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Effects of an integrated collision warning system on teenage driver behavior

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ABSTRACT

Introduction: Crash warning systems have been shown to provide safety benefits, but no studies have examined how teenagers respond. This study sought to find out whether young, inexperienced drivers change behavior in response to warnings. *Methods:* Forty 16–17-year-olds drove an instrumented vehicle equipped with a system that warned for lane departures and potential rear-end and lane change/merge crashes. Participants were randomly assigned to experimental or control groups, and their driving was monitored for 14 weeks during 2011–12. For the experimental group, this included a treatment period, when crash alerts were received by drivers, and baseline and post-treatment periods, when warnings were recorded but not received. The control group never received warnings. Data were analyzed to determine whether warnings were associated with changes in driving behavior. *Results:* A total of 15,039 trips were analyzed. Lane drifts accounted for 73% of warnings. Forward collision warning rates doubled for all drivers during the treatment period and continued at an increased rate post-treatment. This was likely a result of the fact that, as time went on, all drivers spent more time following vehicles at close distances. Receiving alerts was associated with effects on following and lane-changing behavior, including more time spent following at close distances (17%), fewer lateral drifts (37%) and fewer unsignaled lane changes (80%). Receiving warnings wasn't associated with an increased likelihood of engaging in secondary tasks. *Conclusions:* Warning systems may result in improved lane-keeping and turn-signal behaviors by novice drivers, but there is some indication they may result in more close-following behaviors. *Practical applications:* There is some evidence that lane departure warning may improve turn-signal use for young drivers. While there is no evidence of safety benefits from the other types of warnings, there is some evidence of an increase in close following behavior but no increase in secondary tasks due to the presence of those capabilities.

1. Introduction

In 2012, 2823 teenagers died in the United States from injuries sustained in motor-vehicle crashes (Insurance Institute for Highway Safety [IIHS], 2013). Motor-vehicle crashes are the leading cause of death among teenagers and resulted in 37% of all injury-related deaths among 16–19 year-olds in 2010 (National Center for Injury Prevention and Control, 2013). Although teenagers drive fewer miles than all but the oldest drivers, they have elevated crash rates per mile driven compared with adults. For police-reported crashes of all severities and for fatal crashes, the crash rate for 16–19-year-old drivers is three times the rate for drivers 20 and older (IIHS, 2014). Risk is highest at age 16; the rate of crashes for all severities is 3 times as high for 16 year-olds as it is for 18–19 year-olds. Teenage driver crash risk is particularly elevated at night and when carrying teenage passengers (Chen, Baker, Braver, & Li, 2000; Doherty, Andrey, & MacGregor, 1998; Preusser, Ferguson, & Williams, 1998; Tefft, Williams, & Grabowski, 2013).

Crash rates for young drivers are high because of their immaturity combined with their inexperience with driving. The crash risk for teenage drivers is particularly high during the first months of licensure (Masten & Foss, 2010; Mayhew, Simpson, & Pak, 2003; McCartt, Shabanova, & Leaf, 2003), when their lack of experience behind the wheel makes it difficult for them to recognize and respond to hazards. Immaturity is apparent in young drivers' risky driving practices such as speeding. A study of nonfatal crashes of newly licensed teenage drivers in Connecticut found that important contributing factors were speeding, losing control of the vehicle or sliding, and failing to detect another vehicle or traffic control device, often due to distraction or inattention (Braitman, Kirley, McCartt, & Chaudhary, 2008). Simons-Morton et al. (2011a) continuously monitored the driving of 42 newly licensed teenagers and their parents. The teenagers had higher rates of crashes/near crashes and elevated acceleration events during starts, stops, turns, and cornering than their parents over the 18-month period following the teenager's licensure (Simons-Morton et al., 2011a). Teenagers

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driving with peers who were classified as risk-takers had higher rates of risky driving behaviors and crash/near crash rates than when they drove without passengers, suggesting that risky driving is peer influenced (Simons-Morton et al., 2011b).

There are an increasing number of advanced technologies available to assist drivers in reducing risky driving and preventing crashes. One aftermarket option includes in-vehicle monitoring that can alert the driver to risky behaviors such as speeding, high acceleration events, or not wearing a seat belt and provide feedback to fleet managers or parents. Farmer, Kirley, and McCartt (2010) evaluated the effects of one such device on the risky driving behavior of newly licensed teenagers. Seat belt use improved when violations were reported to the parent websites, and improved even more when in-vehicle alerts were activated. Consistent reductions in speeding were achieved only when teenagers received alerts about their speeding behavior, believed their speeding behavior would not be reported to parents if corrected, and when parents were being notified of such behavior by report cards.

Other advanced technologies include crash avoidance systems, which monitor driver input and the environment around the vehicle and warn the driver of a potential collision. An analysis of 2004–2008 crash data showed that if all passenger vehicles were equipped with forward collision warning, lane departure warning, blind spot detection, and adaptive headlights, about 1 in 3 fatal crashes and 1 in 5 injury crashes could potentially be prevented or mitigated, presuming the systems perform as advertised and drivers respond to them correctly (Jermakian, 2011). Forward collision warning systems had the potential to prevent or mitigate the most crashes. In a study of insurance collision claims, Mercedes-Benz vehicles with Distronic forward collision warning system reduced property damage liability claims by 7%, compared with the same vehicles without the warning system (Highway Loss Data Institute [HLDI], 2012a), thus providing real-world evidence that crash avoidance technologies are reducing crashes. Vehicles with forward collision warning with autobraking experienced even larger reductions (14%) in property damage liability claims (HLDI, 2011a, 2012a). Similar studies of collision claims have not shown reductions in collisions for lane departure warning systems (HLDI, 2011b, 2012a, 2012b), but field operational tests of vehicles equipped with lane departure warnings systems have demonstrated reductions in lane drifts and improved turn signal use (Sayer et al., 2010; Wilson, Stearns, Koopmann, & Yang, 2007).

In 2010, the University of Michigan Transportation Research Institute (UMTRI) completed the Integrated Vehicle-Based Safety System Field Operational Test (IVBSS FOT), a joint government/industry/academia research program to assess the potential safety benefits and driver acceptance associated with a prototype integrated crash warning system. The system was designed to address rear-end, roadway departure, and lane change/merge crashes for light vehicles and heavy commercial trucks. The FOT compared the driving behavior of 108 adult drivers during a 28 day treatment period when alerts were received by drivers with a 12 day baseline period when system warnings were recorded but not received by drivers. The drivers exhibited some positive effects on driving behaviors, such as increased turn signal use and decreased number and duration of lane departures, but also exhibited some negative effects, including more time spent at short headways and more lane changes (Sayer et al., 2010).

Crash avoidance technologies have the potential to reduce crashes and, in some cases, are proving effective at reducing crashes in the real world. It has been hypothesized that the systems could be especially beneficial for novice drivers to avoid situations that could lead to collisions and also help them develop safe driving habits. However, the systems have not been evaluated with novice drivers. The present study was conducted to determine whether teenagers experience safety benefits from the integrated collision warning system previously evaluated with adults (Sayer et al., 2010). Specifically, the study examined whether the presence of the warning system altered teenagers' driving in terms of metrics such as headway maintenance, lane keeping, and turn signal use and whether any changes were sustained after the integrated warning system was disabled. A secondary objective was to determine whether the integrated collision warning system increased engagement in secondary tasks.

2. Methods

Teenage drivers were recruited to participate in a study in which they drove an instrumented vehicle equipped with an integrated crash warning system that incorporated forward collision warning, lane change/merge warning, lateral drift warning, and curve speed warning. Detailed descriptions of the study vehicles, crash warning systems, driver recruitment, and experimental design are described below.

2.1. Study vehicles

Thirteen 2006–2007 Honda Accord EX 4-door sedans were equipped with a data acquisition system (DAS) that uses several hundred data channels to capture details of the driving environment, driver behavior, integrated collision warning system activity, and vehicle kinematics (Sayer et al., 2008). Data are collected from multiple sources including the vehicle CAN (controller area network) bus, the integrated crash warning system bus, and additional sensors on the vehicle including six short-range radar sensors covering areas to the rear, sides, and front corners of the vehicle; one long-range radar sensor and a camera covering the area in front of the vehicle; a yaw rate sensor and triaxial accelerometer; and a GPS module. Five video cameras were mounted on each vehicle to capture the scene around the vehicle and the driver cabin environment. Three video cameras were located inside the cabin, including a camera mounted in the A pillar to capture the driver's face, a camera mounted near the sun roof to capture the instrument panel and steering wheel area over the driver's shoulder, and a forward-looking camera mounted to the windshield behind the interior rearview mirror to capture the forward scene. A camera was mounted under each side view mirror to capture the view behind the vehicle and in the adjacent lane. All sensor data were collected at 10–50 Hz. Video data were collected at 10 Hz for the forward-looking and face-view cameras and 2 Hz for other cameras. Additional details about the study vehicles and the collision warning system can be found in the IVBBS FOT plan (Sayer et al., 2008).

2.2. Integrated crash warning system

Study vehicles were equipped with an integrated crash warning system that incorporated the following sub-systems: forward collision warning (FCW) that warns drivers of the potential for rear-ending another vehicle; lateral drift warning (LDW) that warns drivers they may be drifting inadvertently from their lane or departing the roadway; lane-change/merge warning (LCM) that warns drivers of possible unsafe lane changes based on the presence of vehicles in adjacent lanes, and includes a blind spot detection system; and curve speed warning (CSW) that warns drivers they are going too fast for an upcoming curve. The crash warning system was active when the vehicle was traveling more than 11.4 m/s (25 mph).

Alerts received by the driver differed for the four sub-systems and were primarily auditory or haptic (physical sensation such as vibration) cues, as seen in Table 1. Audible alerts of an imminent possible crash were presented through speakers in the head restraint. Less urgent lateral drift cautionary alerts were vibrations in the seat pan. Three seconds after a haptic or audible alert, descriptive text in the center-mounted stack display (Fig. 1) confirmed which sub-system had activated the alert.

Drivers were not able to turn off the crash warning system, but they could mute the alerts for up to 6 min by pushing a button. There also

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