INTRODUCTION

In December, the U.S. National Highway Traffic Safety Administration (NHTSA) is scheduled to finalize a rule requiring backup camera systems and related displays on all new light vehicles sold in the U.S. The mandate comes as a result of the Kids Transportation Safety Act, which was signed into law in 2008, requiring new autos sold in the U.S. to provide a means to increase the driver’s field-of-view while backing, and reduce backover accidents. NHTSA determined that a backup camera and related display are the only way to meet that requirement.

According to NHTSA data, every year in the U.S., more than 225 fatalities and 17,000 injuries occur from accidents in which a vehicle moving in reverse strikes a pedestrian or cyclist. Often these tragedies involve small children struck while playing in their driveway or somewhere near their home. The proposed regulations aim to reduce these accidents.

A typical backup camera system consists of a rearward-mounted camera and interior display that provides a view of the area directly behind the vehicle in order to help eliminate the rearward blind zone. The display is either located in the center console or in the interior rearview mirror.

Recent studies designed to evaluate the effectiveness of backup camera systems have suggested that they are effective at helping avoid pedestrians, and that the driver’s ability to avoid a surprise rearward accident can be improved when the display is located in the interior rearview mirror. Exponent sought to build on these studies by constructing a research project designed to, among other objectives:

- Learn more about how drivers use and interact with backup camera systems/displays.
- Identify how drivers incorporate backup camera displays into their typical scan patterns.
- Quantify driver display and mirror usage rates while performing backing maneuvers.
- Determine how quickly drivers identify and react to surprise rearward events in the backup camera display.

METHODOLOGY

The study was designed to compare and contrast the effectiveness of backup camera display locations according to six key sets of data:

1. Object Avoidance
2. Scan Pattern Behavior
3. Gaze Duration
4. Reaction Time
5. Display Usage
6. Driver Evaluation

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A total of 77 participants took place in the study. Each was pre-screened to ensure that they had limited experience using a backup camera system. Each participant drove one vehicle/one display type through a series of driving maneuvers that included four situational reversing tasks: backing into a parking stall, backing out of a garage, parallel parking and backing down a driveway. During the driver’s final situational reversing task, the vehicle backed over a hidden trip wire that introduced a dynamic, surprise event.
Study participants wore an eye tracking device designed to capture eye movement and record glance location, frequency and duration. In-vehicle cameras recorded video footage of each test subject. A computerized vehicle monitoring system recorded braking and acceleration data.

Study participants were not informed of the study’s goals/purpose.

**FINDINGS**

**OBSTACLE AVOIDANCE**

Previous obstacle avoidance studies used static surprise events (i.e. a traffic cone secretly placed behind the vehicle) that were visible in the display immediately upon putting the vehicle in reverse gear. This study used dynamic surprise obstacles triggered once the backover maneuver was underway, meaning that obstacle avoidance success rates were, in part, dependent on the driver’s ability to incorporate multiple display glances throughout the backing process.

- Drivers avoided the surprise event/obstacle 2-3 times more often when a rear camera display was available.
- Obstacle avoidance varied by display type, with the LD the least effective and the IMD and SD equally effective.
SCAN PATH AND GAZE

As noted previously, because of the dynamic nature of the surprise events, obstacle avoidance success rates were, in part, dependent on the driver’s ability to incorporate multiple display glances throughout the backing process. This, in turn, is dependent on the driver’s ability to incorporate display glances into their typical scan pattern.

Arrows indicate scan paths. Percentages shown specify the average amount of time drivers spent gazing at the indicated location as a percentage of the total time spent conducting a backing maneuver.

NO DISPLAY

- Drivers performing backup maneuvers without the aid of a backup camera display exhibited an oval-shaped scan pattern with minimal transitions to and from mirror locations.
- On average, drivers spend 26% of the time looking at their mirrors while conducting a backing maneuver.

IN-MIRROR DISPLAY

- The scan pattern of drivers using an IMD closely mimics that of a driver without a display and requires minimal scan pattern transitions.
- Drivers using an IMD spend 27% of the time looking at the display, and 15% of the time looking at their mirrors. Total productive gazes: 42%.

SMALL DISPLAY

- The scan pattern of drivers using a SD reveals a more complex scan pattern with additional transitions.
- Drivers using an SD spend 14% of the time looking at the display, and 20% of the time looking at their mirrors. Total productive gazes: 34%.

LARGE DISPLAY

- The scan pattern of drivers using a LD reveals a more complex scan pattern with additional transitions.
- Drivers using an LD spend 13% of the time looking at the display, and 15% of the time looking at their mirrors. Total productive gazes: 28%.
GAZE DURATION
The driver’s ability to avoid a potential rearward hazard is directly related to the amount of time spent utilizing the backup camera display and the ease to which the display can be incorporated into the driver’s typical scan pattern.

- Drivers in a vehicle with the IMD utilize it twice as much as those using other display locations.
- Drivers of the IMD made more “productive” glances (glances to mirrors and display) than those using other display locations.
- Drivers spent a similar amount of time gazing at mirrors across display types.
- Display viewing is critical, as it’s the only device showing what’s directly behind you.

OVER-THE-SHOULDER GLANCES
While over-the-shoulder glances can provide the driver with information useful for successfully completing certain backing maneuvers, because every vehicle has a large rearward blind zone, no amount of shoulder turn can provide a view directly behind the vehicle. Drivers using a shoulder turn as their primary means of backing minimize their ability to identify a potential hazard visible only in their backup camera display.

- Drivers in a vehicle with the IMD looked over their shoulder 51% less than drivers in a vehicle with ND.
- Smaller reductions of 26% and 10% by drivers in vehicles with the SD and LD, respectively, compared with ND.

DISPLAY USAGE
This study did not require users to use the backup camera display, but it did note the percentage of drivers who incorporated the display into their backing process.

- A vast majority of drivers aged 18-59 are likely to incorporate displays into their backing maneuvers.
- Older drivers tend not to use backup camera displays no matter which location they are in.
- More drivers used the IMD compared with any other display location:
  - 39% more compared with SD
  - 21% more compared with LD
- 100% of women who drove a vehicle with an IMD used it.

REACTION TIME
This study captured brake and acceleration data for each test participant. Reaction time was calculated as the difference between the time the obstacle appeared (triggered by the vehicle as it backed over a trip wire) and brake onset.

- Drivers in a vehicle with the IMD braked twice as fast after the appearance of the obstacle compared to other displays.
- At 3 mph, the IMD’s faster reaction time improves stopping distances:
  - 6.64 feet compared with the LD
  - 7.52 feet compared with the SD
SURVEY RESPONSES

As noted previously, each test participant drove one vehicle equipped with one display type/location. After each test subject completed the driving portion of the experiment, they were shown each of the remaining test vehicles and the respective location/operation of the other backup camera displays. A brief survey was then conducted.

**Which display location do you think would be the safest to view?**

- 60% of drivers chose the IMD as being in the safest location. Only 32% and 8% chose the LD and SD, respectively.

**Which display location do you think is the most intuitive location for the rear camera video?**

- 58% of drivers thought the IMD was the most intuitive location, compared to only 33% and 9% for the LD and SD, respectively.

**The rearview mirror display is a safety feature in the vehicle.**

- Participants believe the mirror display is a safety feature.

**Which display location do you think is the most intuitive location for the rear camera video?**

- Most drivers, regardless of the display type they used in the study, think the IMD is the most intuitive location for rear camera video.

**Do you think the mirror display is a logical location for other types of driver information? If so, what type(s)?**

- Participants believe the mirror display is logical place for safety and navigation information.
SUMMARY/CONCLUSIONS

The IMD is the only display location that consistently performed the best in all of the measured criteria. The in-mirror display is:

• used more than other display locations
• is effective at reducing collisions with unexpected obstacles
• allows drivers to react faster to surprise events identified in the display
• is more easily integrated into the driver’s typical scan pattern
• is perceived as being in a safer, more intuitive location than center console-based displays
• is perceived as a location for safety information

ABOUT EXPONENT

Exponent is an engineering and scientific consulting firm providing solutions to complex problems. Exponent’s multidisciplinary organization of scientists, physicians, engineers, and business consultants brings together more than 90 technical disciplines to address complicated issues facing industry and government today. The firm has been best known for analyzing accidents and failures to determine their causes, but in recent years it has become more active in assisting clients with human health, environmental and engineering issues associated with new products to help prevent problems in the future.

STUDY SPONSOR – GENTEX CORPORATION

Founded in 1974, Gentex Corporation (The Nasdaq Global Select Market: GNTX) is the leading supplier of automatic-dimming rearview mirrors and camera-based driver-assist systems to the global automotive industry. The Company also provides commercial smoke alarms and signaling devices to the North American fire protection market, as well as dimmable aircraft windows for the commercial, business and general aviation markets.

Based in Zeeland, Michigan, the international Company develops, manufactures, and markets interior and exterior automatic-dimming automotive rearview mirrors that utilize proprietary electrochromic technology to dim in proportion to the amount of headlight glare from trailing vehicle headlamps. More than half of the Company’s interior mirrors are sold with advanced electronic features, including displays, hands-free microphones, vision systems, interior lighting, and telematics components. More than 98 percent of the Company’s net sales are derived from the sale of auto-dimming mirrors to every major automaker in the world.

REFERENCES

2 Mazzae EN (2010). Drivers’ use of rearview video and sensor-based backing aid systems in a non-laboratory setting. NHTSA-2010-0162

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