

Considerations in HMI Design of a Reverse Braking Assist (RBA) System

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ABSTRACT

The Reverse Braking Assist (RBA) feature is designed to automatically activate full braking in a backing vehicle. When this feature activates, a backing vehicle is suddenly stopped or may slide to a stop. During this process, an understanding of the driver's behavior may be useful in the design of an appropriate human-machine-interface (HMI) for the RBA. Several experimental studies were done to examine driver behavior in response to an unexpected and automatic braking event while backing [1]. Two of these studies are reported in this paper. A 7-passenger Crossover Utility Vehicle was fitted with a rear-view camera, a center-stack mounted LCD screen, and ancillary recording devices. In the first study, an object was suddenly placed in the path of a backing vehicle. The backing vehicle came to a sudden and complete stop. The visual image of the backing path on the LCD prominently showed that an obstacle was present in the backing path of the vehicle. Concurrently, a continuous auditory alarm sounded to indicate the presence of an obstacle in the rear. Further, a warning text message 'CAUTION CHECK BEHIND' was flashed across the top quarter of the LCD screen. The same test vehicle was used in the second study. All test conditions in the second study were identical to those in the first study with the exception that no camera view of the reversing path of the test vehicle was provided to the driver. The textual and auditory warnings were identical in both studies. Results of the two studies show that the application of full and sudden braking during the backing maneuver caused the driver to immediately place their foot on the brake within approximately 0.8sec of RBA activation. Almost immediately after, the driver began to explore his/her visual environment to look for 'the threat'. In the absence of a visual image of the reversing path, and even though the auditory and textual warnings were continuously available to the driver, 25% of all participants backed over the obstacle in the rear. But when a visual image of the backing path was available to the backing driver, as in the first study, none of the test participants backed over the obstacle. These and additional results of eye gaze data are presented in more detail, and their implications for HMI design are discussed.

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INTRODUCTION

Young drivers, primarily, and even older drivers who go through driver training schools are taught that when backing their vehicle, they must look behind them prior to starting and during the reversing maneuver. Rotation of the upper body, head and eyes acts to complement the limited view provided by the rear-view and side mirrors during backing. However, the profile of many modern day vehicles is such that the immediate vicinity of a backing vehicle or the sudden appearance of an obstacle may not be visible to the driver at all times during backing. Vehicle based technologies are rapidly being adopted to assist the driver during backing, e.g. cameras that provide an image on a screen inside the vehicle of the area surrounding the vehicle, ultrasonic and proximity sensors that can be coupled to auditory or tactile buzzers or

visual warnings inside the vehicle to indicate the presence of an object or person in the backing path of the vehicle [2, 3]. The expectation is that the backing driver would take timely note of the hazard and respond appropriately. However, even with advanced technologies designed to help drivers backup their vehicles, backover accidents where a person is struck, and backing accidents where an object is struck, are not entirely preventable. Data being collected in the Strategic Highway Research Program 2-Naturalistic Driving Study (SHRP2-NDS) currently in progress may provide insight into the real-world performance of driver assistance provided by backing aid technologies. It is well understood that the availability of backing aids in vehicles affects driver backing behavior as recorded in eye gaze patterns, upper torso rotation, and accelerator and braking action [4]. Further, it

has also been reported that if an unexpected obstacle is behind and in the path of a backing vehicle and the driver does not have sensory confirmation of its existence, then the driver is unlikely to initiate immediate hard braking to bring the vehicle to a timely stop [5]. Even when the rear camera view is presented to the driver, collision avoidance with the unexpected obstacle is not certain [6], possibly because drivers do not fully utilize the available backing assist systems. The addition of audible or vibratory or visual warnings to the visual backup view appears to affect drivers' awareness of an impending collision [7, 8, 9]. But there is a decrease in drivers' compliance with warnings if there are false or inconsistent alarms [2].

Reverse Braking Assist (RBA) systems are designed to help the driver during backing. The system is based, in part, on the use of ultrasonic and proximity sensors to detect objects or persons in the immediate vicinity of a backing vehicle. When sensors detect that a backing collision is imminent, hard braking is automatically activated and the backing vehicle is momentarily brought to a complete stop. A sudden and largely unexpected activation of the brakes, the vehicle's sudden and rapid deceleration and brake pedal vibration give the impression to the driver that 'something' happened [1]. In-vehicle camera view of the rear, e.g. in center stack, or rearview mirror, is available to the driver for sensory (visual) confirmation. Also, an auditory alarm can provide a concurrent warning of the presence of an obstacle in the backing path. But it is unclear how the driver behaves or what s/he does when the vehicle is suddenly, unexpectedly and instantly brought to a complete stop. An understanding of driver behavior immediately following automatic brake activation while backing could be useful to determine some aspects of the requirements of the human-machine-interface (HMI) for an RBA system.

A series of experiments were conducted to understand driver behavior that is specific to sudden, full and automatic braking during backing [1]. An earlier paper reported on the first set of experiments in which driver backing behavior for a false braking event was observed [4]. In this paper, we report on a subsequent set of experiments in which driver behavior when backing was observed for sudden braking in the case when a rear camera view was available, and when no rear camera view was available.

METHOD

Two experimental studies were conducted. In both studies, test participants were asked to back out of a parking spot wherein their test vehicle was parked between two other (also parked) vehicles. Shortly after the test participant had begun to move backwards, their vehicle was brought to a sudden and complete stop with automatic braking. Each participant completed the test only once. In both studies, a true positive driving scenario was used, i.e. at warning onset, a surprise object (a 28-inch tall lime green cone selected for clear contrast on the center stack video display) was rapidly

pulled from behind an adjacent vehicle and positioned in the center, approximately 1 ± 0.5 ft behind the stopped vehicle's rear bumper. In both studies a video and data record was kept of the drivers' foot movements (i.e. on brake, on accelerator, neither, both), drivers' eye/head movements for the duration of the test, and CAN (controller area network) signals from the vehicle, including accelerator throttle percentage, brake pedal position, steering wheel angle, velocity, and transmission ('PRNDL') position. The difference in the two studies was in the type of in-vehicle visual information presented to the driver.

In study #1, the driver was presented with a camera view of the backing path. When an obstacle in the reversing path was detected, the camera view was superimposed with a text warning that appeared horizontally across the upper quarter of the screen that said "CAUTION CHECK BEHIND!!" This text warning remained displayed as long as there was an obstacle detected in the rear camera view and the vehicle was in 'Reverse'. Concurrently, an auditory tone sounded inside the vehicle. This tone is the (continuous) portion of the Ford Reverse Park Aid (RPA) solid warning alert that is activated when an obstacle in range is detected when a vehicle is backing. The RPA auditory alert was designed to continuously sound as long as the obstacle was behind the test vehicle, and the vehicle was in 'Reverse'.

In study #2, no camera view of the backing path was presented to the driver and the screen was blank. However, when an obstacle in the reversing path was detected, a text warning appeared horizontally across the upper quarter of the screen that said "CAUTION CHECK BEHIND!!" Concurrently, the same auditory tone sounded as in study #1. Further detail of the experiment is provided in the following sections.

Apparatus: The test vehicle for both studies was a 7-passenger Crossover Utility Vehicle equipped with a custom rear-view camera and rear-scene video display mounted on the center stack. The 800×480 , 7" color LCD rear-camera display showed a camera view of the rear scene when the transmission was shifted into Reverse. Because the RBA feature was not available in the test vehicle, an artificial braking strategy that emulated the feature was employed. The vehicle's brake module was programmed to activate full-braking capability to bring the vehicle to a sudden and complete stop when the vehicle had been moved approximately 10-12 ft. in reverse. This distance ensured that the test vehicle would partially clear the adjacent parked vehicles. The choice of backing speed was left to the discretion of each test participant.

A concurrent event notification was presented in a text banner displayed above the rear scene imagery on the center stack screen. The warning text ("CAUTION CHECK BEHIND!!") remained displayed as long as the vehicle transmission was in Reverse and an obstacle was in position behind the vehicle. The total duration of brake hold, as determined from previous studies, was 1.1 sec [1, 4]. One laptop was used for braking event control, presentation of the

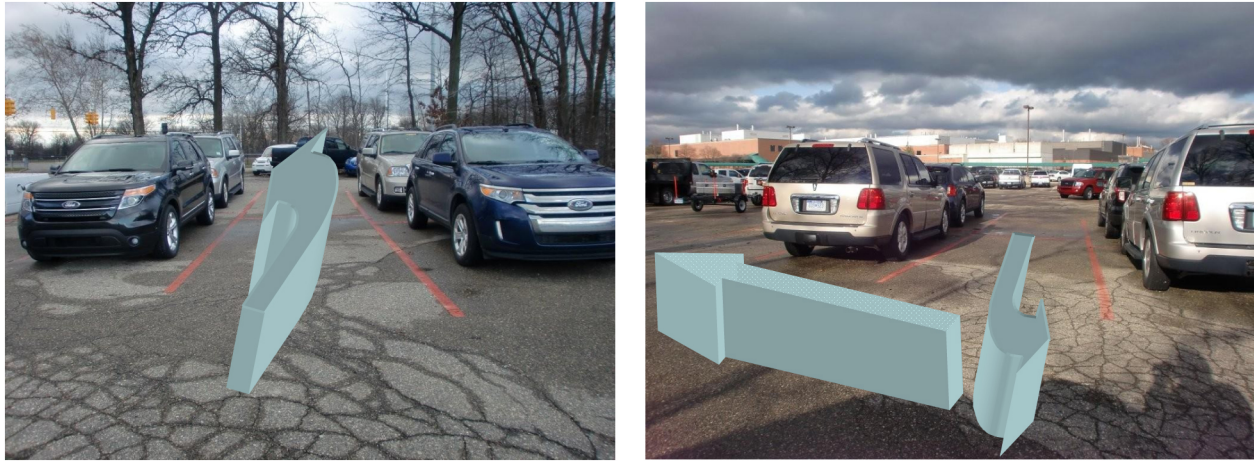


Fig. 1. Venue for Study

text message and auditory warning. A second designated laptop was used for data recording with CANAPE© and CANcase.

Participants: For study #1, data are reported on N=23 Ford Motor Company employee volunteers who had no prior knowledge of the experiment or the technology being tested, and were not part of active or passive safety product development. They participated as part of their normal workday. The sample included 17 males and 6 females between the ages of 23 and 60 years (mean = 44.2 years, standard deviation = 10.4 years). Six of the 23 participants (26%) had daily-use vehicles that were equipped with a rear-view camera.

For study #2, data are reported on N= 20 Ford Motor Company employee volunteers of whom 12 were male and 8 were female. They ranged in age from 29 years to 58 years. Data for one participant was not included in the final analysis due to a procedural error in the conduct of the experiment. The final sample comprised 19 participants, 11 males and 8 females. As in study #1, participants had no prior knowledge of the experiment or the technology being tested, and were not part of active or passive safety product development. Six of the 19 participants (31%) had daily-use vehicles that were equipped with a rear-view camera.

It is difficult to comment on how and to what extent data obtained from employee volunteers could be generalized to the wider driving public. However, the sample of volunteers covered a wide range in age and driving experience.

Venue: The test venue was an employee parking lot where the parking spaces were set for echelon parking, i.e., at an angle. Four vehicles were used to create the space within which the subject vehicle was maneuvered. These vehicles consisted of a Ford Edge, a Mercury Mariner, and two Lincoln Navigators, as seen in Fig. 1

PROCEDURE

In each study, the participant was escorted to the vehicle and seated. An informed consent form was signed. S/he was

told that the purpose of the study was to examine driver response to new in-vehicle safety technologies. S/he was told that the vehicle was equipped with a variety of active safety systems that could warn the driver as and when necessary. No specific indication was given that a prototype backing aid warning system was the focus of the testing. As part of the demographic intake, the participant was asked if s/he had used and/or was familiar with various active safety and convenience systems, e.g. blind spot detection, forward collision warning, automatic braking, adaptive cruise control, etc. The participant was told that s/he would be alone in the vehicle. The participant was then asked to back out of the parking spot, then drive some distance forward and meet up with the experimenter for the test.

In study #1, the driver backed out of the test vehicle parking spot. The rear view image was available on the center stack mounted LCD. When RBA activated, a 3-ft tall lime green traffic cone was rapidly pulled from behind an adjacent vehicle, and positioned in the center, approximately 1 ± 0.5 ft behind the stopped test vehicle's rear bumper. The cone was visible to the driver in the rear view camera display but was not visible in either the side or center mirrors. RBA activated for a period of 1.1sec and held the vehicle stopped. The auditory warning tone sounded. At the end of this period, the brakes were released but the warning text and auditory RPA tone were active for as long as the obstacle was behind the backing vehicle. After about 20-25 sec, the experimenter walked over to the stopped test vehicle, and debriefed the test participant. The total duration of the test, beginning with the intake and concluding with the debriefing, was about 15-18 min.

In study #2, the test procedure was identical to that in study #1. The only exception was that no camera image of the rear was available to the driver at any time. When RBA activated, only the text and auditory warnings were available to the driver, as long as the obstacle was in the path of rearward travel and the test vehicle was in 'Reverse'. The total duration of this test was about 18-20 min.