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A video based run-off-road training program with practice and evaluation in a simulator

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ABSTRACT

A run-off-road (ROR) event occurs when one or more of a vehicle's wheels leaves the roadway and begins to travel on the surface or shoulder adjacent to the road. Despite various countermeasures, ROR crashes continue to yield a large number of fatalities and injuries. Infrastructure-based solutions do not directly address the critical factor of driver performance preceding and during an ROR event. In this study, a total of 75 individuals participated in a pre–post experiment to examine the effect of a training video on improving driver performance during a set of simulated ROR scenarios (e.g., on a high speed highway, a horizontal curve, and a residential rural road). In each scenario, the vehicle was unexpectedly forced into an ROR scenario for which the drivers were instructed to recover as safely as possible. The treatment group then watched a custom ROR training video while the control group viewed a placebo video. The participants then drove the same simulated ROR scenarios. The results suggest that the training video had a significant positive effect on drivers' steering response on all three roadway conditions as well as improvements in vehicle stability, subjectively rated demand on the driver, and self-evaluated performance in the highway scenario. Under the highway conditions, the treatment group reduced the frequency of spinouts from 70% in the pre-training events to 16% in the post-training events ($\chi^2(1) = 23.32$, $p < 0.001$) with no significant improvement found for the control group. In the horizontal curve, spinouts were reduced for the treatment group from 50% in the pre-training events to 30% in the post-training events ($\chi^2(1) = 8.45$, $p = 0.004$) with the control group also not showing any significant improvement. The results of this study suggest that even a short video about recovering from ROR events can significantly influence a driver's ability to recover. It is possible that additional training may have further benefits in recovering from ROR events.

1. Introduction

Despite many advances in traffic safety, one type of crash which continues to yield a large number of fatalities and injuries is unintended roadway departures or run-off-road (ROR) crashes. In 2011, around 60% of single-vehicle crashes in the U.S. occurred on the shoulder, median, or off the roadway altogether (NHTSA, 2013). ROR is defined as the condition when one or more of a vehicle's wheels leaves the roadway and begins traveling on the shoulder or surface adjacent to the road. Vehicles may leave the roadway for a variety of reasons, from gradual drifting due to inattention, to sudden obstacle avoidance; however, the driver's reaction immediately following a roadway departure is a critical factor that influences the safety consequences of the scenario. In fact, several studies have shown that the most frequent critical factor in ROR crashes is driver performance (Liu and Ye, 2011). Roadway conditions such as surface friction differences, roadway edge drop-off (lip-height), or roadside obstacles, combined with the natural and instinctive reaction to overcorrect with the steering wheel, make recovering from ROR dangerous and unexpectedly difficult (Liu and Subramanian, 2009; Liu and Ye, 2011).

A number of countermeasures currently exist to help mitigate the effects of ROR events and the resulting crashes. Most of these solutions involve roadway infrastructure modifications designed to help keep vehicles on the roadway and reduce the probability or severity of crashes if departures do occur (Neuman et al., 2003).

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Several infrastructure techniques (e.g., shoulder rumble strips, skid-resistant pavement surfaces, lip-height maintenance, widened/paved shoulders, and guardrails) have been installed on numerous miles of roadways resulting in varying success in reducing ROR crashes (Neuman et al., 2003; Lord et al., 2011; Graham et al., 2011). However, the overall gains associated with roadway modifications remain small since not all roads can be retrofitted with these modifications. Additionally, the most critical factor in ROR crashes, driver performance, is not directly addressed by passive roadway infrastructure (Liu and Ye, 2011). A more direct solution involves specifically targeting the driver's behavior so that inappropriate control actions, such as the common overcorrection technique, do not occur in the first place and collisions may be avoided altogether.

In addition to roadway modifications, there are many types of vehicle-based ROR intervention technologies. Today all new vehicles in the U.S. are equipped with electronic stability control (ESC) (NHTSA, 2007) and many new models include lane departure warning (LDW) or lane keeping assist (LKA) technologies (Enache et al., 2009; Glaser et al., 2010; Edwards et al., 2013). These systems have generally demonstrated success in providing drivers with warnings or assisted control when the vehicle is slowly skidding or drifting off the road. However, the effectiveness of these systems is limited in more extreme departure cases and ultimately the driver's performance still remains critical in preventing ROR crashes. A few ROR safety systems include a more active approach in assisting the driver throughout the ROR recovery process (Benito and Nilsson, 2006; Black et al., 2008; Black and Wagner, 2011; Freeman et al., 2015a). These particular systems are designed to work with the driver by predicting the driver's performance and implementing control accordingly, providing force feedback or warnings to illicit desired driver response, or taking complete control of the vehicle from the driver. Despite promising results associated with each of these ROR-specific safety systems, they remain premature for commercial implementation. For example, an autonomous recovery control system may completely eliminate the driver from the ROR recovery process (Freeman et al., 2015a) but the implications of such systems on overall traffic safety are not well known. Additionally, until the benefits of autonomous systems are well tested and documented, these types of ROR prevention will not be implemented.

The current study investigates driver education as a potential ROR countermeasure. Driver education is not only an easily implementable intervention but also may directly address the driver's behavior in these critical safety situations. There is a plethora of research related to the effect of novice driver training and driver education, with only a smaller subset of studies found for training in emergency situations. For example, Katila et al. (2004) demonstrated that skid training was associated with confidence while driving in slippery conditions without an increase in crash risk associated with overconfidence. Damm et al. (2011) demonstrated that in terms of response time, speed, and vehicle positioning, early-trained novice drivers were more likely to respond with efficient evasive actions, similar to experienced drivers, than traditionally trained novices during simulated prototypical crash scenarios. Clark et al. (2013) demonstrated that novice drivers were able to proficiently exhibit safe driving skills following exposure to a safe driving program focused on braking skills, obstacle avoidance, loss of control, and tailgating. Additionally, several recent publications in driver training for emergency situations have focused more on the importance of improving risk and hazard perception (Rosenbloom et al., 2008; Wang et al., 2010; Underwood et al., 2011); however, no published research results exist for driver training in the specific context of ROR. The ROR training evaluated in the current study seeks to fill the gap that other hazardous situation training has left unaddressed and is designed to fit well in a secondary driver education program or safe driving practices course such as that presented in Jensen et al. (2011).

Driver education has received substantial attention especially from highly motorized countries throughout the world. Unfortunately, many studies have not shown significant positive effects of general driver education or training programs (Stock et al., 1983; Jones and McCormac, 1989; Gregersen, 1994; Williams et al., 2009). However, some benefits have been observed in studies of more advanced skill training (Katila et al., 2004; Rosenbloom et al., 2008). Regardless of the controversy related to driver education benefits, these studies indicate that experimental evaluations of programs are imperative for developing an effective training program (Mayhew et al., 1998; Mayhew and Simpson, 2002; Mayhew, 2007; Lonero and Mayhew, 2010). Although the current study focuses solely on one potential hazard of driving, the realization of ROR training as a standard part of driver education necessitates that it undergo proper evaluation. To that end, this study advances on the findings of Freeman et al. (2013) where the potential benefits of ROR training in a simulator environment were demonstrated through a pilot study.

2. Methods

2.1. Participants

The participants in this study were recruited through the Clemson Psychology Research System that identifies student volunteers interested in participating in research studies across the university. Some students were incentivized to participate through the Research System as part of their curriculum requirements; however, other participants volunteered to participate with no compensation or credit. The study was approved by the Clemson University Institutional Review Board (IRB# IRB2009-184). A total of 75 subjects (43 males and 32 females) participated in the study with a mean age of 21.12 years-old (SD = 2.94, range = 18–36). All participants were required to have a current U.S. issued driver's license. The average driving experience of participants in the study was 5.25 years (SD = 2.97) with 36% of subjects indicating they had experienced an ROR event. About 91% of the participants indicated that they had taken a novice driver-training course in the past, and 17% had participated in a secondary safe driving practices course.

2.2. ROR training video

In this study, ROR training was conducted through the use of a video-based tutorial. The use of video training helped to eliminate variability in training instruction between subjects and also greatly improves the impact potential of a final training product as resources can be shared digitally over the Internet and supplemented with local instructor-led training. The concepts presented in the video were comprised of educational material published by leaders in the automotive safety industry. Educational materials (e.g., brochures and manuals) published by organizations such as AAA (AAA, 2006), Pearson Education (Drive Right) (Crabb et al., 2010), and the Roadway Safety Foundation (RSF, 2009) were synthesized into a cohesive educational video.

The video presented the participant with introductory information on the occurrences and severity of ROR crashes and fatalities. This information was used to highlight the significant impact of ROR and provide motivation for the training. Examples of ROR events were shown in the video with specific factors associated with ROR including differences in surface frictions between the road and shoulder, the lip-height, and roadside obstacles. The video also described the potentially improper