Accident Analysis and Prevention 87 (2016) 92–101

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Differences in glance behavior between drivers using a rearview camera, parking sensor system, both technologies, or no technology during low-speed parking maneuvers

David G. Kidd*, Anne T. McCartt

Insurance Institute for Highway Safety, 1005 North Glebe Road, Arlington, VA 22201, United States

ARTICLE INFO

Article history:
Received 28 October 2014
Received in revised form
22 September 2015
Accepted 22 November 2015
Available online 4 December 2015

Keywords:
Glance behavior
Backing technology
Behavioral adaptation
Rearview camera
Parking sensors

ABSTRACT

This study characterized the use of various fields of view during low-speed parking maneuvers by drivers with a rearview camera, a sensor system, a camera and sensor system combined, or neither technology. Participants performed four different low-speed parking maneuvers five times. Glances to different fields of view the second time through the four maneuvers were coded along with the glance locations at the onset of the audible warning from the sensor system and immediately after the warning for participants in the sensor and camera-plus-sensor conditions. Overall, the results suggest that information from cameras and/or sensor systems is used in place of mirrors and shoulder glances. Participants with a camera, sensor system, or both technologies looked over their shoulders significantly less than participants without technology. Participants with cameras (camera and camera-plus-sensor conditions) used their mirrors significantly less compared with participants without cameras (no-technology and sensor conditions). Participants in the camera-plus-sensor condition looked at the center console/camera display for a smaller percentage of the time during the low-speed maneuvers than participants in the camera condition and glanced more frequently to the center console/camera display immediately after the warning from the sensor system compared with the frequency of glances to this location at warning onset. Although this increase was not statistically significant, the pattern suggests that participants in the camera-plus-sensor condition may have used the warning as a cue to look at the camera display. The observed differences in glance behavior between study groups were illustrated by relating it to the visibility of a 12–15-month-old child-size object. These findings provide evidence that drivers adapt their glance behavior during low-speed parking maneuvers following extended use of rearview cameras and parking sensors, and suggest that other technologies which augment the driving task may do the same.

1. Introduction

Drivers look at a number of locations around the vehicle to maintain awareness of their surroundings and navigate when backing up. The pattern of glances to different fields of view varies in complex ways when performing different types of low-speed maneuvers (Huey et al., 1995). Traditional fields of views like mirrors and windows typically provide sufficient information about the vehicle's surroundings to back up safely. However, these fields of view do not provide a complete view of the entire area directly behind the vehicle, creating a blind zone in rear visibility. This can be problematic, especially when there are shorter objects behind the vehicle. The United States federal government estimates that many of the 15,000 people injured and 210 deaths occurring each year in backover crashes involving light vehicles are younger than 5 years old (National Highway Traffic Safety Administration (NHTSA), 2014).

Rearview cameras and parking sensor systems can help drivers detect objects in the blind zone. Cameras present an image of the area directly behind the vehicle on an in-vehicle display, and sensor systems provide audible or visual warnings when an object is detected directly behind the vehicle. One study found that among a selection of 2010–2013 model year vehicles, on average, sensor systems reduced the blind zone for child-size objects simulating the heights of a 12–15-month-old, a 30–36-month-old, and a 60–72-month-old child by up to 48% and cameras reduced it by up to 99% (Kidd and Brethwaite, 2014). A number of experimental studies have shown that cameras alone and combined with sensors help prevent backovers with child-size objects in the blind zone (e.g., Hurwitz et al., 2010; Mazzae, 2010, 2013; Mazzae et al., 2008),

* Corresponding author.
E-mail address: dkidd@iihs.org (D.G. Kidd).

http://dx.doi.org/10.1016/j.aap.2015.11.030
0001-4575/

but sensor systems alone are minimally effective (Kidd et al., 2015; Llaneras et al., 2005). In 2014, NHTSA implemented a rule requiring vehicles under 10,000 pounds to be equipped with technology that expands the driver's field of view to include a 10-ft by 20-ft area directly behind the vehicle (Office of the Federal Register, 2014); currently rearview cameras are the only technology that meet this requirement.

The information that cameras and sensor systems provide about areas visible and invisible in traditional fields of view may change drivers' glance behavior. For instance, the image displayed from a camera and information from a sensor system are sometimes displayed in the center console or instrument panel away from mirrors or windows, where drivers have usually looked during low-speed maneuvers in the past. Information from the camera and sensor system also overlap to some extent with what can be seen in the vehicle's mirrors or through its windows. Drivers may glance at the mirrors or through the windows less because they believe these views do not provide any additional information beyond what cameras or sensor systems provide. Alternatively, drivers may prioritize using a camera or sensor system over using mirrors or glances because these technologies provide information about the areas immediately behind the vehicle, which are not visible in mirrors or through windows and may be perceived as most pertinent to low-speed maneuvers.

Several studies have noted changes in drivers' use of mirrors or glances through the windows during low-speed maneuvers when they have a camera or sensor system compared with not having the system. Rudin-Brown et al. (2012) reported that experienced users of a rearview camera system or sensor system used the vehicle side mirrors less during a set of staged parking maneuvers compared with when these systems were off. Similarly, McLaughlin et al. (2003) found that among drivers who performed five parking tasks with and without technology, drivers looked at the driver side mirror for a significantly shorter period of time when they had a camera than when they did not have a camera. Kim et al. (2012) also found that, on average, drivers with a review camera, either in the center console or inset in the rearview mirror, spent less time looking at their mirrors compared with drivers without a camera. In a telephone survey of early adopters of cameras and sensors, one in five owners of vehicles with a sensor system reported that they look over their shoulder less often than they would if they did not have the technology (Jenness et al., 2007). In contrast, Mazzae et al. (2008) found no evidence that drivers whose vehicles had a camera or a camera and sensor combination had different glance patterns than drivers without technology during low-speed maneuvers performed over 4 weeks of daily driving.

Although cameras and sensor systems can help drivers see areas directly behind the vehicle, the systems have limitations. For instance, most rearview cameras provide an expansive view of the area behind the vehicle but do not show the sides or rear corners of the vehicle, which are visible in the side mirrors. Additionally, objects in the camera image may be hard to perceive if the image size in the display is too small (Satoh et al., 1983) or if the image is degraded or obscured (e.g., dirt covering the camera lens, low contrast). Sensor systems can detect objects immediately behind the vehicle and notify an unaware driver using visual or audible warnings, but these systems do not reliably detect every object, have a limited range, and drivers may only respond to the warning if they see what is causing it (Mazzae and Garrott, 2006). Furthermore, sensor systems have performance limitations and may not detect objects if drivers reverse too fast (Llaneras et al., 2005).

Past research has noted changes in drivers' glance behaviors when they have a rearview camera or sensor system during low-speed maneuvers, but it is unclear if these changes are similar across cameras, sensors, and the combination. Given recent rule-making it appears that most if not all vehicles will have rearview cameras, so it is important to understand how this and other parking aids influence glance behavior. Such information is important because there may be negative safety outcomes if any changes in glance patterns result in reduced awareness of the vehicle's surroundings or do not take into account the limitations of the technology. The purpose of this study was to characterize the glance behavior of experienced users of a camera, sensor system, or both technologies and drivers who do not use these technologies. Specifically, experienced users of a camera, sensor system, or both technologies were expected to use their mirrors and look over their shoulder less frequently, on average, during low-speed maneuvers than drivers without these technologies.

2. Method

2.1. Participants

Data used for this analysis come from 111 drivers (55 men, 56 women) who participated in a study on the effectiveness of a camera, a sensor system, and both technologies combined for preventing a collision with an unexpected stationary or moving object in the backing path (Kidd et al., 2015). Participants were licensed drivers recruited from the Dynamic Research, Inc. (DRI) participant database. Participants were 18–58 years old with a mean age of 36 years (*SD* = 11), had primarily driven a sport utility vehicle (SUV) for the past 6 months, and reported driving at least 7000 miles per year.

2.2. Study location and vehicle

The study was conducted in an outdoor public parking lot at the StubHub Center in Carson, California. Testing took place during the daytime when a major event was not taking place at the StubHub Center and there was no precipitation. The parking lot was closed to vehicular traffic during testing.

Participants drove a 2013 Chevrolet Equinox LTZ with safety and navigation packages. This vehicle was selected in part because its visibility reflected the average visibility among a group of six 2013 mid-size SUVs measured in Kidd and Brethwaite's (2014) study. The Equinox was equipped with a rearview camera system and an ultrasonic rear parking sensor system. The rearview camera's angle of view was 130°. The camera image was displayed on a 7-in. diagonal-width screen in the center console. Guidelines designed to help the driver align the vehicle were not displayed on the screen. The vehicle's owner manual stated that the rear parking sensor system could detect objects up to 8 feet behind the vehicle, but a functional test performed by Kidd and Brethwaite (2014) found that the system detected a 42.7-in. tall by 4.5-in. wide cylinder only up to 5 feet behind the rear bumper. The rear parking sensor system beeped when objects were detected behind the vehicle. The frequency of beeps increased as the distance between an object and the vehicle decreased and became a steady tone when an object was less than 1 ft away. A visual symbol was displayed in the camera display to supplement the auditory warning. It was a yellow triangle with an exclamation mark inside that increased in size and changed from yellow to red as the vehicle moved closer to an object. The triangle was located in the approximate location where a detected object was shown in the camera image.

2.3. Study design

Participants were assigned to one of four backing technology conditions (no-technology, sensor, camera, camera-plus-sensor) based on the backing technology in their current vehicle or past experience with a sensor system. Specifically, 16 participants (eight males) without any backing technology in their SUV were assigned