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Context-sensitive distraction warnings – Effects on drivers' visual behavior and acceptance ☆

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ABSTRACT

In this study, we investigated the effects of context-sensitive distraction warnings on drivers' in-car glance behaviors and acceptance. The studied prototype warning application functions on a smart phone. The novelty of the application is its proactive and context-sensitive approach to the adjustment of warning thresholds according to the estimated visual demands of the driving situation ahead. In our study, novice and experienced drivers conducted in-car tasks with a smart phone on a test track with and without the warnings. The application gave a warning if the driver's gaze was recognized to remain on the smart phone over a situation-specific threshold time, or if the driver was approaching a high-demand part of the track (an intersection or a tight curve). Glance metrics indicated a significant increasing effect of the warnings on glance time on road while multitasking. The effect varied between 5% and 30% increase depending on the in-car task. A text message reading task was the most visually demanding activity and indicated the greatest effect of the warnings on glance time on road. Driving experience did not have an effect on the efficiency of the warnings. The proposed gaze tracking with current smart phone technology proved to be highly unreliable in varying lighting conditions. However, the findings suggest that location-based proactive distraction warnings of high-demanding driving situations ahead could help all drivers in overcoming the inability to evaluate situational demands while interacting with complex in-car tasks and to place more attention on the road. Furthermore, survey results indicate that it is possible to achieve high levels of trust, perceived usefulness, and acceptance with these kinds of context-sensitive distraction warnings for drivers.

1. Introduction

Modern smart phones offer car drivers a lot of useful services on the road such as navigation, entertainment, communication, and information on nearby points-of-interest. However, a concern has been addressed lately on the increasing smart phone usage while driving and the related inattention towards the traffic environment (Fitch et al., 2013; Klauer et al., 2006).

From earlier research it is known that driver inattention is a major cause of safety-critical incidents in traffic. In a naturalistic driving study with one hundred car drivers (Klauer et al., 2006), it was concluded that almost 80 percent of all crashes and 65% of all near-crash situations involved visual inattention, i.e., the driver's eyes were not on the road the moment before or at the moment of the incident.

As a cause of visual inattention by secondary activities in these safety-critical events, the use of a mobile device (mainly mobile phone) was by far the leading factor by at least 30% of the cases (Klauer et al., 2006). Another naturalistic driving study on the topic by Fitch et al. (2013) indicated that drivers engaging in visually complex tasks with their smart phones have a three-time higher safety-critical incident risk compared to drivers who pay attention to the road ahead.

Unfortunately, the most obvious solution to the problem, legislative measures, does not seem to work. For instance, in Finland a recent poll by the Finnish Road Safety Council revealed that over 30% of drivers admit texting while driving, despite of the fees on hand-held device usage and distracting in-car activities while driving (Jääskeläinen and Pöysti, 2014). This means that there is an urgent need for other, more effective means to mitigate the negative effects of driver distraction by mobile devices. Other possible approaches are, for instance, driver education and

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technological counter-measures. In order to provide efficient counter-measures, the priority should be on means that are widely accepted by the drivers (Donmez et al., 2007). In this paper, we study the efficiency and acceptability of context-sensitive distraction warnings that could serve this purpose.

2. Distraction algorithms and driver acceptance

Due to the increasing significance of driver distraction to traffic safety, a number of distraction detection algorithms and distraction warning systems are currently under development by car manufacturers (National Highway Traffic Safety Administration, 2013a; Lee et al., 2013). These warning systems operate on the basis of distraction detection algorithms, i.e., algorithms that are meant to detect when the driver is distracted. However, there are basic conceptual difficulties in defining and operationalizing accurately what is distracted (inattentive) driving (Regan et al., 2011). This places great challenges for the sensitivity and reliability of the algorithms in detecting distracted driving, and consequently, to drivers' acceptance of the distraction warnings.

Liang et al. (2012) studied 24 different possible algorithms that could be used for detecting distraction and evaluated their ability to predict crash risk based on behavioral data collected in the 100 car study by Klauer et al. (2006). They concluded that the most sensitive indicator for crash risk seemed to be algorithms that measure instantaneous changes in off-road glance duration, that is, individual glance durations seem to matter. 1.5th power of glance duration, glance history, or glance location, did not significantly improve the sensitivity.

Even if the algorithms are highly valuable for indicating the general statistical link between off-road glance durations and crash risk, environmental and external situational factors (e.g., driving speed, road curvature and road type) were missing in all of the evaluated 24 algorithms (Liang et al., 2012). That is, one can argue that the severity of an off-road glance duration should be in a relationship with the visual demands of the driving situation, as suggested by the naturalistic driving study of Tivesten and Dozza. (2014) as well as the 100 car study report by Klauer et al. (2006). Taking into account the situational visual demands of the driving task could further improve the sensitivity of the single glance algorithms.

The existing and proposed distraction warning systems and detection algorithms do not utilize context and driver data to the extent that could be possible with modern technology. Instead, the algorithms focus only on off-road glance durations and the direction of gaze (National Highway Traffic Safety Administration, 2013a). Context-sensitivity of distraction warning systems could decrease substantially the high levels of false alarms experienced with the current systems (National Highway Traffic Safety Administration, 2013a). In addition, context-sensitivity could improve the visibility of the system behavior by providing the driver a possibility to better associate the criticality of the warnings to the observable demands in the driving environment (e.g., an intersection ahead). All these factors should increase driver acceptance of these systems and make the systems more reliable. In addition, positive learning effects could be expected if the driver learns to associate the warnings to certain driving environments or situations observed ahead.

Like other available technical solutions to mitigate the negative effects of driver distraction, such as braking and lane-keeping assistants, most of the distraction warning systems today are reactive, that is, the systems react to observed distraction or its negative effects by counter-measures (e.g., Wege and Victor, 2014; You et al., 2012). This means often already a degraded driving performance.

Other, somewhat context-sensitive counter-measures act as workload managers, limiting the access of drivers to certain in-car services when the situational demands are considered to reach a certain level of high demand (Green, 2004). These kinds of forced solutions are rarely well accepted by the drivers. In addition, the high workload conditions are often recognized based on the high levels of activity by the driver (e.g., steering frequency, Green, 2004; Broström et al., 2006), whereas lack of sufficient attention on the driving task manifests often as low levels of activity compared to what the situational driving task demands would require (Regan et al., 2011).

The ideas about drivers themselves acting as dynamic workload managers and driver assistant systems for this purpose are relatively new (Donmez et al., 2008). A basic requirement for this kind of tactical behavior is that the driver is capable to evaluate the dynamic demands of each driving situation ahead. In-car tasks undermine this ability because it has been shown that drivers can have a low level of awareness of their own performance as well as the elements in the road environment while multitasking (e.g., Schömig and Metz, 2013; Young et al., 2013; Horrey et al., 2009). For instance, Young and Salmon (2012) have suggested that high levels of cognitive workload due to in-car task demands can have a negative effect on driver's situation awareness of the road environment, which could at least partially explain this inability. The study by Lee et al. (2007) indicated that brief glances off road together with cognitive load are additive in their effects on drivers to miss safety-critical events in the driving environment.

In addition, even if the drivers would be aware of the situational driving demands, the most popular survival strategy in multitasking while driving seems to be “ASAP”; the in-car task is completed as soon as possible without considering the situational driving demands. Horrey and Lesch (2009) showed that although drivers seemed to be aware of the demands of the driving situation in their experiment, the drivers did not tend to postpone the presented secondary tasks even if they were given the chance. Based on the findings, the authors suggested that training drivers on tactical decisions and planning of timing in multitasking is worth considering. The effects of this type of training of tactical and strategic skills has been tested by Horrey et al. (2009), giving promising results. Another possibility is to provide real-time feedback for the drivers (Donmez et al., 2007), or both real-time and retrospective feedback (Roberts et al., 2012) on distracted behaviors. The study by Donmez et al. (2010) indicated the positive effects of combined real-time and retrospective feedback on distracted driving behaviors among young high-risk drivers, in particular. Roberts et al. (2012) suggested that systems providing immediate feedback on distracted behaviors are experienced in general as less pleasant and less easy to use than retrospective feedback systems. However, the specific implementation of the warnings can be argued to have a significant effect on the acceptability of the real-time warnings.

Instead of mere feedback, one possibility is to give the drivers proactive suggestions to postpone in-car tasks if the driving situation ahead is recognized as high demanding. A proactive and context-sensitive distraction warning system that would adjust warning thresholds according to the expected visual demands of the driving situation ahead and indicate these in real-time for the driver could in principle answer the issues raised by earlier research. In this paper, we study one possible implementation of such a prototype system called VisGuard (“Vision Guard”, Kujala, 2013).'

3. VisGuard: prototype features

In order to study the effects of context-sensitive distraction warnings on the drivers' visual behaviors and driver acceptance,