EVALUATION OF THE PERFORMANCE OF AVAILABLE BACKOVER PREVENTION TECHNOLOGIES FOR LIGHT VEHICLES

Elizabeth N. Mazzae
W. Riley Garrott
National Highway Traffic Safety Administration
United States
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ABSTRACT

In response to Section 10304 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the National Highway Traffic Safety Administration (NHTSA) conducted a study of existing backover prevention technologies for light vehicles. The objective was to assess how well current, commercially-available backover prevention technologies perform in detecting objects, particularly small children. Eleven available backover avoidance technologies were identified and examined. The object detection performance of sensor-based systems was measured using a set of test objects in both static and dynamic conditions. Visual systems, including rearview camera systems and cross-view mirrors were examined to determine their field of view and subjectively estimate the clarity of the image they provide of the area behind the vehicle.

Sensor-based systems generally exhibited poor ability to detect pedestrians, particularly children, located behind the vehicle. Systems' detection performance for children was inconsistent, unreliable, and in nearly all cases quite limited in range. Based on calculations of the distance required to stop from a particular vehicle speed, detection ranges exhibited by the systems were not sufficient to prevent many collisions with pedestrians or other objects.

The rearview video systems examined had the ability to show pedestrians or obstacles behind the vehicle and provided a clear image of the area behind the vehicle in daylight and indoor lighted conditions. While the auxiliary mirror systems tested also displayed any rear obstacles present, their fields of view covered a smaller area behind the vehicle than did the video systems tested, and the displayed images were subject to distortion caused by mirror convexity and other factors (e.g., window tinting) making rear obstacles more difficult to recognize in the mirror. In order for visual backing systems to prevent crashes, drivers must look at the video display or auxiliary mirror, perceive the pedestrian or obstacle, and respond correctly.

INTRODUCTION

To assess the performance capabilities of existing, commercially-available, systems designed to detect obstacles present behind a backing light vehicle, the following testing was performed:

1. Static field-of-view measurements for selected backover avoidance sensor-based systems based using a variety of test objects.
2. Repeatability of static field-of-view measurements for selected backover avoidance sensor-based systems using three test objects.
3. Dynamic range measurements for selected backover avoidance sensor-based systems using a limited set of test objects.
4. Response time measurements for selected backover avoidance sensor-based systems.
5. Field-of-view measurements for selected rearward pointing video cameras.
6. Field-of-view measurements for selected auxiliary mirrors designed to augment driver rearward visibility.
7. Measurements of the blind spot behind the vehicle for selected contemporary vehicles.

AVAILABLE TECHNOLOGIES FOR AIDING DRIVERS IN DETECTING REAR OBSTACLES DURING BACKING MANEUVERS

According to a recent NHTSA-sponsored effort to document advanced technologies for passenger vehicles [1], in 2006 there were 31 vehicle manufacturers (vehicle makes) and 100 different model lines offering object detection systems sold as “parking aid” systems and/or rearview cameras in the U.S. market. Twenty-six of the model lines offer a parking aid system and/or rearview camera as standard equipment. These systems are intended to aid drivers in performing low-speed (typically at or below 3 mph) backing and parking maneuvers by providing some form of signal (typically an auditory tone) to indicate the presence of, and distance to, obstacles behind the vehicle.

In surveying the various technologies available, it was noted that all systems offered by original equipment (OE) manufacturers were advertised as “parking aids” rather than safety systems, while aftermarket systems were marketed as safety systems with the ability to warn drivers of children present behind backing vehicles. While the OE parking aid systems do not purport to detect pedestrians, they were included in this testing to fully address the congressional directive requesting an examination of “available technologies for detecting people or objects behind a motor vehicle” [2]. Furthermore, examining available parking aids allows NHTSA to inform consumers about their capabilities and permits comparison of their performance with aftermarket systems utilizing similar technology.

Both sensor-based systems and visual systems require the attention and the appropriate response of the driver in order to succeed in achieving crash avoidance. Systems that are purely visual are passive, in that the driver has to look at the display, perceive the object(s) displayed in it, and then take action to avoid backing into the object. Sensor systems are somewhat active in that they draw the driver’s attention to the presence of an object behind the vehicle that they might not have seen. Systems can be designed to be even more active using automatic braking to slow the vehicle if a rear obstacle is present. Thus, the different types of systems can require different levels of effort from the driver to avoid a crash. Figure 1 illustrates in a timeline fashion the steps in detecting and avoiding a rear obstacle as a function of system type.

Sensor-Based Technologies

There are two main technologies used for sensor-based backing systems: ultrasound and radar. Radar technology can be further subdivided into sensors that use the Doppler effect to detect the presence of objects and those that use frequency modulated continuous wave radar to determine the position of objects relative to the sensor.

Ultrasonic object detection systems emit a burst of ultrasonic (a typical frequency is 40 kHz) sound waves backward from the vehicle. Objects struck by the sound waves reflect them, creating an “echo.” The amplitude of the echo depends upon the reflecting material, shape and size [3]. Since sound travels at approximately 1,100 feet per second in room temperature air, the time from the emission of the sound waves to hearing the echo can be used to determine the distance to the reflecting obstacle.

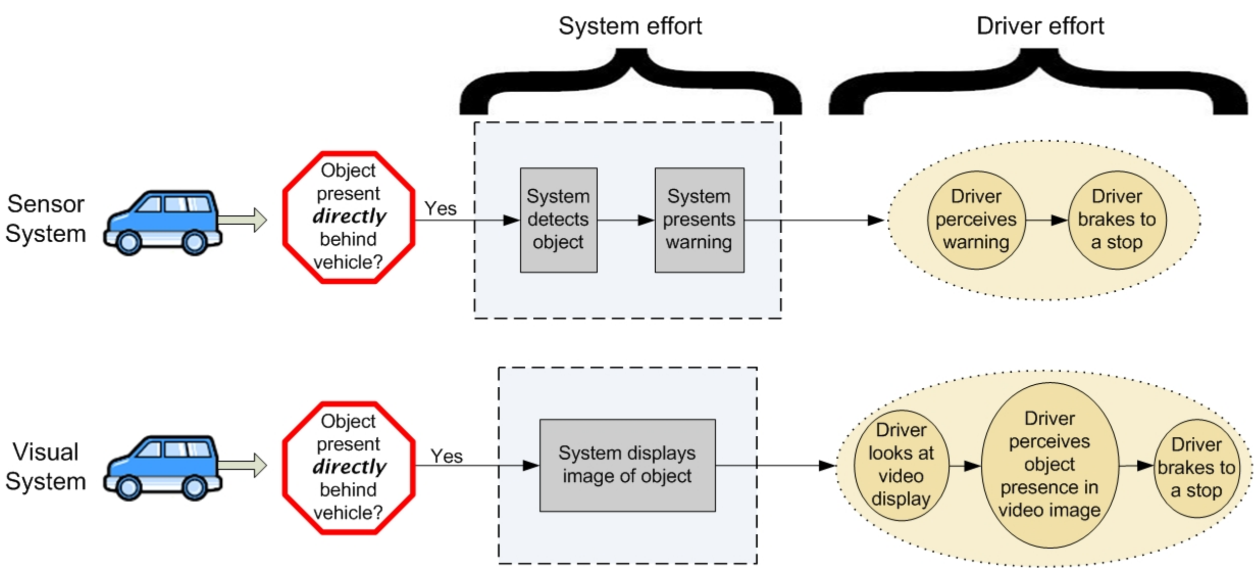

Figure 1. Steps to detecting and avoiding rear objects as a function of system type.

Ultrasonic object detection systems are available as original equipment on a large range of vehicles. They are also available as an aftermarket product. Prices range from approximately $56 to $400 (equipment only, installation additional). Systems typically consist of two to six ultrasonic sensors, a driver interface, and the necessary wiring.

Radar sensors come in two varieties for short-range, vehicle-based applications. One type of radar sensor uses the Doppler effect to detect the presence of objects that are moving with respect to the vehicle (i.e., if the vehicle is stationary, then the object must be moving to be detected, if the vehicle is moving then the object must either be stationary or moving at a different velocity than the vehicle to be detected). The difference in relative velocities changes the frequency of the reflected radar waves. The amount of frequency shift is proportional to the relative velocity difference. Note that Doppler effect radar systems cannot, in general, detect stationary objects while the vehicle is stationary. Doppler radar can determine relative velocities with high accuracy.

Doppler radar can also determine the distance to objects behind the vehicle. This can be done by changing the frequency of the emitted radar waves (the technique used by the Doppler radar sensor studied during this research) or by emitting multiple bursts of radar waves.

Doppler radar object detection systems are available for aftermarket installation at prices ranging from approximately $200 to $300. The system for a vehicle will consist of a Doppler radar sensor, a driver interface, and the necessary wiring.

A second type of radar sensor uses frequency modulated continuous wave radar to determine the position of obstacles relative to the vehicle. This technology can detect objects that are not moving relative to the vehicle and gives a more accurate measurement of distance to an object than does Doppler radar. The ability to detect objects that are not moving relative to the vehicle is both an advantage and a disadvantage; it is advantageous in that it gives the ability to detect stationary objects behind the vehicle when the vehicle is not moving (think of a bicycle parked behind the vehicle) but a drawback in that the field of view of the system must be such as to avoid objects that are not a problem (e.g., the concrete of the driveway). Having to avoid objects that are not a problem tends to leave holes in the detection zone in which objects that should be detected will not be seen.

Frequency modulated continuous wave radar object detection systems are available as original equipment on a number of vehicles. The system for a vehicle will consist of one radar sensor, a driver interface, and the necessary wiring.

For both types of radar sensors, the detectability of objects within their field of view depends upon their radar cross section; the larger the radar cross section the more likely an object is to be detected. (For Doppler effect sensors, detectability also depends upon whether the object is moving relative to the sensor. Objects that are stationary relative to the sensor will not be detected.) The radar cross section of an object depends upon its size, geometry, and material composition. For example, large, angular, metallic objects have very large radar cross sections. On the other hand, some geometries and materials are virtually invisible to radar.

Visual Technologies

Visual technologies for detecting people and objects behind a backing vehicle include systems such as rear camera systems, and convex mirrors. These systems show the driver what is behind the vehicle, but unless coupled with sensor technology, do not alert the driver to any unseen obstacles.

Several models of aftermarket video backing aid systems were found to be sold on the internet for prices ranging from approximately $400 - $600 or more. These rear camera systems typically included small dashboard-mountable LCD displays, while a few were offered that included the LCD display as part of a replacement rearview mirror.

Rear-mounted convex mirrors, frequently called “cross-view mirrors” are available which seek to provide improved indirect rear visibility. The implementation examined during this study is one in which these mirrors are mounted at the inside, rear corners of the vehicle and face toward the centerline of the vehicle. These mirrors were found on one vehicle, a 2003 Toyota 4Runner, in which they were mounted at each rearmost pillar. We also examined an aftermarket convex mirror system called “ScopeOut” that sought to provide the driver with a view of vehicles approaching a backing vehicle at a perpendicular angle. Since a portion of the field of view of these mirrors covers the area directly behind the vehicle they were included in this study. The ScopeOut system literature stated that mirrors provided rear visibility by looking forward into the vehicle’s center rearview mirror, thus giving the driver additional information about what may be in the vicinity of the vehicle's rear without having to turn around to look. The inexpensive, aftermarket system mounted to the rear window glass using adhesive tape. Another implementation of rear-mounted convex mirrors, which is more commonly used for medium duty trucks (such as delivery trucks), is that of a single convex mirror mounted diagonally out from the left rear corner of the vehicle using an overhead bracket.

Systems Selected for Testing

Eight sensor-based systems were selected for examination: four original equipment systems and four aftermarket systems. One of each of the original equipment and aftermarket sensor systems included rearview video as part of the system. One original equipment rearview camera system was examined. Two mirror systems were examined: one original equipment system and one aftermarket system. Table 1 presents details of the systems.

Table 1. Backover Avoidance Systems

	System Type	System Name (Vehicle)	Technology	Number of Sensors	Display Type
OEM	Single-Technology Sensor	"Park Distance Control" (2006 BMW 330i)	Ultrasonic	4 sensors	LCD color graphical display, auditory alert
		Rear Sonar System (2005 Nissan Quest)	Ultrasonic	4 sensors	Auditory alert
	Multiple Technology	Extended Rear Park Assist (2005 Lincoln Navigator)	Ultrasonic/ Radar	2 ultrasonic, 1 radar	Auditory alert
		Ultrasonic Rear Parking Assist, Rear Vision Camera (2007 Cadillac Escalade)	Ultrasonic/ Video (integrated)	1 camera (Viewing angle not provided)	LCD color video, 3 LEDs, auditory alert
	Visual	RearView Monitor (2005 Infiniti FX35)	Video	1 camera (Viewing angle not provided)	LCD color video
		(2003 Toyota 4Runner)	Convex mirrors	2 mirrors	Located at rearmost pillars
After-market	Single-Technology Sensor	Poron "Mini3 LV Car Reversing Aid"	Ultrasonic	3 sensors	LED distance display, auditory alert
		Sense Technologies "Guardian Alert"	Doppler Radar, X-Band	1	LED, 3 colors
		Sense Technologies "Guardian Alert"	Doppler Radar, K-Band	2	LED, 3 colors
	Multiple Technology	Audiovox "Reverse Sensing System", "Rear Observation System"	Ultrasonic, Mini-CCD camera	4 sensors; 1 camera (Viewing angle not provided)	3 inch LCD display in rearview mirror
	Visual	Sense Technologies "ScopeOut"	Convex mirrors	2 mirrors	Mounted to inside of rear window

METHOD

Testing was conducted to measure a variety of aspects of object detection performance of sensor-based systems. Measurements included static field of view, static field of view repeatability, and dynamic detection range for a variety of test objects. The ability of systems to detect an adult male walking in various directions with respect to the rear of the vehicle was assessed. Sensor system detection performance was also assessed in a series of static and dynamic tests conducted using 1-year-old and 3-year-old children. Response time of sensor-based systems was also measured for a standard object.

An examination of rearview video and auxiliary mirror systems was also conducted. The examination consisted of field of view measurement and a subjective assessment of displayed image quality.

Test Objects for Sensor-Based Systems

How well a sensor system can detect a particular object depends on a variety of factors including the composition of the object, its shape, size, and distance from the sensor. The object detection capabilities of sensor-based backing systems were measured using a variety of "test objects" (e.g., traffic cones). Test objects of various heights, diameters, shapes, and a range of cross-sections were used to represent obstacles that a backing system may need to detect in the real world.

Human subjects, including 1-year-old and 3-year-old children as well as an adult male, also participated as "test objects." Protocols involving human subjects were approved by an independent institutional review board. Vehicles were stationary and secure during all test trials with pedestrians.

Table 2 presents the complete list of objects used in sensor performance testing conducted indoors and indicates whether the object was presented statically or dynamically. Table 3 presents similar information for tests conducted outdoors. All tests were conducted with the test objects oriented in an upright orientation (e.g., standing), except where noted.

Table 2. Sensor Test Objects and Test Type – Indoor Testing

TEST OBJECT	STATIC	DYNAMIC
Traffic cones (12, 18, 28, 36-inch)	X	
20-inch PVC pole	X	
40-inch PVC pole (per ISO 17386)	X	2, 3, 4 mph
20-foot PVC pole, horizontal	X (vertical test)	
Parking curb, plastic	X	
Hybrid III 3-year-old crash dummy (210-0000)	X	2, 3, 4 mph
CRABI 12-month-old crash dummy (921022-0000)	X	2, 3, 4 mph
Child, 3 years old	X	Walking, running, riding toy
Child, 1 year old	X	Walking, riding toy
Adult, male (6' 1", 190 lbs)	X (also laying on ground)	Walking (laterally, longitudinally, diagonally with respect to vehicle)

Table 3. Sensor Test Objects and Test Type – Outdoor Testing

TEST OBJECT	STATIC	DYNAMIC
Car backing straight to a 36-inch traffic cone		Slow (<5 mph)
Car backing straight to a car (Toyota Camry sedan)		Slow (<5 mph)
Car backing straight to a mild grass slope		Slow (<5 mph)
Car backing straight to a 17% concrete slope		Slow (<5 mph)
Cozy coupe (toy car)		2, 3 mph
Adult, male (6' 1", 190 lbs)	X	Walking (laterally, longitudinally, diagonally with respect to vehicle)

Traffic cones and poles were chosen as test objects since their conical and cylindrical shapes, when positioned vertically upright, present the same appearance to the sensors despite any rotation about their vertical axis. This quality renders them likely to achieve a more repeatable response in objective testing. This is likely the reason that a PVC pole was recommended as a test object in the International Standard's Organization's (ISO) Standard 17386, "Transport information and control systems – Maneuvering Aids for Low Speed Operation (MALSO) – Performance requirements and test procedures" [4]. The 40-inch "ISO pole" (pictured in Figure 2) was included in this testing to assess the performance of systems in detecting this object.

Figure 2. ISO Pole behind Nissan Quest test vehicle.

Another goal in test object selection was to investigate whether any object could be identified that would have a similar sensor system detection pattern to that of a child's. Identifying such an object would be useful in the development of any possible future performance measure for backover avoidance systems. Since conducting research involving human subjects requires detailed review and approval of test protocols, the availability of a suitable surrogate test object for a child would prove quite useful and more convenient. To this end, Anthropometric Test Devices (ATDs), or crash dummies were used to assess sensor system responses to them. The particular ATDs used in this testing included the Hybrid III Three-Year-Old child (H-III3C) dummy (height, 37.2 in.) and the Child Restraint/Air Bag Interaction (CRABI) dummy (height, 29.4 in.). The crash dummies are constructed from steel and rubber with fiberglass heads surrounded by polyurethane skins. For testing, the crash dummies were dressed in long-sleeved knit shirts and long knit pants typically worn for crash testing, as shown in Figure 3. Crash dummies were also fitted with knit hats to simulate hair, and the 3-year-old ATD was fitted with shoes. Children participating in testing also wore long sleeved shirts, long pants, and shoes.

Test objects that were too heavy to be moved repeatedly by hand or that were not self-supporting were suspended from above via monofilament line of 75 pound test connected to a modified engine hoist and boom fixture. The hoist was also used to suspend and stabilize movement of the ISO pole during dynamic testing.

Figure 3. Photographs of ATDs used in testing

Test Grid

Dimensioned floor grids facilitated measurement of the horizontal area in which objects were detected by sensors systems. The grids were comprised of 1 foot squares. The indoor grid was created using colored vinyl tape and was 60 by 50 feet. The 20 by 25 foot outdoor grid was painted on level, asphalt pavement.

Apparatus for Controlled-Speed Dynamic Testing of Sensor-Based Systems

For controlled-speed dynamic sensor system object detection tests, a pulley system was used to tow the hoist and boom fixture with suspended test object laterally behind the vehicle. The hoist was positioned such that it was outside the range of detection of the sensor system. A pulley system used weights, which were dropped by remote control, to cause a steel-braided cable to pull the hoist with attached test objects. Using this method, objects were moved at specific speeds across lines of the grid parallel to the vehicle's rear bumper.

Apparatus for Sensor-Based System Response Time Testing

Sensor system detection response time was measured using a remote-controlled fixture containing an aluminum plate that would pop up from the ground. The 20.25 in. by 35.5 in. plate was hinged to a plywood board that rested on the ground. The aluminum plate began in a horizontal position resting atop the plywood board. A spring was attached 14 inches up from the pivot point position on each side of the aluminum plate and to the plywood 3 inches before the pivot point. The plate was held down (with springs fully extended) prior to deployment using a latch. A solenoid was triggered by wired remote control to release the latch. When the cam was released it pushed the bottom of the aluminum plate upward, initiating the movement. The springs provided the force to move the plate into its deployed vertical position. Braided stainless steel cables connected the plywood plate to the back side of the aluminum plate to limit its travel. Testing was conducted indoors on a flat, level, concrete surface.

Instrumentation

All tests were recorded in digital video format with sound. These video data documented the test object's position with respect to the vehicle as well as the system's response to the object's presence (if any). A Sony TRV-90 digital video camera was mounted on a tripod positioned approximately 30 feet behind the test vehicle to capture a wide-angle view of objects' positions behind the test vehicle. A second, identical camera was located inside the vehicle to capture any visual and/or auditory warnings produced by the systems. System detection performance data were also recorded by hand.

Vehicle Preparation Procedure

Before testing, each test vehicle's tires were set to the manufacturer's recommended pressure and the fuel tank was filled to achieve a standard vehicle pitch. Backing system sensors were wiped to ensure they were free of dirt or other substance that might impact sensor performance.

Vehicles were tested with the engine off, but the transmission in reverse gear and the ignition on to provide power to the sensor system being tested. Conducting testing with the vehicle's engine off ensured the safety of test staff and participants, as well as eliminated the need to vent exhaust fumes. To prevent draining of the vehicle's battery, a 12 volt power supply was connected during testing. The power supply used was an Astron Model SS-30M.

RESULTS

Sensor-based systems generally exhibited poor ability to detect pedestrians, particularly children, located behind the vehicle. Systems' detection performance for children was inconsistent, unreliable, and in nearly all cases quite limited in range. Based on calculations of the distance required to stop from a particular vehicle speed, detection ranges exhibited by the systems were not sufficient to prevent collisions with pedestrians or other objects.

Findings For Sensor-Based Systems

- Sensor-based systems generally exhibited poor ability to detect pedestrians, particularly children, located behind the vehicle. Systems' detection performance for children was inconsistent, unreliable, and in nearly all cases quite limited in range. Testing showed that, in most cases, the detection zones of sensor-based systems contained a number of "holes" in which a standing child was not detected. The size of the pedestrian did seem to affect detection performance, as adults elicited better detection response than did 1-year-old or 3-year-old children.

- All eight of the systems could generally detect a moving adult pedestrian (or other objects) within their detection zone area when the vehicle was stationary. However, all of the sensor-based systems exhibited some difficulty in detecting moving children.

- The reliability (i.e., ability of systems to work properly without an unreasonable failure rate) of sensor-based systems as observed during testing was good, with the exception of one aftermarket, ultrasonic system that malfunctioned after only a few weeks, rendering it unavailable for use in remaining tests. In examining consistency of system detection performance, it was noted that all of the sensor-based systems tested exhibited at least some degree of day-to-day variability in their detection zone patterns. Results of static sensor-based system detection zone repeatability showed a range of performance quality. Inconsistency in detection was usually seen in the periphery of the detection zones and typically was not more than 1 foot in magnitude.

- Sensor-based systems typically have detection zone areas that only cover the area directly behind the vehicle. However, not all crashes involve pedestrians located directly behind the vehicle.

- A majority of systems tested were unable to detect test objects of less than 28 inches in height.

- While ultrasonic systems can detect stationary obstacles behind the vehicle when the vehicle is stationary, Doppler radar-based sensors, by design, cannot. Doppler radar-based sensors also cannot detect objects moving at the same speed and direction as the vehicle on which they are mounted.

- None of the systems tested had large enough detection zones to completely cover the blind spot behind the vehicle on which they were mounted. The sensor with the longest range of those tested could detect a 3-year-old child out to a range of 11 feet. The closest distance behind any of the six vehicles tested at which a child-height object could be seen by the driver, either by looking over their shoulder or in the center rearview mirror, was 16 feet.

- Response times of sensor-based systems ranged from 0.18 to 1.01 seconds. International Standards Organization (ISO) 17386 [4] contains a recommended maximum system response time of 0.35 seconds (measured using a PVC pole that enters the detection zone from above). Only three of the seven systems tested met the ISO limit. Given the observed sensor system response times, the ranges at which systems tested were able to detect children were insufficient to allow time to brake the vehicle to a stop prior to many collisions (assuming typical backing speeds; Huey, et al. [5] stated that only about 50 percent of the vehicles that back into pedestrians are traveling at speeds below 2.0 mph). Based on the analysis in that report [5], a system must have a range great enough to provide for a median maximum backing speed of at least 5 mph to provide sufficient time for braking to a stop before a collision.

- In order for sensor-based backover avoidance systems to assist in preventing collisions, the driver must perceive the warning generated by the system and respond quickly and apply sufficient force to the brake pedal to bring the vehicle to a stop. Time was not available in the context of this research to study drivers' tendency to respond appropriately to backing system warnings. However, a study sponsored by General Motors [6] raises questions as to whether the driver will respond quickly and with sufficient force applied to the brake pedal to bring the vehicle to a stop in response to a warning.

Visual System (Rearview Cameras and Auxiliary Mirrors) Findings

NHTSA also examined visual systems including rearview video camera systems and auxiliary mirror systems designed to augment driver rearward visibility. The examination of these systems included assessment of their field of view and potential to provide drivers with information about obstacles behind the vehicle.

Visual systems, unless combined with an object detection technology, only display what is behind the vehicle. The rearview video systems examined had the ability to display pedestrians or obstacles behind the vehicle clearly in daylight and indoor lighted conditions. While the auxiliary mirror systems tested also displayed any rear obstacles present, their fields of view covered a smaller area than did the video systems tested, and the displayed images were subject to distortion caused by mirror convexity and other factors (e.g., window tinting) making rear obstacles more difficult to recognize in the mirror.

Based upon this research, the following observations relating to the rearview video systems and auxiliary mirrors examined were made:

- Rearview video systems provided a clear image of the area behind the vehicle in daylight and indoor lighted conditions. The video systems showed pedestrians or obstacles behind the vehicle within a range of 15 or more feet and displayed a wider area than was covered by the detection zones of sensor-based systems tested in this study. The range and height of the viewable area differed significantly between the two OE systems examined. In addition to the limited field of view, the limited view height of one system seemed to complicate the judgment of the distance to rear objects.

- In order for rearview video systems to assist in preventing backing collisions, the driver must look at the video display, perceive the pedestrian or object in the display, and respond quickly and with sufficient force applied to the brake pedal to bring the vehicle to a stop. The true efficacy of rearview video systems cannot be known without assessing drivers' use of the systems and how drivers incorporate the information into their visual scanning patterns. Determining typical drivers' interactions with rearview video systems would require complex human factors testing. Sufficient time was not available to perform such testing in the context of this research. However, two studies sponsored by General Motors raise questions regarding whether rearview video is adequate to prevent drivers from colliding with pedestrians or obstacles behind the vehicle.

- The examination of rearview auxiliary mirror systems revealed that neither of the two systems tested fully showed the area directly behind the vehicle. Both mirror systems had substantial areas directly behind the vehicle in which pedestrians or objects could not be seen.

- Visually detecting a 28-inch-tall traffic cone behind the car using the rearview auxiliary mirrors proved to be challenging for drivers. The convexity of the cross-view mirrors caused significant image distortion making reflected objects difficult to discern. Concentrated glances were necessary to identify the nature of rear obstacles. A hurried driver making quick glances prior to initiating a backing maneuver may not glance long enough to allow them to recognize an obstacle presented in the mirror.

DISCUSSION

In order to fully estimate the benefits obtainable from implementation of backover avoidance systems, it is necessary to have an idea of how drivers will use the systems and the rate of their compliance with system warnings. It is not known whether drivers will interact effectively with backing aids such that a reduction in crashes will occur with implementation of these systems. Additional research is needed to confirm whether drivers' trust of sensor-based systems is irreparably problematic. Also warranting examination is how drivers incorporate the information presented by sensor-based or visual systems into their visual scanning patterns.

CONCLUSIONS

In summary, results showed that the performance of ultrasonic and radar parking aid and aftermarket backing systems in detecting child pedestrians behind the vehicle was typically poor, sporadic (i.e., exhibiting many "holes" and variability), and limited in range. Based on calculations of the distance required to stop from a particular vehicle speed, detection ranges exhibited by the systems tested were not sufficient to prevent collisions with pedestrians or other objects given a vehicle backing at typical speed [7]. While the sensor-based systems tested showed some deficiencies, particularly in detecting small pedestrians, it may be possible to improve system performance and detection range.

The rearview video systems examined had the ability to show pedestrians or obstacles behind the vehicle and provided a clear image of the area behind the vehicle in daylight and indoor lighted conditions. While the auxiliary mirror systems tested also displayed any rear obstacles present, their fields of view covered a smaller area than did the video systems tested, and the displayed images were subject to distortion caused by mirror convexity and other factors (e.g., window tinting) making rear obstacles more difficult to recognize in the mirror. In order for visual backing systems to prevent crashes, drivers must look at the video display or auxiliary mirror, perceive the pedestrian or obstacle, and respond correctly.

Additional details on this research can be found in a recently published NHTSA report titled, "Experimental Evaluation of the Performance of Available Backover Prevention Technologies" [8].

Future Research Plans

This testing showed that, while current rear-object sensing technologies may perform adequately as parking aids, none of the sensor technologies examined, in their current forms, seemed adequately capable of preventing backover crashes with pedestrians. Rearview video systems display objects behind the vehicle, but require effort from the driver to check the visual display and discern whether any obstacles are present. Additional research and development is needed to develop an effective pedestrian backover countermeasure system. To this end, NHTSA plans to continue to investigate ways to reduce the incidence of backover crashes and to encourage industry to continue its research and development activities in this area. NHTSA's efforts will include further examination of crashes, investigation of technology improvements, investigation of the feasibility of development of objective tests and technology-neutral performance specifications for backing safety systems, and assessment of drivers' use of backing system technologies (e.g., rearview video systems).

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