Not just for Kids – Simulation for Evaluation of Senior Drivers

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ABSTRACT

Statistics show that in the United States, there are about 38 million licensed drivers over age 65, which currently represents about 1/8 of our population. By 2024, this figure will DOUBLE to 25%. Given this anticipated increase in senior citizens (and senior drivers) among our population, the current research is intended to address the driving capabilities of our older population, as accident and injury risk has been statistically shown to increase (when normalized per miles driven) with advanced age. Our primary objective is to perform a preliminary Pilot study that allows our research team to establish the potential of supplementing traditional driver evaluation for senior persons with a motion-based full field-of-view driving simulator. Within a simulator, a variety of driving scenarios can be implemented that sufficiently challenge drivers in a way that, due to safety and logistical concerns, cannot be accomplished within the confines of a real vehicle. Longer-term, a driving simulator can be used to define driving tasks that are most likely to be affected by stages of early-stage dementia, and used to measure, capture, and analyze associated vital driver performance metrics.

For this study, each driver was evaluated using a conventional driver evaluation mechanism: in-clinic (i.e., to measure cognition, motor and visual skills) and in-vehicle (i.e., to measure one's mechanical ability to operate a vehicle). Prior to these examinations, each driver was also evaluated within a driving simulator, using the same metrics used for the in-vehicle examination. A subsequent data analysis was performed to identify any trends or correlations between the three evaluation mechanisms. Ultimately, it is hoped that the insight gleaned from this Pilot study will help to inform recommendations for making simulation-based technologies more successful as a long-term supplementary driver evaluation mechanism, for this age demographic specifically.

ABOUT THE AUTHORS

Dr. Kevin Hulme serves as Senior Research Associate at the New York State Center for Engineering Design and Industrial Innovation (NYSCEDII). He received his Ph.D. at the University at Buffalo in Mechanical Engineering, with a specialty multidisciplinary analysis and optimization. Over the last decade, Kevin has gained hands-on expertise in the development of motion-based driving simulation for a number of federally funded research and clinical initiatives in Transportation Engineering, Education and Training.

Mrs. Lisa Thorpe is an Occupational Therapist at the Erie County Medical Center (ECMC). She has over 20 years of experience as a Driver Rehabilitation Specialist, working on driver evaluations (both clinical and vehicle segments) with seniors over age 65.

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INTRODUCTION

Roadway safety continues to be a major public health concern, particularly among the senior (65+) demographic. According to the Insurance Institute for Highway Safety (IIHS, 2011), by 2030, people aged 65+ are expected to represent 25 percent of the total driving population. Here in Western New York State, all 12 counties have 65+ populations that are greater than the National average (12.9%), with the top five counties having populations that are 20% or greater than the national average. See Figure 1.

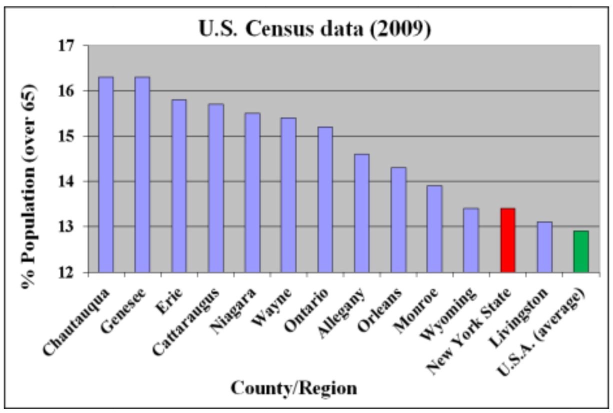

Figure 1 - Western N.Y. 65+ population (by County)

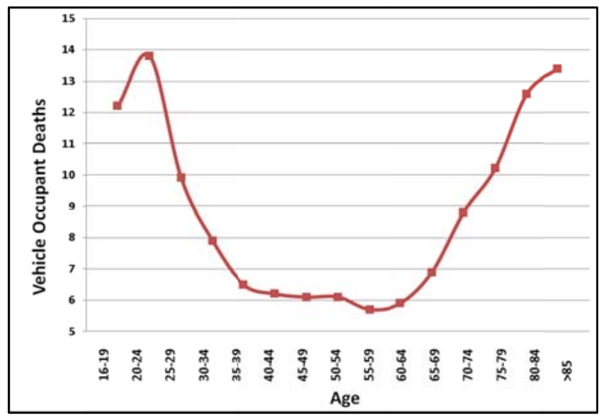

Figure 2 – Fatal Crashes by age (normalized)

Figure 2 shows crash fatalities according to driver age (IIHS, 2011), both sexes combined. Above age 65 (right side of curve), fatal crashes (normalized per miles driven) are seen to exhibit a steady and alarming increase. There are many age-related conditions that can have a negative impact on a person's driving capabilities. Dementia-related diseases, including Alzheimer's Disease (AD) create functional decline that negatively impacts driving performance. Dementia and AD afflict more than 7 million people in the U.S., and 35 million people worldwide (Osterman, 2009). This number is expected to double every 20 years (Prince and Jackson, 2009). Furthermore, recent research (AA, 2012) shows that six in ten people with Alzheimer's Disease will wander at some point – many within their vehicles -- and only four percent of those who leave home can find their way back. If they aren't found within 24 hours, the risk of serious injury or death increases exponentially.

Studies of crashes have found that failure to yield the right-of-way is the most common error among seniors. Not surprisingly, compared with younger drivers, senior drivers are more likely to be involved in certain types of collisions — angle crashes, overtaking or merging crashes, and especially intersection crashes (Mayhew et al., 2006). A driving simulator can be used to define driving tasks that are likely to be affected by stages of dementia (e.g., left turn management, traffic signs and signals, lane maintenance), and to capture driver performance metrics (e.g. speed, lane position, stopping behavior at intersections) that would be impractical to attain within an actual moving vehicle. The controlled and measurable environment of a simulator can be used to implement scenarios that sufficiently challenge "suspect" drivers (i.e., drivers with known or suspected cognitive impairment) in a way that, due to safety and other logistical concerns, could not be accomplished within the confines of an actual vehicle.

The intent of this study is to serve as a first step towards standardized implementation of simulators for senior driver evaluation, resulting in safer roadways. A subsequent validation would then allow the simulation-based evaluation protocols (which are capable of being implemented in varying levels of fidelity) to be broadly disseminated and deployed by external organizations (local, regional, and national) resulting in fewer accidents and fatalities.

LITERATURE OVERVIEW

Various other research groups have made recent attempts at simulation-based approaches for standalone driving studies with the aging/elderly population. For example, the AgeLab at MIT promotes safe driving research with older drivers, and examines the associated risks of health and medicine to driving (e.g., Reimer et al., 2006). Wayne State University has an "Advanced Mobile Operations Simulator" to evaluate cognitive driving skills of senior citizens and persons with disabilities (King, 2009). The Driving Safety and Rehabilitation Research Laboratory (DSRRL) at Purdue is used to perform assessments to identify weaknesses in driving-related performance (Justiss et al., 2006). The National Older Driver Training and Research Center (NODRTC, 2010) at the University of Florida has implemented the "Early Availability Driving Simulator", to assess the capabilities and limitations of older drivers (Classen et al., 2009). As well, the world-renowned National Advanced Driving Simulator (NADS) has been used to identify requirements for advanced driver assistance systems that specifically address safety needs of older drivers (e.g., McGehee et al., 2004).

As a final note, researchers from USC concluded (in their literature review) that "while road tests, simulators, and neuropsychological tests are important, each has…limitations" (Adler et al., 2005). Inspired by this statement, and by the aforementioned sampling of past literature, we will develop and demonstrate deployable driving simulation evaluation tools to supplement existing protocols (i.e., in-clinic and in-vehicle) for senior driver assessment. The unique direction employed here: a hybrid approach of merging physical and virtual road testing for risk assessment of older drivers, <u>provides a tertiary mechanism for senior driver performance evaluation, and serves as a novel assessment technique that will strive to substantially impact ongoing health care practice and clinical research</u>.

BROADER IMPACTS – WHO WILL BENEFIT?

The supplementary driver evaluation mechanism (presented here) for senior drivers, particularly drivers with known or a suspected cognitive deficiency, will serve numerous purposes:

- The simulation environment will provide a safe training grounds for senior drivers, and will be particularly beneficial for exercising roadway scenarios that are too challenging for an in-vehicle assessment.
- The simulation environment will provide older drivers, their family members, and caregivers a concrete review of specific driving deficits (e.g., performance graphs) to substantiate the need (in the interest of driver safety) for a restricted driver's license or driving limitations as confirmed by the conventional driver evaluation.
- The simulation environment will assist conventional driver training evaluators in challenging the cognitively impaired older driver in a more measurable, repeatable, and objective driving environment.
- Additionally, all drivers on the roadway will benefit from the far-reaching potential of the current research, which strives to improve roadway safety among this demographic of our driving population, where there have been a disproportionate number of negative driving outcomes (per miles driven) (e.g., Figures 1-2).
- The driving modules developed for this study could be leveraged by other "vulnerable groups" within our driving population, including drivers with Post-Traumatic Stress Disorder (PTSD), drivers with Attention Deficit and Hyperactivity Disorder (ADHD), and certainly typical teenagers, for whom traffic accidents continue to be the leading cause of death (CDC, 2012).
- Although we employ a motion-based driving simulator for the current study, our extensible software environment has been developed so that is can be deployed upon simulators of all fidelities.

The primary intent of the current study is to establish the potential of simulators in senior driver evaluation. This would allow our simulation-based evaluation protocols and challenge scenarios to be broadly disseminated, deployed, and implemented by external organizations (local, regional, and national).

DATA MEASURES (Cognitive and Clinical)

One important feature of the current study was to assess the cognitive state of our driving participants in conjunction with the in-simulator and in-vehicle tasks they were asked to perform. Accordingly, a number of Cognitive/Clinical assessments were performed before/after the simulator exam, and other additional tests before the in-vehicle exam. These were issued to: a) measure cognitive status, b) to quantify any side effect symptoms from driving the simulator, and c) to quantify one's ability to drive a vehicle, using a number of accepted clinical assessments.

Prior to boarding the simulator (at NYSCEDII), participants were issued two standardized cognitive examinations. First was the Mini-Mental State Examination (MMSE) (Folstein et al., 1975), used to estimate the severity of any cognitive impairment. In approximately 10 minutes, it samples functions including arithmetic, memory and orientation. Second was the Montreal Cognitive Examination (MoCA) (Nasreddine et al., 2005), which is also a 10 minute test of similar nature which assesses short-term memory, visuospatial abilities, attention, concentration, and working memory. Both the MMSE and the MoCA are scored on a 0-30 scale, where 30 is a perfect score, scores in the low 20's represent mild cognitive impairment, and lower scores represent severe cognitive impairment.

Despite the advantages that simulators offer, one major disadvantage to their implementation is a common side effect known as simulator sickness, a motion sickness-like malady that can include a wide range of symptoms, including headache, sweating, vertigo, nausea, vomiting, and others (e.g., Johnson, 2005). Accordingly, participants were issued the Motion Sickness Assessment Questionnaire (MSAQ) (Gianaros et al., 2001) both pre- and post-simulator. The MSAQ consists of a series of 16 simple questions which are rated on a 1-9 scale, with "1" being minor, and "9" being severe. Each of the 16 questions falls into one of four categories of common sickness symptoms: Gastrointestinal, Central, Peripheral, and Sopite-related. The overall motion sickness score is obtained by calculating the percentage of total points scored: (sum of points from all items/144) × 100.

Prior to driving within the test vehicle (at ECMC), participants were issued a number of in-clinic tests. Refer to Table 1 for a summary of the major clinical tests offered prior to the physical driving exam.

Please note that routine history taking was omitted specifically so that the evaluators (both at NYSCEDII and at ECMC) did not have any knowledge of the cognitive status of the subject (i.e., "mild dementia" or "well elderly"). This "blind" status was a desired component to the research study.

Table 1 – Clinical Tests (ECMC)

Test	Purpose/Comment
Motor Skills	Strength and Coordination
Brake Reaction	AAA standard test (time in sec.)
Stroop	Interference in reaction time
Trail Making B	Visual attention and task switching
Clock Drawing	Cognitive and adaptive functioning
Light Touch	Sensory (hands and toes)
Field of Vision	Horizontal; NYS DMV standard
Night Sight A	Meter Illumination (AAA test)
Night Sight B	Glare Recovery (AAA test)

EXPERIMENT DESCRIPTION (NYSCEDII)

A high-fidelity driving simulator was implemented for the present study. This motion-based simulator (Figure 3) consists of a six degree-of-freedom motion platform with a passenger cabin that includes: 2 front seats w/ seat belts, a steering wheel and foot pedals, a full front vehicle console, rear and side-view mirrors, and an emergency stop switch. Our steering unit features 900 degrees of angular rotation, a mechanical force-feedback capability, rear-wheel paddle shifters for turn signal indictors. Our visualization system consists of four screens, each 8 feet wide by 6 feet high, mounted together using exact 120 degree internal angles, thus forming the front half of a perfect Hexagon. The front three screens are augmented by a fourth screen that provides rearward viewing capability. Each screen is front-projected by an SXGA+ (1280x960, 4:3) native resolution LCD Projector. Our simulator includes an external stereo 2.1 (front-left, front-right, and L.F.E. subwoofer) channel sound system. The simulation system is powered by a tower graphics workstation that has dual-core 2.16 GHz Intel Xeon processors, 12 GB Memory, and a state-of-the-art graphics processor. (e.g. graphics/motion/audio cueing and real-time simulation analysis).

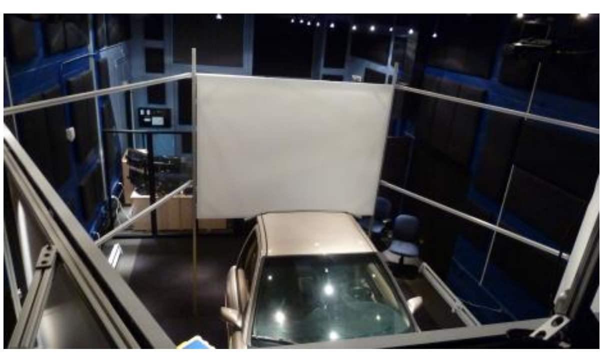

Figure 3 - NYSCEDII driving simulator

Figure 4 - Simulator and Driving Environment

Once on-board the simulator, the driver was asked to perform three drives of increasing duration. The first was a brief practice “acclimation” drive (3 minutes), primarily to get used to the controls and the environment. This was followed by a left-hand turn drive-around the block (~ 6 minutes), followed by a drive that examined hazard management, multi-tasking, and road signs (~ 9 minutes). Refer to Figure 4, which illustrates the simulator (hardware) and a depiction of the residential driving environment (software). Figures 5-6 represent the excursion maps for Scenarios 1 and 2, and Table 2 lists the posted speed limits for each segment of both Scenario paths.

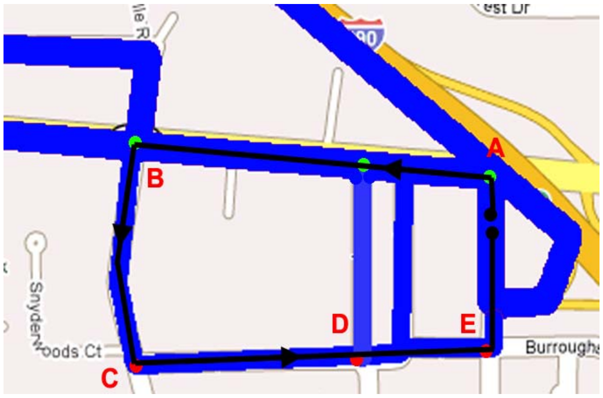

Figure 5 - Drive Scenario #1

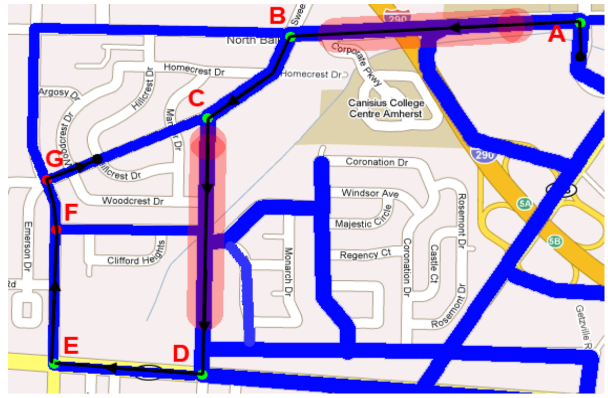

Figure 6 - Drive Scenario #2

A variety of performance data was collected, both quantitative (i.e., as measured by the simulation software) and qualitative (i.e., as observed by the session evaluator) in nature. Quantitative data includes speed, lane position, acceleration, and specific events such as vehicle collisions, lane swerves, behaviors at signalized intersections, and minimum speed at stop signs. Quantitative data includes an evaluator score sheet that contains ten major categories, each scored from 0 (normal) to 3 (severely impaired).

Table 2 – Scenario Segment Speed Limits (m.p.h.)

Road Segment	Scenario #1	Scenario #2
AB	45	45
BC	35	35
CD	30	35
DE	30	45
EA	40	n/a
EF	n/a	35
FG	n/a	35
GC	n/a	30

Thus, upon completion of the simulator drive(s), each participant scored between 0 (a perfect score) and 30 (severely impaired driving in all categories). The ten performance categories are: *right turns, left turns, lane maintenance, proper following distance, proper lateral distance from cars, control of speed, brake reaction time, visual scanning at stop signs/signals, visual scanning during driving, and orientation/attention.* Lastly, upon exiting the simulator session, participants were asked to complete a brief survey requesting self-feedback (based on one’s own driving performance), technical feedback on the simulator itself, and an overall simulator satisfaction metric.

EXPERIMENT DESCRIPTION (ECMC)

Immediately following the clinical evaluation, the participant was escorted to a 2008 Ford Taurus (Figure 7), dual equipped vehicle, to complete the in-vehicle portion of this evaluation. The participant was oriented to the vehicle, and all necessary adjustment to seat position and mirrors was made prior to the start of driving. During the 20-30 minute excursion, the participant is exposed to the following general driving environments: closed course, residential, commercial, and expressway. As a portion of the examination, the participant is oriented to the location of the hospital (ECMC), and is asked to drive two traffic lights North (on Grider Street). Here, the participant then makes all navigation decisions to return to ECMC. Note that the in-vehicle evaluator uses the very same score sheet that was used for the simulator trials (i.e., a score of 0 to 3 in each of 10 different driving categories).

Figure 7 - ECMC test vehicle

STUDY POPULATION: OVERVIEW

Our study population was recruited largely from flyer postings at regional senior community centers. Flyers were postal mailed to every community center within a thirty mile radius, so more than sixty centers were contacted during our outreach phase. Candidate participants were informed that their participation would require two separate visits, encompassing approximately three hours of their time: one to NYSCEDII (for the driving simulator session and cognitive evaluation), and one to ECMC (for a clinical and in-vehicle driving evaluation). Eligibility criteria for the study (established during a telephone screen) included the following: over 65 years of age, with an active New York State driver's license, and of good general health (i.e., free of seizures, not afraid of closed/dark spaces, does not suffer from excessive motion sickness). Incentive for participation was a $100 gift card, upon completion of both major portions of the study. For this Pilot study, we had a total of 10 recruits (7 males and 3 females). Successful management of this study cohort will emphasize feasibility and initial promise of outcome. The "Senior Driver Simulator Study" (SDSS) participants are summarized in Table 3.

Table 3 - Basic Details of Pilot Study Population

Part. code	Age	Gender
SDSS-01	66	M
SDSS-02	72	M
SDSS-03	66	F
SDSS-04	71	F
SDSS-05	66	M
SDSS-06	77	M
SDSS-07	67	M
SDSS-08	65	F
SDSS-09	70	M
SDSS-10	65	M
Age statistics: Mean: 68.5, Std. Dev.: 3.92		

Table 4 – Cognition Results (NYSCEDII)

Part. Code	MMSE	MoCA
SDSS-01	28	23
SDSS-02	28	24
SDSS-03	29	27
SDSS-04	28	27
SDSS-05	27	24
SDSS-06	26	23
SDSS-07	29	27
SDSS-08	27	27
SDSS-09	29	27
SDSS-10	28	22
Avg.	***27.9***	***25.1***
STDEV	***1.0***	***2.1***

RESULTS AND DISCUSSION

Subsequent to participant trials at both NYSCEDII (cognition, simulator) and ECMC (clinical, vehicle), all collected data was analyzed and tabulated. A selection of results attained during our Pilot study is offered in the Tables and Figures that follow. Our Results are subdivided into six subcategories: Pre-simulator, Simulator, Pre-Test Vehicle, Test Vehicle, Surveys and participant comments, and Evaluator comments.

Pre-Simulator

Table 4 represents the cognitive results that were obtained prior to participants boarding the simulator (NYSCEDII); the results of the MMSE and MoCA tests. Again, these tests are scored on a 0 to 30 scale. Overall, scores were in the "normal" range for both the MMSE and MoCA exams (i.e., mid- to high- 20's). According to the literature, for the MMSE, any score greater than or equal to 25 points indicates a normal cognition. Regarding the MoCA, any score below 26 is indicative of "mild cognitive impairment". Our results indicated a number of slightly below normal scores for the MoCA, namely: SDSS-01 (23), SDSS-02 (24), SDSS-05 (24), and SDSS-10 (22). Based on observation, our clinician's opinion was that that these lower scores were more due to participant nervousness/anxiety, especially considering their favorable scores on the MMSE exam.

Simulator

After drivers were minimally acclimated in the simulator, the first driving scenario was a simple series of left-hand turns driving around the block. The total distance of the excursion was 7750 ft., and drivers were given a total of 400 seconds to complete the excursion. Table 5 provides a listing, for each participant, of the time required to complete the first scenario, and the total distance traveled. Note that only four of the ten participants completed the excursion in the time allotted. This is certainly some indication that most drivers in this cohort tended to drive slowly and cautiously – although this may be partially due to the novelty of the simulation-based driving environment.

To further investigate the speeds at which the participant cohort handled this first scenario, refer to Figure 8, which offers a plot of speed (both maximum and average) for each participant. Note that despite the posted speed limits (see Table 2), only two of the ten drivers felt comfortable enough to reach a maximum speed of over 40 mph. This is inconsistent with normal trends on simulators, whereby it has been documented (e.g., Green, 2005) that drivers drive too fast in simulators. Average speeds for most drivers in the cohort were between 10 and 15 mph, but for SDSS-6, average speeds were below the 10 mph threshold, indicative of overly conservative driving.

Table 5 – Scenario #1 excursion details

Part. code	Time (sec.)	Distance (ft.)
SDSS-01	400	6462.5
SDSS-02	290.3	7750
SDSS-03	400	6260.4
SDSS-04	346.2	7750
SDSS-05	343.1	7750
SDSS-06	400	4796.6
SDSS-07	400	6904.9
SDSS-08	400	6402.0
SDSS-09	400	6693.3
SDSS-10	381.8	7750
Avg.	***376.2***	***6852.0***
STDEV	***37.7***	***953.4***

Table 6 – Scenario #2 excursion details

Part. code	Time (sec.)	Distance (ft.)
SDSS-01	n/a	n/a
SDSS-02	n/a	n/a
SDSS-03	n/a	n/a
SDSS-04	468.5	12500
SDSS-05	494.4	12500
SDSS-06	163.0	3570.1
SDSS-07	546.5	12500
SDSS-08	519.8	12500
SDSS-09	n/a	n/a
SDSS-10	n/a	n/a
Avg.	***438.4***	***10714.0***
STDEV	***156.6***	***3993.5***

The second driving scenario was a longer and more complicated excursion that focused on hazards on the roadway and multi-tasking. The total distance of the excursion was 12500 ft., and drivers were given a total of 600 seconds to complete the excursion. Table 6 denotes the time required to complete the second scenario, and the total distance traveled. Note that only five of the ten participants attempted this excursion (due to simulator sickness issues after the first excursion), and of those, four completed the scenario in the time allotted. The fifth (SDSS-06) had to terminate the session prematurely due to (severe) simulator sickness issues. This termination is the primary reason for the large standard deviations observed. Figure 9 offers a plot of speed (both maximum and average) for each participant for Scenario #2. For the five participants who attempted this scenario, maximum and average speeds were comparable, and overall, more appropriate given the speed limits involved for this excursion. This is partial evidence that drivers were becoming more comfortable driving "normally" within the simulator.

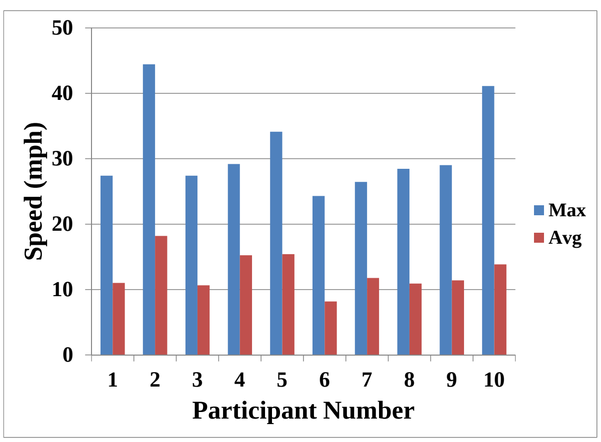

Figure 8 - Speed data, Simulator Scenario #1

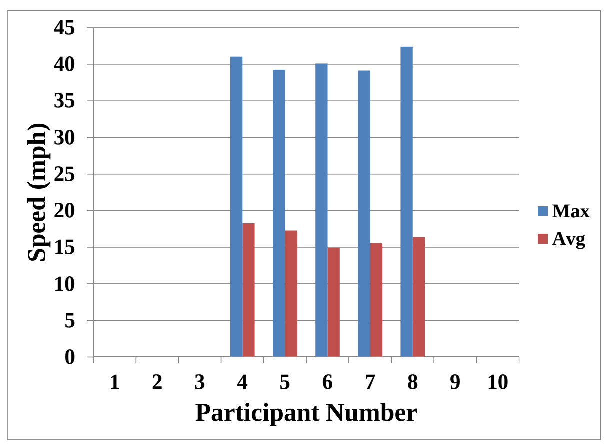

Figure 9 - Speed data, Simulator Scenario #2

Figure 10 is an illustration of overall simulator performance score for each of the ten participants. Refer to the blue series. Recall that each participant is scored from 0 to 3 in each of ten categories, with 0 being a perfect score. Accumulated simulator performance rating scores ranged from a 5 to a 9 for all ten participants. It is surmised that most instances of "poor" performance observed is less attributable to poor driving skills, and more attributable to poor driving skills <u>on a simulator</u>, where all participants were new to the environment. The three most common demerits issued during the simulator test were: *Maintain control of speed* (avg. score: 1.5/3), *Brake Reaction Time* (avg. score: 1.1/3), and *Visual Scan During Drive* (avg. score: 0.9/3). Poor scores on the "brake reaction time" metric were not surprising, as most drivers new to the simulator complain that the brake pedal "doesn't feel right". This is a common problem in driving simulators. From our experience, continued acclimation (and multiple trials) is typically the best cure for this problem. However, with this senior-aged population, more "seat time" could result in other issues pertaining to simulator sickness symptoms. Clearly, this balance would have to be handled delicately in future applications. (*Note that this extra acclimation has **not** been a concern on our simulator with the development team, nor with past participants on our simulator involving teenage drivers. A possible exception has been parents driving with teens as **passengers, rather than operators** – but this is not uncommon*).

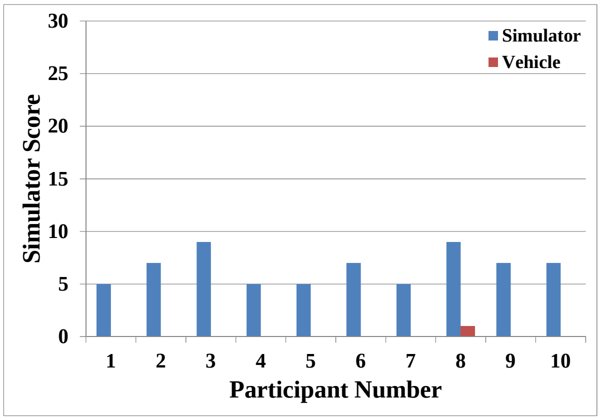

Figure 10 – Performance Score vs. Participant

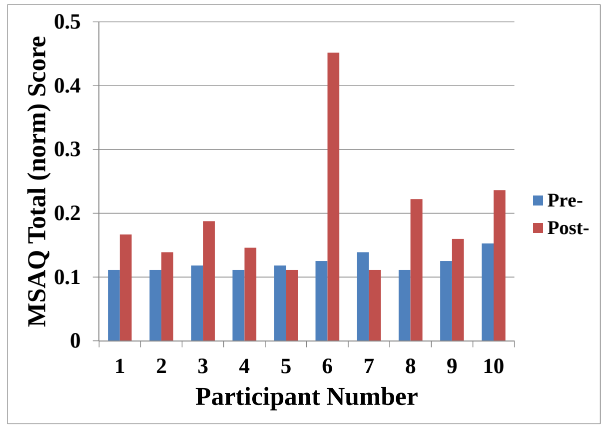

Figure 11 – MSAQ scores (Pre- and Post-)

Figure 11 is a representation of the MSAQ for all participants (both Pre- and Post- simulator), which is a standardized measure of simulation sickness. For all ten participants, the composite Pre-MSAQ scores were right around 0.1, which indicates an average score of a 1-2 (on a 9 scale) for all 16 categories that comprise the questionnaire. The average (composite) pre-MSAQ score was 0.122 across all participants. Based on cohort average scores, the three most common complaints Pre-Simulator can be seen in Table 7.

Table 7 – Pre-Simulator complaints	Table 8 – Post-Simulator complaints
• I feel annoyed/irritated (avg. score: 1.5/9)	• I feel sweaty (avg. score: 2.5/9)
• I feel hot/warm (avg. score: 1.5/9)	• I feel dizzy (avg. score: 2.3/9)
• I feel sweaty (avg. score: 1.3/9)	• I feel queasy (avg. score: 2.1/9)

After 15-20 minutes of total simulator exposure, two participants showed no signs of simulator sickness (SDSS-05 and SDSS-07); five participants showed mild symptoms (SDSS-01, SDSS-02, SDSS-03, SDSS-04, and SDSS-09); two participants showed mild-moderate symptoms (SDSS-08 and SDSS-10), and one participant (SDSS-06) showed extreme (short-term) sickness symptoms. MSAQ scores increased for eight of the ten participants from Pre- to Post- and (slightly) decreased for the other two. The average (composite) post-MSAQ score was 0.193 across all participants. Based on cohort average scores, the three most common complaints Post-Simulator can be seen in Table 8. Note again that some drivers did not complete the second driving scenario, due to ill effects endeavored after the first scenario, but still DID complete the post-MSAQ. It is thus highly likely that if all drivers were to have completed both driving scenarios, the Post-MSAQ scores would have been a bit more pronounced.

Pre-Test Vehicle

Table 9 represents a sampling of the clinical results that were obtained prior to participants boarding the physical test vehicle (ECMC); from left to right are the AAA-brake reaction time (R.T.) (e.g., Parnell et al., 2007) listed in seconds (i.e., lower is better), the Trail Making B (T.M.B.) exam - a neuropsychological test of visual attention and task switching (Bowie and Harvey, 2006), measured in seconds (i.e., lower is better), the Stroop exam (Stroop, 1935), which measures the interference of the reaction time of a task, listed in seconds (i.e., lower is better), and in the final column are the results of the Field of Horizontal Vision (F.O.V.) – shown are the combined left and right scores from a Periometer; NYS DMV standard is 140 degrees (minimum) in the horizontal plane (TA, 2003).

For all four of the clinical tests, scores were within "normal" limits, with some notable (but tolerable) exceptions. For brake reaction time, as measured by AAA's "blue box", most participants demonstrated a time of close to the 0.70 second average, plus or minus a small standard deviation. (ECMC's acceptance standard is < 0.75 seconds). SDSS-06 displayed a 0.80 second reaction time, and the evaluator noted that this participant "required cueing to go faster". Regarding the Trail Making B exam, results showed a wide scatter, with min/max times of 46 and 130 seconds, respectively. Acceptance criteria for this exam vary greatly in the literature; (Stutts et al., 1996) suggests normal times of between 80 and 110 seconds, varying with age.

Table 9 – Pilot Study Results (ECMC)

Part. Code	R.T.	T.M.B.	Stroop	F.O.V.
SDSS-01	0.75	113.0	40.14	170
SDSS-02	0.63	88.0	39.34	150
SDSS-03	0.65	46.8	24.67	155
SDSS-04	0.68	76.0	28.36	160
SDSS-05	0.62	123.0	29.97	160
SDSS-06	0.80	84.0	37.27	150
SDSS-07	0.65	55.30	26.31	170
SDSS-08	0.75	130.0	34.65	155
SDSS-09	0.69	78.2	27.59	150
SDSS-10	0.78	99.31	33.01	155
Avg.	***0.70***	***89.4***	***32.1***	***157.5***
STDEV	***0.07***	***27.4***	***5.6***	***7.5***

Accordingly, perhaps only SDSS-05 and SDSS-08 exhibited performance that was on the high side of normal. Regarding the Stroop test, all participants completed the exam in close to the 32.1 second sample average, with only two participants (SDSS-01 and SDSS-02) performing with times of more than one standard deviation above the average. Finally, horizontal field-of-vision, for all participants, was above the 140 degree standard. All participants were thus deemed "safe" to drive, and continue participation in this study.

Test Vehicle

Figure 10 (*see previous page*) also denotes participant performance scores attained inside the vehicle; refer to the red series. Note again that the same score sheet used here was also used for the Simulator (i.e., ten categories, each scored from 0 to 3, with LOW scores being desirable). Within the vehicle, all ten drivers were measured by their evaluator as being "acceptable" (i.e., a score of "0") across all ten categories, with only one demerit denoted for ANY of the drivers (SDSS-08).

Surveys and Participant Comments

Figure 12 illustrates the overall program rating (on a 10 scale), as scored after the Simulator portion of the program. Taken as a whole, our cohort rated the simulator experience favorably (μ=7.9, σ=1.6). All drivers noted the potential for using simulators as a driver evaluation tool, however complained about the brake pedal not feeling "like their own", and being too sensitive. Most participants would stop long before an intersection, and required some time and practice to get a feel for when to apply braking force, and how much force to apply. Numerous participants also struggled with turning in our wide field-of-view environment. The viewpoint transition disoriented many of our participants. Based on evaluator observations, both of these anomalies contributed (with some significance) to the simulator sickness effects that were noted.

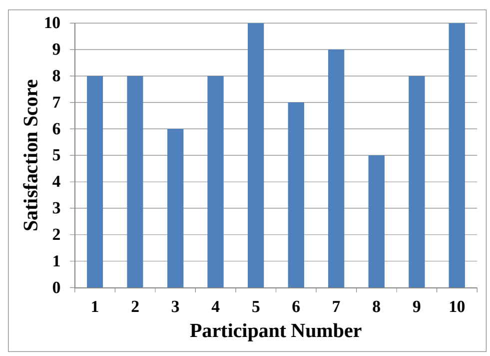

Figure 12 – Overall Program Rating

Evaluator Comments

The NYSCEDII evaluator, based primarily upon performance observations in the simulator, "passed" all drivers. Comparing both data series in Figure 10, Simulator performance scores observed were not as favorable as they were for Vehicle performance scores. This is likely because all participants were new to the simulator environment, perhaps coupled by the fact that the simulator evaluator was more critical in issuing demerits for performance than the ECMC evaluator, who has regular experience working with this driving population. The simulator evaluator finally noted that participants SDSS-03, SDSS-06, and SDSS-08 were passed "with some reservation". ECMC evaluators had generally positive things to say about the entire cohort. All drivers "passed" their portion of the exam. The only restriction issued was a "day time only" driving restriction for SDSS-06, due primarily to poor performance on a number of vision tests during the clinical portion of the examination.

CONCLUSIONS

It is normal for our driving abilities to change with age. Both by reducing risk factors and by incorporating safer driving practices, many can continue driving safely long beyond age 65. We must, however, pay attention to any age-related warning signs that interfere with our ability to drive a vehicle safely, and make appropriate adjustments. To this end, a driving simulator has great potential to serve as a useful (supplementary) mechanism for senior driver evaluation. The primary purpose of this Pilot study has been to demonstrate this potential, and outline the future challenges that must be addressed. At present, in-clinic and in-vehicle evaluations are performed customarily, but there are no standardized metrics in place to concretely determine driving performance for those persons aged 65 and over. Anecdotally, this study cohort was of great value for the ECMC evaluators to formalize, establish and put to practice a performance evaluation "system", and place metrics upon in-clinic items that have been historically quantified by "feel". Our research team was curious to observe if a driver's performance in the simulator (based on both quantified and observed metrics) would confirm (or deny) that of the clinic/vehicle evaluation.

This pilot study successfully informed numerous recommendations for making the simulator more effective for the intended demographic:

- Clearly, practice and acclimation is vital for the success of using simulators. Particularly so, because seniors are likely to be less technologically savvy (than teens, for example) to the game-like nature of typical simulator hardware and software.
- As a result of the above point, observed speeds in the simulator were (at least initially) slower than normal, as seniors were observed to drive very cautiously. This is counterintuitive to "typical" behavior on simulators, especially among teenagers, where participants feel uninhibited and drive too fast and reckless, thereby defeating the purpose of using a simulator in the first place.
- Much can be learned about senior driving behaviors while driving in a straight path at a relatively constant speed. Such would minimize the need for braking behavior, and multi-screen turning (and wide display visualization systems). Clearly, these are areas that induced numerous participant complaints in this Pilot study.
- Sickness is always a concern within a simulator, but particularly so among seniors. Based upon past studies (e.g., Hulme et al., 2011) that analyze the common causes of simulator sickness, there are mitigation approaches that are easy to implement, including: minimized field-of-view, and exhibiting caution with experiment duration (e.g., performing shorter drives, with breaks). Future studies must take these recommendations into account.

FUTURE WORK

The present study served as important first step towards a longer-term goal: standardizing a universally accepted protocol in the supplementary evaluation of senior drivers. Further, the present study has assisted in examining simulation measures that are objective and able to be validated for such a purpose. As demonstrated here, simulation, which provides a SAFE, controlled, measurable, and repeatable test environment, can complement existing protocols (e.g., cognitive and physical exam, in-vehicle field evaluation) to achieve a more accurate "pass or fail" determination of senior driving competence.

One common drawback of implementing simulation on a large-scale is the expense. High fidelity simulators can indeed cost thousands or millions of dollars; while low-fidelity alternatives exist, training effectiveness can often be compromised. Another longer-term outcome of this initial pilot study will be to determine baseline simulator fidelity requirements to present a valid test environment, and develop software tools that meet these minimum requirements, with specific regards to motion properties, field-of-view, and sophistication of user input/controls.

With continued analysis, performance data will indicate that current driving evaluation protocols, alone, are not sufficient – particularly for older drivers with suspected or known cognitive impairment (e.g., mild to moderate dementia). Future studies could confirm our hypothesis that drivers with dementia will exhibit a marked decrease in simulator performance in defined challenge scenarios when not provided ample and explicit navigation cues. Expanded analyses could implement Design of Experiments (DOE) (e.g., Hedayat, et al., 1999) and ANOVA to identify and prioritize the most significant experimental variables and their confounding affects. For example, how impactful was the period of acclimation on driving performance? To what degree did simulator sickness symptoms impact simulator performance? A driving simulator has great potential to serve as a meaningful, repeatable, safe, and cost-effective tertiary evaluation environment, particularly for drivers within this demographic and within other vulnerable populations (e.g., ADHD, PTSD, and of course typical teen drivers).

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