Implementation of Artificial Intelligence to Improve Novice Drivers' Hazard Perception Skills

by

Brandi Stillman

Submitted in Partial Fulfillment of the Requirements
for the Degree of
Master of Computing and Information Systems
in the
Computer Science & Information Systems
Program

YOUNGSTOWN STATE UNIVERSITY

December, 2013

Implementation of Artificial Intelligence
to Improve Novice Drivers' Hazard Perception Skills

Brandi Stillman

Signature:

Brandi Stillman, Student Date

Approvals:

Dr. Abdurrahman Arslanyilmaz, Thesis Advisor Date

Dr. John Sullins, Committee Member Date

Dr. Bonita Sharif, Committee Member Date

Dr. Salvatore A. Sanders, Associate Dean of Graduate Studies Date

ABSTRACT

Commercial off-the-shelf video games, such as Grand Theft Auto 5, bring in hundreds of thousands of sales within the first few days. Why not a teenager's interest in a video game for more educational purposes? Simulation programs are often expensive and rare, but serious games can be made easily available and open for the public. An educational driving simulator in the form of a video game poses an interesting opportunity to reach teenagers, by combining flashy graphics and friendly competition with real-world road hazards. In an attempt to create and test such a program, our team designed artificial vehicles in a driving simulator that generate random traffic and attempt to crash the player vehicle. In this single player game, the player must maneuver the player vehicle to a mission objective. Each of the three players in this study were thirteen year old male students with absolutely no driving experience. These students completed a pre-test, two ten minute missions, and a post-test. Using eye tracker software to analyze horizontal scanning, there did not seem to be significant results to indicate an improvement in hazard perception. However, each student reported an interest in future participation. Therefore, it is recommended that future studies on the current project are continued, with the appropriate software upgrades needed to allow students to operate the game at a normal frame rate (without lag).

Table of Contents

Table of Figures

CHAPTER ONE: INTRODUCTION

In 2013, Grand Theft Auto 5 became the biggest game launch in United Kingdom history. It topped retail records, with an astonishing $1 billion in sales around the world within the first three days. Here is a list of seven Guinness World Records that GTA 5 broke in 2013 [15]:

- Best-selling action-adventure videogame in 24 hours
- Best-selling videogame in 24 hours
- Fastest entertainment property to gross $1 billion
- Fastest videogame to gross $1 billion
- Highest grossing videogame in 24 hours
- Highest revenue generated by an entertainment product in 24 hours
- Most viewed trailer for an action-adventure videogame

Figure 1: The image above is a screenshot from Grand Theft Auto 5.

Youth these days love video games. The humor, the chaos, and the luxury wrap them up in a virtual environment that they can only imagine in their wildest dreams (see figure 1). What better way to appeal to their interests than adding education to an environment that they already enjoy?

Serious games is not a new concept by far. Many professional fields use simulation training, such as military flight simulators, to give employees extra opportunities to practice real life situations. Many of these simulations can create virtual hostile environments, allowing users to experience situations that are dangerous to practice in real life, or do not occur often enough to provide practice opportunities. Many of the flashy commercial off-the-shelf video games (COTS) are popular for amazing graphics, fast-paced action, and social networking abilities. Why can't an educational simulation offer the same experience?

Creating a simulation, or video game, to implement driving abilities, as seen in Grand Theft Auto, may serve as a great opportunity for learning driving techniques. Obviously, a virtual environment with common every day access methods (internet, video game console, etc.) would not improve a user's motor skills. However, with regular practice a user could become aware of common hazards that inexperienced drivers do not usually catch in time. Additionally, with excessive practice (or regular practice over a prolonged time) a user may even begin to anticipate hazards before they occur, as this same adaptation of environment occurs in commercial off-the-shelf video games.

GTA 5 creates a driving environment, but users must complete missions if they want to complete campaign mode (see figure 2). Missions have different objectives, different vehicles, and different payouts. It would be interesting to conduct a study on integrating mini games at each objective. A mini game cannot provide the same unique experience, but there is ample opportunity to improve cognitive abilities with short, simple coordination or puzzle games. The opportunities are endless, but first it is necessary to identify which problem this would solve.

Figure 2: This is a screenshot from a Grand Theft Auto 5 mission.

1.2 The problem

Car crashes are the number one cause of teenage deaths in the United States. Teenage boys are two times more likely to crash than ladies, and more than half of all teenage crash fatalities are due to the victim not wearing his or her seatbelt. The first year of driving is usually the biggest risk for teenage accidents. Drivesteady.com has plenty of facts that will give the average parent night terrors. It also reveals the best way to decrease the likelihood of an accident, practice.

There are many programs in place that attempt to remedy the problem, such as drivers education classes, private driving instructors, and more demanding license requirements. Still, fatalities continue to rise and it is only expected to get worse. A deeper look at the issue reveals that novice drivers learn the majority of their mechanical abilities after only fifteen hours of vehicle operation. The sense of accomplishment novice drivers feel, at that point, causes them to overestimate their ability to operate in situations of duress. In addition to that, proper assessment of roadway hazards requires a complex connection that only experienced drivers are able to recognize. For example, a novice driver that drives through a neighborhood scans the road. They are aware of the objects in the road, some children getting ready to cross, oncoming traffic, and their own position on the road. A good, experienced driver can notice things like a mailman four houses down, opening a fence, letting a little dog out (stay out of the road little dog!). Many experienced drivers are aware of larger surrounding area. Several cars forward, several cars back, or even longer distances through large straight-aways. Common sense says that novice drivers will get better with experience, but real world experience is expensive and dangerous. Given all the facts, it appears the best course of action is to prepare novice drivers with a virtual environment, with the ability to introduce them to dangerous situations. Most people cannot avoid these hazards unless they have previous experience. The use of artificial intelligence to exercise a novice driver's hazard perception skills in a driving simulation program will result in improved hazard perception, while presenting a strong appeal to a teenage audience.

This paper will provide an overview of the severity of the issue, as well as a potential resolution to the problem. There is not a fix out there, the problem is complex and the risk is sensitive. With all the new technologies distracting them, like smart phones and digital billboards, teenagers need to fixate on the road more often, scan for potential accidents more often, and have a more thorough understanding of how a regular situation can result in chaos if preventative steps are not taken to ensure safety. The fact is, not only to do our teenagers need to be skilled, attentive drivers. They should be prepared to encounter other bad drivers. Bad drivers should take some of the blame, because the main reason teenagers crash is they do not see trouble coming from a mile away, literally. This is known as risk perception, an ability shared by many experienced drivers.

1.3 The contents

Following this introduction is a review of numerous articles that analyze the ability to measure and enhance hazard perception in young adult, novice drivers. Although many references are within the last five years, simulation has been studied for more than forty years now. At one time long ago, a state-of-the-art simulator included nothing but a screen and a joystick. With the changes in technology, numerous simulation environments exist with real vehicles, imitating real vehicle movements, and projecting real traffic environments on side-by-side projector images. Of course, our ideal solution needs to be quick and easy to access, so extravagance is not an option.

The third chapter explains the requirements for each of the simulation components. The simulation program is broken up into three elements: environment, artificial vehicles, and player vehicle. While some 3D models were downloaded from the internet, more than 90% of the hard code was written by project team members and all animations were custom created for this study. Buildings, cars, and trees were placed throughout the map with a realistic layout. There are two kinds of artificial vehicles, serving the primary purpose of disturbing the simulation user. The most complex type of vehicle can travel all parts of the map and calculates its path dynamically. The second type of vehicle stays in one parked position, unless a player vehicle hits a nearby trigger that activates it. Once a trigger is activated, this artificial vehicle will backup, in front of the player vehicle. The player vehicle is the third element, providing the user with a number pad for simulation control, a point system to penalize law breakers, and an assortment of helpful views to scan the environment from different angles.

The remainder of the chapter identifies participant factors, like background information and participation rewards. All participants are teenage students from a local school that took a day to visit Youngstown State University for our study. The study took approximately four hours and each participant was needed for about forty-five minutes. Pre-test and post-test were about three minutes long and students were asked to complete missions that took eight to ten minutes each. Students were treated to pizza, activities, and the chance to win a small prize for best in-game performance.

The last two chapters reveal project results and recommendations for improvement. Results were not as supportive as the project team would like, but some findings do support an opportunity for success with future iterations. Some in-game components were planned for, but were not available for the first experiment (this thesis describes the process of the first experiment in this particular study). Other elements may have been completed and functional, but were not included due to technical problems or time constraints.

CHAPTER TWO: LITERATURE REVIEW

2.1 Background

In Australia, even though young drivers represent a small percentage of the total road population (only 15%), they are still responsible for 35% of crash related deaths and a staggering 50% of total injuries that occur during car crashes [10]. Approximately 42.7% of accidents caused by young drivers are from not looking ahead, not using peripheral vision, or not being aware of the traffic behind them[22]. The likely cause of these statistics is not a lack of the ability to maneuver the vehicle, but the lack of understanding how some situations are potentially hazardous [26, 27]. These situations are easier to manage over time; over time a novice driver gains the understanding as they increase their amount of driving experience [20]. Another contribution may be a young driver's inability to judge their own driving skills [10]. Studies show that car accidents with fatalities will increase dramatically (by more than 80%), especially in densely populated countries, such as China [11]. Numerous studies, over the last forty years, have proven that there is no perfect solution to this problem [20].

The young driver paradox is addressed in a 1986 paper by B. A. Jonah entitled. It states that without actually being involved in a car accident or hazardous situation, it can be near impossible to benefit from the driving experience. A hazard is an object, situation, or occurrence that can potentially cause harm to the road user [6]. Over time, people change their reactions to these road hazards, although not consciously [23]. Hazard perception is described has an element of skill, as well as an element of subjective experience. Many experienced drivers can analyze the behavior of surrounding traffic, and avoid a car accident by reacting to a hazard before there is a physical interaction [27]. Some arguments would suggest that a simulator may not be taken seriously by young drivers, thus it cannot accurately measure a change in actually driving performance. However, it is widely known that inexperience is an issue because young drivers have not yet developed a holistic understanding of their position and the environment [6, 8]. For example, they do not search for hidden objects that could eventually cause an accident. Additionally, they do not properly scan the road way. Experienced drivers have a wider range of view, their fixation periods of off road objects is much shorts, and they have a better understanding of hazard cues [6, 7, 28].

2.2 Approach

A common solution to similar problems in any field (involving experience versus inexperience) is a simulation program. Simulation technology has been climbing at impressive rates over the last 20 years. It is used for everything from medical practice flight training. Many simulation programs are built to include variables such as weather, traffic density, and time. It is important for many jobs, such as that of a fire truck driver, where time and situation are key to making tough choices [23]. The ability for a simulator to mimic realism is known as "physical validity" [9]. However, for this particular study we are offering a simulation program to students as a game. Many designers have created games that serve educational purposes. These are commonly known as serious games [2].

Commercial off-the-shelf video games are much more common that most simulation training programs, so serious games may have a lot of promise on a game console or via the internet. It has been shown that a PC based program, being practiced by young drivers, can reduce risk by providing experience [14]. A learning game should be low intensity, so that users are not forced into making bad decisions. Lots of feedback and a clear understanding of the goals are required for an optimal learning experience [2]. One type of training, known as Variable Priority Training (VPT) improves a young driver's ability to pay attention, while performing multiple tasks [10]. There is also a training method called Forward Concentration and Attention Learning (FOCAL), in which 52% of teen drivers analyzed stopped previous habits of removing their focus of the road for more than two seconds. This training method also utilizes multitasking. One of the reasons the requirements of multiple tasks is beneficial is because the amount of time drivers spend looking away from the road is constantly increasing, due to a growing use of handheld technologies inside the car and digital advertisements outside of the car [7]. The task of actually learning how to operate a vehicle has been shown to require only fifteen hours in the majority of cases [10]. In fact, it is proven that abilities like skid control and braking do not reduce the amount of accidents, but training in hazard perception and decreasing accident risk offer a significant reduction rate [28]. This could be from young drivers associating complex traffic conditions as one single factor, meaning all hazards pose equal amounts of risk, which is obviously not always the case. This is where a holistic approach would benefit the young driver [10].

2.3 Considerations

There are some factors to consider, when preparing a simulation program for audience participation. For example, if some participants do not get an adequate amount of sleep, this can have a negative impact on their abilities [25]. It is going to require some encouragement to get young drivers interested in practicing a simulation during free time [20]. There should be some factors in place that will prevent young drivers from underestimating risk, which may be difficult to provide in a virtual environment [10]. Designers have the advantage of creating an experience of situations that are impossible to create in a real world experience, due to budget and safety constraints [2]. However, it is important to note that while simulators can track performance, a simulator has no control over driver behavior. Therefore, it may be difficult to correct any specific bad habits a young driver may have [7]. Although in the past there were many reports of nausea after using some simulators (basically, motion sickness), improvements in technology continue to muffle the physical effects of dizzying situations [11]. There are no other known physical side effects associated with simulation programs, however prolonged screen time and slow frame rates can sometimes cause headaches.

CHAPTER THREE: METHOD

3.1 Environment

This section explains the elements of the prototype used, which is the first official iteration of a game-based, multi-user, online, simulated-training program (GMOST). This program is being developed by a research team, inspired by Dr. Abdurrahman Arslanyilmaz, Assistant Professor of Youngstown State University. This is an ongoing project, therefore this iteration does not have the full functionality of a GMOST program. The driving simulator used during testing is a single-player PC game. It is designed by the project team, with a free version of Unity3D. One might say the first iteration lacks realism due to the lack of some tools, which are only accessible with UnityPro. A more detailed description of future implementations is presented at the conclusion.

The driving simulator provides a general driving environment for those participating in the study (from now on we will refer to them as students). The terrain is flat, with a grass texture. At all major intersections there are street lights. The street lights begin as north and south traffic having the green light, then after a count of 500 frames the light will turn yellow. Once the light turns red, the east and west traffic has the green light and goes through the same process. Lights at every intersection run on one cycle. In other words, if one light is green while you are traveling north, they are all green for any vehicle traveling north or south.

The roads are all flat, straight surfaces with custom textures. A few of the roads are plain asphalt surfaces, but the others have two, three, four, or five lanes. There are two-lane expressways, three lane roads with continuous two-way left-turn lanes, four lane undivided highways, and five lane roads with continuous two-way left-turn lanes (see figure 3). At each of the four edges of the map the outermost roads are connected to build one continuous square. The roads were placed first to create a grid-like pattern, and all other objects were placed relative to this roadway system.

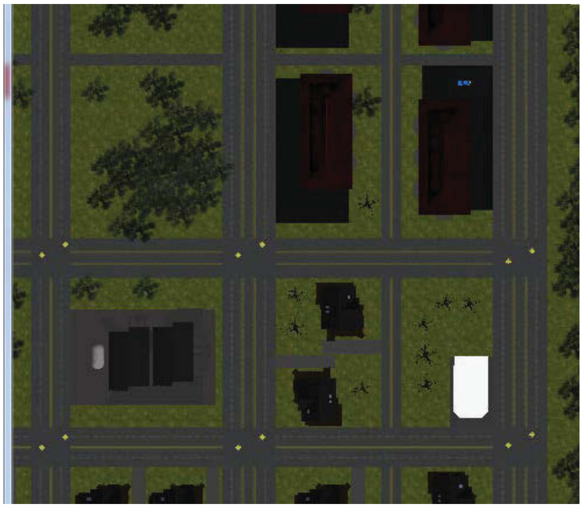


Figure 3: Above view, illustrating different road types.

The roadway system is surrounded by a forest. Around the forest stands a large wall, that prevents students from driving off the map. There are several different types of buildings placed strategically around the map. These buildings hide mission objectives and potential road hazards. The 3D models for these objects were downloaded from TurboSquid.com and archive3d.net. Scattered throughout the map there are trees. Trees seem to be important in the environment, to enhance the feeling of realism. However, steering with a Unity3D physics engine in control does not produce ideal results. We did not feel it was reasonable to penalize the students for difficult steering (that is not the point of the study), so trees do not have colliders included. Objects such as buildings, walls, and vehicles do have colliders, allowing a penalty upon collision. The penalty system is more fully discussed later on.

Figure 4: View of mission objective at hospital, for Mission 1.

Some buildings were placed at specific map locations to be used as mission start positions and objectives (see figure 4). There are five different missions, each with a unique starting point, story line (figure 5), and ending point. Students have ten minutes to complete each mission. If a mission is not complete in ten minutes the game ends.

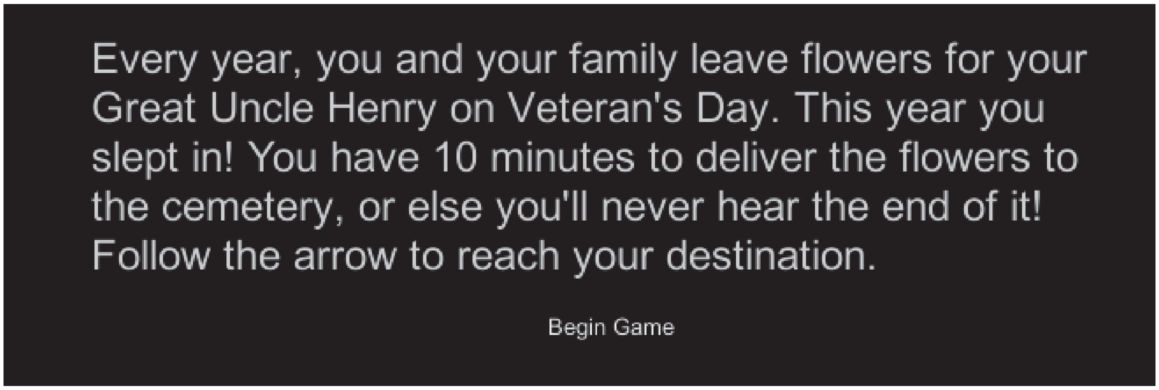

Every year, you and your family leave flowers for your Great Uncle Henry on Veteran's Day. This year you slept in! You have 10 minutes to deliver the flowers to the cemetery, or else you'll never hear the end of it! Follow the arrow to reach your destination.

Figure 5: Instructions as seen after selecting Mission 4.

Mission one begins in the parking lot of a large white office building. The mission requires the student to go to a large red house on the east side of the map, followed by a large black hospital on the west side of the map. Mission one objectives are highlighted with a large, red bubble. The second objective begins in the northernmost block of the map. When a student starts this mission, he will see the message, "You are meeting your friends at a soccer game! Follow the arrow to reach your destination. You have 10

Figure 6: Overview of Mission 3 and Mission 4 objectives.

minutes to get there." The arrow leads to an alleyway on the side of a soccer field, in a somewhat congested area of the map.

The third mission starts in a building on the west side. Upon selection of this mission, students read, "Every year, you and your family leave flowers for your Great Uncle Henry on Veteran's Day. This year you slept in! You have 10 minutes to deliver the flowers to the cemetery, or else you'll never hear the end of it! Follow the arrow to reach your destination." This is a yellow objective in the far southeast corner of the map. The fourth mission is initiated from a driveway in the middle western area of the map. "The Indoor Amusement Park is offering free admission to the first 100 customers. Get there in 10 minutes for your free day of fun. Follow the arrow to reach your destination," is displayed after the student selects this mission. The objective is in the south, within a green, transparent bubble. Mission 5 begins in the southwest, has a first objective in the center, and ends at a school in the southeast corner. It is explained later on that some missions were excluded from the study, due to time constraints. Mission 3 and Mission 4 were included in the study. See figure 6 for these objectives.

3.2 Artificial vehicles

The most difficult element to compose was the artificial vehicles. These vehicles are primarily meant to randomly cruise around the map. They represent the smart artificial intelligence objects that are included, and will be referenced as AIs from now on. They make much more complicated decisions than their counterparts, bots, which have very limited movement. Although technically the bots are considered artificial intelligence elements, for descriptive purposes we will only refer to them as bots. The difference between these two types of artificial vehicles will illustrate why they hold separate titles.

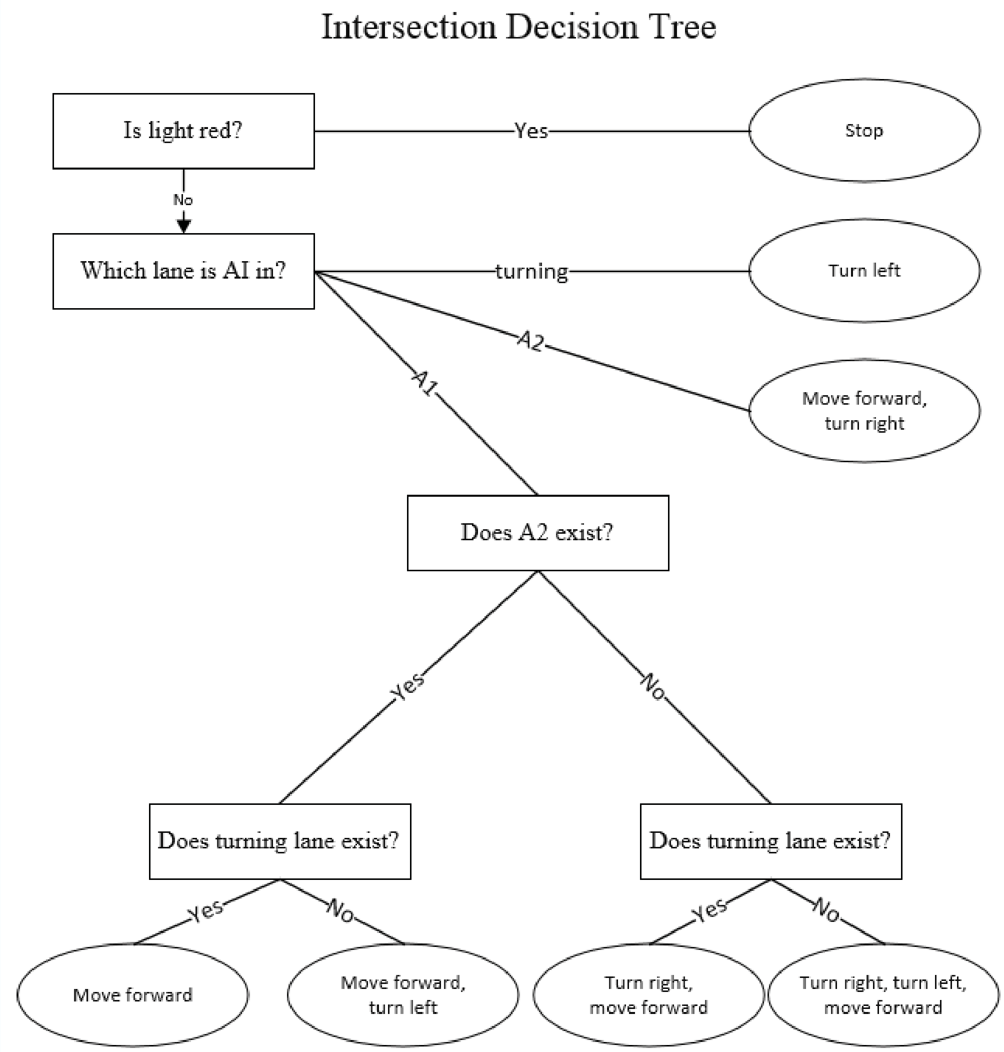


Figure 7: Decision tree as used by AI when determining next direction (calculated prior to entering intersection).

The AIs are responsible for generating random traffic, since traffic is the main component in hazard perception. The AIs follow certain rules that allow them to travel the map freely and recover from any mistakes. For example, if a lag occurs and a few frames are skipped, this may cause an AI to run a red light or rear end another vehicle. This is acceptable, since it is a common occurrence in reality. However, if the AI goes off road and runs into a building, this mistake is corrected via respawn. Frame skips aside, the AIs keep a good following distance, react appropriately at red lights, yield for left turns, and make random navigational decisions on a case-by-case basis.

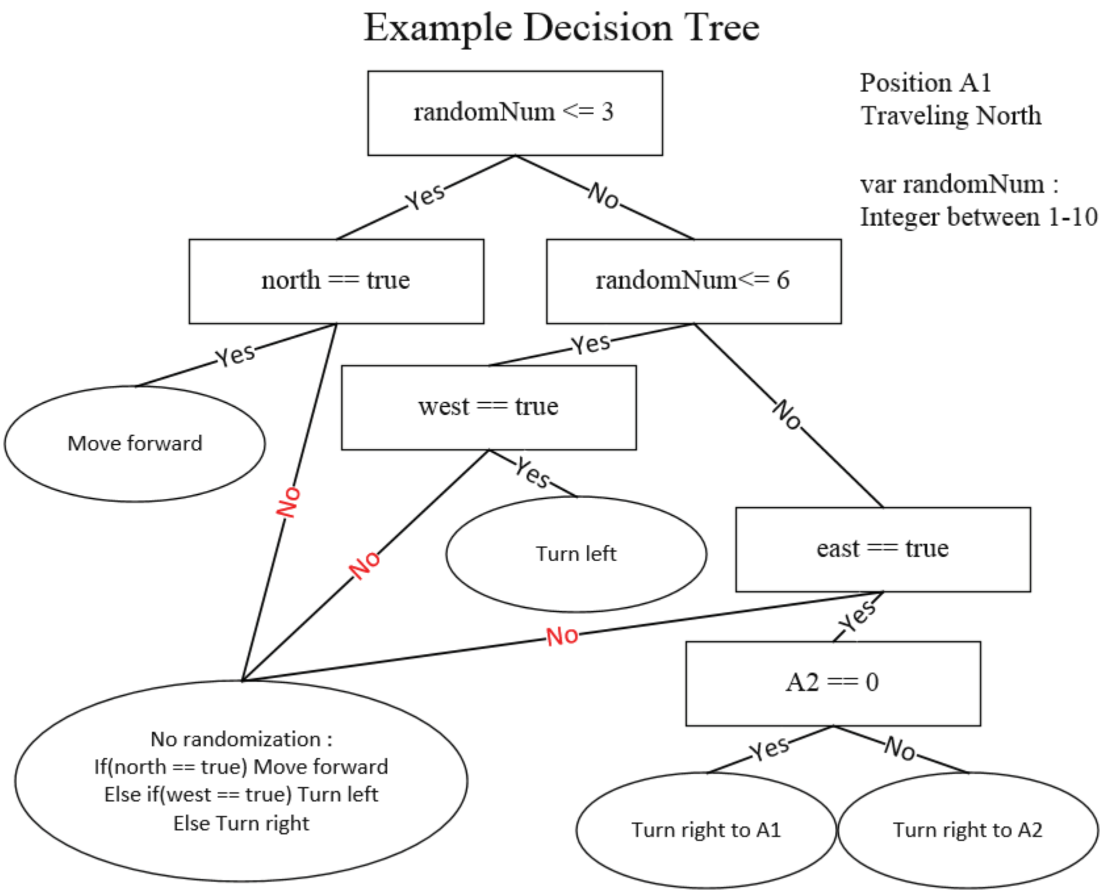


Figure 8: Decision tree for AI vehicle traveling North. This example includes method of random selection.

No matter which mission is selected, there are twenty-six AIs on the map, in total. They each have a start position, and when the game begins they pull out of a driveway or parking lot and begin their journeys. As mentioned previously, these vehicles have some triggers in place to recognize if they stray from the road. Once an AI discovers an off road experience it returns to the initial spawn point and respawns. After that, it pulls onto the road once again, with absolutely no concern for oncoming traffic. This is a perfect opportunity to surprise a student on the road.

The map also holds thirty-one bots. The bots are placed in driveways and parking lots from all regions of the map, but the areas near mission points are more densely populated. These vehicles are triggered when a student approaches a particular spot in the road, or a particular lane. Triggers are not placed uniformly, so there is no pattern that would benefit the hazard perception time of the student. To put things simply, once a student triggers the bot, it will move backward, block the road for a few seconds, then pull back into the driveway. It is very quick and nearly impossible to detect. Many bots were strategically placed in a manner that kept them hidden from approaching vehicles (behind a building for example). If a student collides with a bot, the student will receive a penalty. Due to the Unity3D physics engine, it is impossible to predict the reaction of the bot if there is a collision, but it will attempt to continue its path. It would take a hard impact to push the bot off course, and if this does occur the bot will respawn in its original parked position.

Figure 9: Small green rectangles are triggers. The nearby vehicles pull into the road, once a player has reached a trigger.

3.3 Player vehicle

The player vehicle (PV) gives the student viewing control, the dashboard, a penalty subsystem, and key events. These four subsystems each interact with the student in a different way. Multitasking is an important factor when it comes to hazard perception. Practicing doing many things at once can improve a student's ability to multitask, thus enhancing their perception of the road outside the vehicle while having their attention within it [10].

Figure 10: First-person view shows AIs providing nearby traffic.

The most obvious PV component is the viewpoint. After selecting a mission, the student is placed in a first-person setting. The student can see from ten o'clock to two o'clock, assuming that twelve o'clock is straight ahead from the driver's seat. The forward view does not render the mirrors, but there is a left mirror view, right mirror view, and rearview mirror view that will become full screen when the appropriate key is pressed.

The view returns to first-person once the student releases the button. There is also top view for debugging purposes. It was also used for a few seconds by one of the students.

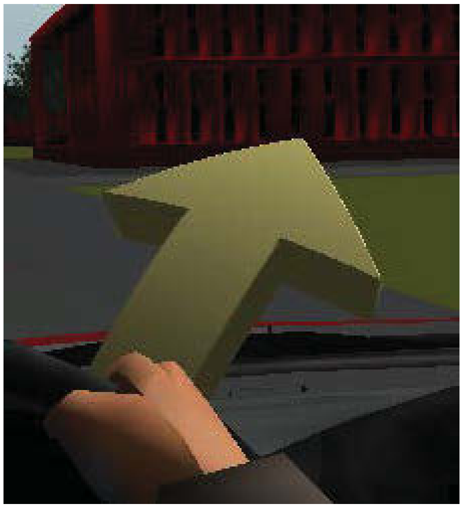


Figure 11: Mission arrow in first person view.

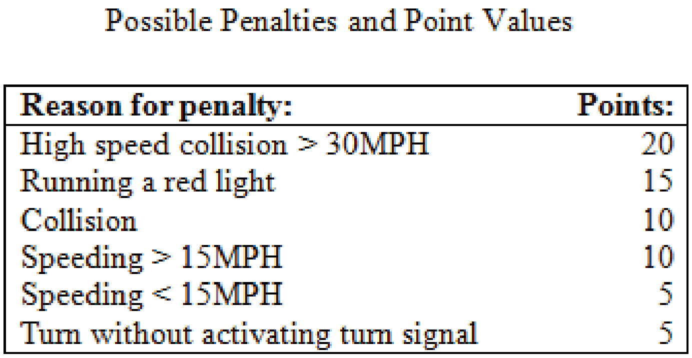
Points 45
Traveling East
on Justice Road
Through red light (+15)
Speed Limit : 35

Figure 12: Navigation display, including points and current points penalty alert.

Slightly below the rearview mirror there is a yellow arrow. This arrow points directly to the mission objective. It is important to note that the arrow only points to the objective; the arrow will not point to a specific turn or road that should be traveled. One might make strategic turns in an opposing direction to trade a series of red lights for stop signs. The colorful domes that surround mission objectives are the objects the arrow points to. When a mission is selected all mission objectives are disabled, except for the one for the selected mission.

The dashboard contains a lot of information about the state of the PV and the environment. It is the virtual appearance of a Cadillac dashboard. Directly in front of the driver's seat there is a speedometer in miles per hour (MPH), a left turn signal indicator, and a right turn signal indicator (transparent unless activated). All other vehicle operation gages on the dashboard are static, and not relevant. To the right of the dashboard is the navigational display. This displays the current direction the vehicle is traveling, the street the vehicle is traveling on (if available), and the amount of points accumulated. Once a penalty is issued, the navigational display will flash an alert for 3 seconds. This alert will reveal the reason for the penalty and the amount of points added.

If the PV is caught driving recklessly, the student is given points. This provides information about whether the student is using the simulator in a realistic manner, and prevents the urge to beat the clock at all costs. Keeping points is an easy way to give students motivation to compete. The desire to hold the best record can promote practice, especially if the simulator is ever released as an online multiplayer with public access. This information is saved, along with the time of the violation, and displayed at the end of the game (when the student reaches the objective, or after ten minutes has passed). Some violations, such as running a red light, speeding, and no turn signal, are followed by a short timeout phase. This is because the project team felt it was necessary for the student to be aware of the mistake, and have a few seconds to correct the behavior. The timeout only prevents the student for receiving a penalty for the same action twice; it does not prevent a penalty when one violation is made followed by a completely different violation within the timeout. The PV should not be invincible from penalty, otherwise this could be used as an advantage.



Possible Penalties and Point Values

Reason for penalty:	**Points:**
High speed collision > 30MPH	20
Running a red light	15
Collision	10
Speeding > 15MPH	10
Speeding < 15MPH	5
Turn without activating turn signal	5

Figure 13: Types of penalties with amount of points given.

The most interactive element of the driving simulator is the use of key codes to control the PV. The student will conduct 100% of PV control from the number pad, found on the right-hand side of many keyboards. The keys eight, two, four, and six (8, 2, 4, 6) move the PV forward, backward, left, and right. Seven and nine (7, 9) activate the left and right turn signals. One, three, and zero (1, 3, 0) display the left mirror view, the right mirror view, and the rearview mirror view in full screen. The letters "T" and "F" can be used to toggle between first-person view and top view. Utilizing any view, other than first-person, will completely obstruct the front view of the PV.

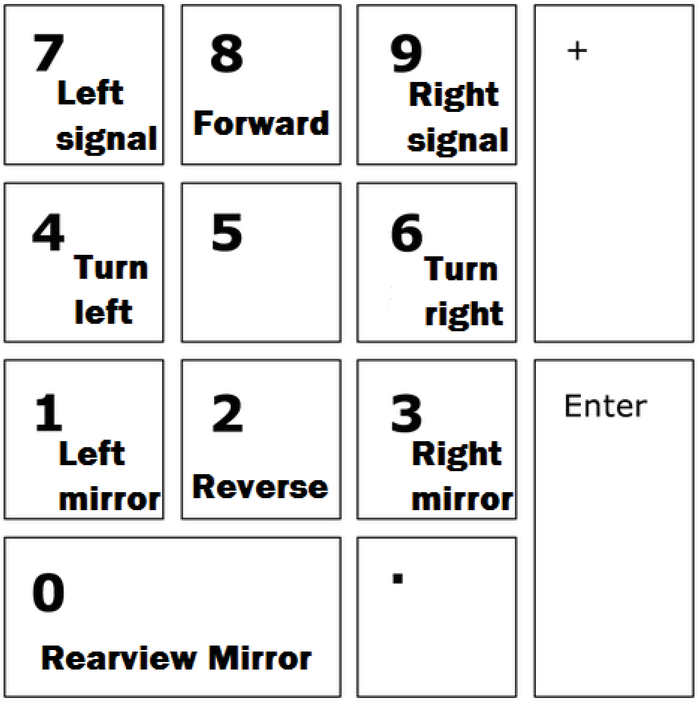


Figure 14: Key controls for player, from number pad (as shown).

3.4 Participant exploration

The background is similar for each of the students that participated in the study. The three males were thirteen year olds from an inner-city school in Youngstown, Ohio. None of the students have their temporary driving permits yet. The driving simulator study is their first, and they have no experience using eye tracking technology. All three indicated that they play video games during their leisure time, one even noted he plays at least thirty minutes every day. Much of this information was collected before taking the pre-test.

Each student worked individually, while other students were elsewhere. The study began with a Pre-test Evaluation form, which required general information from the students, as previously mentioned. The student would then sit down at the computer used for testing, in a usability lab that has access to eye tracking technology. A project team member guided the student through adjusting positions and ran calibration for the eye tracker. After the initial calibration, students were shown a video composed of several video clips. Each of these clips played hazardous situations in traffic, and the student was instructed to click on any hazard that is found. This video is approximately a minute and a half.

After the pre-test, the student is recalibrated on the eye tracker before beginning the first mission of the driving simulator. The student's line of sight is calibrated a third time, before the start of the second mission. All students tested mission 3 and mission 4. Once both missions are over, the student goes through calibration a final time. The hazardous situations video is played again, giving students the opportunity to show improvement in detecting hazardous situations. Since students participated one at a time, each student had a considerable amount of down time. They worked with an engineering exercise, building microbots in a conference room while awaiting their turn. This is not believed to be relevant to the experiment, but practicing mechanical skills prior to a test may have helped warm up the students' cognitive abilities.

As suggested by the National Institutes of Health Office of Extramural Research (NIH), students received some form of compensation for their participation. The best perk had to be getting out of school early. Each student also received a Youngstown State University Cinch Backpack, as well as other YSU memorabilia. Students were also fed for their participation. Study the competition element, the student with the lowest number of points was awarded $10 in cash.

3.5 Analysis approach

Each student completed a Pre-game Evaluation and a Post-game Evaluation. During pre-test, post-test, and game play the eye tracking software recorded students' reactions based on one variable hazard reaction time, using a method by McGowan and Banbury (2004). The pre-test and post-test variables are later compared, and results are determined by the difference. To explain this approach, we identify two research questions:

1. Does the proposed system enhance a young driver's hazard perception as measured by hazard reaction time?
2. Could the proposed system gain popularity as a commercial off-the-shelf (or via internet) serious game?

According to Underwood, there are two variables that can be studied to determine whether or not hazard perception has been improved [27]. The first variable is the width of horizontal scanning. Many of the aforementioned studies measure viewing width before and after a training program. It is suggested that a novice driver has a significantly more narrow scanning pattern that experienced drivers. The second variable measure time of fixation points. Studies previously used fixation to compare novice drivers to experienced drivers, and they have found novice drivers have considerably long fixation point durations as compared to experienced drivers. For this study, only horizontal scanning is being used as a measurable variable. More specific implementation or background information can be found in a document entitled "GMOST Methods" (written by Dr. Abdurrahman Arslanyilmaz, Assistant Professor at Youngstown State University, found in the appendix), explains all factors of the study, variables that were used, and results.

To discover if the proposed system is successful as a serious game, there needs to be an analysis of the amount of education and entertainment that the students receive. The system is educational if the students learned from it, or improved hazard perception as defined above. To decide whether the simulation is entertaining, students were given Post-game Evaluation forms. The Pre-game Evaluation and Post-game Evaluation forms can be found in the appendix. These forms were meant to highlight likes and dislikes in the opinion of the students.

CHAPTER FOUR: RESULTS

After the experiment, which took place on November 22, 2013, project team members studied data that was attained by the eye tracking software throughout each step the students had to undergo. The results were analyzed and the project team continues to improve the simulation program. In general, the simulation program will need a lot of adjustments before it can be considered a GMOST program. However, a look at each aspect of the results as an individual goal offers great promise for the future of the simulator as a serious game.

4.2 Runtime problems

Some unexpected problems arose during experimentation. A mixture of technical issues and time constraints made it difficult to conduct our experiment and caused us to make many changes to the plan. For example, the initial plan was for five students to complete five missions each. Due to a predetermined cut in experimentation time, the experiment was changed to include only three missions. During the day of experimentation, one student was absent and unable to attend the session. After the first student completed his first mission, the entire computer system crashed. From that moment on it was obvious that the computer system did not have sufficient resources to run both the simulation and the eye tracking software. However, since the eye tracking software is an important element in indicating the results of our project, it was absolutely necessary to run both programs simultaneously.

Problems with resolution glitches and excessive processing demands(the game play in addition to the eye tracking software), caused some of the artificial vehicles to present unrealistic behavior (such as driving upside down). While this was not anticipated, the students found it to be entertaining. Other conditions caused by technical error were extreme lag, which did not occur during software tests, but increased more after each mission completion (we reset the entire system after each mission, but it did not help much). It took approximately an hour and a half to experiment with the first student, after experiencing a blue screen and a half hour of software inoperability.

A second let-down was the inability to properly monitor and record students during game play for a significant amount of time. Between the instructors, the project team, and the students' schedule the experiment could not last longer than four hours. This fact, in combination with the technical difficulties, pushed the experiment to require only two missions from each student. In fact, the students had to leave before the fourth and final student was able to participate (this was also because the eye tracking system has difficulty tracking users that wear glasses, since the fourth student could not play without his). This is why only three students are included in the results of the study.

4.3 Anticipated goals

First we want to observe whether the simulator would be an appropriate GMOST program. By definition, GMOST programs should be multiplayer and online. The project team fully intends on implementing both of these, but it was unfortunately not a possibility for the first experiment. Future versions of the simulator will integrate an online interface that allows students to compete simultaneously, working on the same map to accomplish different goals. Another factor in GMOST requirements is simulation-training. During pre-test, game play, and post-test, eye tracking software traced the retinal patterns of each student. The width of horizontal scanning showed an insignificant difference between the pre-test and post-test. In fact, in some cases it seems as though the student was less accurate after training with the simulator. Therefore, it does not appear that the driving simulator improved the students' hazard perception.

The second goal involves considering the simulator a serious game. Obviously, education is a major part of this objective. However, the fact that there was no evidence found to support the idea that students learned anything during game play, it was clear that after attempting the first mission each student we penalized significantly less. This suggests that even though there were no recorded support with the eye tracking system there is still plenty of opportunity for improving skills. Students were involved in fewer collisions and reached their final objectives with less time. Perhaps the simulator could be proven as a learning environment if the project team records more detailed information about student behavior during game play, such as speed, ignoring lights and signs, and turn signal habits.

4.4 Usability

The most successful aspect of the program was the fun factor. One of the students made a comment that he would play the game if it had easy access. Another student told the project mentor that he had a lot of fun playing the game. The third student made a comment on his Post-game Evaluation that said he would play the game online, if was available in multiplayer so that he could compete with his friends. All students indicated interest in seeing skill-building mini games, an advanced steering system, the addition of audio components, and permanent public score keeping. Implementing such elements can only increase the popularity of the simulator among young drivers.

The Post-test Evaluations mentioned difficult vehicle control. In part, this is due to poor processing. Additionally, Unity3D is known for causing unrealistic movement in the case of using a physics engine to control vehicles. This causes the player vehicle to slowly veer to the right, resulting in the player pressing the left key to realign, which often resulted in a loss of control from turning too quickly or doing so during a lag issue. Hopefully, the veering issue will be resolved in the next update of Unity3D.

For the participants and much of the project team, this is only the first experiment in an ongoing project. Youngstown State University students will continue to develop the system next semester. A lot was learned during the first experiment, and project members are well aware of key issues that should be resolved before further experimentation can take place. For now, the obvious problem is lag. Lag is caused by many issues such as rendering difficulty, processing power, and interference caused by using incompatible software. It also upsets the students by making the simulator inappropriately challenging and steering control extremely difficult. A longer evaluation of the system, with more defined recommendations, is presented during the conclusion.

CHAPTER 5: CONCLUSIONS & FUTURE WORK

In summarization, the simulator will need to undergo many improvements before it can reach GMOST software status, but the initial experiment shows great user interest for a teenage audience. This is acceptable, since teenagers are the primary concern in driving safety at the moment. More and more teenagers are driving and accident fatalities continue to increase annually, so it should follow that a new method of driver training is definitely in high demand. Gaining popularity for a simulation training program and offering public access are both great ways to get young drivers to continuously go through the hazardous situations without having to risk their lives. Even though the results for improved skills were not promising, the simulator may be more effective in the future. The vast complications at runtime are impossible to work around, but by following some simple recommendations that could change quickly.

5.2 Recommendations

First and foremost, the entire project team needs to start developing with UnityPro. That alone would solve many of the problems. Here is a list of benefits to using UnityPro instead of the free version:

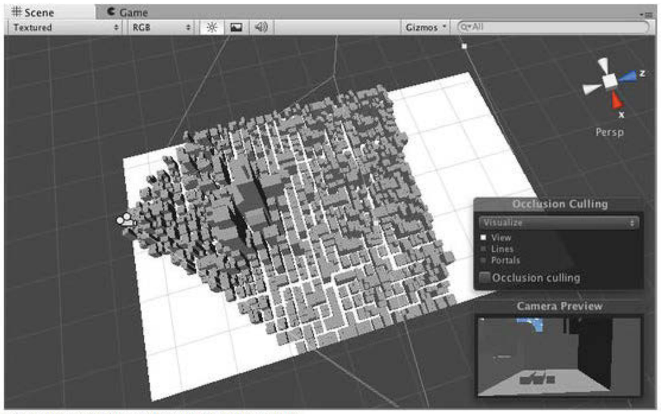
- Rendering cameras on a plane
- Displaying movies
- Occlusion culling
- Static batching

The use of any one of these tools could make a significant difference in game play. I will provide a synopsis of improvements that would be made with these features.

The ability to render cameras on a plane (a flat 3D object) is needed to create vehicle mirrors. The use of mirrors would make it easier for users to detect oncoming vehicles on the side and rear. It would especially useful for navigating the five lane roads, where it is common for multiple cars to be in multiple lanes, traveling in the same direction. Another improvement that can be made with this feature is the addition of a minimap. Minimaps are very common in driving games such as Grand Theft Auto and Mario Kart. They can be used to compare current location to target location, or as indication of where competitors are located. Our simulator originally used an indicator in the dash board to point towards goals, but the indicator used rendering on a plane to display the indicator which was actually about 100 meters above the player vehicle, pointing towards the objective. This method worked well, but the change to the large arrow did turn out to work much better, since it was easier to follow (probably because the large pointers are common in COTS games).

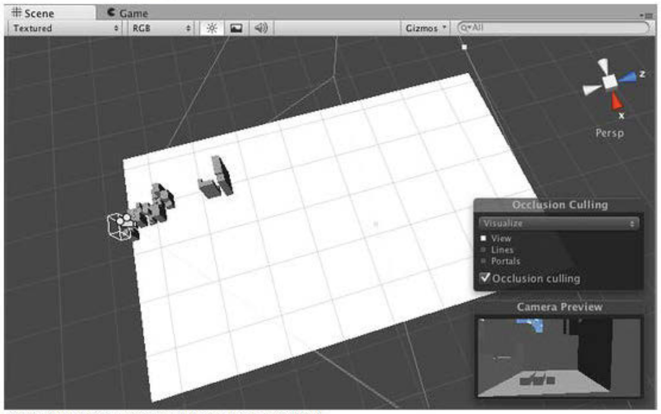
Displaying movies is essential for any project that requires video rendering. The simulation was meant to display commentary videos at the end of each mission, explaining which mistakes they made and how they can avoid making them in the future. These commentaries were recorded by experienced drivers, driving in real traffic. The implementation of videos is very simple, and many studies have shown that commentary videos are considered very helpful during simulation. A lot of time, popular COTS games show videos in between user objectives, either before or after each goal (or sometimes both). This helps the user visualize the story line. In some racing games, it is also common to playback game play, to highlight user success or display user failure. For example, a player might make an amazing lane change to avoid an accident, have a habit of driving over the double yellow lines, or bulldoze through some elementary school students. Record game play and playing it back to the user from a third-person perspective will show them things they cannot see from behind the wheel.

Occlusion culling is the highest demand feature from UnityPro for this project. Occlusion culling makes a large improvement in game play processing by significantly reducing the number of objects that need to be rendered. Figure 15 illustrates a project without occlusion culling (top) in comparison to a project with occlusion culling (bottom). The top image shows what UnityFree will render during game play. The objects rendered only include the objects within the angle of the camera. This is known as frustum culling, and is already a lot better than the alternative method of rendering all objects within the entire environment. However, the difference between rendering everything and frustum culling does not compare to the improvements made from using occlusion culling.



☐ Occlusion culling

The scene rendered without Occlusion Culling



☑ Occlusion culling

The same scene rendered with Occlusion Culling

Figure 15: Top showing frustum culling (default), in comparison to occlusion culling on bottom (UnityPro only).

Another processing improvement would be made by using static batching. UnityPro allows better runtime processing by allowing the developer to make some objects static. Static objects are rendered before game play, and the process of displaying these objects to camera does not require as much effort with the volatile memory used during game play. It is said that this could be problematic, if you have an overabundance of static objects that can change position it will slow down the game. For best results, only objects that do not move should be indicated as static objects.

The GMOST project does not include any plan of implementing minigames, but this could be an essential addition to the program. Minigames are often short and precise, therefore not optimal for practicing hazard perception, because the user is aware that things happen quickly. However, these games can be used for skill building in subject areas that will still improve their driving abilities. Perhaps one minigame will be the opposite of Frogger, and a driver will have to inch their way through the street while many pedestrians cross at different paces. Maybe another minigame will push a vehicle straight down the road, leaving the user to only control the ability to click on vehicles that show signs of backing out of a driveway without yielding. Another minigame can require users to quickly identify a specific number of hazards that exist in a particular image, or click on the most dangerous element of an image when considering road hazards, or present accident situations, pause before impact, and have the user select the best option for avoiding collision. The possibilities are endless.

Further recommendations are limited to things that the project team already intends on implementing. With the use of UnityPro, the project team will include commentary videos and occlusion culling. This should get better user results, because it is likely that the large lag took a lot away from the user experience, including the opportunity to react in a timely manner. The project team will also build the program for online use, which will not be difficult since Unity allows programs to be built for many different interfaces (PC, web, Andriod, iOS, Xbox). Once an online interface has been created, the implementation of multiplayer will make a significant difference in user enjoyment. Students can compete with their friends, and may be able to do so from any location.

5.3 Closing statement

The experiment was an enjoyable experience for participating students and YSU project team. The most important recommendation is to continue development. Teenage car accidents are far too common, and like most dire situations this one does not receive proper attention. It is possible that if the project continues, the popularity is more likely to bring in more attention than the results. No matter what the results are, no parent is going to encourage their teenagers to play video games. That doesn't mean that the program cannot be successful, it only means the project team should focus on the appeal of the students and not their caretakers. Multiplayer functionality alone presents social networking, friendly competition, and a desire for more offline practice. Overall, the ideal solution is to improve hazard perception skills of novice drivers by continuing traditional methods and complementing them with easy access to a modern, entertaining learning system that could be used by anyone, anywhere, at any time.

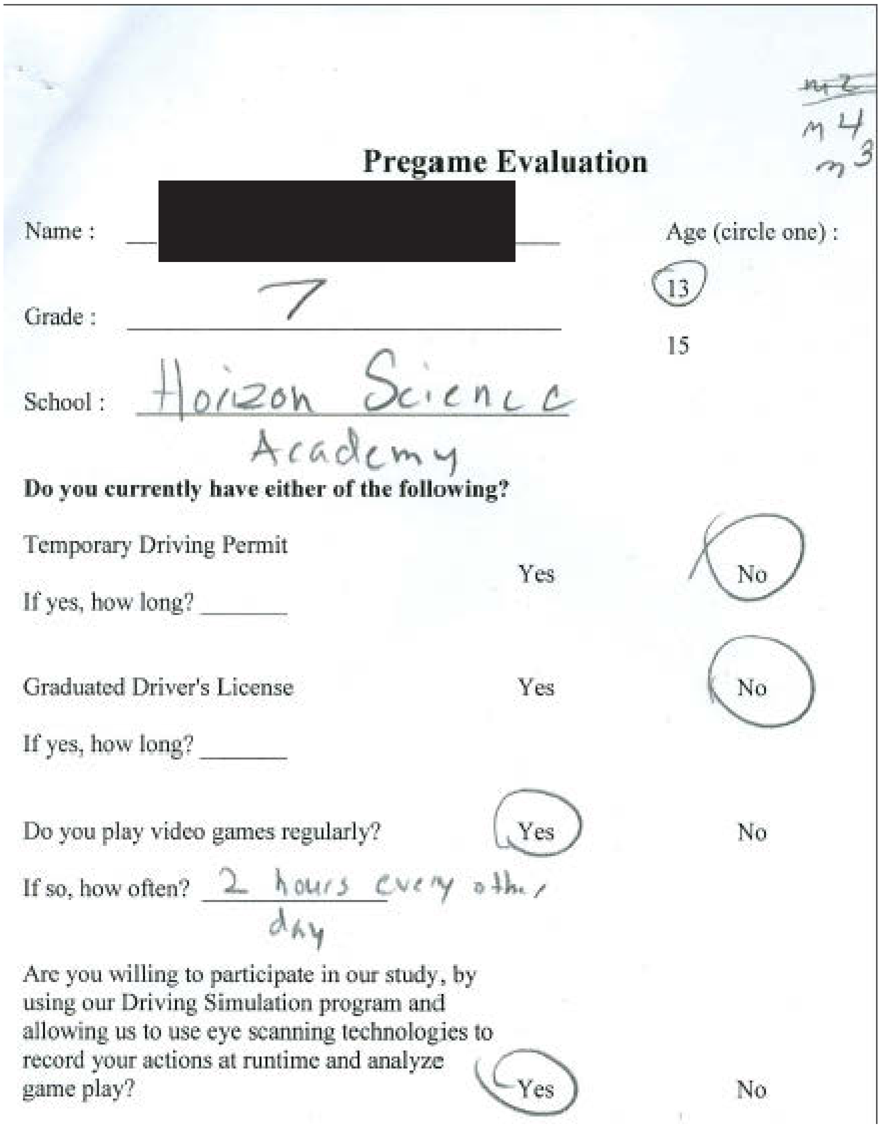
APPENDIX

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **Brandi Stillman** successfully completed the NIH Web-based training course “Protecting Human Research Participants”.

Date of completion: 03/10/2013

Certification Number: 1140216



~~m2~~
m4
m3

Pregame Evaluation

Name : [redacted]

Age (circle one) : [✓ 13] 15

Grade : 7

School : Horizon Science Academy

Do you currently have either of the following?

Temporary Driving Permit — Yes [✓ No]

If yes, how long? _______

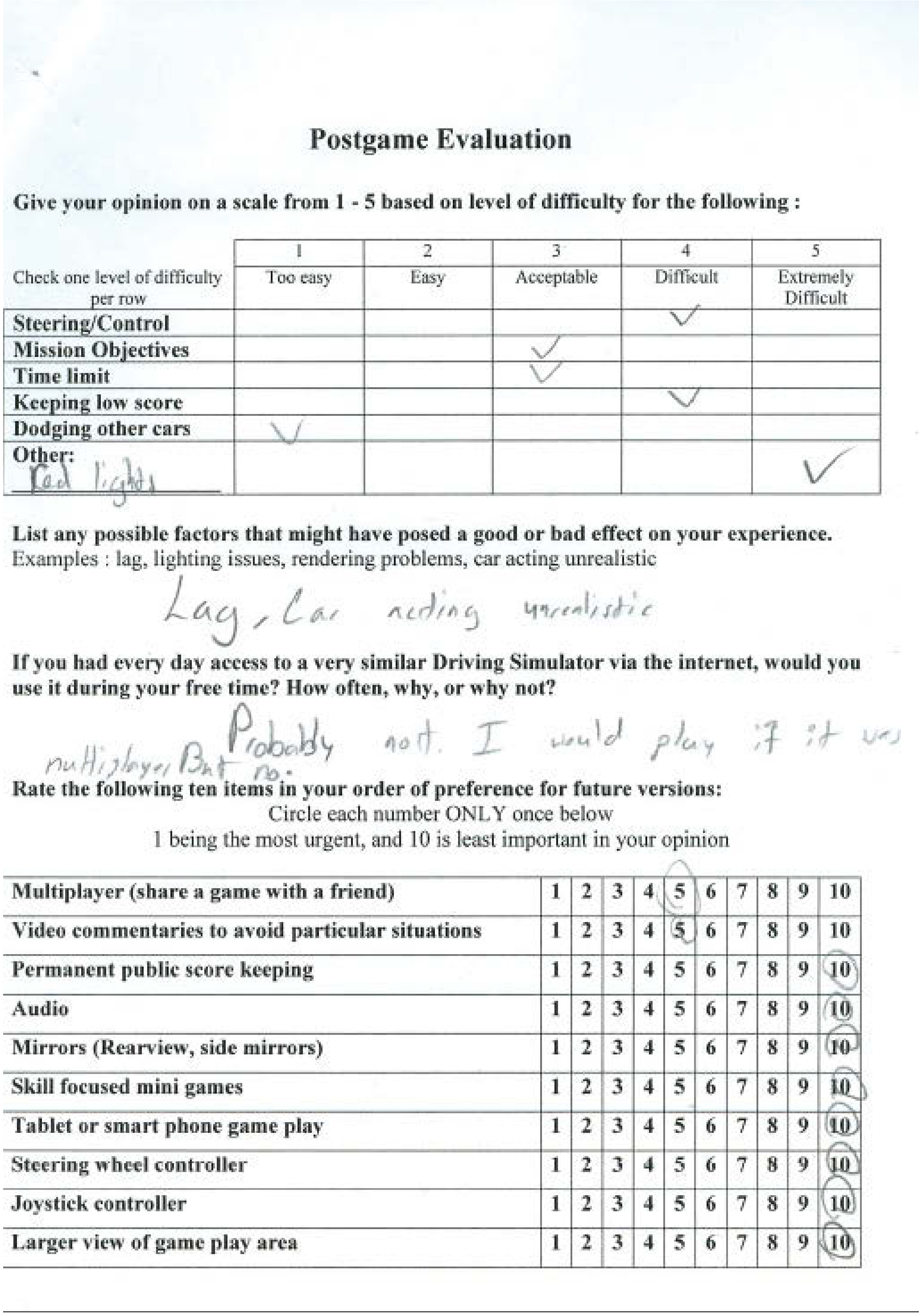
Graduated Driver's License — Yes [✓ No]

If yes, how long? _______

Do you play video games regularly? [✓ Yes] No

If so, how often? 2 hours every other day

Are you willing to participate in our study, by using our Driving Simulation program and allowing us to use eye scanning technologies to record your actions at runtime and analyze game play? [✓ Yes] No



Postgame Evaluation

Give your opinion on a scale from 1 - 5 based on level of difficulty for the following :

	1	2	3	4	5
Check one level of difficulty per row	Too easy	Easy	Acceptable	Difficult	Extremely Difficult
Steering/Control				✓	
Mission Objectives			✓		
Time limit			✓		
Keeping low score				✓	
Dodging other cars	✓				
Other: Red lights					✓

List any possible factors that might have posed a good or bad effect on your experience.

Examples : lag, lighting issues, rendering problems, car acting unrealistic

Lag, Car acting unrealistic

If you had every day access to a very similar Driving Simulator via the internet, would you use it during your free time? How often, why, or why not?

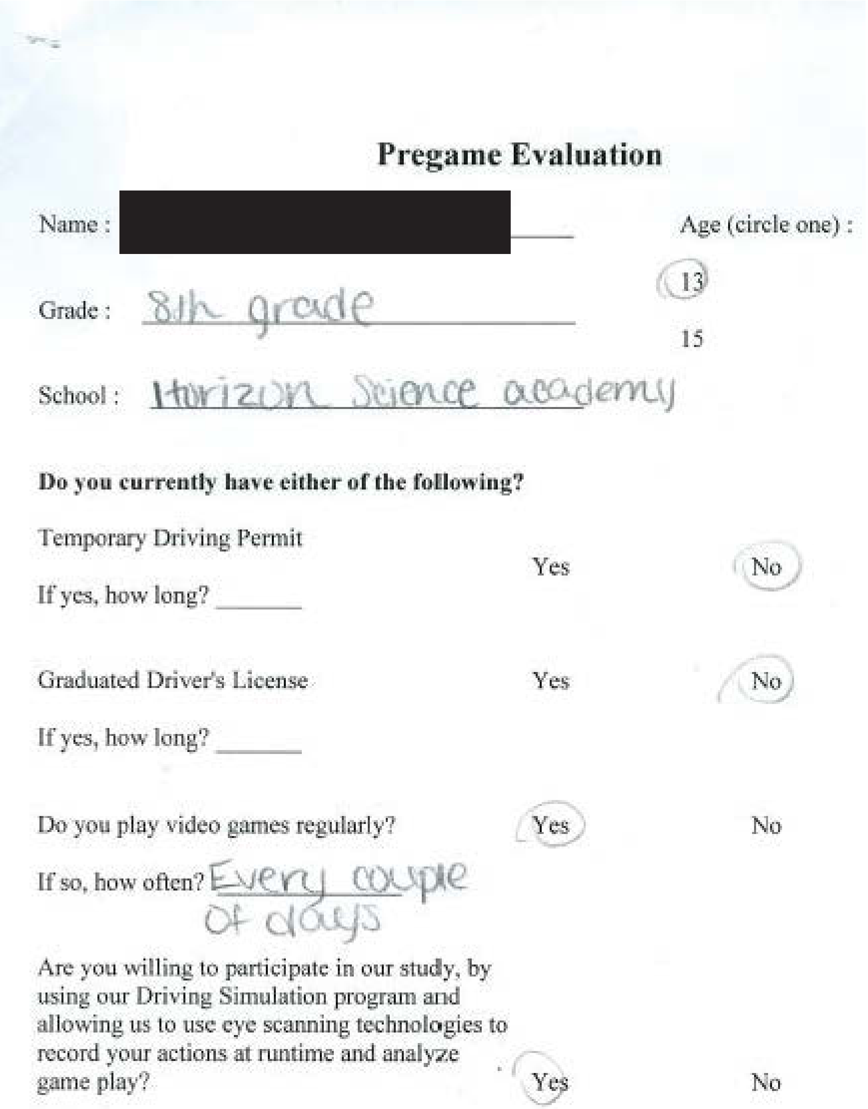
Probably not. I would play if it was multiplayer, But no.

Rate the following ten items in your order of preference for future versions:

Circle each number ONLY once below

1 being the most urgent, and 10 is least important in your opinion

Multiplayer (share a game with a friend)	1	2	3	4	[✓ 5]	6	7	8	9	10
Video commentaries to avoid particular situations	1	2	3	4	[✓ 5]	6	7	8	9	10
Permanent public score keeping	1	2	3	4	5	6	7	8	9	[✓ 10]
Audio	1	2	3	4	5	6	7	8	9	[✓ 10]
Mirrors (Rearview, side mirrors)	1	2	3	4	5	6	7	8	9	[✓ 10]
Skill focused mini games	1	2	3	4	5	6	7	8	9	[✓ 10]
Tablet or smart phone game play	1	2	3	4	5	6	7	8	9	[✓ 10]
Steering wheel controller	1	2	3	4	5	6	7	8	9	[✓ 10]
Joystick controller	1	2	3	4	5	6	7	8	9	[✓ 10]
Larger view of game play area	1	2	3	4	5	6	7	8	9	[✓ 10]



Pregame Evaluation

Name : [redacted]

Age (circle one) :

[✓ 13]

15

Grade : 8th grade

School : Horizon Science academy

Do you currently have either of the following?

Temporary Driving Permit — Yes [✓ No]

If yes, how long? _______

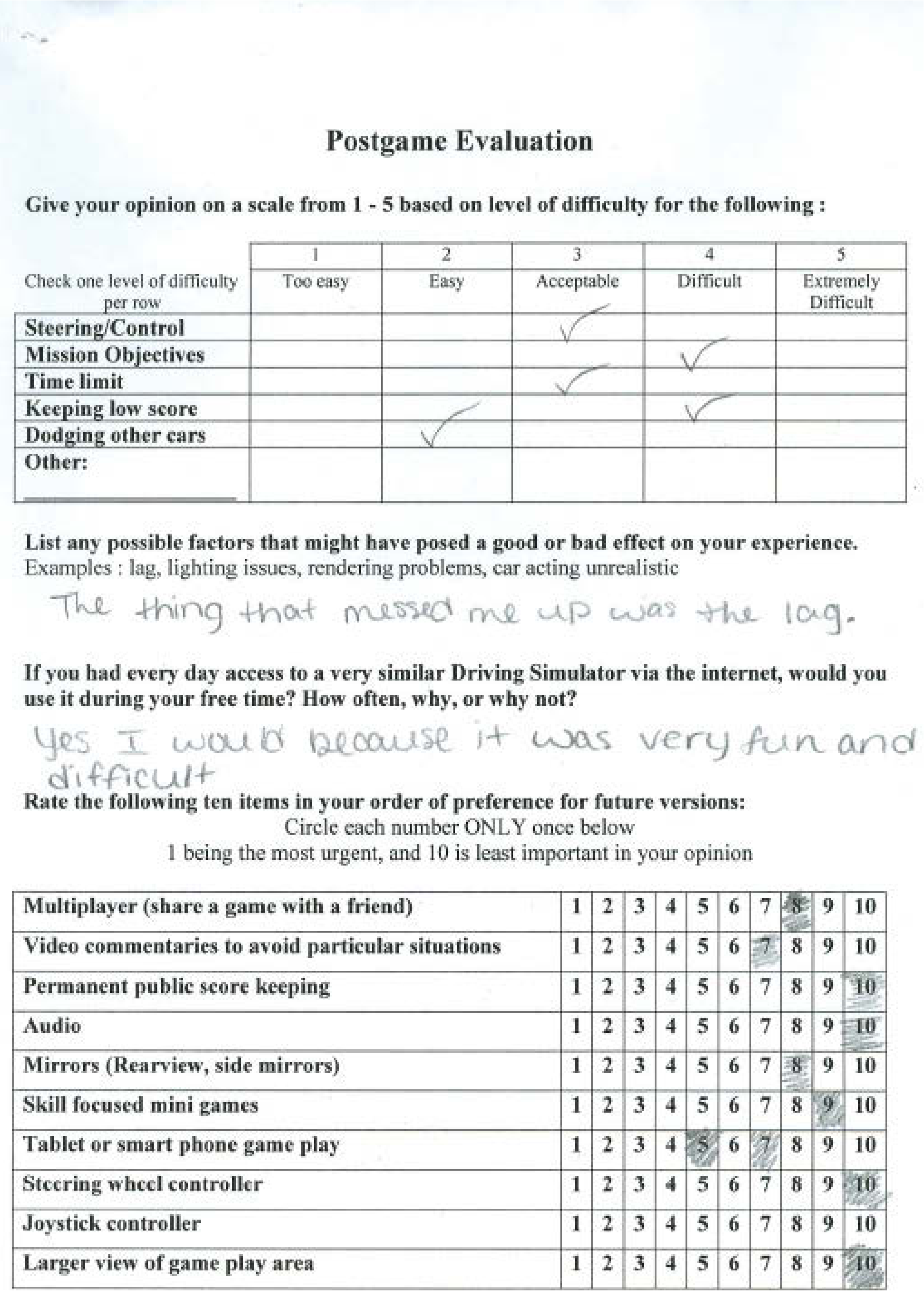
Graduated Driver's License — Yes [✓ No]

If yes, how long? _______

Do you play video games regularly? — [✓ Yes] No

If so, how often? Every couple of days

Are you willing to participate in our study, by using our Driving Simulation program and allowing us to use eye scanning technologies to record your actions at runtime and analyze game play? — [✓ Yes] No



Postgame Evaluation

Give your opinion on a scale from 1 - 5 based on level of difficulty for the following :

	1	2	3	4	5
Check one level of difficulty per row	Too easy	Easy	Acceptable	Difficult	Extremely Difficult
Steering/Control			✓		
Mission Objectives				✓	
Time limit			✓		
Keeping low score				✓	
Dodging other cars		✓			
Other: ________					

List any possible factors that might have posed a good or bad effect on your experience.
Examples : lag, lighting issues, rendering problems, car acting unrealistic

The thing that messed me up was the lag.

If you had every day access to a very similar Driving Simulator via the internet, would you use it during your free time? How often, why, or why not?

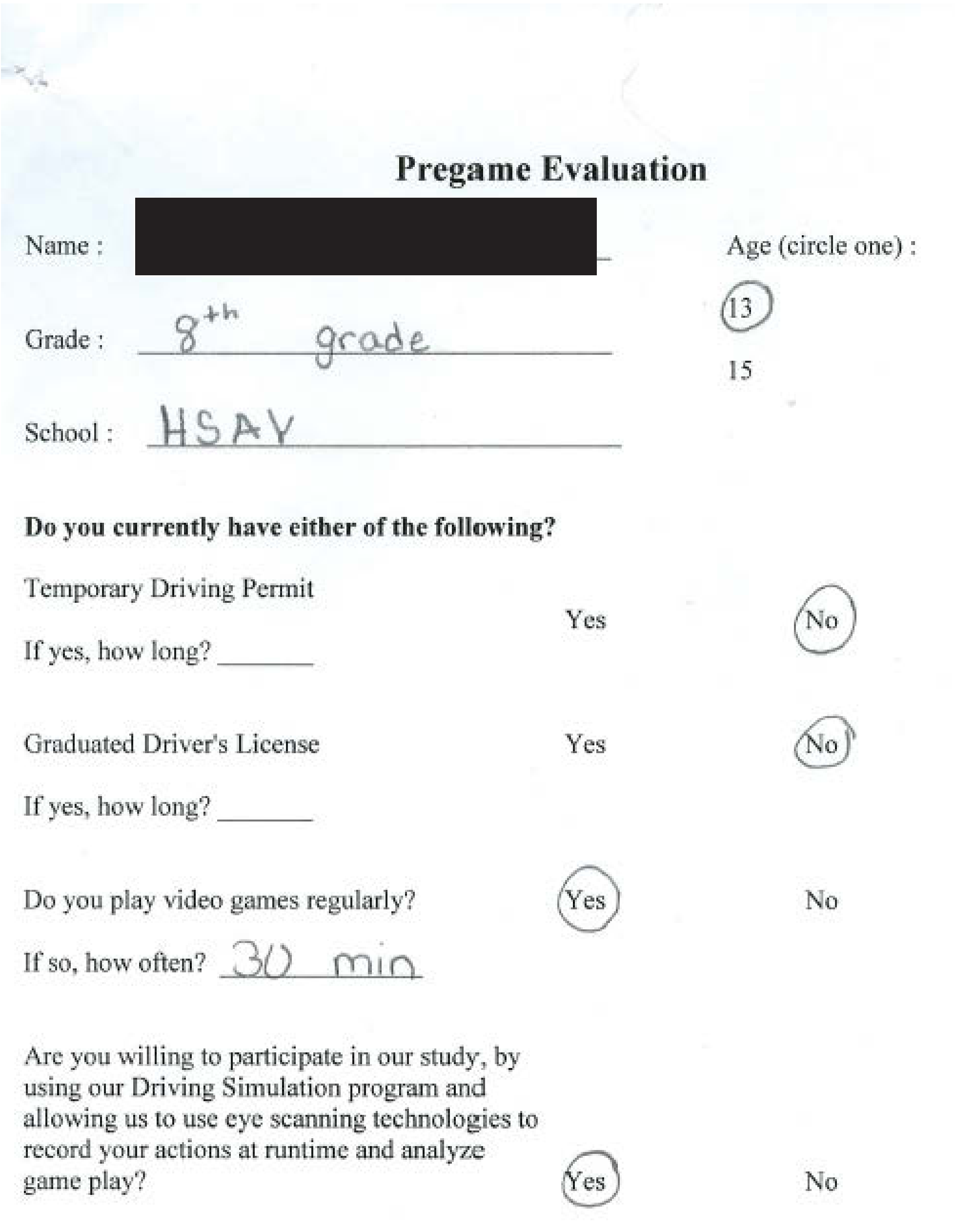
Yes I would because it was very fun and difficult

Rate the following ten items in your order of preference for future versions:

Circle each number ONLY once below

1 being the most urgent, and 10 is least important in your opinion

Multiplayer (share a game with a friend)	1	2	3	4	5	6	7	[✓ 8]	9	10
Video commentaries to avoid particular situations	1	2	3	4	5	6	[✓ 7]	8	9	10
Permanent public score keeping	1	2	3	4	5	6	7	8	9	[✓ 10]
Audio	1	2	3	4	5	6	7	8	9	[✓ 10]
Mirrors (Rearview, side mirrors)	1	2	3	4	5	6	7	[✓ 8]	9	10
Skill focused mini games	1	2	3	4	5	6	7	8	[✓ 9]	10
Tablet or smart phone game play	1	2	3	4	[✓ 5]	6	[✓ 7]	8	9	10
Steering wheel controller	1	2	3	4	5	6	7	8	9	[✓ 10]
Joystick controller	1	2	3	4	5	6	7	8	9	10
Larger view of game play area	1	2	3	4	5	6	7	8	9	[✓ 10]



Pregame Evaluation

Name : [redacted]

Age (circle one) :

[✓ 13]

15

Grade : 8th grade

School : HSAY

Do you currently have either of the following?

Temporary Driving Permit Yes [✓ No]

If yes, how long? _______

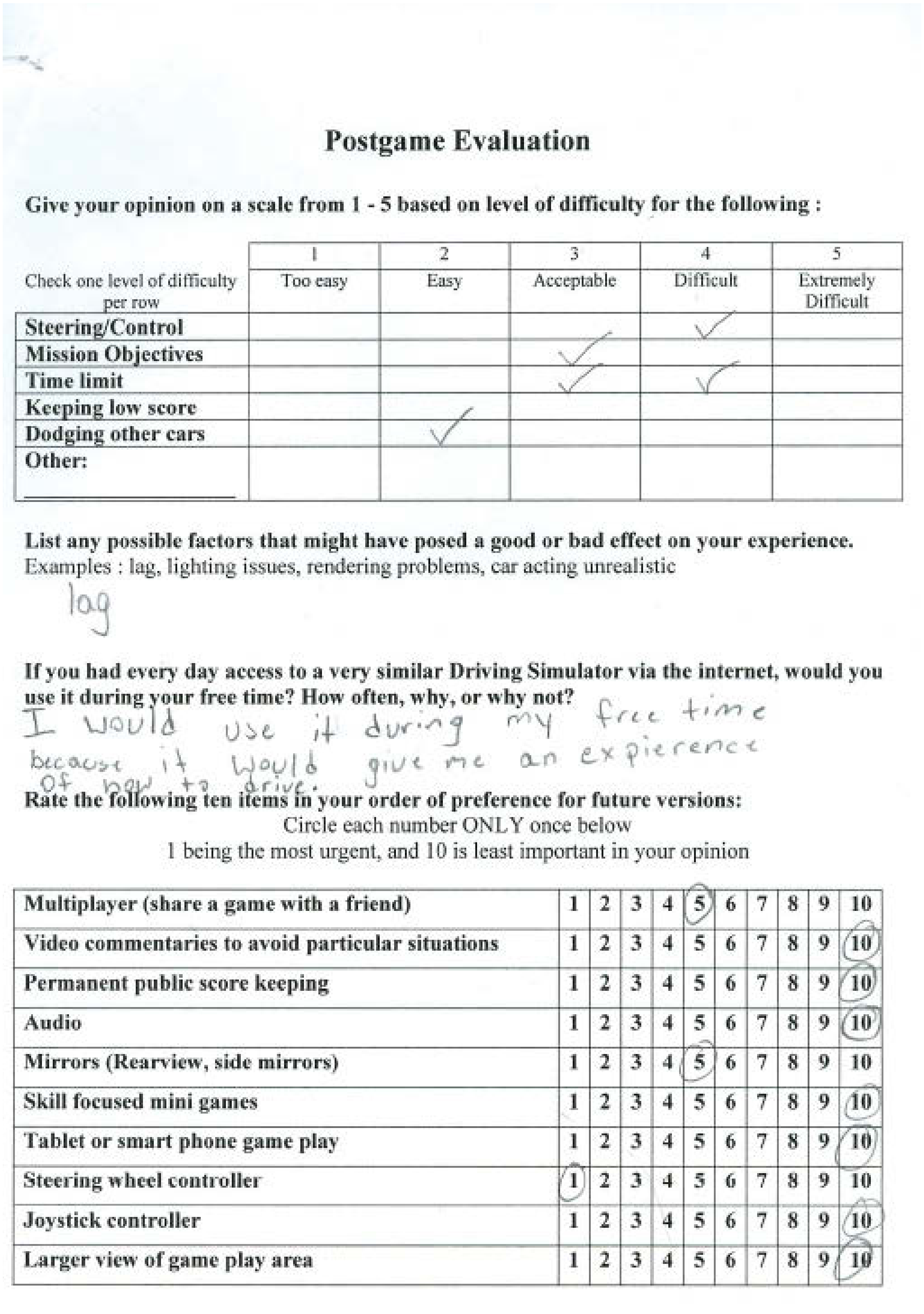
Graduated Driver's License Yes [✓ No]

If yes, how long? _______

Do you play video games regularly? [✓ Yes] No

If so, how often? 30 min

Are you willing to participate in our study, by using our Driving Simulation program and allowing us to use eye scanning technologies to record your actions at runtime and analyze game play? [✓ Yes] No



Postgame Evaluation

Give your opinion on a scale from 1 - 5 based on level of difficulty for the following :

Check one level of difficulty per row	1 Too easy	2 Easy	3 Acceptable	4 Difficult	5 Extremely Difficult
Steering/Control				✓	
Mission Objectives			✓		
Time limit			✓	✓	
Keeping low score					
Dodging other cars		✓			
Other: ____________________					

List any possible factors that might have posed a good or bad effect on your experience.
Examples : lag, lighting issues, rendering problems, car acting unrealistic

lag

If you had every day access to a very similar Driving Simulator via the internet, would you use it during your free time? How often, why, or why not?

I would use it during my free time because it would give me an expierence of how to drive.

Rate the following ten items in your order of preference for future versions:
Circle each number ONLY once below
1 being the most urgent, and 10 is least important in your opinion

Multiplayer (share a game with a friend)	1	2	3	4	[✓ 5]	6	7	8	9	10
Video commentaries to avoid particular situations	1	2	3	4	5	6	7	8	9	[✓ 10]
Permanent public score keeping	1	2	3	4	5	6	7	8	9	[✓ 10]
Audio	1	2	3	4	5	6	7	8	9	[✓ 10]
Mirrors (Rearview, side mirrors)	1	2	3	4	[✓ 5]	6	7	8	9	10
Skill focused mini games	1	2	3	4	5	6	7	8	9	[✓ 10]
Tablet or smart phone game play	1	2	3	4	5	6	7	8	9	[✓ 10]
Steering wheel controller	[✓ 1]	2	3	4	5	6	7	8	9	10
Joystick controller	1	2	3	4	5	6	7	8	9	[✓ 10]
Larger view of game play area	1	2	3	4	5	6	7	8	9	[✓ 10]

GMOST Methods

Participants

Three middle school students (13-14 years old) were recruited from a local school to test GMOST on a dependent variable: hazard reaction time. This study was a pre- and post-test repeated measure design, where the participants took a pre- and a post-test consisting of the same instrument, hazard perception videos as explained below. The participants' post-test scores were compared to their pre-test scores for the analysis of GMOST on the dependent variables.

Hazards and the Hazard Perception Videos

The GMOST training program and the pre-and post-test videos were created for 9 most commonly occurring hazards. The hazard is defined as situations in which a collision or near miss between the student's vehicle and another driver's vehicle might occur. The videos were created by (1) downloading hazard videos for the nine potential hazards on youtube, (2) editing them, and (2) compiling them into one video. The videos on youtube were searched and selected based on whether they show genuine traffic scenes from the perspective of the driver and they show the nine pre-determined potential hazards - following too closely (cars in front braking due to a blockage further ahead), failure to yield, running red light/stop sign, collision with pedestrian (pedestrians stepping out into the road ahead), vehicles pulling out of side streets (swerving to avoid), improper backing, driver inattention.

GMOST Program

During the experimental sessions, the students were instructed to drive their assigned vehicles as they were the drivers driving down the road to accomplish their assigned tasks. They were asked to avoid hazardous situations, and obey the traffic rules. They were given time to complete their assigned tasks, and depending on the duration of task completion and the safety of their journey, they earned points. They were asked to complete a total of three different tasks before they take the post-test.

Measurements

During the pre-test, post-test, and the experiment, students' eyes were calibrated for the eye tracker that was installed on the computer where the students took the pre- and post-test as well as the experiment. While they were watching the pre- and post-test videos, their hazard detection times and the extent of horizontal eye scanning were scored. The scoring was done by the same raters on pre- and post-tests and using the same rubric. Of primary interest was the difference between the pre-test and post-test scores.

Hazard Reaction Time: Hazard reaction time was measured using a method by McGowan and Banbury (2004). The students were asked to click on the hazard using a computer mouse. That is, students had to identify the location, as well as the timing, of each hazard, in an attempt to reduce error variance. The participants' response times through clicking on the areas for the hazardous situations were measured using an eye tracking software that recorded the location and timing of mouse clicks, and the visual tracking data. The participants' eye fixations were used to determine whether these responses are to the potential hazardous situation at all. The eye tracking software monitored the eye movements including the participants' eye fixations during their response to the potential hazards. Participants' earliest responses to each potential hazard were measured and converted into a reaction time. The overall score were the mean response latency across all potential hazardous situations. If a participant missed a potential hazardous situation, the reaction time for that event was substituted (Smith, Horswill, Chambers, and Wetton, 2009) by one second later than the latest reaction time among the other two students. Because none of the three students were able to detect one of the hazards (vehicle pulling from the side street) in the pre-test, this hazard was excluded from the study. Students watched the videos and went through the experiment one by one in the usability lab.

Data Analysis

To determine whether the GMOST makes any difference in hazard reaction time and horizontal visual scan, we ran a 1×2 Analysis of Variance with the hazard reaction time (HRT) as the dependent variable and the repeated pre- and post-test as the independent variables. Students' hazard reaction times were measured two times to see the change that our intervention, the GMOST, caused in hazard perception skills amongst young and inexperienced drivers after using the GMOST.

Results:

There was not a statistically significant effect on students' hazard reaction skills as measured by the hazard reaction times in pre- and post-test (Wilks' Lampda = .417, F (1, 24) = .681, p = .05).

This result suggests that the GMOST does not have an effect on students' reactions to hazard. Specifically, our results suggest that when young drivers use our application (GMOST), they do not react to hazard faster than when they do not use our application. However, their reactions to hazards were slower after they used our application.

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
PrePostGroup	Pillai's Trace	.028	.681[a]	1.000	24.000	.417	.028
	Wilks' Lambda	.972	.681[a]	1.000	24.000	.417	.028
	Hotelling's Trace	.028	.681[a]	1.000	24.000	.417	.028
	Roy's Largest Root	.028	.681[a]	1.000	24.000	.417	.028

Within Subjects Design: PrePostGroup

Youngstown
STATE UNIVERSITY

One University Plaza, Youngstown, Ohio 44555
Office of Grants and Sponsored Programs
330.941.2377
Fax 330.941.2705

April 2, 2013

Dr. Abdurrahman Arslanyilmaz, Principal Investigator
Ms. Brandi Nicole Stillman, Co-investigator
Mr. Joseph Costello, Co-investigator
Mr. Sruthi Bandarupalli, Co-investigator
Department of Computer Science & Information Systems
UNIVERSITY

RE: HSRC PROTOCOL NUMBER: 133-2013
TITLE: Early Development of Hazard Perception Skills through a Game-based Multi-player Online Simulation Training (GMOST)

Dear Dr. Arslanyilmaz, et.al.:

The Human Subjects Research Committee of Youngstown State University has reviewed your response to their concerns regarding the above mentioned protocol and determined that your protocol now meets YSU Human Subjects Research guidelines. Therefore, I am pleased to inform you that your project has been fully approved.

Please note that your project is approved for one year. If your project extends beyond one year, you must submit a project Update form at that time.

Any changes in your research activity should be promptly reported to the Human Subjects Research Committee and may not be initiated without HSRC approval except where necessary to eliminate hazard to human subjects. Any unanticipated problems involving risks to subjects should also be promptly reported to the Human Subjects Research Committee.

We wish you well in your study.

Sincerely,

Cathy Bieber Parrott
Chair, YSU Institutional Review Board

CBR:cc

c: Dr. Kriss Schueller, Chair
Department of Computer Science & Information Systems

Youngstown
STATE UNIVERSITY
100 years
1908-2008
A PROUD PAST
A PROMISING FUTURE

www.ysu.edu YSU

Bibliography

[1] Armsby, P., Boyle, A.J., Wright, C.C., 1989. Methods for assessing drivers' perception
of specific hazards on the road. Accident Analysis and Prevention 21, 45–60.

[2] Backlund, P., Engstrom, H., Johannesson, M., and Lebram, M., "Games for traffic education: An experimental study of a game-based driving simulator," *Simulation & Gaming*, vol. 41, no. 2, pp. 145–169, 2010.

[3] Benda, H.V., Hoyos, C.G., 1983. Estimating hazards in traffic situations. Accident Analysis and Prevention 15, 1–9.

[4] Bolstad, A.C., Hess, M.T., 2000. Situation awareness and aging. Situation Awareness Analysis and Measurement, 277–302.

[5] Borowsky, A., Oron-Gilad, T., Parmet, Y., 2009. Age and skill differences in classifying
hazardous traffic scenes. Transportation Research Part F 12, 277–287.

[6] Borowsky, A., Shinar, D., and Oron-Gilad, T., "Age, skill, and hazard perception in driving," *Accident Analysis and Prevention*, vol. 42, pp. 1240–1249, Feb. 2010.

[7] Chan, E., Pradhan, A., Pollatsek, A., Knodler, M., and Fisher, D., "Are driving simulators effective tools for evaluating novice drivers' hazard anticipation, speed management, and attention maintenance skills?," *Transportation Research*, vol. Part F, Apr. 2010.

[8] Charlton, S. and Starkey, N., "Driving without awareness: The effects of practice and automaticity on attention and driving," *Transportation Research*, vol. Part F, pp. 456–471, Apr. 2011.

[9] Damm, L., Nachtergaele, C., Meskali,M., and Berthelon, C., "The Evaluation of Traditional and Early Driver Training With Simulated Accident Scenarios," *Human Factors*, vol. 53, no. 4, pp. 323–337, Aug. 2011.

[10] Deery, H., "Hazard and Risk Perception among Young Novice Drivers," *Journal of Safety Research*, vol. 30, no. 4, pp. 225–236, 1999.

[11] Elsevier Publishing, "Using driving simulators to assess driving safety," *Accident Analysis and Prevention*, vol. 42, pp. 785–787, 2010.

[12] Endsley, M.R., 1995. Toward a theory of situation awareness in dynamic systems. Human Factors 37, 32–64.

[13] Finn, P., Bragg, B.W.E., 1986. Perception of the risk of an accident by young and older drivers. Accident Analysis and Prevention 18, 289–298.

[14] Fisher, D., Pollatsek, A., and Pradhan, A., "Can novice drivers be trained to scan for information that will reduce their likelihood of a crash?," *Injury Prevention*, pp. i25–i29, Apr. 2006.

[15] Jackson, M., "News: GTA 5 retail sales pass $1 billion in three days - ComputerAndVideoGames.com," *GTA 5 retail sales pass $1 billion in three days*. [Online]. Available: http://www.computerandvideogames.com/430331/gta-5-retail-sales-pass-1-billion-in-three-days/. [Accessed: 08-Nov-2013].

[16] Gitelman, D.R., 2002. ILAB: a program for postexperimental eye movement analysis. Behavior Research Methods, Instruments and Computers 34 (4), 605–612.

[17] Hakamies-Blomqvist, L., Wiklund, M., Henriksson, P., 2005. Predicting older drivers' accident involvement – Smeed's law revisited. Accident Analysis and Prevention 37, 675–680.

[18] Haworth, N., Symmons, M., Kowadlo, N., 2001. Hazard Perception by Inexperienced Motorcyclists, Report No. 179. Monash University Accident Research Centre.

[19] Holm, S., 1979.Asimple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6, 65–70.

[20] Keating, D., "Understanding adolescent development: Implications for driving safety," *Journal of Safety Research*, vol. 38, pp. 147–157, Mar. 2007.

[21] Mason, M., "Validation of the Hazard Perception Test for New Drivers," Cranfield University, 2003.

[22] Pollatsek, A., Narayanaan, V., Pradhan, A., and Fisher, D., "Using Eye Movements to Evaluate a PC-Based Risk Awareness and Perception Training Program on a Driving Simulator," *Human Factors*, vol. 48, no. 3, pp. 447–464, 2006.

[23] Raheb, R., "Simulation: The Next Step in Driver Training," *Fire Engineering*, pp. 30–36, Nov-2010.

[24] Sagberg, F. and Bjornskau, T., "Hazard perception and driving experience among novice drivers," *Accident Analysis and Prevention*, vol. 38, pp. 407–414, 2006.

[25] Smith, S., Horswill, M., Chambers, B., and Wetton, M., "Hazard perception in novice and experienced drivers: The effects of sleepiness," *Accident Analysis and Prevention*, vol. 41, pp. 729–733, Mar. 2009.

[26] Underwood, G., Chapman, P., Bowden, K., and Crundall, D., “Visual search while driving: skill and awareness during inspection of the scene,” *Transportation Research*, vol. Part F, no. 5, pp. 87–97, Mar. 2002.

[27] Underwood, G., Crundall, D., and Chapman, P., “Driving simulator validation with hazard perception,” *Transportation Research*, vol. Part F, pp. 435–446, Apr. 2011.

[28] Vidotto, G., Bastianelli, A., Spoto, A., and Sergeys, F., “Enhancing hazard avoidance in teen-novice riders,” *Accident Analysis and Prevention*, vol. 43, pp. 247–252, Aug. 2010.

[29] Waller, P. F., Elliott, M. R., Shope, J. T., Raghunathan, T. E., & Roderick, J. A. L. (2001). Changes in young adult offense and crash patterns over time. Accident Analysis & Prevention, 33, 117–128.

[30] Wallis, T. S. A., & Horswill, M. S. (2007). Using fuzzy signal detection theory to determine why experienced and trained drivers respond faster than novices in a hazard perception test. Accident Analysis & Prevention, 39, 1177–1185.

[31] Wang, Y., Zhang, W., & Salvendy, G. (2010). Effects of a simulation-based training intervention on novice drivers’ hazard handling performance. Traffic Injury Prevention, 11, 16-24.

[32] Williams, A. F., & Shabanova, V. I. (2003). Responsibility of drivers, by age and gender, for motor-vehicle crash deaths. Journal of Safety Research, 34, 527–531.

[33] Yan, X., Abdel-Aty, M., Radwan, E., Wang, X., & Praveen, C. (2008). Validating a driving simulator using surrogate safety measures. Accident Analysis & Prevention, 40, 274–288.