Using Multimodal Displays to Signify Critical Handovers of Control to Distracted Autonomous Car Drivers

Ioannis Politis, School of Computing Science, University of Glasgow, Glasgow, UK
Stephen Brewster, School of Computing Science, University of Glasgow, Glasgow, UK
Frank Pollick, School of Psychology, University of Glasgow, Glasgow, UK

ABSTRACT

Until full autonomy is achieved in cars, drivers will still be expected to take over control of driving, and critical warnings will be essential. This paper presents a comparison of abstract versus language-based multimodal warnings signifying handovers of control in autonomous cars. While using an autonomous car simulator, participants were distracted from the road by playing a game on a tablet. An automation failure together with a car in front braking was then simulated; a rare but very critical situation for a non-attentive driver to be in. Multimodal abstract or language-based warnings signifying this situation were then delivered, either from the simulator or from the tablet, in order to discover the most effective location. Results showed that abstract cues, including audio, and cues delivered from the tablet improved handovers. This indicates the potential of moving simple but salient autonomous car warnings to where a gaming side task takes place.

KEYWORDS

Audio, Autonomous Cars, Games, Handover, Multimodal Feedback, Speech, Tactile, Tactons, Urgency, Visual, Warnings

INTRODUCTION

Autonomous cars are becoming a more and more popular topic of research, although not without concerns from the public over the safety of this new technology (Kyriakidis, Happee, & Winter, 2014). To address such worries, there is careful examination of road accidents involving autonomous vehicles from technology providers (Google, 2015b). This shows the importance of safety while automation is becoming more robust. Car autonomy is a staged rather than binary process, with levels of autonomy increasing as driver involvement decreases (National Highway Traffic Safety Administration, 2013; SAE J3016 & J3016, 2014). Therefore, user interfaces are required that improve safety when driver involvement is reduced but still necessary. The handover, the point of transition of control from the car to the driver, and vice versa, is a critical part of this interaction. An effective warning mechanism for such a critical case is essential, as lack of clarity over who has control of the vehicle at a given moment can be catastrophic, e.g. (Politis, Brewster, & Pollick, 2015a).
In parallel, as vehicle automation increases, drivers are more likely to engage in tasks other than driving. Gaming is a popular activity that drivers are expected to engage in while the car is in autonomous mode, and is a topic of ongoing research, e.g. (Krome, Goddard, Greuter, Walz, & Gerlicher, 2015; Neubauer, Matthews, & Saxby, 2014). Due to the high level of concentration required by a game, a particularly demanding scenario would be attending to a critical handover while gaming. A critical handover often examined is an automation failure, since it happens unexpectedly, leaving little time to react (Gold, Dambock, Lorenz, & Bengler, 2013; Mok et al., 2015; Pfromm, Khan, Oppelt, Abendroth, & Bruder, 2015). Signifying handovers with multimodal warnings (Naujoks, Mai, & Neukum, 2014; Politis et al., 2015a), using varying message contents (Koo et al., 2014) and evaluating transition times (Gold et al., 2013; Christian Gold & Bengler, 2014) are important aspects of this critical case. However, there is no work on how critical handovers can be facilitated by multimodal warnings originating from the game area. In this study, we use an engaging tablet gaming task and test the time required to resume driving during an automation failure. Handover notifications are moved to the tablet and abstract versus language-based multimodal warnings are compared as alerts for this scenario, both being novel interventions.

**Multimodal Displays Varying in Urgency**

Multimodal displays have consistently shown advantages in alerting drivers to various road events. Simple spatial vibrotactile cues coming from the direction of a threat improved reaction times of drivers (Ho, Tan, & Spence, 2005). Ho, Reed & Spence (Ho, Reed, & Spence, 2007) showed added benefit when a vibrotactile cue and a car horn sound were delivered in combination. The benefit of directionality in the cues was also observed by (Serrano, Di Stasi, Megías, & Catena, 2011), who found improved recognition performance of whether a road scene was hazardous or not when cues were presented form the direction of the hazard. In our study, we present the cues either from the front, where a threat is approaching, or from the tablet on which the participants are playing a game. In this way, we evaluate the effect of warnings from the area which the participants are focused on compared to the direction of an approaching threat which they are not attentive to.

In terms of design, reflecting the urgency of the event in the warning has repeatedly shown benefits. Politis, Brewster, & Pollick (2014a, 2013, 2014b) used all unimodal, bimodal and trimodal combinations of cues varying in urgency to achieve lower response times and higher perceived urgency for more urgent cues. In this paper, we use these results to design multimodal warnings that convey the increased urgency needed for a critical situation. Further, Politis, Brewster & Pollick (2015b) extended the comparison in all unimodal, bimodal and trimodal combinations of abstract and language-based warnings and found an advantage of abstract cues in terms of recognition times in a non-critical situation, but no difference in terms of reaction times in the presence of a critical event. In this work, we compare highly urgent abstract and language-based multimodal warnings presented from different locations in the context of autonomous cars, a comparison that has never been attempted.

**Handovers of Control in Autonomous Cars**

The case of an automation failure has been studied in the past as a likely reason for a handover of control. Gold et al. (2013) investigated automation failures when drivers were distracted through a tablet side task. A pure tone and a visual icon called the drivers back to the wheel during an unexpected event. These warnings were either delivered 5 sec or 7 sec before the required handover. It was found that 5 sec was a better time to prepare drivers to resume control. Gold & Bengler (2014) extended this discussion, reporting that during a handover of control, both time (how long it takes) as well as quality (driving performance during and after resumption of control) are important issues to be considered. In our work, we use the above ideas, by simulating an automation failure that coincides with a critical event, which makes driver intervention essential. We also measure both time and quality of the car to driver handovers in this scenario and present similar or quicker times of transitions achieved with the used warnings.
An Exact and Efficient Privacy-Preserving Spatiotemporal Matching in Mobile Social Networks
Xiuguang Li, Yuanyuan He, Ben Niu, Kai Yang and Hui Li (2016). *International Journal of Technology and Human Interaction* (pp. 36-47).

Psychological and Social Problems of Automation and Computerization
[www.igi-global.com/chapter/psychological-social-problems-automation-computerization/45288?camid=4v1a](www.igi-global.com/chapter/psychological-social-problems-automation-computerization/45288?camid=4v1a)