participants  □ for some participants (describe for which participants): ______
   Please explain the need for the waiver. ______
   As provided in 45 CFR 46.116(c), an IRB may waive the requirement for the investigator to obtain informed consent from research subjects if it finds that all of the following criteria are met. Please explain how your study meets each of the criteria below:

<table>
<thead>
<tr>
<th>Criteria for Waiver of Consent</th>
<th>How is this criterion met within this study?</th>
</tr>
</thead>
<tbody>
<tr>
<td>The research involves no more than minimal risk to subjects.</td>
<td></td>
</tr>
<tr>
<td>The waiver will not adversely affect the rights and welfare of the subjects.</td>
<td></td>
</tr>
<tr>
<td>The research could not be carried out practicably without the waiver.</td>
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</tbody>
</table>
Whenever appropriate, the subjects will be provided with additional pertinent information after they have participated in the study.

b. If you will obtain consent from your participants, please submit all applicable Informed Consent documents with application (e.g., adult consent forms, parental permission forms, minor assent forms, informational letters, verbal consent scripts).

Consent Document Templates

Who will obtain the participants’ consent? Check all that apply:  □ Principal Investigator  ✔ Co-Investigator  □ Research Assistants  □ Contracted/Hired Data Collection Firm: ______

□ Other: ______

c. Will you use concealment or deception in this study? □ Yes  ✔ No

If yes, please see guidance regarding Research Involving Deception or Concealment here, submit a copy of the debriefing statement / plan you will use, and request a waiver of some required elements of consent below (see 18e).

d. Will you collect participants’ signatures on all consent documents?  ✔ Yes  □ No

If no, you will need a waiver of documentation (signature). See questions below.

For what groups will you need this waiver of documentation?

□ for all participants  □ for some participants (describe for which participants):

   ______

As provided in 45 CFR 46.117(c), an IRB may waive the requirement for the investigator to obtain a signed consent form for some or all subjects if it finds that either of the following sets of criteria are met. Please indicate under which criteria you would like to request a waiver of documentation for this research study:

□ That the research presents no more than minimal risk of harm to subjects and involves no procedure for which written consent is normally required outside of the research context.

□ That the only record linking the subject and the research would be the consent document and the principal risk would be potential harm resulting from a breach of confidentiality. If the subject wants documentation linking the subject with the research, the subject’s wishes will govern.

e. Do you plan to use all of the required elements in the consent form (see list below)?  ✔ Yes  □ No

If no, you will need to request a waiver of some required elements. See chart below.

For what groups will you need this waiver of some required elements?

□ for all participants  □ for some participants (describe for which participants):

   ______
Please explain the need for the waiver request. _____

A list of all required elements is given below. Please indicate which of these elements you would like to have waived. (In the case of a study involving deception or concealment, the IRB must waive the requirement to use all elements that are not truthfully presented in the initial consent document.)

<table>
<thead>
<tr>
<th>List of Elements of Informed Consent</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ participation involves research</td>
</tr>
<tr>
<td>☐ purposes of the research</td>
</tr>
<tr>
<td>☐ duration of participation</td>
</tr>
<tr>
<td>☐ procedures to be followed</td>
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<tr>
<td>☐ identification of experimental</td>
</tr>
<tr>
<td>procedures</td>
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<tr>
<td>☐ foreseeable risks / discomforts</td>
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<tr>
<td>☐ benefits to subjects or others</td>
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</tbody>
</table>

As provided in 45 CFR 46.116(c), an IRB may waive the requirement for the investigator to present all required elements to subjects if it finds that all of the following criteria are met. Please explain how your study meets each of the criteria below:

<table>
<thead>
<tr>
<th>Criteria for Waiver of Elements of Consent</th>
<th>How is this criterion met within this study?</th>
</tr>
</thead>
<tbody>
<tr>
<td>The research involves no more than minimal risk to subjects.</td>
<td></td>
</tr>
<tr>
<td>The waiver will not adversely affect the rights and welfare of the subjects.</td>
<td></td>
</tr>
<tr>
<td>The research could not be carried out practically without the waiver.</td>
<td></td>
</tr>
<tr>
<td>Whenever appropriate, the subjects will be provided with additional pertinent information after they have participated in the study.</td>
<td></td>
</tr>
</tbody>
</table>

19. Procedures:

a. What data will you collect? **Quantitative and qualitative data will be collected.**

b. How will you obtain the data (e.g., surveys, interviews, focus groups)? **Qualitative data will be collected through questionnaires. The questionnaires ask for general background information and specific questions pertaining to the items that will**
be taught in the training modules within the simulator environment. The questionnaires will help evaluate the participant's driving habits and driver safety knowledge. The quantitative data will be collected from the driving simulator's on-board software algorithms.

c. If data collection tools will be used, how much time will it take to complete these tools? 15 minutes.

d. How many data collection sessions will be required? Will this include follow-up sessions? There will be one data collection session for the given participant.

e. How will you collect data?

☐ in-person contact ☐ telephone
☐ snail mail ☐ email
☐ website ☐ other, describe _____

Include copies of surveys, interview questions, data collections tools and debriefing statements. If survey or interview questions have not been fully developed, provide information on the types of questions to be asked, or a description of the parameters of the survey / interview. Please note: finalized survey or interview instruments will need to be reviewed and approved by amendment, before implementation.

f. Will you audio record participants? ☐ Yes ☒ No

g. Will you video record participants? ☐ Yes ☐ No

h. Will you photograph participants? ☐ Yes ☒ No

If you will audio or video record or take identifiable photographs of participants, please consult the IRB’s Guidance on the Use of Audio / Video Recording and Photography here. Please include all the information addressed by this guidance document in the application and, where appropriate, in the consent document(s).

20. Protection of Confidentiality: Describe the security measures you will take to protect the confidentiality of the information obtained. Will participants be identifiable either by name or through demographic data? If yes, how will you protect the identity of the participants and their responses? Where will the data be stored and how will it be secured? Who will have access to the data? How will identifiers be maintained or destroyed after the study is completed?

Description: To ensure complete confidentiality, participants will not be linked with the data collected during data gathering and analysis. No names will be assigned to the data files. Only members of the research team will have access to the data files, which will be stored solely on a laptop owned and operated by Clemson University Automotive Safety Research Institute. No identifiers will be made linking individuals to their associated data files. The research assistants (Dionne Norfleet and Matthew Jensen) will have only reminiscence linking a test subject to their associated data file.
21. Risk / Benefit Analysis:

a. Describe all potential risks (before protective measures are put into place) and benefits for this study. Risks can include physical, psychological, social, legal or other risks connected with the proposed procedures. Benefits can include benefits to the participant or to society in general.

**Description:** The health issues include possible dizziness and nausea brought on by motion sickness due to the fixed base driving simulator and multiple projection screens. The benefits for the participant include gaining knowledge of key driving strategies and techniques. This research will try to provide an improved understanding of the overall effectiveness and possible teaching applications using driving simulators.

b. Describe the procedures to be used to protect against or minimize potential risks. Assess the likely effectiveness of these procedures.

**Description:** There will be water and crackers available to minimize the effect of motion sickness.

22. Agreement, Statement of Assurance, and Conflict of Interest Statement by the PI:

I have reviewed this research protocol and the consent form, if applicable. I have also evaluated the scientific merit and potential value of the proposed research study, as well as the plan for protecting human participants. I have read the Terms of Assurance held by Clemson University and commit to abiding by the provisions of the Assurance and the determinations of the IRB. I request approval of this research study by the IRB of Clemson University.

I understand that failure to adhere to any of these guidelines may result in immediate termination of the research. I also understand that approval of this research study is contingent upon my agreement to:

1. Report to the IRB any adverse events, research-related injuries or unexpected problems affecting the rights or safety of research participants (All such occurrences must be reported to the IRB within three (3) working days.);
2. Submit in writing for IRB approval any proposed revisions or amendments to this research study;
3. Submit timely continuing review reports of this research as requested by the IRB; and
4. Notify the IRB upon completion of this research study.

**Conflict of Interest Statement:**

Could the results of the study provide an actual or potential financial gain to you, a member of your family, or any of the co-investigators, or give the appearance of a potential conflict of interest?

☒ No.
☐ Yes. I agree to disclose any actual or potential conflict of interest prior to IRB action on this study.

__________________________________________________________  ______________________
Signature of Principal Investigator  Date

23. Statement of Assurance by Department Chair (or supervisor if PI is Department Chair):

I have reviewed this research protocol and the consent form, if applicable. I verify this proposed research study has received approval in accordance with department procedures. I have evaluated the plan for protecting human participants. I have read the Terms of Assurance held by Clemson University and commit to abiding by the provisions of the Assurance and the determinations of the IRB. I request approval of this research study by the IRB of Clemson University.

__________________________________________________________  ______________________
Signature of Department Chair  Date

Submission Instructions:

Expedit ed applications are processed as received. There is no deadline for submitting expedit ed applications for review. Please allow three weeks for processing.

Full applications are accepted according to the schedule given here. Researchers are encouraged to attend the meeting at which their protocol will be reviewed, in order to be available to answer any questions IRB members might have about the protocol.

Please submit this application and all associated documents electronically to the IRB staff. The signed, hard-copy of the application may be mailed or delivered to the Office of Research Compliance, 223 Brackett Hall, Clemson, SC 29634-5704.

Prisoner Research Addendum:

 If your study involves prisoners as participants, click here to complete the Prisoner Research Addendum. Once completed, please submit the Addendum with your Expedited / Full Review Application.
Additional Research Team Members
Clemson University Institutional Review Board (IRB) *(Version 1.23.2009)*
*Clemson University IRB Website*

All research team members must have completed IRB-approved human research protections training.

Use this sheet as many times as necessary.

<table>
<thead>
<tr>
<th>Name: Matthew Jensen</th>
<th>E-mail: <a href="mailto:mjensen@clemson.edu">mjensen@clemson.edu</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Department: Mechanical Engineering</td>
<td>Phone: 812-236-0714</td>
</tr>
<tr>
<td>Faculty</td>
<td>Graduate student</td>
</tr>
<tr>
<td>Staff</td>
<td>Undergraduate student</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name: Dr. Philip Pidgeon</th>
<th>E-mail: <a href="mailto:ppidgeo@clemson.edu">ppidgeo@clemson.edu</a></th>
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<tr>
<td>Department: Automotive Safety Research Institute</td>
<td>Phone: 864-656-5613</td>
</tr>
<tr>
<td>Faculty</td>
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<td>Faculty</td>
<td>Graduate student</td>
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<tr>
<td>Staff</td>
<td>Undergraduate student</td>
</tr>
</tbody>
</table>
Consent Form for Participation in a Research Study
Clemson University

Virtual Driving Instruction Using an Automotive Driving Simulator (Dated: June 2009)

Description of the research and your participation

You are invited to participate in a research study conducted by Dr. John Wagner (Department of Mechanical Engineering) with assistance from Dr. Kim Alexander, and Dr. Philip Pidgeon (Clemson University Automotive Safety Research Institute), and graduate engineering students Dionne Norfleet and Matthew Jensen. The purpose of this research is to determine the effectiveness of using an automotive driving simulator to improve driver safety through virtual driver education and training.

Your participation will involve completing one pre-questionnaire and one post-questionnaire. These questionnaires will help determine your driving habits and driver safety knowledge. The questionnaires should require no more than five minutes each to answer. In addition, you are asked to complete two virtual training modules on a driving simulator.

The amount of time required for your participation will be no more than one hour.

Risks and discomforts

There are certain risks and/or discomforts associated with this research. The health issues include possible dizziness and nausea brought on by motion sickness due to the fixed base driving simulator and multiple projection screens. There will be water and crackers available to minimize the effects of motion sickness and a test can be stopped immediately at the request of the participant.

Potential benefits

There are benefits to you that would result from your participation in this research. You will gain knowledge of key driving strategies and techniques. This research will evaluate the effectiveness and teaching applications of driving simulators for safe driving initiatives.

Protection of confidentiality

We will do everything we can to protect your privacy. To ensure complete confidentiality, participants will not be linked with the data collected during data gathering and analysis. No names will be assigned to the data files. Only members of
the research team will have access to the data files, which will be stored solely on a laptop owned and operated by Clemson University Automotive Safety Research Institute. No identifiers will be made linking individuals to their associated data files. The research assistants (Dionne Norfleet and Matthew Jensen) will have only reminiscence linking a test subject to their associated data file. Your identity will not be revealed in any publication that might result from this study.

In rare cases, a research study will be evaluated by an oversight agency, such as the Clemson University Institutional Review Board or the federal Office for Human Research Protections, that would require that we share the information we collect from you. If this happens, the information would only be used to determine if we conducted this study properly and adequately protected your rights as a participant.

**Voluntary participation**

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study.

**Contact information**

If you have any questions or concerns about this study or if any problems arise, please contact Dr. John Wagner at Clemson University at 864.656.7376. If you have any questions or concerns about your rights as a research participant, please contact the Clemson University Institutional Review Board at 864.656.6460.

**Consent**

I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.

Participant’s signature: ___________________________ Date: ___________

A copy of this consent form should be given to you.
Appendix B: Pre/Post Questionnaires and Results

The questionnaires completed by the human test subjects provide a baseline of the content administered. Both the pre-questionnaire and the post-questionnaire have been presented in the Appendix. The subject responses to the questionnaires are summarized in Tables B.1 and B.2.
VIRTUAL DRIVING INSTRUCTION USING AN AUTOMOTIVE DRIVING SIMULATOR 
PRE-QUESTIONNAIRE

INSTRUCTIONS: The following questionnaire contains questions that seek knowledge on your driving behaviors characteristics. Please answer the following questions as accurate as possible.

Age: ____ Sex: M F (Circle One)

How many years have you had a US driver’s license? ____

1. What type of vehicle do you usually drive? (Circle One)
   Compact Medium/Large Sedan Van Motorcycle
   SUV/Truck Other

2. Approximately how many miles do you drive each year? (Circle One)
   0-5,000 5,001-10,000 10,001-20,000 20,001+

3. What type of roads do you usually drive on? (Circle One)
   Rural Urban Highway

4. How do you rate your driving skill? (Circle One)
   Poor Below Average Average
   Above Average Outstanding

5. Have you ever rear-ended another vehicle? (Circle One) Yes No
   a. If yes, on how many separate occasions have you rear end another vehicle? (Circle One)
      1 time 2 times 3 times 4+ times
   b. If yes, please circle the situation that most closely resembles the cause.
I didn’t realize the other vehicle was slowing down or stopping

I wasn’t paying attention

I was driving too fast for conditions (e.g., rain, snow, etc.) and did not stop in time

I was following too closely

6. **Have you ever swerved to avoid hitting another vehicle?** (Circle One)
   - Yes
   - No

e. **If yes, how often does this occur?** (Circle One)
   - Once a year
   - Once a month
   - Once a week
   - Regularly

b. **If yes, please circle the situation that most closely resembles the maneuver outcome?**
   - Avoided hitting the vehicle by running off the road
   - Entered an unoccupied lane to avoid hitting the vehicle
   - Avoided hitting the vehicle, but hit another vehicle/object
   - Swerved but still hit the vehicle

7. **Have you ever swerved to avoid hitting an object/animal/pedestrian in a roadway?** (Circle One)
   - Yes
   - No

e. **If yes, how often does this occur?** (Circle One)
   - Once a year
   - Once a month
   - Once a week
   - Regularly

b. **If yes, please circle the situation that most closely resembles the maneuver outcome?**
   - Avoided hitting the object/animal/pedestrian by running off the road
   - Entering an unoccupied lane to avoid hitting the object/animal/pedestrian
   - Avoided hitting the object/animal/pedestrian, but hit another vehicle/object
Swerved but still hit the object/animal/pedestrian

8. **Please explain how you determine a safe vehicle following distance.**
   ____________________________________________________________
   ____________________________________________________________

9. **How often do you think other drivers break your safe following distance “rule” stated in Question 8?**
   Never          Sometimes          Often          Always

10. **How often do you break your own safe following distance “rule” stated in Question 8?**
    Never          Sometimes          Often          Always

11. **How often do you drive above the speed limit?**
    Never          Sometimes          Often          Always

12. **Do you occasionally travel below the posted speed limit? (Circle One)**
    Yes   No

   a. **If yes, what are some of the situations?**
      ____________________________________________________________
      ____________________________________________________________

13. **Have you had any formal driver training? (Circle One)**
    Yes   No

   a. **If yes, please explain.**
      ____________________________________________________________
      ____________________________________________________________
## PRE-QUESTIONNAIRE RESULTS

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<tr>
<th>Subject</th>
<th>Age</th>
<th>Sex</th>
<th>DL-Years</th>
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<th>2</th>
<th>3</th>
<th>4</th>
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<tr>
<td>PS5</td>
<td>22</td>
<td>M</td>
<td>6</td>
<td>Medium/Large Sedan</td>
<td>0-5,000</td>
<td>Highway</td>
<td>Outstanding</td>
<td>No</td>
<td>NA</td>
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<tr>
<td>PS6</td>
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<td>M</td>
<td>8</td>
<td>Medium/Large Sedan</td>
<td>0-5,000</td>
<td>Urban</td>
<td>Above Average</td>
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<td>NA</td>
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<tr>
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<td>F</td>
<td>8</td>
<td>Medium/Large Sedan</td>
<td>5,001-10,000</td>
<td>Highway</td>
<td>Average</td>
<td>No</td>
<td>NA</td>
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<tr>
<td>PS10</td>
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<td>M</td>
<td>8</td>
<td>Compact</td>
<td>5,001-10,000</td>
<td>Rural</td>
<td>Above Average</td>
<td>No</td>
<td>NA</td>
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<tr>
<td>PS11</td>
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<td>F</td>
<td>10</td>
<td>Medium/Large Sedan</td>
<td>5,001-10,000</td>
<td>Highway</td>
<td>Average</td>
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<td>NA</td>
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<td>F</td>
<td>4</td>
<td>Medium/Large Sedan</td>
<td>10,001-20,000</td>
<td>Highway</td>
<td>Average</td>
<td>Yes</td>
<td>1 Time</td>
</tr>
<tr>
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<td>M</td>
<td>9</td>
<td>Medium/Large Sedan</td>
<td>10,001-20,000</td>
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<td>Above Average</td>
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<td>NA</td>
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<td>F</td>
<td>3</td>
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<td>Highway</td>
<td>Above Average</td>
<td>Yes</td>
<td>1 Time</td>
</tr>
<tr>
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<td>25</td>
<td>F</td>
<td>9</td>
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<td>10,001-20,000</td>
<td>Highway</td>
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Table B.1: Human Test Subject Summarized Answers to Pre-Questionnaire
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<th>6a</th>
<th>6b</th>
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<th>9</th>
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<td>PS5</td>
<td>Yes</td>
<td>Once a year</td>
<td>Running Off Road Yes</td>
<td>Once a Year</td>
<td>Entered Unocc. Ln</td>
<td>Distance</td>
<td>Sometimes</td>
<td></td>
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<tr>
<td>PS6</td>
<td>Yes</td>
<td>Once a year</td>
<td>Entered Unocc. Ln Yes</td>
<td>Once a Week</td>
<td>Entered Unocc. Ln</td>
<td>Time (2s)</td>
<td>Often</td>
<td></td>
</tr>
<tr>
<td>PS8</td>
<td>No</td>
<td>NA</td>
<td>NA Yes</td>
<td>Once a Year</td>
<td>Running Off Road</td>
<td>Time (3s)</td>
<td>Often</td>
<td></td>
</tr>
<tr>
<td>PS9</td>
<td>Yes</td>
<td>Once a year</td>
<td>Entered Unocc. Ln No</td>
<td>NA</td>
<td>NA</td>
<td>Time (1s)</td>
<td>Often</td>
<td></td>
</tr>
<tr>
<td>PS10</td>
<td>Yes</td>
<td>Once a year</td>
<td>Entered Unocc. Ln No</td>
<td>NA</td>
<td>NA</td>
<td>Time (2s)</td>
<td>Often</td>
<td></td>
</tr>
<tr>
<td>PS11</td>
<td>Yes</td>
<td>Once a year</td>
<td>Entered Unocc. Ln Yes</td>
<td>Once a Year</td>
<td>Swerved Still Hit</td>
<td>Distance</td>
<td>Often</td>
<td></td>
</tr>
<tr>
<td>PS12</td>
<td>No</td>
<td>NA</td>
<td>NA No</td>
<td>NA</td>
<td>NA</td>
<td>Distance</td>
<td>Often</td>
<td></td>
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<tr>
<td>PS13</td>
<td>Yes</td>
<td>Once a year</td>
<td>Entered Unocc. Ln No</td>
<td>NA</td>
<td>NA</td>
<td>Time (3s)</td>
<td>Sometimes</td>
<td></td>
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<tr>
<td>PS14</td>
<td>Yes</td>
<td>Once a Month</td>
<td>Entered Unocc. Ln Yes</td>
<td>Once a Month</td>
<td>Entered Unocc. Ln</td>
<td>Distance</td>
<td>Often</td>
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<tr>
<td>PS15</td>
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<td>Once a year</td>
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<td>Running Off Road</td>
<td>Distance</td>
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<td>Once a Year</td>
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<td>Time (2s)</td>
<td>Often</td>
<td></td>
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<td>Once a year</td>
<td>Running Off Road Yes</td>
<td>Once a Month</td>
<td>Entered Unocc. Ln</td>
<td>Distance</td>
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Table B.1: Human Test Subject Summarized Answers to Pre-Questionnaire (continued)

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<th>12a</th>
<th>13</th>
<th>13a</th>
<th>Classification</th>
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<td>PS5</td>
<td>Sometimes</td>
<td>Often</td>
<td>No</td>
<td>NA</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Intermediate</td>
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<tr>
<td>PS6</td>
<td>Sometimes</td>
<td>Always</td>
<td>Yes</td>
<td>Known Police Area/Bad Weather/Traffic</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Intermediate</td>
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<tr>
<td>PS8</td>
<td>Often</td>
<td>Often</td>
<td>Yes</td>
<td>Sleepy/No Rush</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Intermediate</td>
</tr>
<tr>
<td>PS9</td>
<td>Sometimes</td>
<td>Often</td>
<td>Yes</td>
<td>Bad Weather/Unfamiliar Area</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Intermediate</td>
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<tr>
<td>PS10</td>
<td>Often</td>
<td>Often</td>
<td>Yes</td>
<td>Bad Weather</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Intermediate</td>
</tr>
<tr>
<td>PS11</td>
<td>Sometimes</td>
<td>Sometimes</td>
<td>Yes</td>
<td>Bad Weather</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Expert</td>
</tr>
<tr>
<td>PS12</td>
<td>Sometimes</td>
<td>Often</td>
<td>No</td>
<td>NA</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Novice</td>
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<td>PS13</td>
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<td>Often</td>
<td>No</td>
<td>NA</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Expert</td>
</tr>
<tr>
<td>PS14</td>
<td>Sometimes</td>
<td>Sometimes</td>
<td>Yes</td>
<td>Bad Weather/No Rush</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Novice</td>
</tr>
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<td>PS15</td>
<td>Often</td>
<td>Always</td>
<td>No</td>
<td>NA</td>
<td>No</td>
<td>NA</td>
<td>Novice</td>
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<td>PS16</td>
<td>Sometimes</td>
<td>Sometimes</td>
<td>Yes</td>
<td>Bad weather/traffic</td>
<td>No</td>
<td>NA</td>
<td>Expert</td>
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<tr>
<td>PS17</td>
<td>Sometimes</td>
<td>Always</td>
<td>No</td>
<td>NA</td>
<td>Yes</td>
<td>Driver's Ed</td>
<td>Expert</td>
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</tbody>
</table>

Table B.1: Human Test Subject Summarized Answers to Pre-Questionnaire (continued)
VIRTUAL DRIVING INSTRUCTION USING AN AUTOMOTIVE DRIVING SIMULATOR
POST-QUESTIONNAIRE

INSTRUCTIONS: Please read each statement below. Circle the number in the block which best describes your response to the statement (i.e., if you “strongly agree”, “strongly disagree”, “agree”, or “disagree”)

<table>
<thead>
<tr>
<th>Attitude Measured</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 If the back end of the leading vehicle passes a noticeable object on the side of the road, a driver should adjust their speed to pass that object 3 seconds later.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2 When the back end of the vehicle in front of you passes a noticeable object on the side of the road, you should immediately pass that object.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>3 I believe that 3 seconds is too much time as a safe following distance “rule”.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4 If children are playing on a side walk, you should slow down.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5 When I am driving, I do not always slow down when I see children playing on the sidewalk.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6 The presence of children along the roadway should affect how people drive.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7 I should slow down when I see a deer crossing sign.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8 Drivers don’t pay attention to deer crossing signs.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9 The presence of deer crossing signs on the road should affect how others drive.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10 You should always slow down at construction/work zones.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11 It is not necessary to obey construction/work zone speed limits when workers are not present.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12 Entering a construction/work zone should affect a driver’s speed.</td>
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### POST QUESTIONNAIRE RESULTS

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<td>Free</td>
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<td>4</td>
<td>3</td>
<td>Free</td>
<td>4</td>
<td>3</td>
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<td>Free</td>
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<td>Free</td>
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<td>1</td>
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<td>23</td>
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<td>4</td>
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Table B.2: Human Test Subject Summarized Answers to Post-Questionnaire
Appendix C: Following Etiquette Simulator Code

The following Appendix presents the DriveSafety automotive simulator code for Runs 1, 2, and 3 in the “Following Etiquette” virtual training module. Note that Runs 1 and 3 were identical. However, Run 2 contained “help messages” embedded in the program.
Run 1 and 3

Version 1.5

#EndIncludes

#StartPoint "StartPoint6" 1107.5368857794313 12.55464411069735 0.0 0

EntityCreate "LeadVehicle" "VW Golf Yellow" 1107.3 20.0 0.0 0 NeverDestroy

InitScript {

EntityJoinRoadway LeadVehicle
EntitySetRoadwayVelocity LeadVehicle Fixed 70 MPH

SimSelectDataCollectionElements Collision CollisionVelocity EntityName EntityVelocity HeadwayDist HeadwayTime ProjectName SubjectID SubjectName SubjectX SubjectY Time Velocity
SimCollectData On 60 LeadVehicle
}

ExitScript {

Run 2

Version 1.5

#EndIncludes

#StartPoint "StartPoint6" 1107.5368857794313 12.55464411069735 0.0 0

EntityCreate "LeadVehicle" "VW Golf Yellow" 1107.3 20.0 0.0 0 NeverDestroy

InitScript {

EntityJoinRoadway LeadVehicle
EntitySetRoadwayVelocity LeadVehicle Fixed 70 MPH

VTriggerCreate VTHeadwayCheck {
if  {::HeadwayTime < 2.0  } {
VisualsDisplayText TooClose 2 .5 .5 3 255 0 255 1 "Too Close"
} elseif  {::HeadwayTime > 3.0  } {
VisualsDisplayText TooFar 2 .5 .5 3 255 0 255 1 "Too Far"
}
VTriggerAdd VTHeadwayCheck 5 Hz
SimSelectDataCollectionElements Collision CollisionVelocity EntityName
EntityVelocity HeadwayDist HeadwayTime ProjectName SubjectID SubjectName
SubjectX SubjectY Time Velocity
SimCollectData On 60 LeadVehicle

ExitScript {
Appendix D: Situational Awareness Simulator Code

This Appendix contains the simulator script code for the “Situational Awareness” virtual training module. The code for Run 1 may be labeled as base run. The code titled Runs 2 and 3 contains the scripts for the virtual obstacles.
Run 1

Version 1.5

#EndIncludes

#EndPoint "DogStartPoint" 1104.3 312.0 0.0 0

EntityCreateKinematic "Person2" "Child" 1111.2327436430705 457.3096902224832 0.15000000596046448 0

EntityCreateKinematic "Person3" "Caucasian Male" 1110.6185059346233 457.88553807415315 0.15000000596047158 0

EntityCreateKinematic "Person4" "Caucasian Male" 1089.6192542770543 464.33503401285765 0.15000000596045737 0

PathCreate "DogPath" {
  PathPoint 1110.0 463.0 0.15
  PathPoint 1091.15 465.02 0.15
}

EntityCreateKinematic "Dog" "Dog, Walking" 1110.0 463.0 0.0 0

TriggerCreate "DogTrigger" Time 1110.0 463.0 0.2 4.0 Subject {
  EntitySetPathVelocity Dog 10 MPH
  EntityTraversePath Dog DogPath FirstNode Stop
}

EntityCreateKinematic "Deer" "Deer--Walking" 420.5 682.0 0.7 180

PathCreate "DeerPath" {
  PathPoint 421.11 680.41 0.6
  PathPoint 422.99 676.59 0.34
  PathPoint 427.85 678.82 0.33
}
PathPoint 425.81 683.48 0.64

}

TriggerCreate "DeerTrigger" Time 420.5 681.8 0.7 4.0 Subject {
EntitySetPathVelocity Deer 10 MPH
EntityTraversePath Deer DeerPath FirstNode Stop
}
#EndTrigger Do not add below this line

#StartPoint "DeerStartPoint" 618.6 702.0 0.0 0

EntityCreate "Vehicle23" "Dump Truck" 892.1 709.4 -0.0 270 NeverDestroy

EntityCreateKinematic "Person26" "Caucasian Male" 850.3120772417197 707.3888915582553 0.0 0

EntityCreateKinematic "Person27" "Caucasian Male" 874.1437431864108 707.3888915582553 0.0 0

EntityCreateKinematic "Person28" "Caucasian Male" 848.1234548590461 707.1457112935126 0.0 0

EntityCreateKinematic "Person29" "Caucasian Male" 837.0992828574203 706.9835911170154 1.421085475202004E-14 0

EntityCreate "DumpTruck" "Dump Truck" 819.0 707.0 -0.0 270 NeverDestroy

TriggerCreate "DumpTruckTrigger" Time 828.1 706.7 0.0 4.0 Subject {
EntityJoinRoadway DumpTruck
}
#EndTrigger Do not add below this line

#StartPoint "DumpTruckStartPoint" 942.4 702.0 0.0 0

InitScript {

}

ExitScript {

}
Run 2 and 3

Version 1.5

#EndIncludes

EntityCreate "Vehicle27" "Bicycle" 510.88616914180983 586.1422766052432 0.1500000059604787 0 NeverDestroy

EntityCreate "Vehicle28" "Bicycle" 489.4 594.1 0.2 180 NeverDestroy

EntityCreateKinematic "Person30" "African American Female" 489.1389595002891 502.5418652126828 0.15000000596046803 0

EntityCreateKinematic "Person33" "Child" 509.9515051970157 496.6354261291316 0.15000000596046448 0

EntityCreateKinematic "Person31" "Caucasian Male" 512.3 496.5 0.2 270

EntityCreateKinematic "Person32" "African American Male" 489.1 504.7 0.2 180

EntityCreateKinematic "Person34" "Dog, Walking" 488.31036216477315 503.4733277902851 0.15000000596046448 0

TriggerCreate "DogTrigger" Time 510.9 509.1 0.2 4.0 Subject {
  EntitySetPathVelocity Dog 15 MPH
  EntityTraversePath Dog DogPath FirstNode Stop
}

#EndTrigger Do not add below this line

EntityCreateKinematic "Dog" "Dog, Running" 511.0 509.0 0.2 180

PathCreate "DogPath" {
  PathPoint 511.0 504.6 0.15
  PathPoint 492.13 501.81 0.15
}

EntityCreate "Vehicle43" "Celica Purple" 501.7797171229106 443.3471839231129 0.0 0 NeverDestroy
EntityCreate "Vehicle44" "Grand Prix Blue" 497.75953865924885 476.530189864823 -7.105427357601002E-15 180 NeverDestroy

EntityCreate "Vehicle45" "Grand Prix Tan" 501.9574202828921 534.5666803201789 0.0 0 NeverDestroy

TriggerCreate "DogData" Time 492.0 543.1 0.2 4.0 Subject {
  SimCollectData On 60 Dog
}
#EndTrigger Do not add below this line

EntityCreateKinematic "Person4" "Caucasian Male" 1089.6192542770543 464.33503401285765 0.15000000596045737 0

EntityCreateKinematic "Person3" "Caucasian Male" 1110.6185059346233 457.88553807415315 0.15000000596047158 0

EntityCreateKinematic "Person2" "Child" 1111.2327436430705 457.3096902224832 0.15000000596046448 0

#EndPoint "Beginning" 1301.6 480.8 0.0 0

EntityCreate "Vehicle46" "School Bus" 626.8 697.8 0.0 90 NeverDestroy

EntityCreate "Vehicle47" "Semi Cab-over Tractor" 769.8022161618886 697.9151007356384 0.0 90 NeverDestroy

PathCreate "DumpTruckPath" {
  PathPoint 805.02 701.85 0.0
  PathPoint 789.36 701.47 0.0
  PathPoint 777.0 705.58 0.0
}

EntityCreate "Vehicle23" "Dump Truck" 892.1 709.4 -0.0 270 NeverDestroy

EntityCreate "DumpTruck" "Dump Truck" 819.0 707.0 -0.0 270 NeverDestroy

EntityCreateKinematic "Person29" "Caucasian Male" 837.0992828574203 706.9835911170154 1.4210854715202004E-14 0
EntityCreateKinematic "Person28" "Caucasian Male" 848.1234548590461 707.1457112935126 0.0 0
EntityCreateKinematic "Person27" "Caucasian Male" 874.1437431864108 707.3888915582553 0.0 0
EntityCreateKinematic "Person26" "Caucasian Male" 850.3120772417197 707.3888915582553 0.0 0

#StartPoint "DumpTruckStart" 954.2 705.0 0.0 0
TriggerCreate "DumpTruckJoinTrigger" Time 934.5 705.4 0.0 4.0 Subject {
  EntityJoinRoadway DumpTruck
  SimCollectData On 60 DumpTruck
}
#EndTrigger Do not add below this line

TriggerCreate "DumpTruckPathTrigger" Time 828.1 706.6 0.0 1.0 Subject {
  EntityTraversePath DumpTruck DumpTruckPath FirstNode Stop
}
#EndTrigger Do not add below this line

EntityCreate "Vehicle48" "Grand Prix Blue" 1099.8389973963438 697.339913429624 -0.04557730607747601 90 NeverDestroy
EntityCreate "Vehicle49" "Grand Prix Blue" 1093.0801713851088 701.3694459390807 0.0 6483104350557767 -90 NeverDestroy

PathCreate "DeerPath" {
  PathPoint 1237.44 649.79 0.34
  PathPoint 1233.73 645.52 0.0
  PathPoint 1227.56 643.8 -0.32
}

EntityCreateKinematic "Deer" "Deer--Walking" 1239.6 650.3 0.4 180
EntityCreate "Vehicle51" "Motorcycle" 1269.4 606.1 0.1 0 NeverDestroy

EntityCreate "Vehicle50" "Four Runner Aqua" 1259.1 613.9 -0.1 135 NeverDestroy

TriggerCreate "DeerTrigger" Time 1237.4 649.8 0.3 4.0 Subject {
    EntitySetPathVelocity Deer 20 MPH
    EntityTraversePath Deer DeerPath FirstNode Stop
}

#EndTrigger Do not add below this line

InitScript {
    EntityJoinRoadway Vehicle27
    EntityJoinRoadway Vehicle28
    EntityJoinRoadway Vehicle43
    EntityJoinRoadway Vehicle44
    EntityJoinRoadway Vehicle45
    EntityJoinRoadway Vehicle46
    EntityJoinRoadway Vehicle47
    EntityJoinRoadway Vehicle48
    EntityJoinRoadway Vehicle49
    EntityJoinRoadway Vehicle50
    EntityJoinRoadway Vehicle51

    SimSelectDataCollectionElements ALL
    SimCollectData On 60 Deer
}

ExitScript {

}
Appendix E: Following Etiquette Graphical Results

The human test subject quantitative data gathered from the DriveSafety simulator will be presented in this Appendix. The subject velocity, $v_S$, lead car velocity, $v_L$, and subject headway time, $t_H$, was plotted for each subject. The target headway time, $h$, was 3 seconds which has been represented by a horizontal line in each graph.
Figure E.1: Subject PS5 Following Etiquette Results for Run 1 and Run 2

Figure E.2: Subject PS8 Following Etiquette Results for Run 1 and Run 2
Figure E.3: Subject PS9 Following Etiquette Results for Run 1 and Run 2

Figure E.4: Subject PS10 Following Etiquette Results for Run 1 and Run 2
Figure E.5: Subject PS11 Following Etiquette Results for Run 1 and Run 2

Figure E.6: Subject PS12 Following Etiquette Results for Run 1 and Run 2
Figure E.7: Subject PS13 Following Etiquette Results for Run 1 and Run 2

Figure E.8: Subject PS15 Following Etiquette Results for Run 1 and Run 2
Figure E.9: Subject PS17 Following Etiquette Results for Run 1 and Run 2
Appendix F: Situational Awareness Graphical Results

As mentioned in Chapter 4, the simulator data for the remaining 9 subjects are presented in Figures F.1 through F.45 for the “Situational Awareness” module. The first two graphs for each subject represent the subject velocity and acceleration patterns for all three runs. The second set of graphs illustrates the subject lane position and steering angle throughout the runs. The last graph for each subject shows the subject normalized brake angle during the obstacle encounter for all of the runs.
Figure F.1: PS6 Velocity Versus Time (Base Run, Run 1, and Run 2)

Figure F.2: PS6 Acceleration Versus Time (Base Run, Run 1, and Run 2)
Figure F.3: PS6 Lane Position Versus Time (Base Run, Run 1, and Run 2)

Figure F.4: PS6 Steer Offset Versus Time (Base Run, Run 1, and Run 2)
Figure F.5: PS6 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)

Figure F.6: PS8 Velocity Versus Time (Base Run, Run 1, and Run 2)
Figure F.7: PS8 Acceleration Versus Time (Base Run, Run 1, and Run 2)

Figure F.8: PS8 Lane Position Versus Time (Base Run, Run 1, and Run 2)
Figure F.9: PS8 Steering Offset Versus Time (Base Run, Run 1, and Run 2)

Figure F.10: PS8 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)
Figure F.11: PS9 Velocity Versus Time (Base Run, Run 1, and Run 2)

Figure F.12: PS9 Acceleration Versus Time (Base Run, Run 1, and Run 2)
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<th>Lane Position Offset (m)</th>
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Figure F.13: PS9 Lane Position Versus Time (Base Run, Run 1, and Run 2)

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</tbody>
</table>

Figure F.14: PS9 Steering Offset Versus Time (Base Run, Run 1, and Run 2)
Figure F.15: PS9 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)

Figure F.16: PS10 Velocity Versus Time (Base Run, Run 1, and Run 2)
Figure F.17: PS10 Acceleration Versus Time (Base Run, Run 1, and Run 2)

Figure F.18: PS10 Lane Position Versus Time (Base Run, Run 1, and Run 2)
Figure F.19: PS10 Steering Offset Versus Time (Base Run, Run 1, and Run 2)

Figure F.20: PS10 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)
Figure F.21: PS12 Velocity Versus Time (Base Run, Run 1, and Run 2)

Figure F.22: PS12 Acceleration Versus Time (Base Run, Run 1, and Run 2)
Figure F.23: PS12 Lane Position Versus Time (Base Run, Run 1, and Run 2)

Figure F.24: PS12 Steering Offset Versus Time (Base Run, Run 1, and Run 2)
Figure F.25: PS12 Brake Versus Time (Base Run, Run 1, and Run 2)

Figure F.26: PS13 Velocity Versus Time (Base Run, Run 1, and Run 2)
Figure F.27: PS13 Acceleration Versus Time (Base Run, Run 1, and Run 2)

Figure F.28: PS13 Lane Position Versus Time (Base Run, Run 1, and Run 2)
Figure F.29: PS13 Steering Offset Versus Time (Base Run, Run 1, and Run 2)

Figure F.30: PS13 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)
Figure F.31: PS14 Velocity Versus Time (Base Run, Run 1, and Run 2)

Figure F.32: PS14 Acceleration Versus Time (Base Run, Run 1, and Run 2)
Figure F.33: PS14 Lane Position Versus Time (Base Run, Run 1, and Run 2)

Figure F.34: PS14 Steering Offset Versus Time (Base Run, Run 1, and Run 2)
Figure F.35: PS14 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)

Figure F.36: PS15 Velocity Versus Time (Base Run, Run 1, and Run 2)
Figure F.37: PS15 Acceleration Versus Time (Base Run, Run 1, and Run 2)

Figure F.38: PS15 Lane Position Versus Time (Base Run, Run 1, and Run 2)
Figure F.39: PS15 Steering Offset Versus Time (Base Run, Run 1, and Run 2)

Figure F.40: Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)
Figure F.41: PS16 Velocity Versus Time (Base Run, Run 1, and Run 2)

Figure F.42: PS16 Acceleration Versus Time (Base Run, Run 1, and Run 2)
Figure F.43: PS16 Lane Position Versus Time (Base Run, Run 1, and Run 2)

Figure F.44: PS16 Steering Offset Versus Time (Base Run, Run 1, and Run 2)
Figure F.45: PS16 Brake Versus Time (Base Run, Run 1 in left column, and Run 2 in right column)
Appendix G: Virtual Driving Training Videos

The two virtual driving training modules included custom training videos that were created and produced by D. Norfleet. The accompanying videos (2:07 and 1:22 minutes) are on the attached CD. There were three video clips for the “Following Etiquette” module and two video clips for the “Situational Awareness” module that should be played for the student driver.