Leveraging Simulation to Augment Risky Driving Attitudes and Behaviors

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ABSTRACT

Young, novice drivers continue to be responsible for a disproportionate amount of negative driving outcomes. A novice driver's lack of: i) exposure, ii) semantic knowledge of driving situations, and iii) understanding of risky situations make them particularly vulnerable to costly mistakes while driving. Texting while driving (TWD) is a behavior commonly engaged in by novice drivers that greatly increases the risk for accidents, injuries and mortality. Cell phone use while driving causes deficits in performance (e.g., impaired attention to signs; braking and lane positioning deficits due to visual, motor, and cognitive distraction). While many drivers recognize that TWD is a serious problem, many admit to engaging in the behavior frequently. Studies have demonstrated that drivers perceive their own distracted driving performance to be better than their actual performance. This suggests that drivers may be engaging in dangerous behavior because they believe it affects the driving performance of others, but not their own. This is a major ongoing public health concern.

Past studies have suggested that receiving concrete performance feedback can correct perceptions of risk of driving while engaging in a distracting task, and improve subsequent driving performance. In this regard, Simulation can serve an effective tool for Education and Training. Accordingly, the current study leverages a high fidelity driving simulator to provide performance feedback for a pilot cohort of novice adult drivers while driving distracted. The primary goal is to change attitudes towards and subsequently reduce TWD behavior with the use of the performance feedback during the simulated TWD exercise. Along with the simulator-acquired data and graphs (e.g., speed, lane position), TWD behaviors are measured objectively with a performance monitoring "Car Chip" device installed within each participant's vehicle during the study observation period. Car Chip records including the dates and times of each participant's drives are compared against each participant's text messaging records (containing dates and times of texts sent or received) for any overlap, objectively measuring in-vehicle TWD behavior. The current study presents a novel approach for evaluation and intervention to reduce distracted driving behaviors specifically for the most at-risk driving population.

ABOUT THE AUTHORS

Karen L. Morris is a Senior Research Support Specialist with the Center for Children and Families at the University at Buffalo. She obtained her Master's in Public Health from the University at Buffalo in 2011. Presently, she serves as Project Coordinator for STEER, a federally-funded multi-year randomized trial that seeks to improve driving outcomes for teens with Attention-Deficit Hyperactivity Disorder. Her research interests include preventive health program development and the dissemination of programs in the community.

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Kevin F. Hulme is the technical lead of the Motion Simulation Laboratory at the New York State Center for Engineering Design and Industrial Innovation (NYSCEDII), and focuses on the custom design and development of ground vehicle simulations for applications in: clinical research, education and training, and next-generation transportation studies. Recent areas of focus include: standardization of simulators in teen driver safety, fidelity requirements in simulation system specification, and multi-participant civilian driving simulators.

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INTRODUCTION AND MOTIVATION

Texting while driving (TWD) is a behavior that is commonly engaged in by novice drivers. Studies and recent statistics have demonstrated that TWD increases risk for vehicle crashes, and crash-related injuries and mortality. Engaging in cell phone use while driving causes several deficits in driving performance, including: reduced attention to road signs, braking deficits, and deficits in lane positioning due to the visual, motor, and cognitive distraction (Hosking & Young, 2009; Drews et al., 2009). As such, engaging in TWD increases the risk of crashes (and near-crashes) **to 23 times** that of a non-distracted driver (Olson et al., 2009). Laws prohibiting cell phone use while driving have been unsuccessful in reducing this behavior, and may actually be causing distraction-related collisions to increase (HLDI, 2010). As unintended motor vehicle accidents are the leading cause of death for 15 to 24 year olds, and distracted driving is common among this age group, the prevention of TWD and other distracting tasks while driving is of major public health significance (Minino et al., 2010; PIALP, 2009)

While most drivers recognize that TWD is a serious problem, many admit to engaging in the behavior frequently. A recent poll by the AAA Foundation for Traffic Safety found that 83 percent of drivers rated distracted drivers and cell phone use while driving as a serious or extremely serious problem, however, 46 percent of them also indicated they had recently used a cell phone while driving (AAA Foundation, 2008). In addition, studies have demonstrated that drivers perceive their own distracted driving performance to be better than their actual performance (Horrey et al., 2008). This suggests that drivers may be engaging in a behavior they view as dangerous because they believe it affects the driving performance of others, but not their own. Some researchers have suggested that receiving feedback regarding driving performance can correct perceptions of risk while engaging in a distracting task, and can improve driving performance (Donmez et al., 2008).

The current study seeks to use TWD performance feedback from a high-fidelity driving simulator to change attitudes towards TWD, and ultimately, attempt to reduce TWD behavior. TWD behaviors will be measured objectively through the use of a monitoring device placed in the participant's vehicle that measures the date and time of each trip taken. Each participant's vehicle trip records will be compared against the participant's text message records for any overlap. Overlap would indicate that the participant engaged in text messaging while the car was operational; overlap objectively indicates in-vehicle TWD. As few interventions aimed at reducing TWD exist beyond health education, the current study presents a unique opportunity to develop and evaluate an intervention to reduce distracted driving behaviors and related motor vehicle accidents, injuries, and deaths for the most at-risk populations.

LITERATURE REVIEW

TWD is a form of distracted driving, where a cell phone is (often illegally) used to send or receive messages, and causes the driver to be visually, manually, or cognitively distracted from driving, thereby increasing the risk of crashing (Young and Regan, 2007). Drivers who engage in TWD are more than 23 times more likely to be involved in a motor vehicle crash (or near-crash) than non-distracted drivers (Olson et al., 2009). Young individuals are at particular risk; due to their inexperience, they must allocate a greater proportion of their attentional resources to the operational tasks related to driving (Hosking and Young, 2009). TWD has been shown to result in various impairments in driving performance, including reductions in a) the ability to be attentive of traffic signals, b) control in lane changing, and c) forward scanning while driving (Hosking & Young, 2009).

In recognition of the prevalence of negative outcomes for TWD by the scientific community, media and public, many TWD intervention programs have been developed. Currently, 43 states have a ban on TWD, and New York State has a 5-point $150.00 penalty if reprimanded using a cell phone while driving (GTSC, 2013). These laws, however, do not seem to be causing the decline of cell phone use while driving. In California, for example, rates of collisions have actually increased since enacting the ban (HLDI, 2010). Concurrently, cell phone application developers have made attempts to minimize/mitigate the growing TWD public health dilemma. Manufacturer technology exists (i.e. a Smartphone App) that blocks the phone's call or texting capabilities when the phone is recognized to be moving at a rate that is indicative of driving (e.g., AT&T, 2013). Other cell phone applications and in-vehicle technology have been developed to read messages to the driver to eliminate the visual impairments caused by TWD (e.g., iSpeech, 2014), despite the fact that hands-free phone use has been shown to be as cognitively impairing to driving (Copeland, 2013). Similarly, in-vehicle monitoring devices have been developed to detect and alert the driver during moments of driver distraction; however, little is known about the effectiveness of these methods (Lee et al., 2013). Moreover, these technologies rely on user willingness to download and use, and could be considered to be a "harm reduction approach", intended to reduce the negative health impacts of a behavior, rather than eliminate the negative behavior altogether.

Various past studies have attempted to quantify the magnitude of the TWD problem. Using a driving simulator, Hosking and Young (2009) found that drivers engaging in TWD spent 400% more time not looking at the road, experienced more variability in measured distance from other vehicles, and more variability in lane positioning compared to non-distracted drivers. Another study (Olson et al., 2009) observed that distracted drivers averaged 4.6 seconds (out of a 6 second interval) with their eyes off of the road. This study further indicated a very low prevalence of TWD as it was measured among older drivers. Clearly, this of particular importance for the novice driver group because TWD is known to be common in this demographic and is exacerbated by the inherent lack of experience among novice drivers. TWD has been shown to result in poorer reaction time, and more intense braking (Drews et al., 2009), and numerous studies have demonstrated that individuals overestimate their driving performance while engaging in distracting tasks while driving. If drivers do not feel at risk of crashing due to TWD, they are unlikely to employ strategies to mitigate the risky behavior. Newer drivers are more likely to underestimate their risk while overestimating their driving ability, and thus engage in riskier driving behaviors (Deery et al., 1999, Kidd and Horrey, 2010). A recent study showed novice male drivers believed that they were better at driving safely while TWD than others, and were more likely to TWD as a result (Lantz and Loeb, 2013).

To compensate for the deficits created by distracting tasks, drivers often choose to switch back and forth from a distracting task to the primary driving task; however this strategy does not offer any improvements in performance (Horrey et al., 2010). One would assume that if a driver is able to accurately gauge the cognitive load (i.e., distraction) of a task, they would choose to engage in that task when driving demands are lessened (e.g., stopped at a traffic light), but drivers seem to have difficulty judging both. Rather, when given the option to initiate a distracting task while parked, drivers often instead choose to initiate the task after pulling onto the road (Horrey et al., 2010). Researchers (e.g., Kidd and Horrey, 2009) have suggested that driving experience may not alter perceptions of driving ability because such feedback is rarely received following licensure. It is critical to note that **receiving driving performance feedback has been shown to correct perceptions of risk and driving performance** (Donmez et al., 2008). Driver performance perception that is more correctly calibrated to actual performance capabilities is more likely to result in driving practices that are comparable to actual skill level (Deery et al., 1999). External feedback regarding driving performance could be useful to correct underinflated risk perceptions (Kidd and Horrey, 2009). As such, the primary motivation for the current study is to provide participants in our pilot cohort with objective driving performance feedback resulting from a simulated TWD activity. Our intention is to increase perceptions of risk and negatively affect attitudes of TWD, to ultimately decrease TWD behavior. Actual TWD behaviors are objectively recorded prior to and following the simulated TWD activity (by identifying overlap in text messaging and driving records) in order to measure any TWD behavior change pre- and post-simulated TWD activity. In the next section, we suggest the Broader Impacts of the work presented in this paper.

BROADER IMPACTS

The research presented in this paper presents a specific application of using technology and simulation in an educational context that is intended to influence attitude and subsequent behavior. In our case, the application involves addressing the issue of texting-while-driving (TWD), certainly, one of the major contributors to distracted driving accidents, collisions, and fatalities. Not surprisingly, teenagers are among the drivers most impaired by distraction. In fact, "cell phone usage" is currently the #2 contributor to young driver accidents, with documented statistics that are on the rise. A recent in-vehicle study showed that teen drivers were distracted almost 25% of the time they are behind the wheel. Electronic devices, such as texting, emails, and downloading music, were among the largest sources of distractions (AAA Foundation, 2012). Alarmingly, a recent study found that even hands-free texting and calling are far from risk free (Copeland, 2013).

The application of a simulator to adjust attitude/behavior could easily be extended (beyond cell phone and portable device usage) to "distractions" in general, and even more broadly, best practices in safe driving. As experienced drivers are well-aware, the act of driving is implicitly a multi-tasking event. Distractions are ever-present, both internal and external to the vehicle, and internal and external to the driver. Almost no research has examined the many **other** potential driving distractions often believed to be common and problematic among teenage drivers (AAA Foundation, 2012). A recent analysis (NHTSA, 2013) investigated law enforcement data from across the country, reported when documenting fatal crashes. The analysis, which considered data from 2010 and 2011, can be seen in Table 1 (Claims Journal, 2013). A driving simulator could provide a safe, authentic, measurable, repeatable, and controllable environment within which to safely examine the relative impact of various types of distractions on driving in an effort to sway attitudes and behaviors of young trainees learning to drive. The field of driver safety requires **empirical studies**, as we will demonstrate in this paper, to better perform a detailed "cause and effect" analysis surrounding these data trends, with the goal of reversing them over time.

Certainly, the research proposed here also suggests other avenues of research possibilities in alternate training contexts that are likewise influenced by attitude and behavior. One application that comes to mind is Pilot Training, both for commercial and military applications, where pilots need to be trained to remain focused, despite a multitude of internal and external distractions. A recent military training investigation of a crash of an F-16 found that the pilot failed to properly prioritize tasks and visually scan the area, which "led to a situation where the pilot lost awareness of his position to the aircraft in front of him." Air Force investigators blamed the accident on a lack of visual scanning, improper prioritization of tasks, and selective attention (Laster, 2011). In commercial aviation, there is no room for distraction when a pilot's job is to get people safely to their destinations. Training methods are evolving to ensure their pilots are not distracted by laptops, cellphones and unnecessary conversations (Levin, 2010). For successful next-generation pilot training, a simulator could be instituted for a similar protocol, the hope being that attitudes and behaviors could be positively influenced early in the process of learning to effectively and safely control an aircraft.

Table 1 – Top 10 causes of Driver Distraction in Fatal Car Crashes

Rank	Distraction	% drivers
1	Generally distracted (daydreaming)	62
2	Cell phone use (talking, texting)	12
3	Outside person, object or event	7
4	Other occupants in car	5
5	Using/reaching for a vehicle device	2
6	Eating or drinking	2
7	Adjusting audio or climate controls	2
8	Using integral vehicle device (seats)	1
9	Moving object in vehicle (a pet)	1
10	Smoking related	1

Figure 1 - Driving simulator

Figure 2 - Simulator and Driving Environment

RESEARCH FACILITIES (Driving Simulator)

A high-fidelity driving simulator was implemented for the TWD research study. This simulator (Figure 1) is comprised of a six degree-of-freedom motion platform with a passenger cabin that includes: 2 front seats w/ seat belts, a steering wheel (with paddle shifters for indicating turns and lane changes) and foot pedals, a full front vehicle console, rear and side-view mirrors, and an emergency stop switch. Our visualization system consists of four screens: three forward and one rearward. Each screen is front-projected by an SXGA+ (1280x960, 4:3) native resolution LCD Projector, and our system 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, and the virtual driving environment is intended to provide familiar surroundings to the simulator participant. Refer to Figure 2. The hardware arrangement described here, along with variations of the same software environment has been used successfully for a number of education, training, clinical, and research applications. These include: a) laboratory exercises that allow engineering students to "see and experience" road vehicle dynamics (Lewis et al., 2011) as part of a course curriculum; b) STEER (Strategies for Teens' Effective Entry to the Roadway) (Fabiano and Hulme et al., 2011), a parent-teen intervention intended for an ADHD population, that integrates a driving-targeted behavioral parenting program; and c) a sponsored program that aims to standardize a nationally accepted revision to existing driver training policies and practices – including simulation as a core component (Hulme et al., 2013).

EXPERIMENT DESCRIPTION

Executive Overview

TWD behavior was measured for a total of eight weeks, four weeks both prior to and following a TWD simulated intervention. The TWD simulated intervention included obtaining driving performance from each driver on the simulator and then used to provide objective feedback to the participant on their impairment in driving while distracted (described further below). A self-contained driver performance logger, the Car Chip Pro (Davis Instruments, 2013) was inserted into the On-Board Diagnostics (OBD-II) computer port of the participant vehicle for the entire eight week period. This Car Chip Pro was used to trace actual vehicle data during every day driving: miles driven and time-related data (e.g., number of hours driven per week, time-of-day when drives take place). Each participant's driving records were then compared to the participant's itemized texting records for date and time overlap, objectively indicating TWD behavior. Our research team has had previous success with the Car Chip Pro on a related effort with a teen driving cohort (STEER; Fabiano and Hulme et al., 2011). Participants returned approximately eight weeks after initial deployment and the Car Chip was removed.

Figure 3 – TWD Drive Path (map view)

Figure 4 – TWD Drive Path (scene image)

Simulated Intervention

At the fourth week, participants were asked to attend a TWD simulated exercise using the University at Buffalo's driving simulator (refer to Figures 1-2). Before driving the TWD road course, participants are given the opportunity to first drive a 5-minute practice to acclimate to the driving simulator. Participants drive on roads that mimic residential and city streets surrounding the University at Buffalo. Figure 3 is a map-view of the drive path requested of each TWD participant. The driver starts on the West side of Hartford Road (single lane, 30 m.p.h. speed limit), and drives West to a stop sign. After turning right onto Sweet Home Road (single lane, 35 m.p.h. speed limit), the driver proceeds Northbound until they reach Maple Road (double lane, 45 m.p.h. speed limit). There, they turn right again (at a stop light), and head East. This continues until they reach Flint Road (single lane, 30 m.p.h. speed limit), at which point they turn right (at a stop light) to head South. This is where the TWD course concludes. Drivers are allowed a maximum of 4 minutes to complete the drive path, which is approximately 1.5 miles in length. Figure 4 is a scene graph at the intersection of Hartford and Sweet Home, near the beginning of the course. Participants were asked to drive the TWD course twice: the first time under normal driving conditions, and the second time while distracted. During the distracted course, two text messages were sent to each participant's cell phone at separate intervals of the course. The first text message was sent just before the (approximately ½ mile) Northbound Sweet Home stretch, and the second was sent just before the (approximately ½ mile) Eastbound Maple Road segment. The participants were instructed to read and respond to the study investigator's text messages while driving.

Each participant's virtual lane positioning (measured in feet) and speed (measured in miles per hour) are recorded (at 60 Hz.) for both the baseline ("practice") and distracted ("TWD") drive. Using this data, Matlab is used to post-process graphs of driver performance; specifically, the position of the vehicle relative to the road markers (e.g., the center of the street, the center of the lane, and the outer edges of the road) and the travel speed of the vehicle (relative to the posted speed limits). When "practice" and "TWD" drive data are compared, the relative impairment in driving while distracted becomes apparent. These printouts were used to debrief the participants. Discrepancies between the two courses were pointed out to the participants, and they were asked to discuss the real-world implications of their simulator performance in an effort to negatively change attitudes and perceived risk of engaging in TWD. Following the intervention, participants were followed for another four week period, wherein driving and texting records were collected to determine post-intervention TWD behavior.

Measures of Attitude Change

Participants completed a questionnaire developed using the Theory of Planned Behavior (Azjen, 1991) to assess attitude towards engaging in TWD, and commonly used to theoretically explain behavioral change in an effort to increase or decrease health behaviors. "Behavior" is explained to occur as a function of a person's attitude towards the behavior, their perception of the consequences of the behavior, the social influences relative to the behavior, and their perception of control to engage in (or not) the given behavior. Several questions gauging perception of risk of crashing while engaging in TWD, and perception of the severity of accidents or injuries that result from TWD were also requested. This theory has been used to successfully predict TWD behavior (Nemme & White, 2010) as well as other health domains (e.g., Armitage, 2005, Health & Gifford, 2002). Showing any change in attitude or risk perception towards TWD, therefore, should be predictive of change in TWD behavior.

PILOT STUDY COHORT

All study protocols were submitted and approved by the University at Buffalo's Institutional Review Board. Participants were recruited through the use of flyers posted at the University at Buffalo and initial eligibility phone screens conducted with all interested participants. Participants were eligible for the current study if they were between the ages of 18 and 24, have engaged in text messaging, and have operated a motor vehicle. This population was specifically chosen as they represent a high-risk group in the adult population and one to focus on with the current intervention (Hoff et al., 2013). Participants must also have been able and willing to access their itemized texting records online on a weekly basis and have been willing to provide the study investigator with a printed copy the records. Study subjects received compensation for their participation in the form of $5 (weekly) gift cards, and the opportunity to drive on the simulator.

Table 2 – Pilot Cohort Demographics

Present Age: Mean (SD)	20.57 (1.99)
Sex:	
• % Male	57%
• % Female	43%
Race:	
• White/Caucasian	100%
Enrolled in School:	
• Yes	100%
NYS Driver's License:	
• Yes	86%
• No	14%
Age at Licensure: Mean (SD)	17.14 (1.35)
Close call due to TWD:	
• Yes	29%
✓ Almost rear-end	50%
✓ Almost hit while changing lanes	50%
Received a Ticket for TWD:	
• No	100%

Due to some recruitment difficulties and time constraints, eight participants were recruited and seven completed the entire pilot study. The eighth participant withdrew three weeks in to the study as they were not sufficiently able to provide texting records, and thus ineligible to participate. Participants were four men and three women with a mean age of 20.57 (SD=1.99) years. All were enrolled in at least their first year of college. The entire sample self-identified as Caucasian and all but one (86%) had a New York State driver's license. The mean age of attaining licensure for the sample was 17.14 (SD=1.35). Two of the seven participants (29%) had reported previously experiencing a motor vehicle crash "close-call" as a result of TWD. None of the participants had reported receiving a traffic ticket for engaging in TWD. This (and related) pilot cohort information is summarized in Table 2.

STUDY RESULTS

Texting-While-Driving Behavior

Overall, no significant differences were found in any analyses of TWD behavior. These results are not surprising given the wide variability in texting behaviors in both the pre- and post-intervention periods, including several participants who texted very infrequently (see Figure 5). Although not significant with the present sample, this intervention may be useful for "moderate" texters, two of whom (from this cohort sample) appeared to have reduced TWD following the intervention. This may provide promise for a refined future intervention, whereby participants are recruited based upon those who specifically admit to texting frequently (i.e., those who are at a higher risk of negative outcomes due to pre-existing attitudes and behaviors). Note: several weeks of one participant's (TWD002) behaviors were unable to be obtained due to the individual crossing several time zones (not accounted for by the Car Chip).

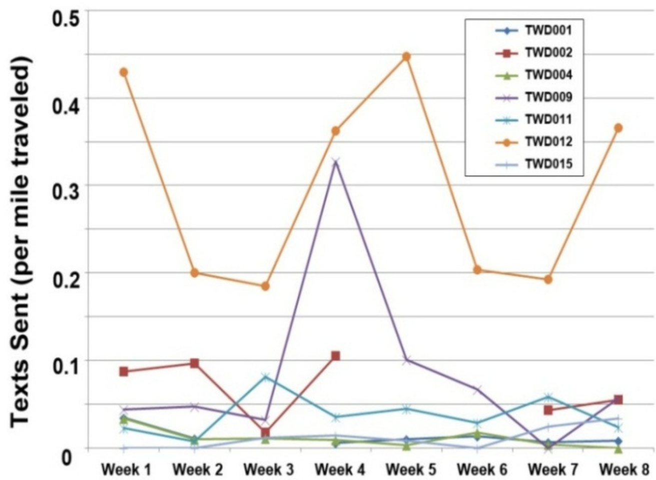

Figure 5 – Texts Sent, Normalized by Miles Traveled (per week, per participant)

TWD Attitude Change

Participants responded more negatively to questions gauging their attitudes towards TWD at baseline (M=2.93, SD=.92; please see Table 3) compared to immediately following the intervention (M=2.17, SD=.84) and this difference was statistically significant (t(6)=6.05, p<.05). However, this effect was not maintained through follow-up indicating a short-term attitude change that reverted back to similar scores on TWD attitude questions four weeks later (F(2, 12)=2.695, P=.310). Participants did not significantly differ in their perceptions of how likely or severe crashes were to be if someone engaged in TWD from baseline (M=4.57, SD=.91) compared to intervention (M=5.04, SD=.86) or follow-up (M=4.57, SD=1.08); F(2, 12)=1.837, P=.234).

Table 3 - TWD Attitudes

Likert Range: (1-2-3-4-5-6-7)	Baseline Mean (SD)	Intervention Mean (SD)	Follow-up Mean (SD)
Attitudes Dangerous/bad (1) to Safe/good (7) to TWD	2.93 (.92)	2.17 (.84)	2.36 (.97)
Risk Unlikely (1) to Likely (7) to crash/injure	4.57 (.91)	5.04 (.86)	4.57 (1.08)

Table 4 – Simulator-measured Performance

	Baseline Drive Mean (SD)	Texting Drive Mean (SD)	Effect Size (Cohen's *d*)
Frequency of lane deviations	2.67 (1.21)	3.83 (2.14)	0.67
Total time spent outside of lane center (sec.)	8.67 (5.85)	15.67 (12.64)	0.71
Ratio of drive spent outside of lane center	0.04 (.03)	0.08 (.06)	0.69

TWD Driving Impairment

Most participants demonstrated considerable impairment in driving while distracted including more variable lane positioning compared to their non-distracted, baseline course (see Table 4). While these results were not statistically significant due to the reduced sample size, the effect sizes nonetheless suggest a meaningful trend in impairment of driving while distracted that would likely be significant with a larger sample (Cohen, 1988). As observed via the Matlab-plotted simulator performance data, participants crossed the outer or inner lines of their lane more frequently on their distracted course and spent a considerably greater amount of time outside of their lane center. For example, Figures 6 and 7 show the Matlab-plotted simulated driver performance for one driver in our pilot cohort. In Figure 6 (lane position), note how the drive path (red) dangerously weaves to both sides of the lane – towards the lane center (green) on the left, and towards (and in one instance – OVER) the curb (black) on the right. The former could be indicative of a head-on or side-swipe collision with vehicles from the stream of oncoming traffic, and the latter could be indicative of a physical collision on the side of the road (e.g., a pedestrian). The speed data (conveyed in Figure 7) is equally compelling, when the practice (blue) and TWD (red) excursions are compared. Note that the observed speeds in the TWD excursion are, on the whole, faster. This likely indicates that the participant temporarily loses regard for the posted speed limit while they are focusing on reading/writing a text message. In the study, we frequently observed that TWD participants drove ***slower*** than their baseline drive in an effort to compensate for their risky behavior. In such situations, driver lane position continued to be erratic despite (often, prohibitively unsafe) reduced speeds.

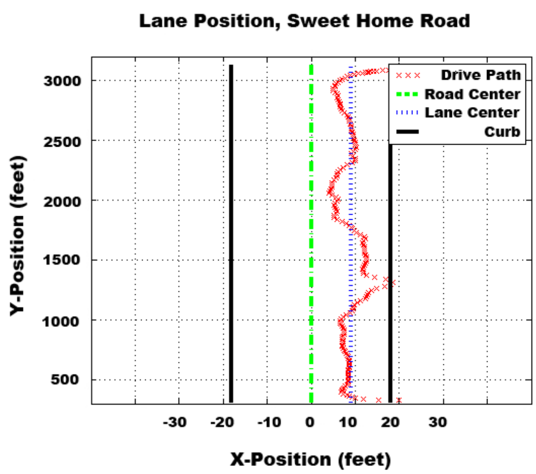

Figure 6 – TWD012 – Lane Position

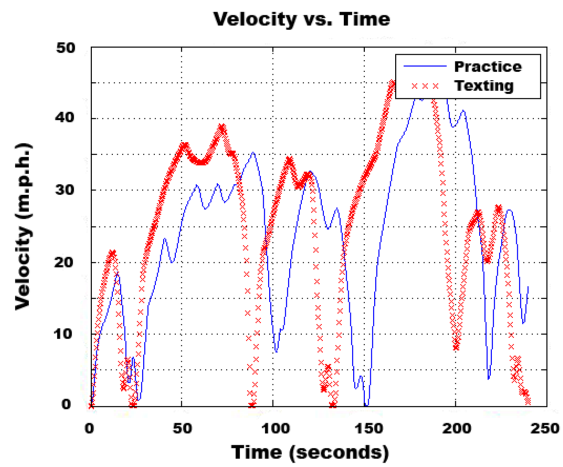

Figure 7 – TWD012 - Velocity

STUDY LIMITATIONS AND DISCUSSION

The current study experienced inherent limitations due to the study design, which was susceptible to bias from various extraneous variables. For example, while the participants were asked to report whether someone else had driven their vehicle over the course of the assessment periods, it is possible that this was inaccurately reported and that any texts that occurred during that period were mistakenly included attributing to a higher base rate of texting behaviors. Likewise, it is possible that participants (at times) drove a vehicle other than their own, and therefore those driving trips were not used to determine texting overlap. It is possible that the Car Chip Pro's time was not precisely calibrated with the individual's cell phone records and that some texts were inaccurately recorded. In addition, due to limitations on how the Car Chip Pro records excursion data, exact travel speed at the time of any texts is not known. Thus, it is not known if the participants mostly engaged in TWD while their vehicles were driving rapidly, stopped at a stop light, or if they were pulled over. During the simulated intervention, participants were asked to read and respond to text messages while their cars were moving on a road straightaway. If most participants typically engage in TWD while stopped, the intervention may not have been as meaningful, because impairment was demonstrated in situations that differed from when they normally choose to engage in TWD. This may be an important consideration in examining why the participants did not report any significant differences in perception of risk or why negative attitudes were not maintained, despite the feedback they received regarding their severe driving impairments while distracted.

The absence of significant change in perception of risk may have also been attributable to defensive processing; the participants were skeptical of the real-world accuracy of the simulator (and the TWD performance results) because it threatened their perception of their health, or was not congruent with their preconceived attitudes towards TWD. Participants may not have changed their perception of TWD riskiness because feedback regarding their real-life behavior was not relayed. With greater resources, study staff could meet with participants with a greater frequency (e.g., weekly) to objectively demonstrate what overlap existed (i.e., real-world TWD behavior coupled with simulator TWD crash-risk information) to more compellingly adjust attitudes and perception of risk.

Despite the shortcomings of this pilot study, trends in the data suggest that participant's demonstrated severe impairment while TWD on the simulator. Most notably, maximum deviation from lane center was greater when they were distracted (e.g., up to 12 feet off of the roadway center for one participant) which resulted in either driving on the side of the road or in the oncoming lane of traffic lane for some period of time. All participants spent more time of their distracted courses with at least one point of their vehicle outside of their lane. On average, the participants spent 15.67 seconds with one edge of their vehicle on or outside of the road (compared to an average of 8.67 seconds during their baseline drive – likely due to simulator acclimation). While some participants seemed to improve (e.g., either with regard to a) time spent off the road, or b) the number of lane crosses in their distracted course), their speed became more variable. If, however, their speed was more controlled, their ability to maintain their vehicle in their lane suffered. It would seem that all participants recognized their deficits and tried to compensate – typically by reducing speed while texting. Importantly, these participants knew they were participating in task measuring deficits, and likely tried to perform better than the typical texting population (i.e., those that do not receive immediate feedback). This has large implications for thinking of the typical, novice driving population that admits to TWD often and represents a large portion of the drivers on the road.

CONCLUSIONS

The current study served as a proof-of concept scientific experimentation to leverage simulation to provide texting-while-driving (TWD) human performance feedback for a pilot cohort of novice adult drivers. The intent of the study was to use technology and simulation in an effort to modify attitudes and behaviors towards one of the most prominent modern-day driving distractions. This continues to be a major public health pandemic that affects all of us – as drivers ourselves, as fellow occupants of the road, and as family members of teenagers. The current study represents a novel protocol for evaluation and intervention in an effort to reduce distracted driving behaviors – specifically, for the most at-risk driving population. Further, the work presented here is highly relevant to Human Systems Engineering. Moving forward, how we (as humans) approach the daily task of operating a motor vehicle will remain a major human factors challenge, especially as mobile device, in-vehicle, and infrastructure technology continue to evolve.

Although results were limited due to the size of the pilot study, it appears as though relaying TWD performance did not have any significant impact on reducing TWD behaviors overall, except for "moderate" texters, as suggested previously. Note that the cohort recruited for this pilot study consisted entirely of college-age young adults, who, for the most part, had multiple years of driving experience. The authors strongly opine that the TWD intervention is likely to have the longest lasting impact upon pre-licensed drivers, early in the process of learning to drive, before adverse attitudes and behaviors have the chance to manifest. Perhaps too, a longer pre- and post- follow-up period, or relaying actual TWD feedback on a regular (e.g., weekly) basis could have helped to more definitely influence change over time; this certainly speaks to the inherent difficulty of implementing this intervention community-wide.

As TWD seems to be socially reinforcing for those that engage in it, perhaps anti-texting messages from key individuals in teen or young adult communities would offer a feasible supplementary method to reducing TWD behaviors. The results of the current study also demonstrate that it may be ideal to not solely focus on the individual or on social domains, but rather, look to improving TWD ban enforcement or encouraging the development of technology to prevent TWD behaviors altogether (e.g., cell phone jamming technology in cars). Furthermore, caregiver involvement seems to be a critical component in reinforcing risk-averse driving attitudes and behaviors from the onset of driver education. Parent-Teen contracts (e.g., Allstate Foundation, 2014) with rewards for verifiable good behavior could be a successful supplementary method for promoting safe driving practices.

FUTURE WORK

The current project served as a proof-of-concept demonstration of a protocol for using simulation to alter attitudes and behaviors for TWD. The intended focus of this study was on young drivers, who are early in the process of learning to drive, impressionable, and savvy to the gaming/simulation technology that was leveraged for the stated purpose. Upon completion of this first phase, we offer three ideas for how to escalate our findings to the next level:

1) The seven participants from the current TWD pilot cohort served to provide a preliminary data set from which our research protocol could be instituted, and from which our program can be better understood. On a limited budget, it was an ambitious undertaking. With additional funding support, our goal is to attain a larger sample size to establish baseline statistical significance. More specifically, to attain a minimally acceptable confidence level of 90% and confidence interval of ±10%, a sample size of 68 would be required (Creative Research Systems, 2012). The normalized cost of such a study would be drastically reduced now that the training materials have been developed, refined, pilot tested, and verified.
2) As demonstrated in this pilot cohort, simulation can complement existing protocols (e.g., in-vehicle field evaluation) for evaluating human factors associated with transportation, and ongoing public health priority. The current study has taken strides towards verifying our test method, and to some degree, the collection of in-vehicle data has served as a preliminary means for validation. The latter could be improved, in a follow-up study, by having our test cohort drive the exact same roads after which our virtual environment has been modeled. Testing could take place in both daytime and nighttime settings, with differing levels of traffic (e.g., drive-to-work, rush-hour), with measured traffic volumes and traffic signal timings incorporated in to the simulation environment. Future studies may also incorporate video recording in participant's vehicles to determine **when** most participants choose to engage in TWD. This may have important implications for tailoring anti-texting messages to be more context specific and thus, more meaningful.
3) As was introduced in Table 1, there are a multitude of internal and external distractors that have been demonstrated to have a negative impact on driving performance. Primarily, these include "internal distractions" (i.e., mindlessness or daydreaming) which is, by far, the leading cause of negative driving outcomes due to "distractions" (Claims Journal, 2013). A closely related topic of interest (relevant both to ground vehicle transport and to aircraft pilots) is drowsy driving. According to the NSF's "Sleep in America" poll (NSF, 2014), 60% of adult drivers say they have driven a vehicle while feeling drowsy in the past year, and more than one-third claim to examine these types of empirical "cause and effect" analyses, which are largely absent in modern-day literature, especially for all distractor classifications (cognitive, visual, and mechanical).

ACKNOWLEDGEMENTS

The authors would like to acknowledge the National Institutes of Child Health and Development (NICHD) (R01HD058588, PI: Fabiano) for partial funding support for this work. Ms. Morris would like to thank Marlana Howard and Rebecca Norton from the Center for Children and Families, and NYSCEDII (particularly Jacob Deutsch) for support with simulator operation and data analysis. Lastly, the authors would like to thank Milliken Research Associates and Moog, Inc., for ongoing support relating to the Driving Simulator and its environment.

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