Differences in Novice and Experienced Driver Response to Lane Departure Warnings that Provide Active Intervention

Nicole Hollopeter
University of Iowa
Iowa City, IA 52242

Timothy Brown
University of Iowa
Iowa City, IA 52242

Geb Thomas
University of Iowa
Iowa City, IA 52242

It is widely known that young drivers are over-represented in the crash data for reasons such as risk perception and acceptance, age, gender, experience, exposure, and social contexts. The current mitigations implemented to address this issue consist mainly of graduated driver's licenses and parental involvement programs. However, as technology begins to find its way into transportation in the form of advanced driver assistance systems, there is a need to understand whether these technologies will be a benefit or a detriment to young novice drivers. This effort investigates the reactions of young novice drivers to a control intervention lane departure warning. The results show less urgent reactions to the warning from novice drivers compared to the older more experienced drivers tested. Young novice males were found to have degraded performance compared to their novice female peers as well as older more experienced male drivers. This study provides useful insights concerning the necessary investigations of effects of advanced driver assistance systems on young novice drivers and the associated young driver safety epidemic.

 DOI 10.1177/1071181312561467

INTRODUCTION

It is widely known that young drivers are vastly over-represented in motor vehicle crash rates. For years, teenage drivers as an age group have been considered to pose the greatest risk to themselves and other road users and are more likely to be injured or killed in a motor vehicle accident than their more experienced counterparts (Ferguson et al., 1996; McCartt et al., 2009; Rivara, 1982). This issue has become a great concern to the degree that the National Institute of Child Health and Human Development (NICHD), the National Highway Traffic Safety Administration (NHTSA), and the National Center for Injury Prevention of the Centers for Disease Control and Prevention (CDC) assisted in organizing an expert conference on the topic in 2002 (Simons-Morton, 2002).

According to the Insurance Institute for Highway Safety, teenagers accounted for 12 percent of all passenger vehicle crash deaths and represented 10 percent of the total deaths from all motor vehicle crashes in 2009. This representation left 3,466 teenagers dead as a result of a motor vehicle crash within the span of a year, accounting for a staggering 33 percent of all deaths among 13-19 year olds (Insurance Institute for Highway Safety, 2009). If one were to calculate the number of years of life lost, motor vehicle crashes rank third overall. That is to say that motor vehicle crashes are the third highest consumer of years a person would have been expected to live had they not died, ranking just behind cancer and heart disease (Subramanian, 2006).

A common explanation for the disproportionate number of motor vehicle deaths among young novice drivers is the idea that their over-representation is due to the low number of miles driven by young novices. However, the disproportionality remains after controlling for exposure. In the United States, although teenagers drive less than all but the oldest individuals, their numbers for crashes and crash deaths remain disproportionately high when viewed on a per mile basis (Insurance Institute for Highway Safety, 2009). In 1990, 16 year olds had 43 crashes per million miles driven compared to a mere 5 crashes per million miles driven for drivers 25 years of age and older (Ulmer, Williams & Preusser, 1997). Moreover, based on miles driven in 1990, teenagers had three times the risk of being in a fatal crash compared to all drivers (Massie, Campbell & Williams, 1995). When they controlled for the exposure, McKnight and McKnight (2003) found that drivers 16 years of age are 10 times more likely to be in a severe crash than adult drivers.

Methods for reducing the severity of the young novice driver safety problem vary from stricter legislation policies to simply encouraging better parenting skills (Senserrik, 2007; Simmons-Morton, 2007; Haggerty et al., 2006). In particular, changes to licensing practices, updates to existing and implementation of new driver education and training programs, and employment of parental involvement strategies are the commonly researched and evaluated mitigation methods.

Advanced driver assistance systems (ADAS) are vehicle-based technologies designed to assist the driver with the driving task. Much like a stick pusher that automatically compensates for human error in an aircraft to prevent the pilot from entering a stall, ADAS are designed and intended to support the driver and protect against human error in a vehicle. ADAS have been evaluated with general populations over the last two decades and have proven beneficial in decreasing crash risk (Brown, 1994; Marchau, V. et al., 2005). However, while much of the recent literature briefly notes the need for further exploration of ADAS or collision avoidance systems (CAS) and their effects on the young driver safety issue, experiments including young novice drivers as a specific age group are needed (Twisk & Stacey, 2007; Lee 2007).

It has been speculated that ADAS can reduce the impact of poor driving skills and, in conjunction with graduated licensing and training programs, have the potential to make driving safer for young and novice drivers (Senserrick, 2006; Lee, 2007). Braitman et al. (2008) found that run off road was the most common collision type for teens and speculates that Electronic Stability Control (ESC) and Lane Departure Warning (LDW) systems may be effective in preventing crashes. However, the author also notes that because these systems have not yet been evaluated with teens, there is no direct evidence to support such a speculation (Braitman et al., 2008). Moreover, Lee (2007) suggests that using ACWS in conjunction with GDL by tailoring ACWS to the needs of young drivers may mimic the benefits seen from an adult supervisory passenger. However, these technologies also have the potential to be a detriment to young drivers, and thus there is a need for young novice-specific research of ACWS (Twisk & Stacey, 2007; Lee, 2007).

METHOD

Data were collected in the National Advanced Driving Simulator (NADS) from 36 participants. Drivers were divided into equal groups by age (16-18, and 35-55) and gender. Upon arrival, participants provided informed consent and reviewed a training presentation. To prevent participants from becoming fixated on the LDW, they were told during screening and briefing that they were going to experience a vehicle with a number of innovative design features. To assure familiarity with the LDW without focusing the participant‘s attention specifically on the LDW, participants watched a PowerPoint Presentation that identified the purpose of the study as the evaluation of several new in-vehicle technologies, introduced participants to the simulator cab, trained participants on the LDW as well as the other new technologies (i.e. Speed Violation Warning and Trivia Game), provided participants information about the drives, and trained them on the tasks they would need to perform while driving.

Once inside the vehicle, participants were shown each of the new technologies and distraction tasks and reinstructed on how to do each of the tasks. To assist in adaptation to the test vehicle prior to the actual data trial, participants experienced about five minutes of a practice segment of the drive. In order to avoid uncontrolled (participant-initiated) lane departures, the practice segment of the drive primarily involved low speeds and local unmarked roads. To develop participants' experience with the feel of the LDW system, participants were asked to make intentional lane departures to the left and to the right. Participants were also asked to speed up to ten miles per hour over the speed limit to experience the speed warning and mask the importance of the LDW warning. Once the participant was comfortable with the vehicle, the distracter tasks were briefly practiced while driving.

During the main portion of the drive, participants were instructed to drive as they normally would and engage in the distraction tasks when they occurred. Specifically, they were instructed to drive in the simulator vehicle in their normal manner on rural roads. Distracter tasks and forced lane deviations occurred. The lane deviations were implemented during the primary distracter task, but did not occur during every primary distracter task.

Participants

All participants were required to be in good general health, not own or drive a vehicle equipped with a lane departure warning system, and report that they engage in distracting tasks while driving. Participants between the ages of 35 and 55 were required to possess a current valid driver's license for at least two years, and to drive a minimum of 10,000 miles per year. Participants between the ages of 16 and 18 were required to possess a current valid driver's license or permit for at least six months. Novice participants were also stratified for age such that there were three males and three females of 16 years, 17 years, and 18 years.

Apparatus

The National Advanced Driving Simulator (NADS) is located at The University of Iowa‘s Research Park. It consists of a 24-foot dome that houses a 1996 Chevrolet Malibu Sedan. All participants drove the same vehicle. The motion system on which the dome is mounted provides 400 square meters of horizontal and longitudinal travel and ±330 degrees of rotation. The driver feels acceleration, braking, and steering cues as if he or she were driving a real vehicle. A total of eight projectors inside the dome display 360 degrees of scenery and environment. Each of the three front projectors has a resolution of 1600 x 1200; the five rear projectors have a resolution of 1024 x 768. The edge blending between projectors is five degrees horizontal. The NADS produces a complete record of vehicle state (e.g., lane position) and driver inputs (e.g., steering wheel position), sampled at 240 Hz.

LDW System

The simulation study utilized a LDW system with a strong active intervention warning modality. Active warnings provide some automatic partial control of a vehicle‘s behavior (e.g., direction, speed) through steering/braking. While there are currently no published active warning torque specifications, the torque input to the steering wheel was modeled and validated to the greatest extent possible using data available from the Vehicle Research and Test Center (VRTC). The strong steering torque was used as a warning to the driver that they were on the verge of departing the lane boundary and consisted of a 6 N-m input in the direction necessary for appropriate lane return. The LDW simulation was accomplished by condensing the desired features and salient performance specifications into an algorithm that ran in real-time on the simulator. The use of an icon was implemented to indicate the status of the system (i.e. on or off) and was present for all participants. Consistent with current LDW systems, a minimum speed threshold of 35 mph was used to deactivate the system at lower speeds.

Events/Forced Departure

The selection of scenario events was made by first looking at data from the Federal Analysis Reporting System (FARS). In 1998, FARS data estimated that 992,000 crashes involved vehicles departing the roadway (Szabo & Norcross, 2007). Such crash types generally occur at highway speeds and in rural areas and involve a single vehicle that departs the road. Since LDW crash events vary by road type and traffic density, choosing events that can map onto real-world data is important. Given that a rural highway would be the road type, it is possible to consider events that will have the best potential to map onto real world data. The most common events in these rural highway road departures were selected and included where the driver (Najm et al., 2002) :

- Drifts off road to the right
- Drifts over the centerline, with on-coming traffic
- Fails to keep in the lane in a left curve entry.

To ensure a departure at the specified events, it was necessary to force the driver out of their lane. In order to gain an understanding of behaviors associated with the lane departure warning in conjunction with distraction, it was essential to take the driver's eyes off the road just prior to the lane departure events.. Although there were many distracters that could achieve this, it was important to choose a task that could reliably and repeatedly ensure that the driver's eyes are off road for several seconds. Because drivers are able to use peripheral vision to monitor and maintain lane position, it was crucial that the driver's gaze be directed away from the forward view. Moreover, it was desired that the primary task be continuous to ensure that the attention of the driver remained off the road until the lane departure had been triggered. To achieve this, a simulated insect task was used as the primary distracter and was tied to the planned lane departures (Lerner et al., 2011).

Secondary distracter tasks were used to help to mask the importance of the primary distracter. While the secondary distracter tasks were not associated with planned lane departures, it was anticipated that some participants would have occasional unplanned lane departures during these tasks. These unplanned departures assisted in further masking the planned lane departure associated with the primary distracter task.

Distractor Tasks

The insect catch task required participants to turn and reach into the back seat to catch an insect by tracing the path of an insect on a touch screen display. The task began with an auditory buzz noise that simulated the presence of the insect and continued to buzz until the participant successfully caught it by touching the insect with their finger (see Figure 1). The design of the insect ensured that it would be impossible to catch until the lane departure occurred. The insect was also designed to provide variable lengths for the distracter task depending upon the needs of a particular situation or participant. An algorithm directed the insect away from the participant's finger in random directions at varying speeds until the lane departure was successful, at which time the insect maintained a random path that did not avoid the participant's finger and it became possible to quickly catch the insect.

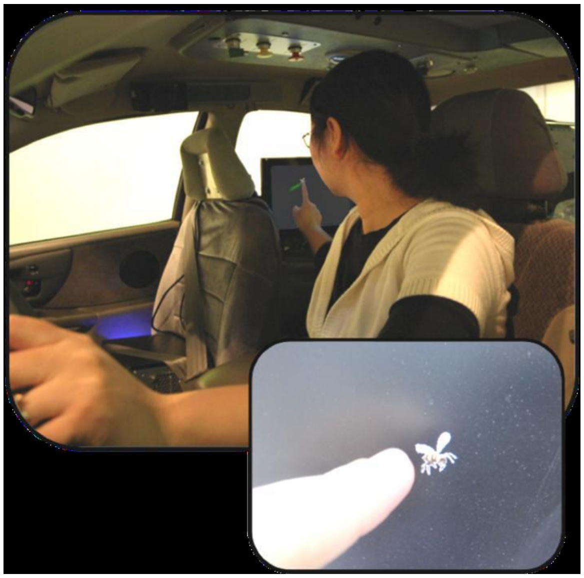

Figure 1. Insect Catch Task

The two secondary tasks were a visual-manual trivia game, and a CD task involving locating the correct CD from the visor above the driver and finding the requested track, using the CD controls, and then ejecting and returning the CD to its original position.

Data Analysis

Before conducting the analysis, the data in which the driver departed the lane in the opposite direction intended, or responded to the departure before the alert were removed. Additionally, extreme outliers (greater than three standard deviations from the mean) were also removed. In an effort to equalize cell size and variances, the data were aggregated across event. Each participant's three events were averaged resulting in equal cell sizes of 9 data points per condition and gender combination (36 total data points).

A 2x2 ANOVA using the SAS General Linear Model was then used to compare the dependent measures by condition (novice, experienced), and gender (male, female). The primary interest was differences by condition, however all main effects and interactions were included in the model. A post hoc t-test was used to determine the least significant difference for the main effects.

RESULTS

All measures were analyzed using the general linear model based on the aggregated data. Of the measures analyzed, there were two statistically significant interactions. Both were seen between condition and gender. The standard deviation of lane position from initial response to stabilization in the lane, $F(1,24)=5.43$, $p=0.029$, and the maximum lateral distance during the lane departure, $F(1,24)=5.12$, $p=0.03$ that the leading edge of the vehicle extends out of the lane from the initial steering response to the warning to stabilization in the lane. The plots for these interaction results are shown in Figure 2 and Figure 3.

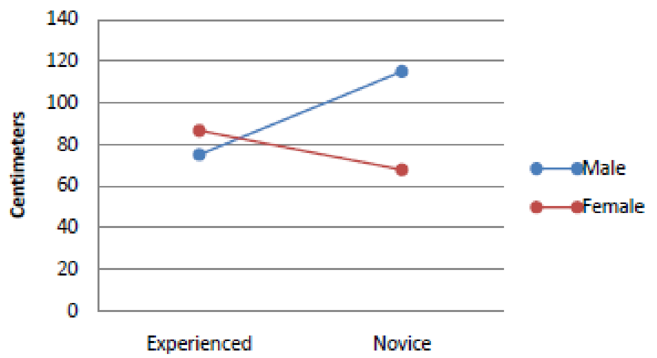

Figure 2. Standard Deviation of Lane Position Interaction

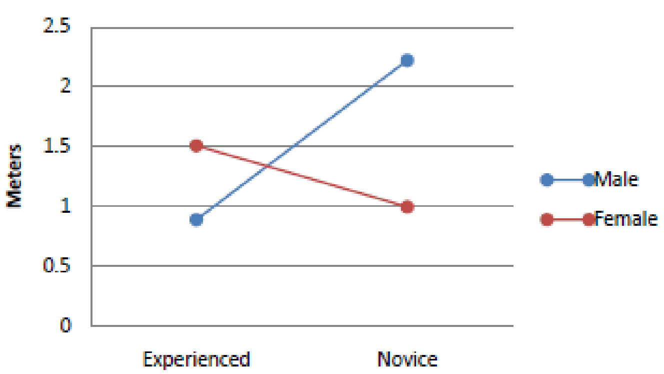

Figure 3. Maximum Lane Exceedance Interaction

Experienced males had an average standard deviation of lane position that was approximately 75 centimeters and experienced female's average standard deviation of lane position was approximately 87 centimeters. The average standard deviation of lane position for novice males was approximately 115 centimeters and novice females had an average standard deviation of lane position of approximately 68 centimeters. The Least Significant Difference test with an alpha of 0.05 showed novice male drivers to have statistically greater variability in lane keeping than both experienced male drivers and novice female drivers.

The average maximum lateral lane exceedance for experienced males was approximately 0.9 meters and was approximately 1.5 meters for experienced females. The average maximum exceedance for novice males was approximately 2.2 meters and novice females had an average maximum lane exceedance of approximately 1.0 meters. The Least Significant Difference test with an alpha of 0.05 showed novice male drivers to have statistically greater maximum departure distances than both experienced male drivers and novice female drivers.

Novice teen drivers had an initial steering response of a significantly lower degree than the adults $F(1,24)=13.91$, $p=0.001$. The initial steering input of adults was just over 30 degrees while the novice drivers had an input that was more than eight degrees less, at about 21 degrees (see Figure 4). Error bars are shown using standard error by condition (Experienced=1.70, Novice=1.72).

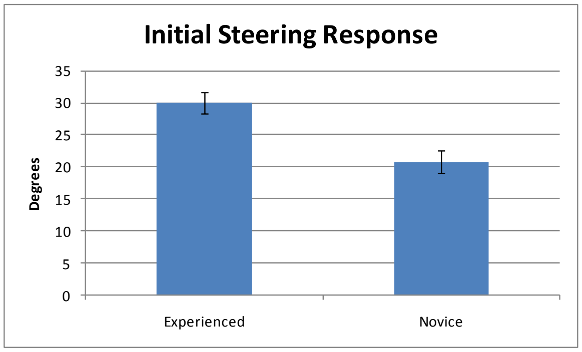

Figure 4. Initial Steering Response after the Warning by Condition

Novice teen drivers had significantly lower peak steering jerk, or rate of change of acceleration over time, than the experienced adults $F(1,24)=4.34$, $p=0.048$. Figure 5 shows that the experienced adult drivers had a peak jerk of 19,600 degrees per second cubed while the novice driver's change in acceleration was only 14,700 degrees per second cubed. Error bars are shown using standard error by condition (Experienced=1,952, Novice=1,592).

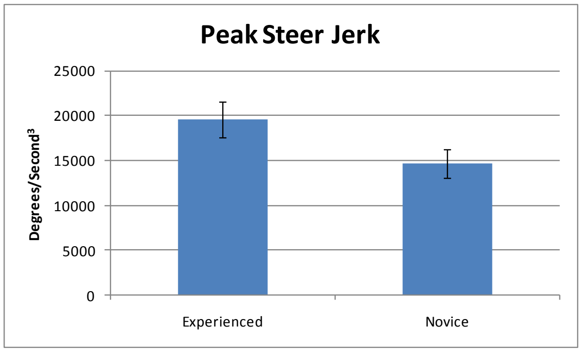

Figure 5. Peak Steering Jerk of Events by Condition

Novice drivers also had significantly fewer steering reversals than the more experienced adults $F(1,24)=10.0$, $p=0.0041$. Experienced adults had an average of 8.62 reversals during an event while novice drivers had an average of only 6.34

reversals (see Figure 6). Error bars are shown using standard error by condition (Experienced=0.52, Novice=0.46).

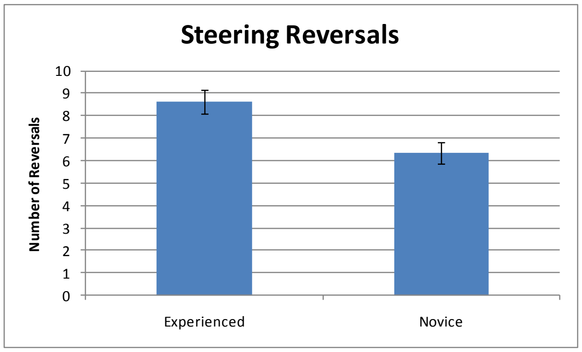

Figure 6. Number of Steering Reversals by Condition

DISCUSSION

Based on the results, novice drivers react differently than experienced drives. Of the behavioral response measures analyzed, half of them showed significant differences between novice and experienced drivers. When a lane departure occurred due to distraction, novice drivers reacted with less input to the lateral control warning than their experienced counterparts. Novice drivers had a substantially smaller initial steering response than the experienced drivers as seen by a steering input that was nearly 10 degrees less. Not only did the input of the novice drivers lack in its amount of rotation, but it also lacked in the force and speed of the steering input. There was a difference of approximately a 5,000 degrees/second^3 in steering jerk between novice and experienced drivers. Overall, the behavioral responses of the novice drivers were weaker than those of the experienced drivers (μNovice < μExperienced). This is may be due to the young novice driver's inability to recognize the risks involved in driving and their associated higher levels of risk acceptance and skewed perceptions of risk. Stein and Allen's (1987) explanation of how the level of risk perceived effects a driver's acceptance threshold, and thus their behaviors, remain both relevant and applicable to these findings. Perhaps, young novice drivers' perception of themselves as being more skillful and their reduced estimations of personal risk as described by Engstrom et al. (2003) produced a false sense of control and a lack of urgency.

ACKNOWLEDGEMENTS

The National Highway Traffic Safety Administration funded this research under contract number: DTNH22-05-D-01002, Task Order 15. These findings represent the views of the authors. The authors would like for further recognize Eric Traube, NHTSA, and Neil Lerner, Westat, for their contribution to this research.

REFERENCES

Braitmann K.A., Kirley, B.B., McCartt, A.T., & Chaudhary, N.K. (2008). Crashes of novice teenage drivers: Characteristics and contributing factors. *Journal of Safety Research*, 39, 47-54.

Brown, Timothy L. (1994). "*An Examination of Active Control Intervention in Prevention of Run-Off-Road Accidents.*" Masters Thesis. Department of Industrial Engineering, The University of Iowa.

Engström I, Gregersen NP, Hernetkoski K, Keskinen E, & Nyberg A. (2003). *Young novice drivers, driver education and training: literature review*. Linköping, Sweden: Swedish National Road and Transport Research Institute.

Ferguson, S.A., Leaf, W.A., Williams, A.F., & Preusser, D.F. (1996). Differences in young driver crash involvement in states with varying licensure practices. *Accident Analysis and Prevention*, 28, 171–180.

Haggerty K.P., Fleming C.B., Catalano R.F., Harachi T.W., & Abbott R.D. (2006). Raising healthy children: Examining the impact of promoting healthy driving behavior within a social development intervention. *Prevention Science*, 7, 257–267.

Insurance Institute for Highway Safety. (2009). *Fatality Facts 2009: Teenagers*. Accessed March 2011, from http://www.iihs.org/research/fatality_facts_2009/teenagers.html

Lee, J.D. (2007). Technology and the teen driver. *Journal of Safety Research*, 38(2).

Lerner, N. Jenness, J., Robinson, E. Brown, T., Baldwin, C. & Llaneras, R. (2011). *Crash Warning Interface Metrics: Final Report* (No. DOT HS 811 470a). Washington, DC: National Highway Traffic Safety Administration.

Marchau, V., Van Der Heijden, R. & Molin, E. (2005). Desirability of Advanced Driver Assistance from Road Safety Perspective: The Case of ISA. *Safety Science*,43(1), 11-27.

Massie D.L., Campbell K.L., & Williams A.F. (1995). Traffic accident involvement rates by driver age and gender. *Accident Analysis and Prevention*, 27, 73-87.

McCartt, A.T., Mayhew, D.R., Braitman, K.A., Ferguson, S.A., & Simpson, H.M. (2009). *Effects of Age and Experience on Young Driver Crashes: Review of Recent Literature*. Insurance Institute for Highway Safety, Arlington, VA.

McKnight, A.J., & McKnight, A.S. (2003). Young novice drivers: careless or clueless? *Accident Analysis and Prevention*, 35, 921−925.

Najm, W.G., Koopmann, J., Boyle, L., & Smith, D. (2002). *Development of Test Scenarios for Off-Roadway Crash Countermeasures Based on Crash Statistics* (No. DOT 809 505). Washington, DC: U.S. Department of Transportation.

Rivara, F.P., & Mueller, B.A. (1982). The epidemiology and causes of childhood injuries. *Journal of Social Issues*, 43, 13–31.

Senserrick, T.M. (2006). Reducing young driver road trauma: guidance and optimism for the future. *Injury Prevention*, 12, i56 –i60.

Senserrick, T.M. (2007). Recent developments in young driver education, training and licensing in Australia. *Journal of Safety Research*, 38, 237-244.

Simons-Morton, B.G. (2002). Reducing young driver crash risk. *Injury Prevention*, 8, ii1 – ii2.

Simons-Morton, B. (2007). Parent involvement in novice teen driving: Rationale, evidence of effects and potential for enhancing graduated driver licensing effectiveness. *Journal of Safety Research*, 38, 193-202.

Stein, A.C., Allen, R.W. (1987). The effects of alcohol on driver decision making and risk taking. In *Noordzij PC, Roszbach R, eds. Alcohol, Drugs and Traffic Safety-T86*. (171–181). New York: Excerpta Medica.

Subramanian, R. (2006). *Motor vehicle traffic crashes as a leading cause of death in the United States, 2003* (No. DOT HS 810 568). Washington, DC: U.S. Department of Transportation.

Szabo, S., & Norcross, R. (2007). *Final Report: Objective Test Procedures for Road Departure Crash Warning Systems* (No. DOT HS 810 829). Washington, DC: Department of Transportation.

Twisk, D.A.M. & Stacey, C. (2007). Trends in risk of young drivers and countermeasures in European countries. *Journal of Safety Research*, 38, 245-257.

Ulmer, R.G., Williams, A.F., & Preusser, D.F. (1997). Crash involvements of 16-year-old drivers. *Journal of Safety Research*, 28, 97–103.