Accident Analysis and Prevention 66 (2014) 158–167

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Visibility of children behind 2010–2013 model year passenger vehicles using glances, mirrors, and backup cameras and parking sensors

David G. Kidd*, Andrew Brethwaite

Insurance Institute for Highway Safety, 1005 N. Glebe Rd., Arlington, VA 22201, USA

ARTICLE INFO

Article history:
Received 12 August 2013
Received in revised form 6 January 2014
Accepted 13 January 2014

Keywords:
Rear visibility
Blind zone
Backup camera
Rear parking sensor

ABSTRACT

This study identified the areas behind vehicles where younger and older children are not visible and measured the extent to which vehicle technologies improve visibility. Rear visibility of targets simulating the heights of a 12–15-month-old, a 30–36-month-old, and a 60–72-month-old child was assessed in 21 2010–2013 model year passenger vehicles with a backup camera or a backup camera plus parking sensor system. The average blind zone for a 12–15-month-old was twice as large as it was for a 60–72-month-old. Large SUVs had the worst rear visibility and small cars had the best. Increases in rear visibility provided by backup cameras were larger than the non-visible areas detected by parking sensors, but parking sensors detected objects in areas near the rear of the vehicle that were not visible in the camera or other fields of view. Overall, backup cameras and backup cameras plus parking sensors reduced the blind zone by around 90 percent on average and have the potential to prevent backover crashes if drivers use the technology appropriately.

1. Introduction

Backover crashes can result in severe and fatal injuries to pedestrians or people standing behind the vehicle. Based on data from the Not-in-Traffic Surveillance (NiTS) system, the Fatality Analysis Reporting System, and the National Automotive Sampling System General Estimates System, an estimated 18,000 injuries and 292 fatalities occur each year due to backover crashes (Austin, 2008). About 2000 of these injuries were estimated to involve children younger than 5. Children are at a higher risk of being involved in a backover crash because their shorter stature makes them harder to see.

One factor that contributes to backover crashes, especially those involving children, is vehicle rear visibility. Rear visibility is typically worse in larger vehicles like trucks and SUVs compared with passenger cars. Consumer Reports (2012) measured the distance from the vehicle's rear bumper to the location where a cone 28 in. tall was first observed by drivers 5 ft, 1 in. and 5 ft, 8 in. tall using glances over the right shoulder. The 28-in. cone was used to approximate the height of a 1-year-old child. For the 5-ft, 1-in. driver, the average rear sight distance was longest for pickups and shortest for minivans. Pickups also had the longest rear sight distance for the 5-ft, 8-in. driver, and midsized sedans had the shortest.

The National Highway Traffic Safety Administration (NHTSA) assessed rear visibility in passenger vehicles using a human driver (Mazzae and Garrott, 2008) and a laser-based measurement system (Mazzae, 2013; Mazzae and Barickman, 2009). The primary measure was blind zone, defined as the area behind the vehicle that was not directly visible using glances over the shoulder or through side windows, indirectly visible using side mirrors and the rearview mirror, or some combination of these fields of view. The blind zone for a 1-year-old child-size object was typically larger for large pickup trucks, cargo vans, and SUVs than it was for passenger cars.

Given that rear visibility is poorer in larger vehicles than smaller vehicles, it is not surprising that larger vehicles are more frequently involved in backover crashes involving children. Pinkney et al. (2006) examined police crash reports in Utah from 1998 to 2003 for crashes involving children younger than 10 struck on a residential driveway. The children were 53 percent more likely to be injured by a pickup truck than a passenger car, relative to registrations of each vehicle type, and 141 percent more likely to be injured by a minivan than a passenger car. They also were more likely to be injured by an SUV than a passenger car, but this difference was not statistically significant.

Mazzae and Garrott (2011) performed a Monte Carlo simulation using data from a naturalistic study of backing maneuvers to estimate the probability of a reversing vehicle striking a pedestrian moving at a constant speed and direction behind the vehicle. The probability of a backover crash was highest when the pedestrian's

* Corresponding author. Tel.: +1 703 247 1642; fax: +1 703 247 1587.
E-mail address: dkidd@iihs.org (D.G. Kidd).

0001-4575/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.aap.2014.01.006

starting position was immediately behind the rear bumper and decreased as the starting location moved away from the rear bumper. A simulated crash occurred in 40 percent or more of the simulated trials where the pedestrian's starting position was located up to 15 ft directly behind the rear bumper. This area is typically not visible to a 50th percentile male driver using mirrors or glances over the shoulder in most vehicles.

Backing technologies like ultrasonic parking sensors and backup cameras can enhance visibility and detection of objects behind the rear of the vehicle and help prevent backover crashes. Ultrasonic parking sensors detect objects behind the vehicle by emitting ultrasonic sound waves from the rear of the vehicle. If an object is present, the wave reflects off the object and returns to the vehicle where it is detected by a sensor. Distance and location information is relayed to the driver with a visual display and/or auditory tone. A disadvantage of parking sensor systems is that they have limited detection range. One study reported that owners typically turned sensor systems off because they were not reliable (Mazzae and Garrott, 2006). Drivers who reverse too fast may also exceed the functional capabilities of sensor systems, rendering them useless (Llaneras et al., 2005). Finally, one study found that sensor systems had difficulty detecting pedestrians, especially moving children (Mazzae and Garrott, 2006).

Backup cameras display the area directly behind the vehicle on a screen generally located in the vehicle center console or rearview mirror. Backup cameras are passive and do not alert drivers about objects behind the vehicle. Thus, the driver must look at the display to detect and respond to obstacles. Some newer vehicles combine sensor-based systems and backup cameras.

Several organizations are working to encourage auto manufacturers to fit vehicles with backing technology. The Insurance Australia Group (IAG) (2013) rates vehicle rear visibility using a reversing visibility index. Ratings are based on the area where a laser positioned at the approximate eye location of a driver 70.1 in. tall and directed through the rear window is observed on a cylinder 23.6 in. tall in an area 5.9 ft wide and 49.2 ft long behind the vehicle (Paine et al., 2003). Vehicles are awarded up to 5 stars based on the area of the test grid where the child-sized cylinder is visible, and an extra 0.5 star is awarded to vehicles with backing technology.

In the United States, NHTSA has proposed rulemaking to require manufacturers to provide drivers a way to see seven cylinders 32 in. tall placed along the perimeter of an area 10 ft wide by 20 ft long directly behind the vehicle when the vehicle is placed in reverse (Office of the Federal Register, 2010). NHTSA's proposed rule does not require a specific technology or any technology at all, but manufacturers' appear to be adopting technological solutions rather than changing vehicle design. Currently, backup cameras are the only technology that will meet the proposed minimum visibility requirements.

To date, assessments of rear visibility have been limited to objects reflecting the height of a 1- or 2-year-old child. Young children represent the "worst case scenario" for rear visibility, but older children are also involved in backover crashes. A study using the Canadian Hospitals Injury Reporting and Prevention Program database found that, between 1993 and 2004, about 12 percent of pedestrian-motor vehicle collisions involving children younger than 5 were backovers (Nhan et al., 2009). Backovers accounted for 4 percent of pedestrian-motor vehicle collisions involving 5–13 year-olds.

The improvement in rear visibility and detection of objects behind the rear bumper provided by different technologies has not been systematically evaluated in different vehicles. The purpose of the current study was to characterize rear visibility for 12–15-, 30–36-, and 60–72-month-old children in 2010–2013 model year passenger vehicles, and measure the additional visibility provided by backup cameras for each age group and areas where each age group was not visible but detected by parking sensors. The image size of vehicles' backup camera displays was also examined to determine whether current camera systems meet the functional requirements proposed by NHTSA.

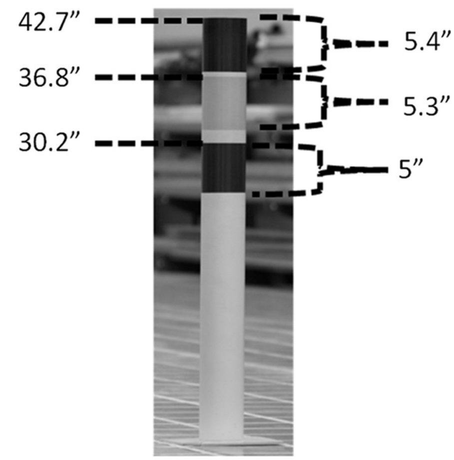

Fig. 1. Visual target and dimensions.

2. Method

2.1. Vehicle sample

Twenty-one 2010–2013 model year passenger vehicles with a backing camera system or a backing camera and rear parking sensor system were evaluated (Table 1). Candidate vehicles were limited to the manufacturers and models available at dealerships in the Charlottesville, Virginia, area. Efforts were made to include 2012 models with the largest sales volumes. At least two vehicles in each of eight vehicle classes were included.

2.2. Target and measurement field

The visual target was a cylinder 42.7 in. tall and 4.5 in. wide (Fig. 1). Three different color bands were painted onto the cylinder. The distance from the bottom of the cylinder to the top of each color band corresponded with the 50th percentile standing heights of a 12–15-, 30–36-, and 60–72-month-old child (Tilley, 2002). The standing heights simulated by the visual target were 30.2, 36.8, and 42.7 in. for each age group, respectively. The height of each color band corresponded with the average head width of a 50th percentile child in each age group (Tilley, 2002). The heights of the color bands simulating the head heights of a 12–15-, 30–36-, and 60–72-month-old child were 5, 5.3, and 5.4 in., respectively.

Visibility from various direct and indirect fields of view was measured using a measurement field 20 ft wide that extended longitudinally 5 ft in front of the rear bumper and 70 ft behind the rear bumper of each vehicle. The measurement field was divided into 1- by 1-foot squares using 1-in. wide tape adhered to a flat concrete surface. Six different fields of view were measured and included the (a) left side mirror, (b) right side mirror, (c) rearview mirror, (d) glances over the right shoulder, (e) areas visible in the backup camera display, and (f) areas detected by the rear parking sensor system. Visibility for the three target heights using each field of view was assessed at each square in the measurement grid. Only visibility judgments made at or behind the rear bumper are reported in the current study.