

Mechanisms of Automatic Transmission Console Shift Selection and Driver Egress

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ABSTRACT

Inadvertent vehicle movement incidents, in which a vehicle rolls away after the driver has exited, may occur in automatic transmission vehicles as a result of environmental, vehicular, and/or driver factors. Some explanations have focused on claimed potential malfunctions or design flaws in the vehicle's console shift mechanism or in the automatic transmission itself. However, growing evidence suggests that driver errors unrelated to vehicle design may in fact be the primary cause of many inadvertent vehicle movement incidents. The present research extends previous work on driver gear-shifting behaviors and vehicle egress by conducting more in-depth analyses of data collected by Harley et al. (2008). First, timing characteristics of shifts into Park measured under hurried conditions were not affected by the presence of driver distraction, further evidence that gear shifting is not a visually-guided process, but rather a ballistic movement that is preplanned and, once initiated, cannot be modified or terminated until the planned action has been completed. Second, a noteworthy mode of vehicle exit reported by Harley et al. (2008) wherein the driver's foot remains on the brake during egress, was found to be associated with rapid vehicle exit times. Such egress patterns may combine with other driver errors (e.g., failure to shift into Park, failure to set the parking brake, and failure to remove the key from the ignition before exiting the vehicle) to allow

inadvertent vehicle movements in which the driver is unable to safely regain control of the vehicle.

INTRODUCTION

Accidents involving inadvertent vehicle movement, in which the vehicle rolls away after the driver has exited, have been reported to cause property damage and personal injuries to the driver, passengers or bystanders. Drivers involved in these accidents often claim that the vehicle "jumped" or "slipped" from Park into another gear and subsequently rolled away. This description of the events often suggests that the proximate cause of such accidents is a claimed malfunction or design flaw in the vehicle. For example, some have alleged that the design of the gearshift mechanism and/or transmission allows the driver to place the gearshift lever between the Reverse and Park detents while attempting to shift into Park. Because it is not fully engaged in the Park detent, the claim is that the gearshift lever allegedly "slips" into Reverse after the driver has exited the running vehicle.

Alternate explanations, based on non-vehicular factors, have also been proposed. As reported in Harley et al. (2008), an informal survey of North Carolina traffic accidents that occurred between 2000 and 2003 turned up at least 90 reports of rollaway incidents. These incidents occurred in vehicles of varying make and model, suggesting that the driver, rather than the vehicle, may be the primary cause of many inadvertent

vehicle movement incidents. One explanation of these accidents is that the driver forgets to shift into Park before attempting to exit the vehicle. Depending on the condition of the vehicle, slope or other environmental factors of the terrain, and the driver's egress pattern, the driver may not realize that the vehicle is in gear until he or she has exited the vehicle and cleared the door. Understanding the process by which a driver secures and exits a vehicle may therefore be an important consideration in evaluations of inadvertent vehicle movement accidents.

Few researchers have empirically examined how typical driver gear-shifting behaviors and egress patterns may contribute to rollaway incidents. Harley et al. (2008) measured the forces that thirty adult drivers applied to a floor-mounted automatic gearshift lever while driving on a closed course. At discrete intervals during the driving task, participants performed a secondary task that required them to secure (i.e., shift into Park) and then exit the vehicle. On select trials, participants were induced to hurry, and distractions were introduced during the driving task. The authors found that even during hurried and distracted trials, drivers shifted into Park using a ballistic movement (i.e., a movement that, once initiated, cannot be modified or terminated until after the planned action has been completed), relying on the kinesthetic feedback from the lever hitting the mechanical stop at the end of the Park gate to determine when they had reached the Park position. In none of the over 900 shifts into Park did a participant stop short of the Park detent and leave the lever between Reverse and Park. The drivers did, however, commit other types of gearshift errors. In 10 participants, 15 errors were observed in which the driver shifted into an unintended gear (e.g., Neutral instead of Drive) and took his or her foot off the brake or hand off the lever (*mis-shift errors*). On two occasions, one participant failed to shift out of a powered gear (i.e., no shift at all) before exiting the vehicle (*failure-to-shift errors*). With one exception, all of the observed gearshift errors were committed under conditions of haste or distraction.

The results of the Harley et al. (2008) study support the hypothesis that mis-shift and failure-to-shift errors are more likely causes of rollaway accidents than an operator leaving the lever between Reverse and Park. In addition, hurried or distracted conditions may increase the likelihood of mis-shift or failure-to-shift errors. These errors may interact with other factors, such as the driver's egress pattern, to increase the likelihood of a rollaway accident.

The research reported here seeks to extend Harley et al.'s (2008) work by examining in greater depth the processes by which drivers shift into Park and subsequently exit the vehicle under hurried or distracted conditions. First, the effects of driver distraction on the

time course of shifts into Park were investigated. If gear shifting is ballistic, as opposed to visually guided (see also McCarthy et al., 1982; Shinar et al., 1998), then introducing distractions should not affect the speed with which participants shift. Second, Harley et al. (2008) observed four participants who continued to depress the brake pedal with their right foot as their left foot contacted the ground outside the vehicle on at least one experimental trial. To assess the extent to which this mode of egress may allow drivers to fully exit a vehicle that has been left in gear before it begins to roll, the timing characteristics of this notable egress pattern were examined and compared with other patterns of egress observed in the experiment.

METHODS

The methods presented here have been described previously and in detail by Harley et al. (2008). No additional testing was conducted for the purposes of the analyses reported herein.

PARTICIPANTS – Thirty participants (13 female; 17 male) ranged in age from 18 to 82. Participants were recruited via a website posting. The only inclusion criteria were that participants be at least 18 years of age and possess a valid driver's license.

Participants were told that the purpose of the study was to better understand how people manipulate various in-vehicle devices and operate a vehicle on a closed course. They were naïve to the true purpose of the study and were not aware that aspects of their gear shifting and egress were being recorded. Participants were also unaware that distractions would be introduced during the driving task. Moreover, they were never told how to move the gearshift lever or exit the vehicle.

INSTRUMENTATION - A 2002 Jeep Grand Cherokee (6-cylinder, 42RE transmission) was instrumented with strain gauges and a string-potentiometer. The strain gauges were mounted to the gearshift lever in a full bridge configuration to allow direct measurement of forces in the fore/aft axis. The strain gauges were applied and calibrated using a standard system of dead weights. During calibration, the weight was hung from the top of the shift lever, such that the load recorded during testing was equal to the actual load that the driver would put on the shift lever during gear shifting. The strain gauges were hidden from the participants' view and did not affect the look, feel, or forces required to move the gearshift lever in any way. The string potentiometer was mounted to the base of the gearshift column to measure displacement of the shifter and to identify in which gear the gearshift lever was positioned. For purposes of synchronizing the video data (discussed below), the electrical signal that illuminates the brake

lamp when the brake pedal is depressed was also captured.

Force data were acquired using an EME NanoDAS Series acquisition system. The NanoDAS utilizes excitation, signal conditioning, analog pre-filtering and data collection (up to 25KHz). The acquisition rate and low-pass filter used were 250Hz and 100Hz, respectively. Video data were collected at a rate of 30 frames per second using four lipstick cameras positioned both within and outside of the vehicle. One camera captured an overview of the driver as he or she sat in the driver's seat. A second camera was focused on the position of the floor-mounted gearshift lever. A third camera captured the driver's foot well inside the vehicle. The fourth camera was attached to the driver's side rear bumper and captured both the illumination of the brake light and the driver's body during vehicle egress.

Though the test track was relatively flat, it was possible for an unsecured vehicle to roll away. To ensure the safety of the participant and the experimenters seated in the vehicle, the Jeep was fitted with an auxiliary brake. Each time a participant applied the vehicle brakes, an experimenter seated in the backseat manually held the pressure on the brakes utilizing an electric solenoid. When engaged, the auxiliary brake prevented the vehicle from moving even when the participant's foot was not depressing the brake. The auxiliary brake did not affect the feel of the brake pedal, did not activate the vehicle's brake lights, and participants were unaware that it existed or that it was being applied.

PROCEDURE – Testing was conducted at the Test and Engineering Center at Exponent, located in Phoenix, Arizona. The study comprised two phases: a static phase and a dynamic phase.

During the static phase the vehicle remained stationary with the engine off and the ignition key in the "on" position. Drivers shifted into either Drive or Reverse, operated an in-vehicle device (i.e., headlights, AC fan) and shifted into Park; this sequence consisted of one trial. A total of 480 static trials were run across 30 participants. For each participant, the static phase consisted of 16 trials: 12 "regular" trials in which participants were instructed to move at whatever speed was comfortable for them, and 4 "hurried" trials. During each of the four hurried trials, the participants performed the same actions as the "regular" trials but in addition were asked to exit the vehicle and re-enter the vehicle after they shifted to Park. Participants were instructed to move as quickly as possible and were provided with monetary incentive of \$50 to complete the "hurried" trials faster than other participants in the study.

During the dynamic phase of the study, participants drove the Jeep on a closed course. The course included

four stopping locations, marked with large boxes, each separated by approximately 100 feet (30.5 m). On each trial, the participants were asked to move the vehicle in either Drive or Reverse to one of the four stopping locations, shift to Park, exit the vehicle with it running, either retrieve two envelopes from the box or place two envelopes into the box, and then re-enter the vehicle. A total of 480 dynamic trials were run across 30 participants. For each participant, the dynamic phase consisted of 16 trials: 12 "hurried" trials and 4 "hurried-plus-distraction" trials. During the "hurried-plus-distraction" trials, the drivers were distracted (e.g., the experimenter began a conversation with the driver, the driver was asked to answer a ringing cellular phone, etc.) immediately before the participant brought the vehicle to a stop. The 16 trials, completed in groups of four, were timed by an experimenter using a stopwatch to encourage participants to complete the trials as quickly, but as safely, as possible. Unbeknownst to the participants, the auxiliary brake was engaged every time the vehicle was brought to a stop at one of the stopping locations.

Gearshift force and displacement data were acquired for only the last eight trials in both the static and dynamic phases. An experimenter seated in the backseat depressed a trigger when the participant shifted the gearshift lever into Park, initiating the capture of data prior to and following the trigger event. For the static phase, this included four "regular" and four "hurried" trials. For the dynamic phase, this included five "hurried" and three "hurried-plus-distraction" trials. Force and displacement data were collected for a total of 456 trials (the remaining trials were not recorded due to limitations of the NanoDAS system). Video data were recorded on all trials.

RESULTS

DISTRACTION AND GEARSHIFTS – Using the force-displacement data collected during the dynamic phase of the experiment, the time course of lever displacement was examined for shifts into Park during both hurried and hurried-plus-distraction trials. Figures 1 and 2 show force-displacement time courses from selected hurried and hurried-plus-distraction trials for Reverse-to-Park (Figure 1) and Drive-to-Park (Figure 2) shifts for a single participant.

From the force and displacement time courses, shift durations and peak forces applied to the lever were quantitatively compared across the two types of trials for both Reverse-to-Park and Drive-to-Park shifts. Shift duration was calculated using the time-displacement data and was defined as the length of time between when the gearshift lever first deviated substantially from the Reverse or Drive gear (i.e., the time point at which the gray trace in Figure 1 begins to decrease sharply).