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Modeling ratings of in-vehicle alerts to pedestrian by leveraging field operational tests data in a controlled laboratory study

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ABSTRACT

We show how to leverage expensive field operational tests (FOT) data in a controlled laboratory study when defining an in-vehicle algorithm that alerts drivers to pedestrians. We used an empirical approach that quantifies the relative level with which drivers are likely to accept alerts to pedestrians. The approach was used in two studies to investigate a range of contextual factors known to influence driver ratings of alerts to pedestrians issued by a driver-assistance system. Regression analysis shows that four factors consisting of combinations of pedestrian location and motion relative to the road ahead of the vehicle explain 85% of the variability in drivers' ratings of alerts. Adding two factors related to the uncertainty of the pedestrians' future path improves the model slightly. These findings suggest that drivers' assessment of the danger associated with pedestrians derives largely from the possibility that they might move into the vehicle's path, even when the vehicle is not on a collision course with the pedestrians. The less probable such an event seems, the less accepted an alert will be. Time to arrival (TTA) improved the regression model only when restricted to pedestrians in clear need of an alert, but was also found to have an effect in alert timing. This finding suggests that four contextual factors largely define the perceptual cues that drivers use to rate alerts to pedestrians.

1. Introduction

About 275,000 pedestrians were killed on the roads in 2013 according to latest World Health Organization (WHO) statistics. That is 22% of the global road fatalities (WHO, 2015). About 20,000 of those fatalities are in the richer countries of the Organization for Economic Co-operation and Development (OECD), where pedestrian fatalities rates vary between 8% and 37% of the total road fatalities (ITF, 2012). Almost half (46%) of the pedestrian deaths in single-vehicle crashes in the U.S.A. involved a pedestrian crossing the road while the vehicle was going straight (Jermakian & Zuby, 2011). Thus, more than half the pedestrian fatalities in the U.S.A. consist of crash scenarios where the pedestrian is not crossing perpendicularly across the path and in front of a vehicle going straight (e.g., where the pedestrian is not on a straight crossing path). Dark conditions may be particularly dangerous for pedestrians walking parallel to the road, as 86% of the pedestrian deaths occur in non-daylight conditions (Jermakian & Zuby).

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The ratio of pedestrian fatalities versus car occupants is increasing. While fatalities among car occupants fell by 54% between 2000 and 2013, pedestrian fatalities decreased by only 36% (OECD/ITF, 2015). Therefore, more efforts should be focused on the protection of pedestrians and other vulnerable road users (WHO, 2015).

In-vehicle alerts for pedestrians at risk usually precede autonomous braking in current pedestrian collision avoidance systems. Such alerts allow the driver to take action before autonomous intervention by the vehicle. The type of Human Machine Interface (HMI) influences the effectiveness of the in-vehicle alerting system. A short brake pulse can be as effective as an automated emergency braking in an assessment of causality cost (Lubbe & Kullgren, 2015). In-vehicle alerts can also assist distracted or otherwise unaware drivers. Although it is difficult to quantify the severity of this problem, we postulate that drivers may be, to some extent, unaware of many of the pedestrians being struck. Specifically, Fredriksson and Rosén (2012) reported that less than half (46%) of the drivers striking a pedestrian applied the brakes before impact. A driver who is made aware of a pedestrian should, in most cases, be able to initiate braking, even if complete collision avoidance may not be possible. Furthermore, in-vehicle alerts may in some conditions be a more appropriate avoidance measure than pre-impact braking in areas with higher vehicle speed – such as in more rural environments. Approximately half (43%) of all pedestrian fatalities were in non-urban areas. (OECD/ITF, 2015).

Research in pedestrian safety has focused on technology and algorithms to detect pedestrians (e.g., Gandhi & Trivedi, 2007). However, we need more than accurate detection to achieve an effective system – we also need to determine *whether* to provide in-vehicle alerts to the detected pedestrian. Understanding drivers' sense of the appropriateness of in-vehicle alerts to pedestrians should, therefore, enable the design of systems that drivers are more likely to accept and pay attention to.

New driver interfaces such as the Dynamic Marker Light function introduced by BMW and Mercedes offer a new HMI that aim to reduce the risk of driver distraction in a potential critical pedestrian encounter on the road. The system projects a spotlight that selectively illuminates the pedestrian (Zydek, 2014). Achieving desired effectiveness is still subject to driver acceptance, i.e., whether or not the driver considers it worthwhile to highlight the pedestrian in the specific situation (Adell, Várhelyi, & Nilsson, 2014). In contrast, new lighting technologies, such as the glare-free high-beam light, are not dependent on any detection technology, and have shown faster detection by drivers of pedestrians on the side of the road as compared with conventional low-beam light (Totzauer, 2012). Such systems should improve the driver's nighttime visibility, but may not be useful in the quest to automate driving or driver support. To our knowledge, a comparison between the effectiveness of the aforementioned systems has yet to be performed. The work reported here set out to determine where the decision threshold for in-vehicle alerts should be set for accurately detected pedestrians.

It is axiomatic that alerts, and possibly collision avoidance measures (e.g., pre-impact braking) should be issued in situations with an immediate risk of impact. In contrast, no action should be taken when the pedestrian is sufficiently far away from the immediate path of the vehicle. Repeated alerts that the driver perceives as unnecessary can lead the driver to neglect the system or to find creative ways of bypassing it. The ensuing erosion of confidence in the system may lead to underuse and even to disuse (Farber & Paley, 1993; Parasuraman & Riley, 1997). Thus, in-vehicle alerts that the driver considers relevant and useful are essential to promoting adoption of, and trust in systems that aim to reduce vehicle-pedestrian accidents.

Lees and Lee (2007) distinguished between false alarms and unnecessary alarms. They defined false alarms as non-useful, unintended alerts that are either inconsistent with the design of the system or characterized by unpredictable activation. In contrast, they defined 'unnecessary alarms' as alerts that are predictable and understood by the driver, but that are not considered useful. Thus, false alarms are often related to detection errors. Evolution of technology will improve performance at detection and reduce the rate of alerts that are false alarms. In contrast, unnecessary alarms are related to the application of an inappropriate alerting criteria or threshold. As Parasuraman and Riley (1997) noted, automation misuse, and disuse often originate in the differences in expectations between users and system designers. Indeed, Helmer (2014) found that participants in a driver simulator study rated *unpredictable* false system activation as hazardous for the surrounding traffic.

Using the definition of Lees and Lee (2007), it is probably without dispute that we would like to eliminate all false alarms. At first, we also assume that we also want to eliminate all unnecessary alarms. This raises the question, "Which alarms are actually unnecessary?" The answer is not obvious: The low base rate of actual collisions means that an alert from a collision warning system would be a very rare event if the alert were to be issued *only* prior to an impending collision. This implies that experience with the system would be rare; there would be no opportunity to develop a sense for when to expect an alert. The driver may not even recognize a rare alert (Lee, McGehee, Brown, & Reyes, 2002; Parasuraman, Hancock, & Olofinboba, 1997). Efficient recall of how to react depends on the frequency of use, which implies that the driver needs to be rather frequently reminded of the workings of the system (Bainbridge, 1983).

In order for an alert to be predictable (though potentially not useful), the driver must have experience with alerts triggered by situations that lie in-between the rare cases where there is a clear need for an alert (impending collisions) and the many cases that drivers perceive as unnecessary. This line of thinking implies that the system needs to issue alerts in situations that do not lead to a collision but that the driver perceives as relevant and useful. Indeed, Farber and Paley (1993) suggested that the ideal warning system would activate in 'alarming' situations even if the driver could avoid the accident without the alert. Such a system would allow the driver to gain experience with the system and to learn how to respond to its alerts.

Exposing drivers to alerts in such 'alarming' situations allows the alerts to become understandable and expected. Acceptance of those alerts are needed in order to gain their benefits. Accordingly, designers of pedestrian warning systems need a