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EMERGENCY BRAKING IN ADULTS VERSUS NOVICE TEEN DRIVERS: RESPONSE TO SIMULATED SUDDEN DRIVING EVENTS

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Abstract

Motor vehicle crashes remain the leading cause of death in teens in the United States. Newly licensed drivers are the group most at risk for crashes. Their driving skills are very new, still very often untested, so that their ability to properly react in an emergency situation remains a research question. Since it is impossible to expose human subjects to critical life threatening driving scenarios, researchers have been increasingly using driving simulators to assess driving skills. This paper summarizes the results of a driving scenario in a study comparing the driving performance of novice teen drivers ($n=21$) 16–17 year olds with 90 days of provisional licensure with that of experienced adult drivers ($n=17$) 25–50 year olds with at least 5 years of PA licensure, at least 100 miles driven per week and no self-reported collisions in the previous 3 years. As part of a 30 to 35 simulated drive that encompassed the most common scenarios that result in serious crashes, participants were exposed to a sudden car event. As the participant drove on a suburban road, a car surged from a driveway hidden by a fence on the right side of the road. To avoid the crash, participants must hard brake, exhibiting dynamic control over both attentional and motor resources. The results showed strong differences between the experienced adult and novice teen drivers in the brake pressure applied. When placed in the same situation, the novice teens decelerated on average 50% less than the experienced adults ($p<0.01$).

Keywords

Driving; Simulator; Assessment; Teenager; Adult; Braking; Emergency

INTRODUCTION

Teenage drivers are disproportionately represented in crash statistics. According to the American Academy of Pediatrics (AAP), a 16-year-old driver is more than 4 times as likely to have a motor vehicle crash as any other licensed driver (1). In fact, the leading cause of death among 16 to 20 years olds is motor vehicle related crashes (2). A crash is often the outcome of a succession of catastrophic events. While scanning abilities and anticipation are the best ways to prevent a crash, evasive maneuvers such as swerving or hard braking are last resort actions that can prevent the accident.

While considerable literature has been published on the technological improvements of brakes (3) and the driver perception-reaction time (4), limited work has been done on the adequacy of the brake pressure applied by a given driver as a response to an emergency situation. The focus of this paper is to understand the adequacy and effectiveness of a braking reaction to an emergency situation and to compare the performance of novice drivers to that of experienced adult drivers. Since it is not possible to place drivers in an on-road dangerous driving scenario that requires emergency braking, a driving simulator can be used to expose drivers to a dangerous situation and assess their performance.

Driving simulators provide a safe, controlled environment for conducting driving research. Challenging or even difficult traffic situations can be programmed and tested in a simulated environment in which dynamic interactions can be safely recorded and analyzed. Weather, time of day, road traction, and traffic density can also be simulated, thus providing researchers opportunities to study a wide range of traffic situations and combinations of driving hazards. In addition, simulators allow for the safe exposure of participants to situations that may involve risk for on-road studies (e.g, texting while driving). A relevant research question when using driving simulation research is to what degree drivers' behavior observed in driving simulators is a reflection of how they drive in reality. While some limitations of the technology have been exposed (5), driving simulators have been shown to help identify driving errors such as following too closely, fail to signal and speeding (6). Therefore, driving simulators offer an important method to measure driving performance, particularly in dangerous situations that cannot be replicated in an onroad environment.

In order to build a driving assessment with solid scientific grounding, Mc Donald et al thoroughly analyzed the National Motor Vehicle Crash Causation Survey (NMVCCS) (7), conducted by the National Highway Traffic Safety Administration (NHTSA). The NMVCCS study data set included a sample of serious crashes that occurred throughout the United States (8) weighted to be nationally-representative—and identified the critical reason for the event immediately leading to each crash. The three most prevalent crash types among young drivers ages 16–18 (left turns at intersections, rear-ending a lead vehicle, running off road on the right side of the road) were the basis for the development of the Simulated Driving Assessment (SDA) that was developed at the Center for Injury Research and

Prevention at the Children Hospital of Philadelphia. The SDA includes 22 adaptations of these 3 most common crash scenarios (9, 10). Two of the scenarios involved ‘sudden’ car events, where a vehicle suddenly comes out of a hidden driveway, forcing participants to brake or swerve in order to avoid the crash. The focus of this paper is the analysis of the performance of the novice teens and experienced adults in the first of these “sudden car” events.

METHODS

Participants

For this study, the investigative team enrolled novice teen drivers, age 16–17 years, who held a Pennsylvania (PA) provisional license for less than 90 days. Teens were recruited via mailings to primary care patients and driving schools, and by word of mouth. The investigators also enrolled experienced adults drivers, aged 25–50 years, who held a PA licensed for over 5 years, with self-reported driving 100 miles or more per week and no crashes or moving violations in the previous 3 years. Individuals were excluded for a self-reported history of migraines, motion sickness, pregnancy or non-English speaking.

The final analytic sample consisted of $n=21$ teens and $n=17$ experienced adults. The teens were 65% male ($n=13$), age $M=16.8$ years ($SD\ 0.3$), and had their provisional license $M=31.5$ days ($SD\ 26.9$). The adult sample consisted of $n=17$ experienced adults. 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

Simulator Hardware—Data was collected at 60 Hz with a fixed-base high fidelity Realtime Technologies, Inc. (RTI)® driving simulator. The driving simulator consisted of a driver seat, three-channel 46” LCD panels (160° field of view) with rearview mirror images inlayed on the panels, active pedals and steering system, and a rich audio environment (FIGURE 1). The graphics were generated by a tile-based scenario authoring software, and real-time simulation and modeling were developed with SimCreator, (RTI®). Visual rendering and graphics were delivered at 1280×1024 resolution with a 60-Hz frame rate. SimObserver, a video capturing system, allowed for analysis of digital video recordings along with recorded simulator data. Videos of the driving scene, of the participant’s hands on the wheel, and of the participant’s foot were recorded.

SDA Scenarios—The driving scenarios used in the Simulated Driving Assessment (SDA) were developed using the SimVista Scene and Scenario Development system (RTI®). This system includes the VRML authoring tool, Internet Scene Assembler (Parallelgraphics®). The combination of Internet Scene Assembler (ISA) and SimVista allowed the development of driving environments through a combination of different roadway tiles including, but not limited to, straight roads, curves, and controlled intersections. The scenarios were customized by choosing from a variety of textures and terrains for the tiles themselves, as well as, through the addition of objects to the scenes, including buildings, vegetation,

vehicles, signage, and pedestrians. The addition of scenario control objects, such as proximity, time, and time-to-collision (TTC) sensors, offered a means to control objects in the environment. A JavaScript-based language was used for function scripting. Proximity sensors, used for programming the SDA, execute an event when the center of gravity of a vehicle, or programmed object, is within the sensor. The proximity sensor's function can be triggered by any chosen entity in the driving environment. Time sensors result in events at specific times based on start and stop values programmed into the sensor. TTC sensors trigger an event after a vehicle intercepts the sensor in relation to a time-to-collision threshold. The use of TTC sensors results in events that are not dependent on vehicle speed. In addition to the programmed roadway configurations, sensors triggered dynamic traffic as the participants passed over them. Detailed vehicle behaviors (speed and trajectory of ambient cars) were programmed via JavaScript. The driving simulator was programmed with SimCreator™ (11), SimVista™ (12) and SimObserver™ (13).

Focus of this analysis: sudden car event

The focus of this paper is to present the results of a scenario where participants were exposed to an emergency situation. In this driving scenario, a car surged from a hidden driveway, exposing all participants to an unexpected event where they need to brake strongly in order to avoid a crash (FIGURE 2). In this scenario, the sudden car was positioned on a hidden driveway. A proximity sensor was positioned at a distance $d = 38$ m (125 feet) from the hidden driveway, and triggered the sudden car to surge on the right with a velocity of 64 km/h (40 mph). The proximity sensor was triggered when the participant's vehicle entered the sensor's geometry. In this event, all participants were free to adjust their velocity. Since the distance to the hidden driveway is a constant, participants had varied Time Headway when the sudden car emerged. For this event, all participants had a Time Headway that was less than 2.5 seconds which qualified the event as an emergency situation.

Data collected

The simulator data collected consisted of both numerical (csv) and video (mpg) files. The SDA included one familiarization drive and three different experimental drives. The focus of this paper is only on the first of two sudden car events, which appeared only in the third exercise. No learning effect for the sudden car event was therefore possible. The second occurrence of the sudden car event was not part of this analysis. Simulator data was logged in four numerical and four video files. All SDA data files were saved locally by the simulator (SimObserver (RTI®)). All data were then uploaded to a secure research server. Driving simulator data was analyzed with Matlab™ (14, 15).

Analytical variables

Post Encroachment Time—Given that the crash variable is a binary variable (a participant will either crash or not crash as defined by any vehicle overlap), and that the number of participants in this study is relatively small, crash surrogates were used to evaluate the near-crash status of the event (e.g. a continuous variable allowed the investigators to quantify how close the participant was to a crash). The variable used is the

Post Encroachment Time (PET) (16). This variable is defined as the time difference between two vehicles passing a common spatial zone. While this variable is difficult to obtain in naturalistic data, as a number of videos and/or lidars are needed to acquire data so as to derive this variable, PET can be computed from driving simulator data. If two car trajectories intersect, the set of spatial points where they intersect can be tagged with the timestamps of both vehicles. It should be noted here that in our analysis the entire geometry of the vehicle was used, and not merely the trajectory of the Center of Gravity (CG). The difference in time of these timestamps is then computed. The minimum of these differences is the PET. A PET value of 0 is a crash. The smaller the PET value, the closer a participant was to a crash.

Time Headway at sudden car incursion—To assess participants' performance in the sudden car event, the Time Headway at sudden car incursion (TH_s) was used. The timesamp t_s was defined as the instant the sudden car entered the participant's lane as seen in FIGURE 2 or more specifically the instant the front left tire of the sudden car crossed the white lane-demarcation line. The variable d_s was defined as the distance from the participant's CG to the center line of the hidden driveway, and V_s the participant's velocity at t_s .

The time headway at incursion TH_s can be computed by:

$$TH_s = \frac{d_s}{V_s}$$

Maximum braking pressure—This paper focuses on the ability of participants to properly brake in the case of an emergency. To assess the quality of the braking pressure, the maximum braking pressure P_{max} exerted by the participant during the sudden car event was defined. If the participant did not brake during the entire event, the variable P_{max} had a value of 0.

Braking Adequacy—In an effort to assess whether a participant braked enough for the emergency situation, the braking pressure exerted by the participant had to be compared to the braking needs given the emergency situation. To this effect the timestamp t_B was defined as the instant the participant started to exert pressure on the brake. This variable was undefined if the participant never braked during the entire event. The longitudinal distance d_B was defined as the distance from the CG of the participant's car at t_B to the center line of the hidden driveway. The velocity V_B was defined as the participant's velocity at t_B . The needed deceleration D_B was defined as the deceleration the participant would need to exert if he were to stop his car, assuming a constant deceleration profile. The energy equation gives:

$$\frac{1}{2}mV_B^2 = B_B d_B$$

where B_B is the resultant of drag and braking forces, and m is the mass of the participant's car.

$$B_B = m D_B$$

Therefore

$$D_B = \frac{V_B^2}{2d_B}$$

It is straightforward to compute D_B deceleration needed to stop the car.

The Braking Adequacy (BA_B) is defined as the ratio of the minimum deceleration D_{min} to D_B .

$$BA_B = \left| \frac{D_{min}}{D_B} \right|$$

The Braking Adequacy ratio BA_B gives a good representation of whether the participant had an adequate braking pressure for the situation. If the Braking Adequacy BA_B is close to 1, the participant was more likely to avoid the crash, assuming he braked long enough. If the Braking Adequacy BA_B is close to 0, the participant was more likely to crash. The Braking Adequacy BA_B is a good quantifier of the braking quality for the emergency situation.

Analytical methods

Descriptive statistics—Descriptive statistics including means, standard deviations, medians, interquartile ranges, ranges, frequencies, and proportions were computed for all analytical variables where appropriate. In order to gauge central tendencies between groups, independent T-tests were used to assess differences in means for normally distributed data and Wilcoxon Rank Sum tests were used to assess distributional differences for non-normally distributed data. Looking for a model that could predict PET based on Time Headway at incursion, a linear regression was performed. Residual values were computed from that linear regression model to compare average reactions between groups. All aggregate analyses were performed using R v3.1.1 (<http://www.r-project.org>).

Missing data, exclusions and limitations—The entire sample of participants (n=38) was used to calculate the total number of crashes and determine Time Headway at incursion for each participant. Subsequent analyses were limited to subsamples based on the availability of data and the analytical question. Of note, more than 80% of the participants were included for all analyses with a range of 29 to the full sample of 38.

In order to quantify the number of near-crashes (as measured by PET), the subsample used included those where a PET could be computed (n=34). The calculation of PET was based on the distance to the closest vehicle which was unavailable for four participants. In order to explore average reactions between groups by using Time Headway at incursion and PET, a non-zero value of PET was required, resulting in a subsample of 29 for this analysis. Five participants with a PET value of 0 were excluded indicating a collision and resulting in a

ceiling effect. These participants had to be excluded in the linear regression analysis. To examine braking behavior in this scenario, participants who did not brake were excluded resulting in a subsample of 35. Of note, all participants fit the criterion of Time Headway <2.5 seconds but three did not brake during the scenario.

RESULTS

Means and standard deviations were computed for the variables defined above. A summary of the results is presented in Table 2.

PET results

The computation of the Post Encroachment Time (PET) values allowed the research team to identify the crashes (PET = 0) in the sudden car event. For this event, 3 teen crashes (16%) and 2 adult crashes (13%) were observed. The mean value for PET for the teen group is 0.40 seconds while the mean value for PET for adult group is 0.82 seconds ($p=0.04$), indicating less near-crashes for the adults.

Relationship between Time Headway at sudden car incursion and PET

The relationship between Time Headway at sudden car incursion and Post Encroachment Time follows a linear model (FIGURE 3). A linear regression on TH_s and PET gives the following results:

$$PET = 1.45 TH_s - 1.13 (R^2 = 92\%, \text{beta} = 1.45, p < 0.01).$$

Participants' data and linear regression are presented in FIGURE 3. Residuals for this linear regression are presented in FIGURE 4 as a measure of how individual performance deviated from the mean performance. By examining the mean value for the residuals, group differences could be examined. The mean value for residuals for the teen group is -0.06 seconds while the mean value for residual for the adult group is 0.08 seconds ($p < 0.01$), indicating improved performance within the adult versus the teen group.

Braking patterns

In order to proceed with the braking analysis, a review of the braking patterns of all participants was conducted so as to identify the potential reasons some participants did not brake. By examining the time series of the brake pressure, and confirming with manual review of the videos, the research team identified 3 participants who did not brake at all during the event: 2 participants were so close to the event, they did not have time to brake (1 ended up crashing, while the other one ended up with a near crash with a PET value of 0.08 seconds). The third participant started with a Time Headway at incursion of 1.49 seconds, allowing a small time margin which, although not very large, was enough to avoid the crash. This participant had a final residual < -0.3 second.

Participants who did not brake during event:

Teens: N=1 (4.8%)

Adults: N=2 (11.2%)

Maximum Brake Pressure

The statistical analysis of the maximum brake pressure P_{max} shows that the mean brake pressure P_{max} for the teen group has a value of 99 N. For the adult group the mean brake pressure P_{max} has a value of 128 N ($p=0.04$).

Braking Adequacy

The statistical analysis of the Braking Adequacy BA_B shows that the mean Braking Adequacy for the teen group has a value of 0.42. For the adult group the mean Braking Adequacy has a value of 0.83 ($p<0.01$).

DISCUSSION

The focus of this paper is to understand the differences in performance between novice teen drivers and experienced adult drivers when placed in an emergency situation where participants have to slam on the brakes to avoid a crash. This study involved an in-depth engineering analysis of the braking pressure on a driving simulator of a group of 21 teens in the 90 days that followed their licensure and a group of 17 experienced adult drivers. The analysis found significant differences both in performance and quality of braking.

While many of the variables are strongly correlated (a short headway time will logically lead to a short PET time and a strong braking reaction), the core of the analysis was not the linear relationship per se but rather the residual differences that remain between teens and adults. This paper developed analytical tools to grade participants' reaction to the event.

Performance analysis

The first part of the analysis demonstrated worse performance, on average, among the teen participants as compared with the adult participants. The mean value for PET for the teen group is 0.40 seconds while the mean value for PET for the adult group is 0.82 seconds ($p=0.04$), indicating more crashes/near-crashes among the teen group participants. Since the PET analysis does not take into account the distance and velocity of the participant when the sudden car emerged, the analysis was refined by considering the Time Headway at the sudden car incursion. No statistically significant difference in Time Headway was found between the groups (Teen mean Time Headway=1.13 s, SD=0.3, Adult mean Time Headway=1.24s, SD=0.47, $p=0.56$).

A novel method was presented to examine individual group variability in PET for a given Time Headway at incursion. By computing through a linear regression the average reaction of a participant for a given Time Headway, the effect of speed and distance on the performance can be mitigated. It becomes possible to compare participants. The near linear relationship between the PET variable and Time Headway at incursion was demonstrated through a linear regression ($R^2=92\%$, $\beta=1.45$, $p<0.01$). The mean of the residuals for the teen group was negative (-0.06 seconds) while the mean residual for the adult group was

positive (0.08 seconds) ($p < 0.01$), indicating that given the same Time Headway at sudden car incursion, teens ended up closer to the car (near-crash situation).

Presented with the same emergency braking situation, experienced adults reacted better than novice teens: adults reacted in such a way that they improved their expected PET by 0.08 seconds while teens' performance was below expectation in the sense that their PET was 0.06 seconds shorter than it should have been.

Braking analysis

The second part of the analysis focused on the quality of the braking reaction and involved two components: maximum brake pressure and whether sufficient brake pressure was applied to avoid a crash (Braking Adequacy). The braking adequacy is a new metric which is defined as the ratio of the strongest deceleration of the participant during the sudden car event to the deceleration needed to stop the car when the participant starts to brake in response to the emergency situation.

Statistically significant lower brake pressure was seen in the teen group than the adult group. The mean value for P_{max} for the teen group is 98 N while the mean value for P_{max} for the adult group is 128 N ($p = 0.04$).

Although brake pressure was lower for teens than for adults, this alone is not necessarily indicative of a poor response. Participants with a shorter Time Headway (because of higher speed or shorter Headway Distance) had to exert more pressure on the brake than participants with longer Time Headways. In an effort to mitigate the effects of speed and distance, the amount of braking was compared to the braking necessary to stop the car just in time to avoid the crash.

The analysis was therefore refined by considering the Braking Adequacy metric for the situation, e.g. the braking pressure that was needed to stop the car given the driver's conditions upon sudden car incursion. Experienced adult drivers had a much higher Braking Adequacy BA_B than the novice teen drivers (experienced adult mean braking adequacy $BA_B = 0.83$ SD 0.44, novice teens mean braking adequacy $BA_B = 0.42$ SD 0.22 $p < 0.01$). Therefore, for the same situation, inexperienced teen drivers braked 50% less than the experienced adults. This poor braking reaction explains largely the poor PET results and low residuals observed for teens and described earlier.

It is important to note however, that a high Braking Adequacy BA_B is not enough to avoid a crash as a strong but late braking reaction will not provide sufficient braking deceleration to prevent the crash. In addition, the Braking Adequacy computes the braking pressure necessary to stop the car. Since the lead vehicle surges from the hidden driveway without ever stopping in the participant's lane, a Braking Adequacy below 1 will usually be enough to prevent a crash. The Braking Adequacy is however a good indicator of performance. In the analysis, all participants who crashed even though they braked (4 participants) had a very low Braking Adequacy $BA_B < 0.4$.

This newly defined metric exposes the fact that even though teens recognized the necessity to brake during the sudden car event, their braking response was inadequate in the sense that they did not slam on the brakes as much as their older peers. This poor reaction led to more crashes and near crashes for the younger, inexperienced group.

The braking performance of a given participant to the sudden car event is the outcome of a number of factors in addition to braking adequacy; however, these factors were not the focus of this study and would be important for future work. The ability of the participant to identify the danger within sufficient time to brake is crucial to avoiding a crash. This ability is usually related to the scanning abilities of the participant. These differences have been described in the literature (17), they were not the focus of this paper. A third factor would be the participant's reaction time. The reaction time is the sum of two terms. The first term is the time elapsed between the recognition of the danger by the participant and his first measurable action, such as the release of the throttle. This first term is difficult to measure as it is challenging, even through thorough analysis of the video track of the eye tracker, to know precisely when the participant truly apprehends a danger. The second term is the time elapsed between throttle release and brake application and depends essentially on the neurological pathways of the participant. Reaction time was not the focus of this paper.

Limitations

This study was not without limitations. For this initial assessment of the validity of the SDA, a small sample size was used. A larger study would be necessary to help generalize the results. It is also important to note that a proximity sensor used when programming the sudden car event was based on the distance to the hidden driveway. A Time to Collision (TTC) sensor would be an alternative that could ensure all participants react to the same Time Headway, making it easier to compare performance.

While it would have been possible for this analysis to compute at each 60Hz measurement timestamp a TTC variable using vehicle speed and distance to the sudden vehicle, offering a way to compare participants reactions for a given TTC value, alternative methods for comparison were used. The linear regression is based on the Time Headway at sudden car incursion. By using this specific timestamp, authors were able to define a common entry point and rate participants according to their respective performance at end point (PET value).

Since a TTC sensor was unavailable for this analysis, the authors normalized the results by defining precise reference points as a baseline for all participants. In analyzing the relationship between Time Headway and PET, the timestamp chosen was the instant of sudden car incursion. The sudden car's velocity is a constant across all participants for that timestamp, so that the Time Headway is strongly correlated with the TTC variable. In addition, the Braking Adequacy's definition uses the participant's velocity in its definition. The object of this definition is precisely to determine the amount of braking needed for a given velocity and Distance Headway.

Future studies should consider TTC sensors to more easily mitigate the effect of speed on the event and facilitate the analysis of participants' performances.

While this study supports differences between the braking behaviors of novice teens and experienced drivers on a driving simulator which have been previously documented (18), a larger study with stronger statistical power would be necessary to precisely document the differences in timing, brake pressure and brake patterns between novice drivers and experienced adults. This study focused on teenage drivers with less than 90 days driving licensure. Even though teens with more experience might not exhibit deficits as strong as novice teens, the impact on safety should not be undermined. In an analysis of a recent naturalistic study, Cheng et al found that if the braking time of drivers were delayed by 0.2s, 17% of near-crashes would have been crashes; and if the braking forces were decreased by 0.1g, 33% of near-crashes would have been crashes (19).

In looking for ways to understand the reasons novice teens braked less than experienced adults in this sudden car event, it is important to keep in mind the limitations of the driving simulator environment. Although the adult participants in this sample were comfortable throughout the study, older participants are sometimes affected by simulator sickness. In addition, teens have more experience with virtual environments through their disproportionate use of video games. It is therefore a possibility that some of the difference between teens and adults could be attributed to these effects. An onroad assessment would be necessary to validate the results described in this paper. In addition, the authors of the study want to stress that even though they identified that novice drivers do not brake adequately in emergency situations on a driving simulator, they do not advocate for programs aimed at enhancing skills to operate in emergency situations. These programs have been shown to be counter effective as drivers tend to overestimate their skills and underestimate risks after such programs (20), (21), (22). The authors' intent is to report observations so that developing Advanced Driver Assistance Systems such as Forward Collision Warning or Emergency Brake Assist systems account appropriately for novice teen driving deficits.

CONCLUSIONS

This study demonstrated through the simulated sudden car event and its analysis, that for the same emergency circumstances, novice teen drivers with 3 months or less of driving licensure braked 50% less than their elder counterparts. This of course led to a higher number of crashes and near crashes for the teen group than for the adult group. Future research should examine braking behavior of teens on the road. Since it is impossible to place people in a critical environment in real life, the authors hope to investigate driving naturalistic data to better understand teen braking behaviour. Poor performance of novice teens can be related to their lack of experience and situational awareness which prevents them from reacting properly to a life threatening event. Their perception, comprehension and prediction skills are still in development, leading to their poor reaction in this emergency braking maneuver.

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REFERENCES

1. Curry AE, et al. Miles to Go: Establishing Benchmarks for Teen Driver Safety. Published by The Children's Hospital of Philadelphia Research Institute and State Farm Insurance Companies®. 2011
2. National Highway Traffic Safety Administration (NHTSA). Traffic Safety Facts 2008: Young Drivers. Data from the U.S. Department of Transportation.
3. Petersen, Andrew; Barrett, Rod; Morrison, Steven. Driver-training and emergency brake performance in cars with antilock braking systems. *Safety Science* 44.10. 2006:905–917.
4. Lerner, Neil D. Proceedings of the human factors and ergonomics society annual meeting. Vol. 37. SAGE Publications; 1993. Brake perception-reaction times of older and younger drivers.
5. Boer, Erwin R., et al. Experiencing the same road twice: A driver-centred comparison between simulation and reality. Proceedings of the driving simulation conference. 2000
6. Mayhew, Daniel R.; Simpson, Herb M.; Wood, Katherine M.; Lonero, Lawrence; Clinton, Kathryn M.; Johnson, Amanda G. On-road and simulated driving: Concurrent and discriminant validation. *Journal of safety research*. 2011; 42(4):267–275. [PubMed: 22017829]
7. Catherine, McDonald C.; Jason, B.; Tanenbaum, Yi-Ching Lee; Fisher, Donald L.; Mayhew, Daniel R.; Winston, Flaura K. Using crash data to develop simulator scenarios for assessing young novice driver performance; Transportation Research Board 91st Annual Meeting, no. 12-1636; 2012.
8. National Highway Traffic Safety Administration. National Motor Vehicle Crash Causation Survey: Report to Congress. Washington, DC: 2008.
9. Winston, Flaura Koplin, et al. Headway Time Errors, Safe Driving Skill, and Experience: An Initial Validation of the Simulated Driving Assessment; Transportation Research Board 93rd Annual Meeting, No. 14-4867; 2014.
10. McDonald, Catherine C., et al. Evaluation of Unintended Training Effects from Collision Scenarios in a Simulated Assessment for Young Novice Drivers; Transportation Research Board 92nd Annual Meeting, No. 13-2794; 2013.
11. SimCreator User's Manual. Realtime Technologies; 2008.
12. SimVista User's Manual. Realtime Technologies; 2012.
13. SimObserver Users's Manual. Realtime Technologies; 2004.
14. Matlab User's Guide. The Mathworks Inc.; 2013.
15. Loeb, Helen S., et al. Simulated Driving Assessment: Case Study for the Development of Drivelab, Extendable Matlab™ Toolbox for Data Reduction of Clinical Driving Simulator Data No. 2014-01-0452. SAE Technical Paper; 2014.
16. Allen BL, Loutit CB. Investigation of Post Encroachment Time as a Traffic Conflicts Technique. Dept of Civil Engineering, McMaster University-, Hamilton, Ontario. 1979
17. Fisher DL, Pollatsek AP, Pradhan Abhishek. Can novice drivers be trained to scan for information that will reduce their likelihood of a crash? *Injury Prevention*. 2006; 12(suppl 1):i25–i29. [PubMed: 16788108]
18. Imtiaz, Ahmed S.; Mueller, Jessica; Stanley, Laura. Driving Behavior Differences among Early Licensed Teen, Novice Teen, and Experienced Drivers in Simulator and Real World Potential Hazards.
19. Cheng, Bo, et al. Analysis of driver brake operation in near-crash situation using naturalistic driving data. *International Journal of Automotive Engineering* 2.4. 2011:87–94.
20. Christie, Ron. The effectiveness of driver training as a road safety measure: An international review of the literature. Road Safety Research, Policing and Education Conference, 2001; Melbourne, Victoria, Australia. 2001.
21. Elvik, Rune, et al., editors. The handbook of road safety measures. Emerald Group Publishing; 2009.

22. Gregersen, Nils Petter. Young drivers' overestimation of their own skill—an experiment on the relation between training strategy and skill. *Accident Analysis & Prevention* 28.2. 1996:243–250.

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FIGURE 1.
Driving simulator at the Center for Injury Research and Prevention at the Children Hospital of Philadelphia.

FIGURE 2.

Sudden Car event: A car emerges out of a hidden driveway. Incursion time is defined as instant sudden car enters the participant's lane.

FIGURE 3.

Linear regression: Post Encroachment time vs. Time Headway at incursion

FIGURE 4.
Residuals on linear regression of PET versus Time Headway

FIGURE 5.
Braking Adequacy teens vs. adults

Table 1**Participants**

		Teens	Adults	Total
Gender	Male	14 (66%)	10 (59%)	24 (63%)
	Female	7 (33%)	7 (41%)	14 (37%)
	Total	21 (100%)	17 (100%)	38 (100%)
Ethnicity	White	20 (95%)	12 (70%)	32 (84%)
	African American	1 (5%)	5 (30%)	6 (16%)
	Total	21 (55%)	17 (45%)	38 (100%)
Age (Median)		16 (IQR, 16–17; range 16–17)	34 (IQR, 28–42; range 25–50)	
Licensure (Median)		35 days (IQR, 7–44; range, 1–88)	15 years (IQR, 11–22; range 8–33)	

Table 2

Results

	Novice teens			Experienced adults			P value
	N	Mean	Standard deviation	N	Mean	Standard deviation	
Time Headway (s)	21	1.13	0.3	17	1.24	0.47	0.56
PET(s)	19	0.4	0.3	15	0.82	0.71	0.04
Residual (s)	16	-0.06	0.09	13	0.08	0.19	<0.01
Max Brake Pressure (N)	20	98.67	70.58	15	128.14	51.99	0.04
Braking Adequacy	20	0.42	0.22	15	0.83	0.44	<0.01