Fostering Trust and Acceptance of a Collision Avoidance System through Retrospective Feedback

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ABSTRACT

A simulator study explored the effects of providing retrospective feedback on drivers' acceptance of a collision avoidance system (CAS) following a false activation. Sixteen experienced drivers undertook two drives, each lasting approximately 20 minutes. During both drives, the CAS identified a rogue pedestrian and intervened by providing an audible warning closely following by emergency braking. Feedback was provided following one of the activations (with the order counterbalanced between participants), in the form of a detailed storyboard 'playback' depicting the system's analysis of the situation. Subjective ratings of trust, confidence, annoyance and desirability, revealed no differences overall between conditions (i.e. with and without post-event feedback). However, there was a tendency for drivers to trust the system more if feedback was provided during their first drive, whereas drivers who were provided feedback during their second drive indicated higher levels of confidence in the system and found it less annoying. There was also a significant rise in the number of drivers who detected the potential pedestrian hazard prior to system activation during their second drive. Results suggests benefits associated with the provision of retrospective feedback, but effects may have been influenced by the experimental design, which exposed participants to similar pedestrian hazard events in consecutive drives. Future investigations, which should continue to explore techniques to enhance trust and acceptance of active safety systems, should therefore adopt a between-subjects design to isolate effects.

Keywords: trust, acceptance, collision avoidance system, retrospective feedback.

1 INTRODUCTION

Accidents involving vulnerable road users (VRUs) remain a major concern for road safety, accounting for almost 40% of road fatalities in Europe, and almost 50% worldwide (WHO, 2015). Pedestrians are one of the most vulnerable road user groups, both in terms of the likelihood of being involved in a near-miss or collision, and the potential ramifications should an incident occur (Clifton et al., 2009). Active safety systems and collision avoidance systems (CAS), such as Pedestrian and Cyclist Detection Systems with Emergency Braking (PCDS+EBR), have the potential to mitigate the risk to VRUs by warning drivers of an impending collision and/or taking evasive action autonomously by braking, steering or both, if a collision becomes imminent or if the driver fails to respond. Moreover, evidence suggest that PCDS+EBR systems have the greatest potential to improve the safety of VRUs, with data indicating a reduction of 7.5% on all road fatalities and 5.8% on all road injuries, representing an estimated 2,100 fatalities and over 62,900 injuries saved per year in the EU-28 based on 2015 accident trends (Silla et al., 2015).

However, current limitations in detection technology and algorithms, combined with the inherent difficulty of predicting pedestrians' behaviour and intentions mean that even state-of-the-art PCDS can be prone to high numbers of false alarms and/or activations (Zhang et al., 2016). Moreover, as the technology moves from 'collision mitigation' (with the aim of reducing vehicle speed/kinetic energy to make the impact more survivable) to 'collision avoidance' (aiming to avoid collisions completely), the number of false alarms and/or activations is naturally expected to increase as the margins of error are much smaller. The frequency and occurrence of false alarms and activations will inevitably influence drivers' attitudes towards the system, potentially encouraging them to neglect it, find creative ways to bypass it, or deactivate it completely (Parasuraman and Riley, 1997). Given that estimated benefits assume full market penetration and complete use (Silla et al., 2015), drivers' acceptance of the technology is therefore important.

In a driving context, acceptance has been described as "the degree to which an individual incorporates the system in his/her driving, or if the system is not available, intends to use it" (Adell, 2009). The determinants of acceptance are therefore complex and derive from a multitude of factors, including trust, the driver's experience of interaction with technology, their understanding of system limits, and the context in which it is implemented. Thus, factors, such as the number and frequency of false alarms, are likely to play a significant role in shaping drivers' trust and acceptance. Moreover, human behaviour is not primarily determined by objective factors, but also by subjective perceptions (Ghazizadeh et al. 2012). This means that acceptance is based on individual attitudes, expectations and experience as well as the subjective evaluation of expected benefits (Schade and Baum, 2007). It has even been suggested that the degree of technological innovation has a lesser effect on acceptance than personal experience (Ausserer and Risser, 2005).

Providing feedback to the user has been shown to have a significant positive effect on the development of trust and acceptance of technology, as it allows the individual to judge system expertise (Miller et al., 2014). From a system-design perspective, feedback can be considered as the information available to the operator regarding the state of the joint human-machine system, and can be provided to enhance immediate performance or induce behavioural change (Donmez, Boyle and Lee, 2008). In a driving context, immediate performance feedback is often inherent within the driving task itself (e.g. headway, lane position), and enables drivers to calibrate and modify their performance or behaviour as necessary, for example, by moderating their engagement in distracting secondary activities (Donmez et al., 2007). Feedback is also often provided regarding the status of on-board safety systems via various interfaces. However, this may be limited to binary states of 'system activated' or 'system idle'. The concern is that a false activation (for example, where the system mistakenly predicts that a pedestrian will enter the vehicle's trajectory and then applies emergency braking), may startle drivers and leave them perplexed regarding the system's actions, particularly if they were unaware of any potential risk; this will likely detriment their trust and acceptance of the technology.

Providing more detailed feedback regarding the behaviour or intentions of a PCDS system will likely increase trust and acceptance, but may interfere with primary task performance and distract drivers if provided in real-time (Arroyo et al., 2006). Moreover, the limited time that can be allocated to concurrent feedback makes it impossible to provide detailed information regarding the event that triggered the warning or system activation. As a consequence, concurrent feedback may not convey the information necessary to explain or guide behaviour. In contrast, providing feedback retrospectively (e.g. when the driver has stopped or at the end of a journey) enables the sharing of richer information (Donmez, Boyle and Lee, 2008). For discretionary systems (e.g. systems designed to improve driving performance and behaviour), this can support the memory of critical incidents and help drivers understand how their behaviour may have contributed to these (Donmez, Boyle and Lee, 2008). It is hypothesized that providing retrospective feedback to drivers regarding the intentions and behaviour of an active safety system, particularly following a false activation, will increase their overall acceptance and trust of the technology. The current investigation explores this using self-reported ratings of trust, confidence, annoyance and desirability, and drivers' visual behaviour.

2 METHOD

Sixteen experienced drivers (10 male, 6 female, age range 23-56, mean age 28.93, mean time with license 10.3 years) undertook two drives, each lasting approximately 20 minutes, in a medium-fidelity, fixed-base driving simulator. The simulator comprises an Audi TT car located within a curved screen, providing 270° forward and side image of the driving scene via three overhead HD projectors. Rear view mirror images are captured digitally and relayed to two 7-inch LCD screens, located to replicate the side mirrors, and a 55-inch curved HD LED television positioned behind the vehicle and visible using the existing interior rear-view mirror. A Thrustmaster 500RS force feedback wheel and pedal set are faithfully integrated with the existing Audi controls. The driving scenario was created using STISIM Drive (v3) software to replicate a mixed driving environment, including residential, urban/town and rural components. Participants wore SMI eye-tracking glasses to capture their visual behaviour, and received a £10 (GBP) shopping voucher as compensation for their time.

Towards the end of each drive, as the vehicle passed through a busy urban environment, a pedestrian walked towards the roadside, as if intending to cross (Figure 1). The PCDS identified the rogue pedestrian (walking at a constant speed of 1.0 m/sec) as a potential hazard, providing an audible warning to alert the driver at a time-to-collision (TTC) of 1.2s, and initiated an emergency braking manoeuvre when the TTC was 0.5s, ultimately bringing the car to a stop at a clearance distance of 3.8m. The pedestrian remained in full view of driver throughout the confrontation, reflecting the most common accident use-case (PROSPECT, 2016). Despite the system's analysis of the situation, the pedestrian actually stopped at the road-side. Thus, the event was expected to be perceived by the driver as a 'false positive' intervention.

Following the 'false' activation, the driver was asked to pull over to the side of the road when it was safe to do so. During one of the two drives (which were counterbalanced), the driver was then provided with retrospective feedback depicting a detailed storyboard 'playback' of the system's analysis of the situation (Figure 2) presented on a Microsoft Surface tablet computer mounted in the centre console of the vehicle. No feedback was provided during the other drive. After each drive, ratings of trust were obtained using the trust in automation questionnaire (Gold et al., 2015, adapted from Jian et al., 2000). This was supplemented by additional bespoke items exploring concepts such as participants' confidence in the system, their annoyance with it, and whether they would choose to have the system in their own vehicle, with responses invited using Likert scales.

Figure 1 - Driver's view of road-scene showing pedestrian approaching roadside (left) and stopped (right), with red circle denoting eye-tracking trace

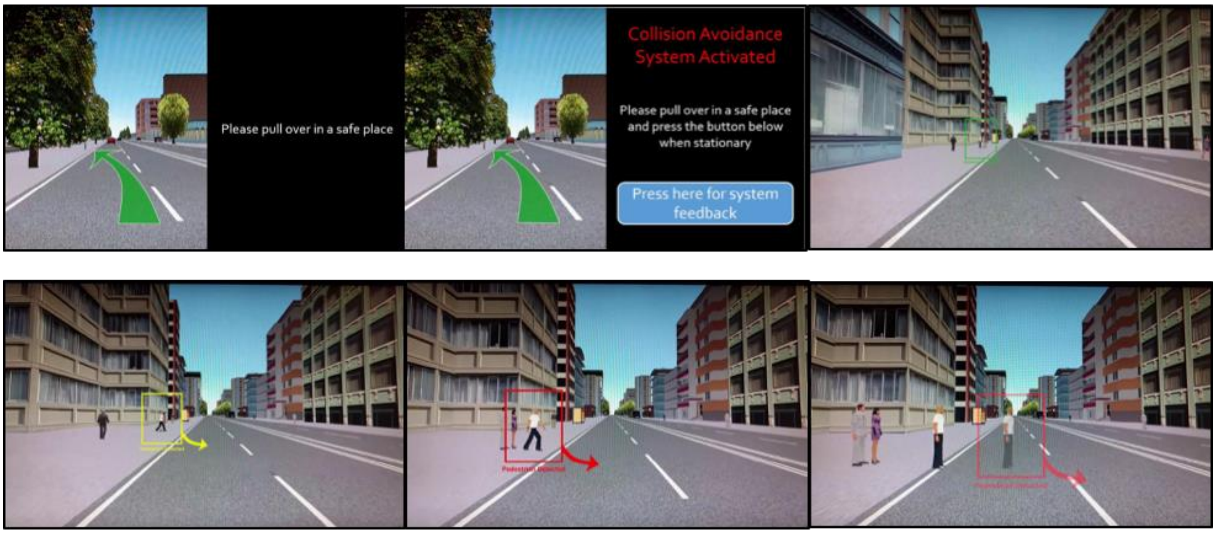
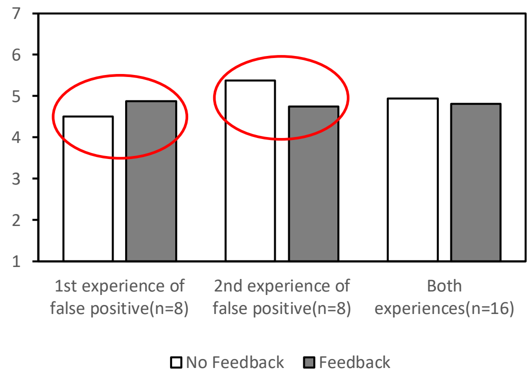


Figure 2 - Storyboard of retrospective feedback provided to drivers

3 RESULTS

Cumulative ratings of trust, confidence and annoyance were calculated. Overall, these revealed no significant differences between conditions (i.e. with and without post-event feedback), but indicated lower trust associated with the second drive ($t(15)=2.83$, $p=.013$), suggesting a potential order effect (for drive 1, mean = 3.63; drive 2 = 2.98). Interrogating these data further, however, it was evident that there was a tendency for drivers to trust the system more if feedback was provided during their first drive. Conversely, drivers who were provided feedback during their second drive indicated lower levels of trust, but higher levels of confidence in the system (Figure 3) and found it less annoying, although ratings of annoyance were generally low throughout. Drivers also indicated that they were more likely to want the system in their own car based on their experience of feedback during their second drive. Eye-tracking analysis revealed a significant rise in the number of drivers who detected the potential pedestrian hazard prior to system activation during their second drive (25% in drive 1 and 81% in drive 2) ($t(15)=4.39$, $p = .001$), suggesting increased vigilance, although it is unclear whether this was a behavioural change inspired by the provision of retrospective feedback during drive 1, or an experimental experience effect (i.e. expectation following repeated exposures to similar pedestrian hazard events in consecutive drives).



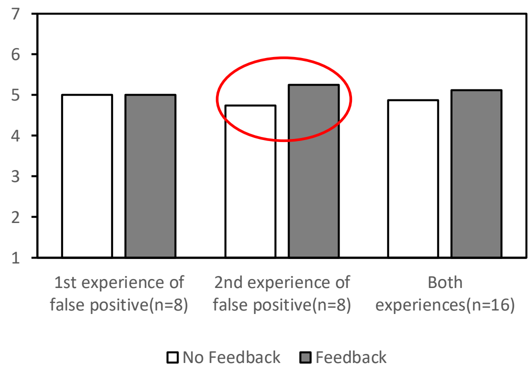


Figure 3 - Subjective ratings showing trust (left) and confidence (right), where 7='strongly agree' and 1='strongly disagree'

4 DISCUSSION

The study explored the effects of providing detailed post-event feedback on drivers' acceptance of a PCDS following a false activation. While the results did not fully support our hypothesis that providing retrospective feedback would increase drivers' overall acceptance and trust of the technology, there are some encouraging findings, which are significant in light of existing research and can be used to inform future studies. For example, previous research has shown that exposure to the first false alarm has the strongest negative effect on trust ratings (the so-called 'first failure effect'; Rovira et al., 2007). Therefore, providing feedback during the first exposure (i.e. the first drive in our study) to counteract this effect, might be expected to elicit higher trust ratings, and this tends to be supported by our data. Nevertheless, some of the findings may be confounded by our experimental design, which adopted a within-subjects approach (due to timing and resource constraints), whereby each participant was exposed to both conditions (i.e. with and without feedback). Although the order of exposure was counterbalanced, it is feasible that exposure to the potential hazard and associated warning/activation during the first drive may have encouraged drivers to be more vigilant during the second drive. The fact that a greater proportion of drivers saw the pedestrian threat during their second drive, prior to system activation, tends to support this statement, although, it is unclear how this may have impacted their behaviour. For example, if drivers were already aware of a potential threat, they may have expected the activation, thereby increasing their confidence in the system when it acted appropriately, as the data suggest – although this may not have been in response to the feedback *per se*. Alternatively, the fact that drivers were already aware of the risk, may have meant that they felt that the intervention was unnecessary, and this could have reduced their confidence in the system or annoyed them (contrary to our findings).

Consequently, it is not possible to isolate effects, making it difficult to draw any robust conclusions. In addition, the relatively small sample (and subsequent between-subjects analysis) limits the statistical power and potential impact of the research. As such, further work is required. In particular, it is recommended that future investigations, which should continue to explore the benefits of providing retrospective feedback on trust and acceptance as the literature encourages, adopt a between-subjects design with a larger cohort of drivers.

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