Demonstration of the Potential for Simulators in Young Driver Training

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ABSTRACT

Roadway safety is a major public health, education, and safety concern. According to the CDC, motor vehicle crashes are the LEADING CAUSE OF DEATH for U.S. teens, accounting for more than one in three deaths in this age group. Teen driver and peer passenger deaths account for almost 25% of total teen deaths from any cause -- more than cancer, homicide and suicide (NSF, 2011). Over time, the use of vehicle and classroom training as the sole mechanisms for driver education has proven less than effective. As a result, supplementary approaches are being considered to better promote teen driver safety. To date, simulators have become widespread in military training, but have been vastly underutilized in civilian vehicle training. There seems to be great, underutilized potential in this regard, as the younger demographic is easily engaged by the video game and amusement ride-like experiences that a typical simulation environment has to offer.

In this research study, we incorporate simulation technology into an engaging educational program for high school-aged teenagers that will make them better prepared for the challenges of driving. Simulation-based training modules have been designed specifically to help students with some of the primary documented causes of error associated with novice drivers: speeding, distractions, and failure to heed right-of-way. The safe and repeatable immersive training environment, modeled after local roadways, contains relevant real-world hazards, and provides valuable and much needed additional "behind the wheel" experience. Two levels of motion fidelity are compared, using the same software environment and analysis structures, to ensure objective training: Low Fidelity: (0-DOF, single-screen), and High Fidelity (6-DOF, surround-screen). Data acquisition areas include: quantitative simulator driving performance, a written exam for each training module, pre- and post- questionnaires to assess transfer knowledge, and qualitative instructor evaluation. Ultimately, this research demonstrates the effectiveness of simulators in young driver training, and analyzes the level of motion fidelity required to offer an authentic training experience. This could lead to the widespread deployment of such simulators, for similar training programs, across the nation.

ABOUT THE AUTHORS

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INTRODUCTION

Roadway safety is a major public health, education, and safety concern. Motor vehicle crashes are the LEADING CAUSE OF DEATH for U.S. teens, accounting for more than one in three deaths in this age group (CDC, 2008). Recent statistics show that drivers aged 16-24 represent 12% of the total driving population, yet account for 20% of all road vehicle accidents (ESAA, 2012). Teen driver and peer passenger deaths account for almost 25% of total teen deaths from any cause -- more than cancer, homicide and suicide (NSF, 2011).

Accordingly, this research demonstrates the creation of an engaging supplementary educational program for high school-aged teenagers, based exclusively around simulation technology, to make teens better prepared for the challenges of driving. According to the Institute for Traffic Safety Management and Research (ITSMR, 2012), the top five contributors to young driver accidents are: *1) Unsafe speed, 2) Failure to yield right of way, 3) Driver inattention or distraction, 4) Driver inexperience, and 5) Following too closely*. Simulation-based training modules have been specifically designed to help students with these primary causes of error. The immersive training environment contains relevant real-world hazards, and provides valuable and much needed additional "behind the wheel" experience to supplement current driver education protocols.

A primary purpose of the study is to compare two levels of motion fidelity to determine the appropriate level of technology required to improve driver training, while using the same software environment and analysis structures: Low Fidelity: (0-DOF, single-screen), and High Fidelity (6-DOF, surround-screen). Data acquisition areas include: quantitative simulator driving performance (e.g., speed, lane position), pre- and post- questionnaires to assess transfer knowledge, and qualitative instructor evaluation. The ultimate objective of this pilot study is to increase safety among young drivers. The successful demonstration of these simulation technologies, in this context, could lead to the widespread deployment of such simulators for similar training programs across the nation.

LITERATURE OVERVIEW

This literature survey focuses on four components of simulator training relevant to the current research: i) Simulation Content, ii) Simulation Measures, iii) Other Applications, and iv) Simulator Fidelity.

i) Simulation Content

According to (Kappé, 2005), driving simulators are constructed from five principal components: vehicle model, visuals, motion, traffic model, and scenarios/instruction. Novice drivers need to learn basic skills (e.g., vehicle operation, steering, maneuvering, and interaction with traffic), without the complexity of the normal driving environment. As noted in (SWOV, 2010), the technical quality of a simulator (when used for driver training) is important; more so is the quality of the simulator lessons – and how they are embedded into the driving course. Past studies have demonstrated that driving simulators can indeed accelerate the process of the acquisition of basic driving skills. (Vlakveld et al, 2003) described how driver simulators can best be used for basic driver training, and emphasized not the technical requirements, but rather the didactical requirements and the development of so-called "courseware".

ii) Simulation Measures

Relatively little is known about how simulator measures relate to on-road driving. A recent study (de Winter et al., 2009) investigated the relationships between three measures (speed of task execution, violations and errors) during initial simulation-based training and the result of the driving test on the road, six months later. The purpose of another recent study (Garcia et al., 2011) was to determine if the experience obtained from a driving simulator could improve driving confidence and reduce the number of violations and collisions for teens. Another recent pilot study (Cox et al., 2009) was undertaken to investigate whether training of novice drivers on a simulator transfers to on-road driving performance. Simulator participants performed "significantly better" on all variables under study while driving on the road; one of the benefits of simulation is the opportunity to master one driving skill at a time, and then combine that skill with others, in an additive manner.

iii) Other Applications of Simulators

Similar technology has been applied to training in other contexts. For example, low-cost commercial motor vehicle (CMV) simulators are available, and may be useful to supplement training, testing, and licensing (Morgan et al., 2011). Cost analyses indicated that simulator training using the study simulator was $35/participant less expensive than conventional training. As more realistic training programs have been developed for simulators, a number of states have begun to use them to train snowplow drivers to complement on-road training. Agencies indicate that simulator training provides tangible benefits, including improved driver safety, fuel savings, and reduced wear and tear on plow trucks. (CTC & Associates, 2008).

iv) Simulator Fidelity

A recent study (de Winter et al., 2007) investigated the role of fidelity on the effectiveness of simulation-based driver training. Improving the force-feel characteristics of pedals is an example that may improve training effectiveness; it addresses a task-relevant cue that is likely to lead to more realistic driving behavior. Results have to be validated by investigating transfer of training to the roads, and have to be weighed against negative effects (e.g., simulator sickness, costs) of simulator training. A recent aviation-based case study (Dahlstrom et al., 2009), explored a number of issues related to simulator fidelity, and found that the limited costs with lower-fidelity simulation could increase availability and frequency of simulator training. Another recent study (Allen et al., 2007) compared three simulator configurations: 1) an instrumented cab with wide angle projected display; 2) a wide field of view desktop system with a three monitor display; 3) a single monitor, narrow field of view desktop system. The results showed that training efficacy varied with simulation fidelity, and that the most effective training seems to depend on wide field-of-view displays.

Summary

None of the previous work identified investigated the fidelity of motion cues - a major component to the current work. Numerous previous efforts placed emphasis on the content of training – even more than the technical aspects of the simulator itself. The content and structure of the training modules will likewise be emphasized in this paper. Also noteworthy from this literature review was the sentiment that low fidelity (or limited feature) simulators can still provide effective training while allowing simulators to be more accessible (due primarily to cost concerns).

To date, simulator training in driver education in North America has been applied mostly as a novelty; no one has attempted a full, multi-module curriculum using a simulator as a focal point for driver training. On a small scale, this notion is being demonstrated in this research, with the hopes that appropriate steps can be taken towards "mainstream" simulator training as a required component to all young driver education.

BROADER IMPACTS

Ultimately, this research aims to demonstrate the effectiveness of simulators in young driver training. This could lead to the widespread deployment of such simulators, for similar training programs, across the nation. Agencies who might be interested in such technology would include high schools, formal driver training agencies (e.g., the American Automobile Association), and law enforcement. Successful programs of this nature could, over time, result in improved driving practices for the teenage demographic, where a disproportionate number of negative driving outcomes have occurred. This could lead to safer roadways for everyone, resulting in a reduction in accidents, injuries, and loss of life. In turn, this could result in reduced insurance rates for all drivers, but particularly those in the high risk pool. Likewise, similar training programs could be developed for other vehicle types in both military and civilian vehicle simulator training, including marine applications, tank training, commercial truck driving, and large equipment training.

ENVIRONMENT DESCRIPTION – SOFTWARE

The scene graphics for the driver training environment are rendered using OpenGL, a 3-D graphics API developed in C++. The primary training environment is a four square mile region that is adjacent to the University at Buffalo (Figure 1).

Figure 1 – Simulator Training Map

The environment includes residential streets, 2-lane roads, 4-lane roads, and a 1-mile segment of the New York State Thruway. This training scenario is useful in that it allows the trainee to practice basic safe driving principals (e.g., speed maintenance, lane positioning, traffic sign and signal management, etc.) within the confines of a controlled and measurable environment. Added to this environment are a number of special hazard scenarios. For example, a road segment was augmented to include roadway cones along both sides, which includes the narrowing of the lanes from two wide-lanes down to a single narrow lane. There are also large construction trucks merging onto and off of the road, forcing the trainee to look side-to-side to avoid collisions. Another hazard includes an aggressive driver (i.e., a "Tailgater") who has been programmed to drive in the exact path of the trainee (only lagging in time by ½ of a second) relentlessly, and sounds the horn obnoxiously. The Tailgater can only be seen rearward within the driver's rear-view mirror.

The primary environment has been augmented by a standalone "Figure 8" test track that is also used for supplementary exercises. Refer to Figure 2. Within the Figure 8, a novice driver can experience how difficult it is to maintain speed, turn around a circle, and stay within one's lane; to make adjustments to and maintain stability of a vehicle while simultaneously turning the vehicle and driving at elevated speeds.

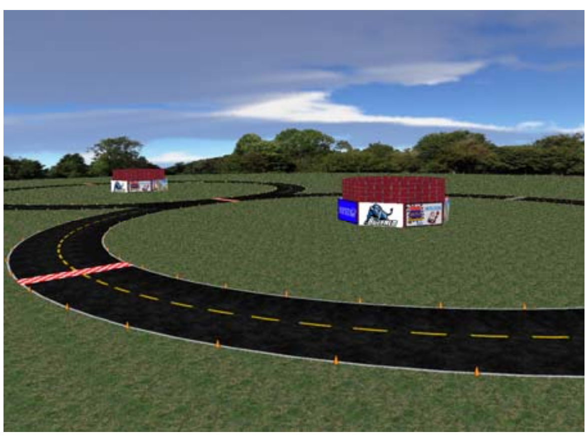

Figure 2 – Virtual "Figure 8" Test Track

ENVIRONMENT DESCRIPTION - HARDWARE

In the current research study, two fidelities of simulators are compared.

1) The "low fidelity" simulator is a 0-DOF (no motion) simulator (Figure 3), comprised of a GT Omega Racing Basic Simulator Frame/Chair, ECCI's Trackstar 6000 steering wheel (with a 240 degree range of motion), Logitech's G25 foot pedals (gas, brake, and clutch), a 32" Panasonic Viera single-screen front monitor (16x9 aspect ratio), and a 2.1 stereo sound system with PC-grade speakers and a subwoofer.

Figure 3 – 0-DOF simulator

Figure 4 – 6-DOF simulator

2) The "high fidelity" simulator is a 6-DOF (full motion) simulator (Figure 4), comprised of: a 6-DOF electric motion simulator, a two-seat Ford Contour passenger cabin, Logitech's G25 racing steering wheel (w/ basic force-feedback capability and a 900 degree range of motion), ECCI's Trackstar 6000 foot pedals (w/ spring resisted gas and clutch pedals, and pressure modulation on the brake pedal), ceiling-mounted SONY projectors, that front-project onto (4) hexagonally arranged Draper visualization screens, 8' wide by 6' high (with three screens in front of, and one screen behind the simulator participants), a 2.1 THX stereo sound system and a full-sized subwoofer.

DATA MEASURES

One of the primary objectives in offering simulation-based training is to see how much each student improves over the duration of each training module. A General Questions and Sign Test (MGQST), will broadly assess transfer knowledge - on general driving/roadway safety - between the beginning and conclusion of a training module. The MGQST contains 10-15 questions concerning: the content of typical road signs, traffic rules and regulations, and basic safe vehicle control.

Each of the five training modules offers a pre- and post- metric in the form of a Scenario-based Questionnaire (SBQ). The SBQ cites objective questions regarding driving scenarios based on the current module agenda. For example, for the first module, drivers are asked to identify the appropriate position to place their hands on the wheel while driving; given numerous options (e.g., 11 and 1, 9 and 3, etc.) For the second module, drivers are shown a photo of two vehicles, and are asked (true/false) if the rear vehicle can legally pass the front vehicle, which would require crossing a solid yellow line.

In addition to questionnaires, we have programmed the simulation software to monitor driver proficiency numerically. For each training module driver, a "score report" is generated that keeps track of metrics that are pertinent to the given module, and safe driving practices in general. Metric include: traveling speed (maximum and average), speed in stop sign zones (e.g., did a drive come to a full stop?), speeds in traffic light zones (e.g., did the driver travel through a yellow light, or a red light?), and module specific (hazard) metrics such as: cone strikes, deer strikes, and collision events.

Despite the advantages that simulators offer, one major disadvantage to their implementation is a common side effect known as simulator sickness (e.g., Johnson, 2005). As simulator sickness is a primary undesirable side effect of using simulators in driver training, we attain a measure of this symptom, for each simulator type, both pre- and post-experiment. To this end, the Motion Sickness Assessment Questionnaire (MSAQ) (Gianaros et al., 2010) was implemented.

Lastly, we have developed a means for attaining an objective measure by the supervisor ("trainer") who is overseeing each training session. In this way, we have a scoring metric that serves as a "human-in-the-loop" component. Accordingly, we have devised a relatively simple score sheet, upon which the supervisor can write down simple "yes/no" answers to basic safe driving behaviors that might be difficult to measure in an automated manner (e.g., Did the driver fasten his/her seat belt? Did the driver look both ways before proceeding? Is the driver leaving an appropriate following distance?) In addition, the supervisor makes general comments regarding each driver's overall performance for each training modules.

STUDY POPULATION: OVERVIEW

We established a number of prerequisites for eligibility in this research study. We chose to recruit ONLY teenagers who had little or no driving experience, so that the training principals would be issued at the very beginning of each driver's learning process. Accordingly, we recruited males and females, aged 14-17, with the requirement that the teenager not yet have their driver's license (a learner's permit was deemed acceptable). A majority of the other conditions for joining the research study were either logistical (i.e., does the teen have reliable transportation to/from the study site?), or health related (e.g., does the teen suffer from seizures or motion sickness?) The study protocol was pre-approved by the Institutional Review Board (IRB) at the University at Buffalo. Subjects were minimally compensated for their time (a $50 gift card) after completing all five of their 2-hour modules. Ultimately, 28 teenagers participated in the five week pilot study, between April-June of 2012. Half of the group received training aboard each of the two (0-DOF and 6-DOF) simulator fidelities. Table 1 provides an overview of the demographics of the study population.

Table 1 – Study Population Overview

Population size (N)	28
Males	16
Females	12
Average age (Male)	15.31
Average age (Female)	15.83
Maximum age (overall)	17
Minimum age (overall)	14
Age (standard deviation)	0.69

APPROACH AND METHODS

Teens were paired up in groups of two, and randomly selected for one of two simulator types (i.e. 0-DOF or 6-DOF). Training content was identical for both simulator fidelities. Each of the five two-hour training modules followed a similar flow in terms of content: First teens arrive, and are presented an audio briefing on the days training module. Next, the teens are asked to complete a number of pre-session surveys (see: *Data Measures*). After these preliminaries are complete, teens are briefly shown how to operate and control the simulator, and are presented a few small hints that are specific to the present module. The majority of the 2-hour session period is then spent with "seat time" on the simulator. Finally, before concluding each training session teens are asked to complete a number of post-surveys, as this was an effective means for determining knowledge retention. The major simulator training content of the modules is described as follows:

Module 1a: Program Orientation

By design, we are dealing with a young demographic that has little (or no) experience operating a motor vehicle. We are obliged to present basic rules and regulations before placing each teen inside the simulators. Accordingly, the orientation portion of the first session briefly outlines guidelines of general driving, which includes basic knowledge on vehicles, road regulations, road safety, and traffic.

Module 1b: Basic Vehicle Control
Within an urban road setting with no traffic, participants learn how to: smoothly operate the gas/brake pedals, turn left/right accurately and smoothly, maintain appropriate vehicle speed relative to conditions, and use signal indicators while making turns and while changing lanes.

Module 2: Beginner Vehicle Control
Within both an urban road setting and a "closed track" "Figure 8" (refer to Figure 2) setting (both without traffic), participants learn how to maneuver around various virtual driving scenarios. Skillsets to be reinforced include: lane position maintenance, impact of speed while amidst a turn, changing lanes (i.e. dotted lines vs. solid lines, and paint markings for center/turning lanes), and traffic signs (e.g., posted speed limit, left/right turn, danger/hazard forthcoming).

Module 3: Vehicle Control in Traffic
Within an urban road setting, this time WITH traffic, participants learn how to maneuver the vehicle amidst accompanying and oncoming traffic, and exercising how to safely change lanes and scan roads. A number of intersection scenarios are encountered, including: a 4-way (with stop sign), a 3-way T-Intersection (with stop sign), and various cross intersections monitored by traffic signals. Lastly, various hazards will be encountered, including a construction zone, and roadway bumps for speed modulation. Figure 5 provides an illustration of the road course.

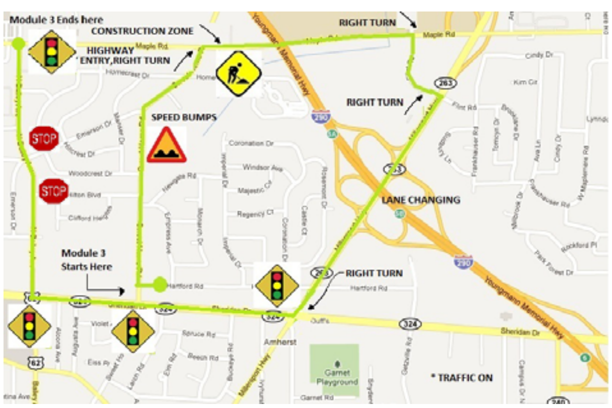

Figure 5 – Module 3 Training Course

Module 4a: Environment Hazards I
Within an urban road setting, again with traffic, participants learn how to maneuver the vehicle within intermediate traffic interacting with various road scenarios, as well as a few additional hazards. Specific scenarios encountered include: merging from one road to another (i.e., measuring appropriate merge timing and vehicle spacing), navigating roundabouts (and heeding the warning of yield signs), and monitoring speed relative to impending hazards, including additional hazard zones (e.g., a deer crossing).

Module 4b: Environment Hazards II
Within an urban road setting, again with traffic, participants learn how to maneuver the vehicle in traffic interacting with various road scenarios and advanced hazards. Featured in this module is a scenario involving highway entering/exiting (i.e., making appropriate gap judgment), maintaining speed relative to existing and oncoming traffic (including large vehicles), and a distracting and stress-inducing tailgater scenario (i.e., forces driver to remain calm, reduce speed, yield to the right side of the road, etc.)

Graduation Course
The final module is the simulation-based "graduation" test course. This virtual road course comprises many of the situations and hazards that were encountered in the previous modules. Upon completion of this module, quantitative and qualitative performance metrics are discussed with each teen participant, along with their past performances encountering similar scenarios. This concrete feedback will help them to better understand what skills and knowledge they have gained from the study, as well as possible areas for improvement.

RESULTS AND DISCUSSION

As one might imagine, the amount of data collected, even for this relatively small pilot study, was substantial. This paper summarizes various highlights. Accordingly, the discussion of results has been decomposed into the four major categories: i) quantitative measures, ii) qualitative measures, iii) module questionnaires, and iv) exit surveys/anecdotal.

i) <u>Quantitative Analysis</u>
One of the primary measures for driving performance is numerical data collected by the driving simulation software, in real-time, as the teen is driving. One area of interest that we chose to investigate is "core" driving skills, as compared across simulator fidelities. One important example is the impact of simulator fidelity on driving speed (mean, median, and maximum).

Refer to Figures 6 and 7. The former is a plot that compares average driving speeds (per training module) across both fidelities of simulators. The trend observed from the plot is that initially, average speeds were faster on the 6-DOF simulator, but over time, participants on the 0-DOF simulator exhibited higher speeds. There is always a period of acclimation required for those new to simulators, as the tendency is to drive much too fast. Once acclimated, we surmise that observed speeds for the 0-DOF simulator may have been faster as those participants were lacking a vestibular cue for longitudinal displacement. This cue, of course, is absent on the 0-DOF simulator, but certainly present on the motion-based simulator.

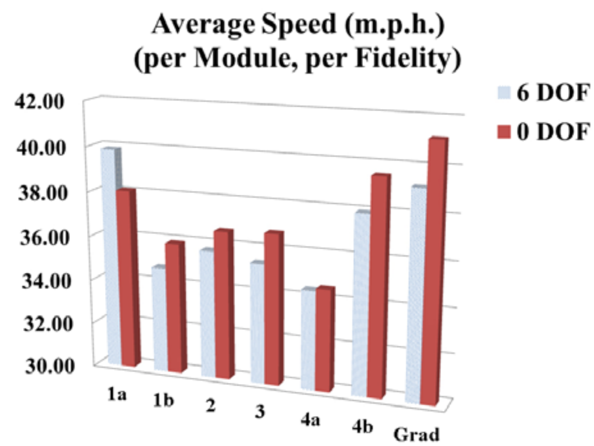

Figure 6 – Average Speeds (per module)

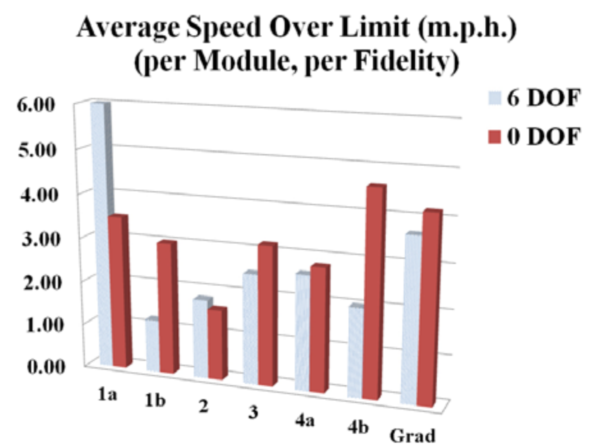

Figure 7 – Speed overages (per module)

Figure 7 displays the average speed overages per training module, and illustrates similar patterns: teens were driving too quickly on the initial module, speeds (on the whole) slowed down (closer to the posted speed limit) for later training modules, and on the whole, speed overages were slightly higher for the 0-DOF simulator. From a training perspective, it is pleasing to observe that speed overages are of a "reasonable" (i.e. < 5 m.p.h.) degree, which indicates that training participants paid respect to the posted speed limits.

In addition to core driving skills, the simulator has been programmed to account for driver performance amidst hazard scenarios. As an example, refer to Figure 8, which illustrates a roadway segment that uses speed bumps to modulate travel speed. The plot shows the average minimum speed observed for each simulator fidelity; as shown, minimum speeds were approximately 1-2 m.p.h. lower in the 6-DOF simulator. Figure 9 demonstrates the time to yield for participants when they encounter the Tailgater, who only relents when the driver yields to the right lane). On average, yield time was just more than 0.5 seconds shorter in the 0-DOF simulator.

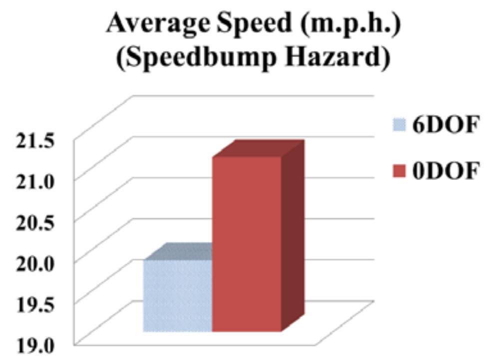

Figure 8 – Hazard Speed Modulation

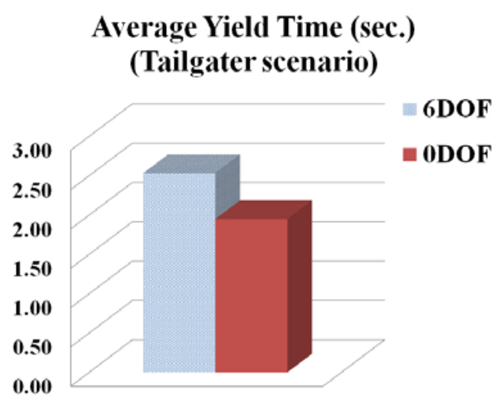

Figure 9 – Tailgater scenario (time-to-yield)

ii) **<u>Qualitative Analysis</u>**

Since all meaningful performance-based measures cannot as easily be captured (and interpreted) by the simulator software engine, another primary metric comes from a human-in-the-loop source. Namely, the training instructors observed a variety of relevant qualitative performance measures during and after participants drive within the simulator.

Three such examples are: turning radius (i.e., did the driver take a turn that was too sharp or too wide?), behavior at signalized intersections (i.e., was the traffic light yellow, or even red when the driver traversed the intersection?), and behavior at stop-signed intersections (i.e., did the driver come to a full and complete stop before proceeding)? For a summary of these observations, refer to Table 2. Shown in this Table is the average number of incidents of each infraction (per module excursion), with data normalized per the number of total participants (14) for each of the two simulator fidelities.

Table 2 – Qualitative Analysis

Infraction	0-DOF	6-DOF
Wide/sharp turns	2.82	2.55
Running Red Lights	1.00	1.55
Rolling through stop signs	0.36	0.27

Although the sample is relatively small, from this evaluator-collected information, we can make a few general observations: turning anomalies were slightly more prevalent on the 0-DOF simulator, as were instances of incomplete stops at stop signs. By a slightly more substantial margin, instances of running red lights were more commonly observed in the 6-DOF simulator. Here, it is less important to focus on the numerical data which, for this sample, has a low statistical significance. Rather, it is more important to make note of the potential for using simple checklists to augment hard (quantitative) measures with instructor-observed (human-in-the-loop) observations regarding these and other core driving skills.

iii) Module Questionnaire Analysis

Questionnaires also served as a valuable mechanism for attaining a better understanding of teen knowledge retention, pre- and post- module. A general questions and signs test (MGQST) was issued prior to each simulation module (and after viewing a brief, module-specific video) to make sure that each student had a basic understanding of the various traffic elements they might encounter on that days exercises. For most modules, teen scores were in the 85-95% range, which demonstrated a solid grasp of roadway fundamentals in advance of boarding the simulator. Figure 10 is a representative chart; this one issued prior to Module 5.

Both pre- and post- each module, students were also issued a scenario-based questionnaire (SBQ) that was specific to the training content of the days exercises. In general, teens scored better on the post- exam for each module as one might expect after receiving a briefing and extensive seat time in the simulator. Figure 11 is representative chart that displays pre- and post- SBQ scores from Module 5.

Lastly, data was collected (pre- and post-) to attain a measure of the presence of any symptoms of simulator sickness by way of the MSAQ. As suspected with a younger demographic, and with relatively brief exposure times in the simulator (i.e., less than 20 minutes per excursion), simulator sickness was not a major issue for this pilot study. Most symptoms that were reported subsequent to simulator exposure (e.g., headache, dizziness, drowsiness) were of a minor nature. One female reported moderate nausea after numerous sessions aboard the 0-DOF simulator, possibly due to the presence of visual cues, but complete absence of motion cues in that environment. There were numerous teens who actually reported sickness symptoms **reducing** from pre- to post-, possibly indicative that the engagement in the simulator served to reduce any mild malaise exhibited upon initial arrival to the Laboratory.

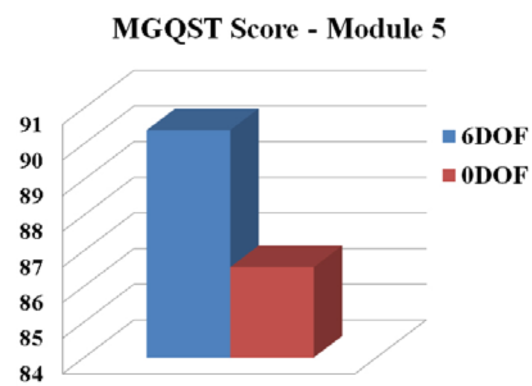

Figure 10 – MGQST sample results

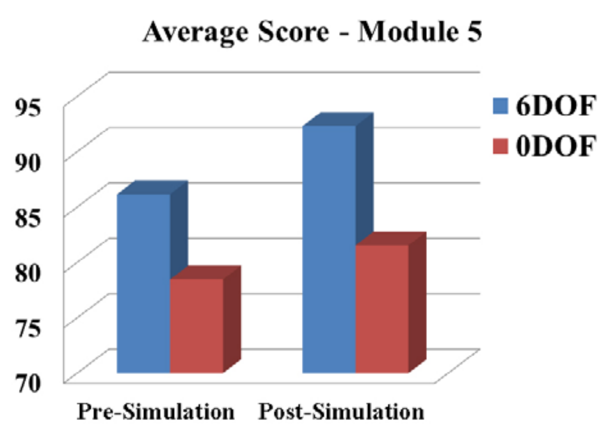

Figure 11 – SBQ sample results

iv) Exit Surveys/Anecdotal

A primary purpose for constructing, and subsequently conducting this pilot research study was to observe the advantages and disadvantages of offering a full simulator-focused driver training program. What elements of the program were successful, and which ones demand improvement? This would allow for valuable adjustments to be made before a more elaborate, full-fledged sequel program might be offered. To this end, a valuable mechanism for collecting program feedback was found to be through exit surveys issued both to teen participants (paper survey) and their parents (on-line Google survey). The surveys included simple Likert-type scoring questions, as well as extensive space for comments, suggestions, and anecdotal feedback.

Teens were asked to rate their overall experience in the simulator training program, on a 1-10 Likert scale. Results, for the 28 teens (14 teens for each simulator fidelity) are listed in Table 3. Results were favorable for simulator training in general, and slightly more so for the 6-DOF simulator, where the average score was larger, with a slightly tighter standard deviation amongst scores in that fidelity type.

Table 3 – Overall Program Satisfaction (teens)

Teen #	0-DOF (rating)	6-DOF (rating)
1	10	9
2	8	10
3	7	9
4	9	9
5	7	9
6	7	9
7	8	10
8	9	10
9	9	10
10	10	10
11	8	7
12	8	9
13	10	9
14	7	9
AVG	8.36	9.21
STDEV	1.11	0.77

Although overall, all teens liked the program to varying degrees, some had constructive criticisms for various elements of the program, and suggestions for improvement. Clearly, some elements cannot be improved as they are implicit restrictions of a given simulator fidelity. To supplement this are a collection of five comments/anecdotes from various teens attained on the same exit survey. See Table 4.

Equally valuable was the feedback we received from the parents of the teens in the program, who had to transport their teens to/from the simulator laboratory for the initial consent visit, and five two-hour simulator sessions. It was valuable to assess their perception of the worthwhileness of the program. A sampling of this feedback is provided in Table 5.

Table 4 – Teen anecdotes from Exit Survey

0-DOF	*"It does not allow you to see your blind spot or the entire intersection"*
0-DOF	*"I didn't feel as real car because we weren't really moving"*
6-DOF	*"Gave good experience on the basics of driving; was realistic in terms of speed and the different effects of speed"*
6-DOF	*"At times felt more like a game than driving"*
6-DOF	*It felt like driving a real car, and made me more aware of how driving feels. I liked that it actually moved around"*

Table 5 – Parent anecdotes from Exit Survey

0-DOF	*"Any training will be helpful to all young drivers. And as it is not instruction given by a parent, they are likely to pay more attention and absorb more information."*
0-DOF	*"Including a broader field of vision to at least include side view mirrors should be considered. I think this also made them clip corners more as they didn't get a real sense of how much room for clearance they had."*
6-DOF	*"My son feels more comfortable in regards to response time, gauging distance, and the feel of being behind the wheel."*
6-DOF	*"My son is a product of a generation that is well-versed in the ways of electronic interactive entertainment, and thought that it could be a bit more developed in this area."*
6-DOF	*"The critical thing my daughter learned is that unforeseen hazards can occur at any moment. Giving her the opportunity to experience these hazards and to see what happens if your actions are not appropriate was fabulous, and gave her the chance to safely practice reacting to those hazards."*

FUTURE WORK

Upon completion of this first phase of young driver simulator training, the research team has numerous ideas for expansion of the current concept:

Intermediate simulator fidelity.

Numerous manufacturers of motion control hardware offer intermediate-fidelity simulators, including: 2-DOF (roll/pitch), 3-DOF (roll/pitch/heave), and 4-DOF (roll/pitch/heave/surge) motion simulators. With a much larger sample size, it could be informative to compare these with the 0-DOF and 6-DOF simulators investigated in the present study, in an effort to identify the minimum motion threshold that is required for sufficient driver training.

A larger study population.

The 28 participants from the current study served to provide preliminary data from which the general operation of the program can be better understood. On a limited budget, it was an ambitious undertaking. The next phase is to attain a larger sample size with statistical significance (e.g., for a confidence level of 95%, and a confidence interval of ±5%, a sample size of 384 would be required). This would require additional resources, but less so normalized per student considering that training materials have now been developed, refined, and pilot tested.

Longitudinal driving data.

Of interest to driving agencies that are trying to gauge the long-term potential value of simulators is the existence of young driver performance metrics, obtained over time (e.g., records of traffic accidents and infractions over the first 3-5 years of driving; e.g., in New York State, the Department of Motor Vehicles MV-15 Form). This information would show if/how simulation training had an impact on one's early years driving performance. It would be informative to compare these numbers to a comparably sized dataset of teenagers who did not receive simulator training (i.e., a control group).

Distracted and impaired driving modules.

It is well known that teen drivers frequently speak and text-message on their cell phones while driving. The riskiness of this behavior is well-documented, with at times tragic consequences (Fox News, July, 2007). Core simulator exercises are envisioned that compare graphical representations of the teen's driving to provide concrete behavioral feedback on driving performance (e.g. with/without cell phone usage). Furthermore, in 2005, nearly one fourth of teenagers killed in automobile accidents were under the influence of drugs or alcohol (CDC, 2005). Drivers would perform "routine" driving tasks with/without a simulated state of driver impairment, and again receive concrete performance feedback.

Detailed Cost Analysis.

"What is the cost of a saved human life?" It is surmised that for many organizations who potentially have an interest in young driver safety (e.g., High School's, Law Enforcement Agencies, Driver Training Agencies), a major detraction towards the widespread implementation of the technology is the perception of high cost. (A single motion-based simulator with a visual system and sound system could easily cost upwards of $100,000). Moving forward, it would be informative to perform a formal cost analysis to estimate the expense of implementing simulators per each live saved, or per each accident prevented.

CONCLUSIONS

With roadway safety a major public health concern, due in large part to the disproportionate number of negative driving outcomes for young drivers, supplementary training approaches are being considered to provide much needed additional "behind the wheel" training experience. Over the last quarter-century, simulators have become widespread in military training, but have been vastly underutilized in civilian vehicle training. In an effort to address this area of interest, we incorporated simulation technology into an engaging preliminary educational program for teenagers. The program's primary intention was to use an in-house software framework to address many of the primary documented causes of error associated with novice drivers, e.g., speeding, vehicle distractions, and failure to heed right-of-way. Over the course of 5 two-hour training sessions, two levels of motion fidelity were compared: Low Fidelity: (0-DOF, single-screen), and High Fidelity (6-DOF, surround-screen).

Based on the limited sample of results (quantitative, qualitative, and other) attained for this study, we can conclude that the 6-DOF simulator was the favored fidelity option. Average speeds, and speed overages were found to be lower (on the whole) for the 6-DOF simulator, post-module test scores (both MGQST and SBQ) were, on the whole, higher for students who learned from the 6-DOF simulator, and finally, survey data (attained both from the teen participants and their parents) was more favorable for the 6-DOF simulator, citing a realistic (motion-based) environment, and a large/wide field-of-view, as examples.

In this pilot study, it is less important to focus on details regarding the numerical data which, for this sample, has a low statistical significance. Rather, it is more important to make note of the potential for employing a series of simple yet diverse measures (i.e., quantitative simulator-calculated driving performance, pre- and post- written exams, pre- and post-questionnaires, and qualitative instructor evaluation) to evaluate teen driving performance upon a variety of core driving skills and common roadway hazards.

Ultimately, this research sought to create a benchmark whose successes (and shortcomings) can be leveraged by future pilot studies with a more ambitious size and scope, with various suggestions offered to this end. The hope is that this and future studies could lead to the widespread deployment of simulators, for similar training programs, across the nation.

ACKNOWLEDGEMENTS

The authors would like to acknowledge funding support from the National Science Foundation's Industry/University Cooperative Research Center (I/UCRC) program; financial, hardware and software support from Moog, Inc., and technical consultation from both Karen Morris and Marlana Howard from the Center for Children and Families (CCF) at the University at Buffalo.

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