Jun 19th, 12:00 AM

Headway Time and Crashes Among Novice Teens and Experienced Adult Drivers in a Simulated Lead Truck Braking Scenario

Catherine C McDonald
University of Pennsylvania, Philadelphia, PA

Inês S Seacrist
The Center for Injury Research and Prevention at Children's Hospital of Philadelphia, Philadelphia, PA

Yi-Ching Lee
The Center for Injury Research and Prevention at Children's Hospital of Philadelphia, Philadelphia, PA

Helen Loeb
The Center for Injury Research and Prevention at Children's Hospital of Philadelphia, Philadelphia, PA

Venk Kandadai
The Center for Injury Research and Prevention at Children's Hospital of Philadelphia, Philadelphia, PA

See next page for additional authors

McDonald, Catherine C; Seacrist, Inês S; Lee, Yi-Ching; Loeb, Helen; Kandadai, Venk; and Winston, Flaura K. Headway Time and Crashes Among Novice Teens and Experienced Adult Drivers in a Simulated Lead Truck Braking Scenario. In: https://doi.org/10.17077/drivingassessment.1524

Presenter Information

Catherine C McDonald, Inês S Seacrist, Yi-Ching Lee, Helen Loeb, Venk Kandadai, and Flaura K Winston

HEADWAY TIME AND CRASHES AMONG NOVICE TEENS AND EXPERIENCED ADULT DRIVERS IN A SIMULATED LEAD TRUCK BRAKING SCENARIO

Catherine C. McDonald[1,2], Thomas S. Seacrist[2], Yi-Ching Lee [2], Helen Loeb[2], Venk Kandadai[2] & Flaura K. Winston[2,3]
[1]School of Nursing, [3]School of Medicine, University of Pennsylvania, Philadelphia, PA, USA
[2]The Center for Injury Research and Prevention at Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, USA
Email: mcdonalc@nursing.upenn.edu

Summary: Driving simulators can be used to evaluate driving performance under controlled, safe conditions. Teen drivers are at particular risk for motor vehicle crashes and simulated driving can provide important information on performance. We developed a new simulator protocol, the Simulated Driving Assessment (SDA), with the goal of providing a new tool for driver assessment and a common outcome measure for evaluation of training programs. As an initial effort to examine the validity of the SDA to differentiate performance according to experience, this analysis compared driving behaviors and crashes between novice teens (n=20) and experienced adults (n=17) on a high fidelity simulator for one common crash scenario, a rear-end crash. We examined headway time and crashes during a lead truck with sudden braking event in our SDA. We found that 35% of the novice teens crashed and none of the experienced adults crashed in this lead truck braking event; 50% of the teens versus 25% of the adults had a headway time <3 seconds at the time of truck braking. Among the 10 teens with <3 seconds headway time, 70% crashed. Among all participants with a headway time of 2-3 seconds, further investigation revealed descriptive differences in throttle position and brake pedal force when comparing teens who crashed, teens who did not crash and adults (none of whom crashed). Even with a relatively small sample, we found statistically significant differences in headway time for adults and teens, providing preliminary construct validation for our new SDA.

INTRODUCTION

Driving simulators can offer a safe alternative to on-road driving for evaluation of driving performance by allowing for controlled manipulations of traffic and objective outcome measures. As teen drivers are at a higher risk for crashes than adults (Centers for Disease Control and Prevention, 2012), they are an important population to target for simulated assessment of driving performance (e.g. Chan et al, 2010). Simulated assessments for teen drivers that measure key driving performance metrics in situations of risk have important potential to inform training needs, assessment, and intervention development. Our new Simulated Driving Assessment (SDA), based on actual crash scenarios in the National Motor Vehicle Crash Causation Survey (NMVCCS) (National Highway Transportation Safety Administration (NHTSA), 2008) was developed with this goal in mind.

Rear-end crashes are a leading crash type for novice teen drivers (Foss et al, 2011) and are a key scenario in our SDA. Simons-Morton et al (2005) found that teens had shorter headway times than the general population. Lenne et al (2011) also found that teens trained in a driver-passenger safe driving behavior program had a longer headway distance than untrained teens. Based on this previous research, we wanted to examine novice teen driver behavior in our SDA by further exploring headway time in a lead truck braking event.

The primary goal of this analysis was an initial examination of the validity of the SDA to differentiate performance according to experience by comparing headway time and crashes among novice teen and experienced adult drivers. This analysis included data from one scenario included in our SDA: a lead truck braking event. Based on previous research, we hypothesized shorter headway times and more simulated crashes for novice teen versus adult drivers in this scenario.

METHOD

Participants

We enrolled novice teen drivers, age 16-17 years, who had received a Pennsylvania (PA) provisional license ≤90 days. Teens were recruited via mailings to primary care patients, driving schools, and word of mouth. We also enrolled experienced adults drivers, age 25-50 years, PA licensed for >5 years, self-reported driving ≥ 100 miles per week and no crashes or moving violations ≤3 years. Individuals were excluded for a self-reported history of migraines, motion sickness, pregnancy or non-English speaking. Our teen sample consisted of n=20 teens who completed the simulated drives. The teens were 65% male (n=13), age M=16.8 years (sd 0.3), and had their provisional license M=31.5 days (sd 26.9). We had n=17 experienced adults complete the simulated drives. The experienced adults were 59% male (n=10), age M=35.8 years (sd 8.3), and were licensed for M=17.9 years (sd 8.0). This study was approved by the Institutional Review Board at the Children's Hospital of Philadelphia.

Materials and Apparatus

We used an integrative literature review, expert opinion, and analysis of existing teen crash data from NMVCCS (NHTSA, 2008) to create the scenarios and metrics in our SDA. We used the three most frequent crash events for teens driving alone or with a peer passenger (left turn events, rear-end events, and run-off the road events) (McDonald et al, 2012). These three potential crash scenarios were used as the theoretical foundation for the SDA development, and we populated the sections between scenarios with stretches of straight roads.

For this initial analysis, we use data from a single rear-end scenario. Data were collected at 60 Hz with a fixed-base high fidelity Realtime Technology, Inc. (RTI)® driving simulator. The driving simulator consists of a driver seat, three-channel 46" LCD panels (160° field of view), rearview mirror images inlayed on the panels, active pedals and steering system, and a rich audio environment. The graphics were generated by a tile-based scenario authoring software, and real-time simulation and modeling are controlled by SimCreator, (RTI®). Visual rendering and graphics are delivered at 1280 x 1024 resolution with a 60-Hz frame rate. SimObserver, a video capturing system, allowed for analysis of digital video recordings along with recorded data.

Design and Procedures

Study visits took place in the driving simulator laboratory at the Center for Injury Research and Prevention. Participants completed a practice drive and three experimental drives. The order of the experimental drives was randomized. Each experimental drive lasted 8-11 minutes and included combinations of the three crash scenarios (left turn events, rear-end events, and run-off the road events), weather conditions, and a mixture of straight and curved roads and intersections. Participants were instructed to follow the speed limits and directional signs, stay in the right lane, and obey traffic laws. The entire study session lasted approximately 1.5 hours.

This current analysis focused on a single rear-end scenario in our SDA, programmed for the participant to drive behind a truck maintaining a speed of 30 MPH; the lead truck braked suddenly to a stop. Each direction on the road had two lanes and the posted speed limit was 35 MPH. Table 1 lists the key variables for analysis.

Table 1. Key variables used in analysis

Variable	Definition	Calculation	Unit
Truck Braking Time	Time when the lead truck first braked (indicated visually by brake lights on)	Timestamp derived from data recorded by the simulator; confirmed with viewing each participant video of simulation.	Seconds
Brake Pedal Force	Force applied to the brake pedal	Recorded by a sensor on the brake pedal and logged by the SimObserver software	Newtons
Headway Distance	Distance between the participant vehicle center of gravity (CG) and the lead vehicle CG	Difference between the CG the participant's car and the lead truck's CG	Meters
Headway Time	Time required to traverse the distance from the participant vehicle CG to the lead vehicle CG	Ratio between the "Headway Distance" and the participant's instantaneous velocity at "Truck Braking Time"	Seconds
Throttle Position	Position of the throttle pedal	Recorded by a sensor on the throttle pedal and logged by the SimObserver software	Degrees
Crash	Overlap of the participant's vehicle and the lead truck vehicle	Derived by taking the position, orientation, and dimensions of the participant and nearest vehicles and determining if any portion of the two vehicles overlapped	Yes=Crash No= Did not crash

Time series data from SimObserver for each drive were imported into MATLAB (Mathworks, Inc., Natick, MA) for data reduction using custom-written MATLAB code. In addition to the variables listed in Table 1, orientation of participant vehicle, participant's velocity as well as nearest ambient traffic vehicle properties (dimension, position, orientation) were used for calculations. Summary statistics, including frequencies, percentages, means, and standard deviations were computed for all categorical and continuous data, as appropriate. Proportion and mean differences were ascertained using a Fisher's exact test and a Wilcoxon rank sum test, respectively. Aggregate analyses were performed using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

Table 2 describes the number of novice teens and experienced adults that crashed and the headway time at the truck braking event. In this rear-end event, we found that teens crashed more often than adults ($p=.009$) and teens had a shorter headway time than did adults at the time of truck braking ($p=.006$). In addition, the teens who crashed ($n=7$) had a significantly shorter headway time M=1.8 seconds (sd 0.5) than participants (both teens and adults) who did not crash M=4.1 seconds (sd 1.5) (p<.001). Although not statistically significant, teens who did not crash had a shorter headway time M=3.5 seconds (sd 1.0) than adults M=4.6 seconds (sd 1.8). Note: none of the adults crashed.

Table 2. Teens and adults crashes and headway times

	Teen Group (n=20)	Adult Group (n=17)	p-value
Crash - N (%)	7 (35%)	0 (0%)	0.009
No Crash N (%)	13 (65%)	17 (100%)	
Mean Headway Time at Truck Braking - sec (SD)	2.9 (1.2)	4.6 (1.8)	0.006
Mean Headway Time (Crash Group) sec (SD)	1.8 (0.5) (n=7)	n/a	
Mean Headway Time (No Crash Group) (sec)	3.5 (1.0) (n=13)	4.6 (1.8) (n=17)	0.086

We examined headway time at the truck braking event for teens and adults in intervals of < 1 second, 1-<2 seconds, 2-<3 seconds, and > 3 seconds (Figure 1). In Figure 1, the labels indicate the teens who crashed (*) and teens who did not crash (o). All adults were labeled with the same symbol (+) (no adult crashed). Only 25% of the adults (n=4) had < 3 seconds headway time at the truck braking event, while 50% of the teens (n=10) had < 3 seconds. All teens with <2 second headway time crashed (n=4), and 50% of the teens (n=3) with headway time of 2-<3 seconds crashed. No adults in the 2-<3 second headway time crashed.

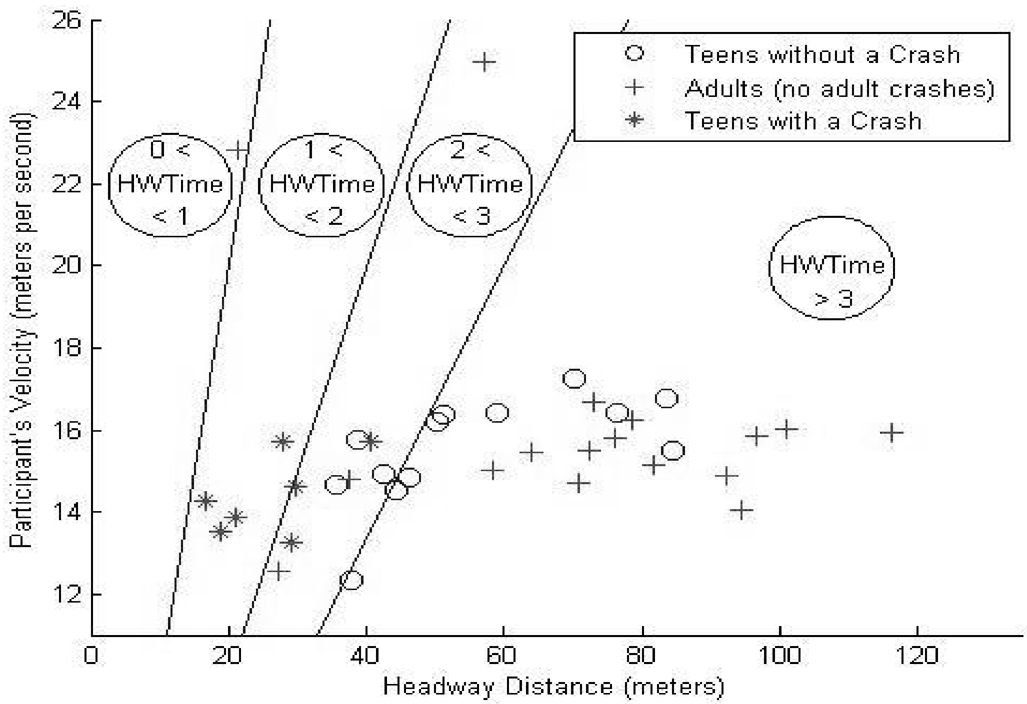

Figure 1. Participant headway time at truck braking event (Note: HWTime=headway time)

We further examined the pattern of braking among the participants in the 2-<3 second headway time interval due to variability in the crash outcomes. Figure 2 depicts throttle and brake pedal of adults and teens with a headway time of 2-<3 seconds. The three lines represent: (A) average throttle position and brake pedal pressure of the adults (none crashed); (T_{crash}) average throttle position and brake pedal pressure of the teens who crashed; and ($T_{nocrash}$) average throttle position and brake pedal pressure of the teens who did not crash. We plotted both the throttle position and brake pedal pressure on one graph for each group (A, T_{crash}, $T_{nocrash}$), as no participant applied both the throttle and brake at the same time. The values above zero on the y-axis reflect throttle position (position=0 indicates full throttle release; position > 0 indicates throttle depression); the values below zero reflect brake depression. Time 0 on the x-axis corresponded to when the truck braked. Time < 0 reflect the participants' behavior prior to the truck braking, while those Time > 0 reflect the participants' behaviors after truck braking.

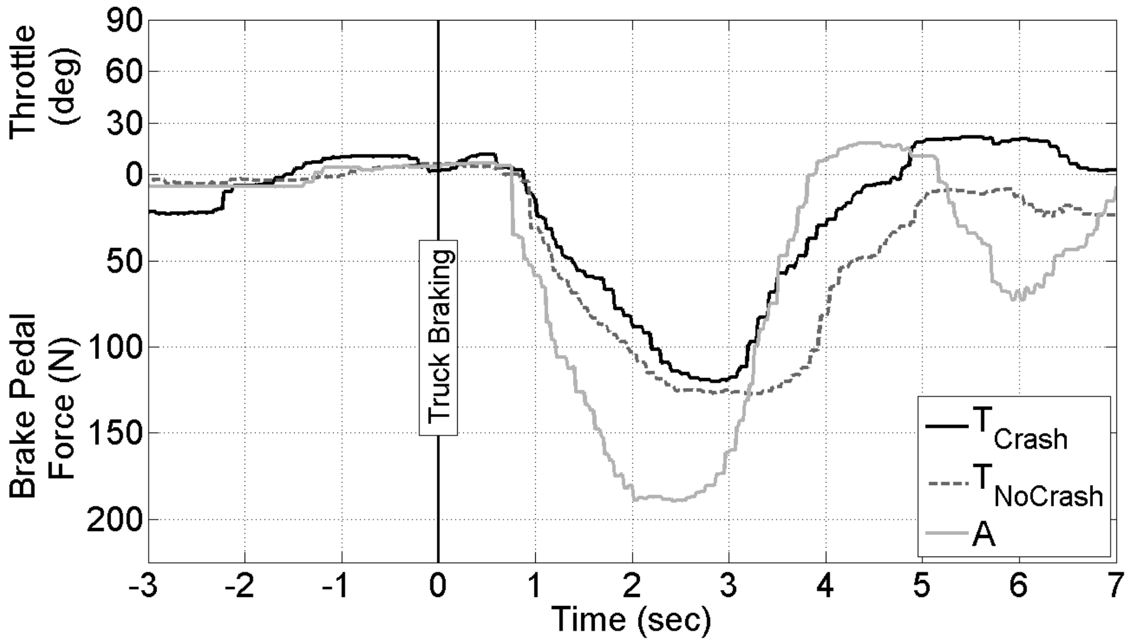

Figure 2. Throttle and brake pedal pressure of teens (n=6) and adults (n=2) with 2-3 second headway time

Note: One adult with 2-<3 s headway time was not included in the plot: the adult swerved around the truck by changing into the left lane (This adult had a headway time = 2.16 sec, velocity= 25m/s).

Before the truck braked (Time < 0), it appears that on average, adults and teens who do not crash demonstrated more refined management of their headway time with minimal depression of the throttle. By contrast, the teens who crashed demonstrated greater use of the throttle. After the truck braked, when compared to the teens, the adults on average began braking at an earlier time and appeared to demonstrate harder and quicker braking -the initial brake pedal pressure magnitude was greater in amplitude and steeper in rate. This pattern appears to hold when comparing the teens who crashed to the teens who did not crash, but the difference in initiation, magnitude and rate of braking is not as great as those differences between the adults and teens.

DISCUSSION

In this initial analysis of data from our new SDA, we found differential performance according to experience by comparing teens and adults in a lead truck sudden braking scenario, one of 21 potential crash scenarios in the full SDA. Consistent with previous research, we found that more teens crashed than adults in this scenario, and on average, teens had a shorter headway time than the adults (Lee et al, 2011; Greenberg et al, 2007). A closer look at the participants with 2-<3 seconds headway time suggests that both timing and magnitude of braking play a role in managing sudden braking of a lead vehicle. We saw that driving experience may influence braking behavior when maintaining a shorter headway time. Our adult drivers may recognize a potential hazard sooner and react more strongly and, ultimately, safely. We plan to use the same metrics to evaluate the remainder of the read-end scenarios in further analyses of the SDA.

There are a growing number of promising training interventions for teen drivers (e.g. Fisher et al, 2002; Isler et al, 2011), each of which addresses a specific task in driving performance. As a novel assessment grounded in actual, common crash scenarios, the SDA has the potential for offering a new outcome for evaluating individual training methods and for comparing outcomes among training methods. As a first step in determining the utility of the SDA for evaluation of training programs against real world crash scenarios, our future work will compare the differential performance of teens who are trained and untrained for a specific driving task, hazard awareness, via a computer-delivered, evaluated training program (Fisher et al, 2002).

Our study was not without limitations. For this initial assessment of validity of the SDA, we had a small sample size; however, we found statistically significant differences between adults and novice teens in headway time and crashes. When examining those participants with a shorter headway time of 2-3 seconds as we do in Figure 2, the sample became too small for statistical analyses and so these results should be viewed as exploratory. Future studies of the validity of the SDA should include larger samples of teens, which will also allow for further validation among larger groups of teens and more in-depth investigation of teen driver performance.

CONCLUSIONS

These results provide preliminary construct validity for our SDA around experience, with data indicating differential performance in a truck braking scenario between novice teens and experienced adults. Our results support the use of the metrics of headway time, throttle position and brake pressure for further analyses of other similar scenarios in our SDA. In addition, the results also point to training teens in maintaining a safe headway time. Future analyses will examine data from the remaining scenarios for differential driving performance between novice teen and adult drivers. With these initial results, the SDA has potential utility as both an assessment tool and as a common outcome measure for evaluation studies.

ACKNOWLEDGMENTS

This project is funded, in part, under a grant with the Pennsylvania Department of Health (PI: Flaura K. Winston). The Department specifically disclaims responsibility for any analyses, interpretations or conclusions. Catherine C. McDonald was previously supported by the National Institute of Nursing Research (NINR) of the National Institutes of Health (NIH) under Award Number T32NR007100 (PI: Marilyn S. Sommers) and is currently supported by K99NR013548 (PI: Catherine C. McDonald). The content is solely the responsibility of the authors and does not necessarily represent the official views of NINR or NIH. We thank Jason Tanenbaum and Dana Bonfiglio for their efforts and Marilyn S. Sommers, Nancy Kassam-Adams, Donald L. Fisher, Daniel V. McGehee, and the Center for Injury Research and Prevention for their support.

REFERENCES

Centers for Disease Control and Prevention. (2010). *Teen drivers: Fact sheet.* Retrieved November, 19, 2012, from http://www.cdc.gov/motorvehiclesafety/teen_drivers/index.html.

Chan, E., Pradhan, A.K., Pollatsek, A., Knodler, M. A. & Fisher, D. L. (2010). Are driving Simulators effective tools for evaluating novice drivers' hazard anticipation, speed management, and attention maintenance skills? *Transportation Research Part F: Traffic Psychology and Behavior, 13*(5), 343-353.

Fisher, D.L., Laurie, N.E., Glaser, R., Connerney, K., Pollatsek, A., Duffy, S.A., & Brock, J. (2002). Use of a fixed-base driving simulator to evaluate the effects of experience and PC-Based Risk Awareness Training on drivers' decisions. *Human Factors, 44*(2), 287-302.

Foss, R. D., Martell, C. A., Goodwin, A. H., O'Brien, N. P. & UNC Highway Safety Research Center. (2011). *Measuring changes in teenage driver crash characteristics during the early months of driving*. Washington, DC: AAA Foundation for Traffic Safety.

Greenberg, J., Tijerina, L., Curry, R., Artz, B., Cathey, L., Kochhar, D., et al. (2007). Driver distraction: Evaluation with event detection paradigm. *Transportation Research Record, 1843*(2003), 1-9.

Isler, R.B., Starkey, N.J. & Sheppard, P. (2011). Effects of higher-order driving skill training on young, inexperienced drivers' on-road driving performance. *Accident Analysis & Prevention* 43(5), 1818-1827.

Lee, S.E., Simons-Morton, B. G., Klauer, S.E., Ouimet, M.C., & Dingus, T.A. Naturalistic assessment of novice teenage crash experience. *Accident Analysis and Prevention, 43*(4), 1472-1479.

Lenne, M. G., Liu, C. C., Salmon, P. M., Holden, M. & Moss, S. (2011). Minimising risks and Distractions for young drivers and their passengers: An evaluation of a novel driver-passenger training program. *Transportation Research Part F: Traffic Psychology and Behavior, 14*(6), 447-455.

McDonald, C. C., Tanenbaum, J. B., Lee, Y-C, Fisher, D. L., Mayhew, D. R. & Winston, F. K. (2012). Using crash data to develop simulator scenarios for assessing young novice driver performance. *Transportation Research Record: Journal of the Transportation Research Board*, 2321, 73-78.

National Highway Traffic Safety Administration. *National Motor Vehicle Crash Causation Survey: Report to Congress*. Washington, DC, 2008.

Simons-Morton, B. G., Lerner, N. D. & Singer, J. (2005). The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accident Analysis and Prevention, 37*(6), 973-982.