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Continuous versus intermittent presentation of visual eco-driving advice

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ABSTRACT

Automatic eco-driving advice has the potential to improve fuel economy and reduce emissions. However, providing eco-driving information to the driver will inevitably draw attention away from the driving task. The objective of this research is to investigate the effects of intermittent versus continuous visual eco-driving information on glance behaviour in an attempt to find the best approach to display eco-driving information from a traffic safety perspective. Twenty-three truck drivers drove on a village road, a rural road and a motorway section in an advanced moving base truck simulator. A number of situations with relevance for eco-driving, such as traffic lights, crests, changes in posted speed limits, and a motorway entrance, were investigated. The level of difficulty of the traffic situations varied. Four conditions were tested: baseline without eco-driving information, intermittent feedback, continuous feedback and self-selected feedback (personalised settings selected by the driver). As expected, the drivers looked at the eco-driving system when it was active, and more so when the traffic situation was less demanding. Importantly, drivers waited longer with their first glance at the display when the traffic situation was more complex. In conclusion, intermittent information is recommended over continuous information as it leads to shorter dwell times, and as it is easier for the system designer to control when the periods of increased glance frequency occur, by presenting the information in strategically advantageous locations that are not demanding for the driver.

1. Introduction

Information and advice for the driver is often presented visually. There are many advantages with this: the information can be more detailed than auditory or tactile information, it is possible to use symbols, pictures and text, and colour coding can provide further detail. The information can remain present over time. One big advantage of a visual presentation, especially for optional information, is the fact that it is not "intrusive", that is, it can potentially be ignored more easily than auditory or tactile information (Mollenhauer, Lee, Cho, Hulse, & Dingus, 1994; Woods, 1995). The disadvantages are obvious, however, and have been studied and reported in many different contexts – if visual information is to be taken in, the driver needs to look away from traffic and focus on the information for a while. Not even head-up displays (HUDs) are the ultimate solution to this problem, as the figure–ground issue remains, with the drivers mentally focusing on the information, such that the traffic scene "disappears" into the background (Ablassmeier, Poitschke, Wallhoff, Bengler, & Rigoll, 2007; Crawford & Neal, 2006). Information that is "nice to have", but not in any way essential, is for the above mentioned reasons well suited

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to be presented visually. It has to be made sure, however, that the information really has an optional character, that is, the driver should not feel compelled to look at the display. A good candidate for information of that type is eco-driving advice.

The desire to drive in an eco-friendly manner is on the rise (Young, Birrell, & Stanton, 2011), and fleet owners have begun to reward their drivers with money and other benefits when they manage to save fuel (Barkenbus, 2010). Non-professional drivers have a direct monetary benefit when they save fuel. Therefore, manufacturers have started to provide the driver with information on how best to save fuel. Advice given during driving ranges from embedded eco-driver systems that evaluate a host of data both from the vehicle and from maps, to simple apps that can be downloaded to any smartphone.

There exists some published research on different ways in which eco-driving information is presented to the drivers. Manser, Rakauskas, Graving, and Jenness (2010) tested an eco-driving system with a continuous visual display in a fixed base driving simulator. The information was presented via the instrument cluster and consisted of symbols indicating growing leaves and a horizontal bar. The growing leaves represented the overall fuel economy of the current trip whereas the horizontal bar provided continuous information regarding the fuel efficiency of ongoing accelerations/decelerations. While the system had a positive effect on fuel savings, it was found that the participants glanced at the system more often when asked to drive fuel efficiently as compared to when they were asked to drive as they would normally. Likewise, Stillwater and Kurani (2012) found that participants who had used a plug-in hybrid vehicle equipped with an eco-driving system during two weeks reported that they saw a distraction potential. The eco-driver system consisted of a rather complex visual system with several continuous displays indicating cumulative and current fuel usage and battery status for the electrical engine. The drivers could personalise the system and enter goals and fuel prices, for example. Drivers were asked to execute those complex manipulations while stationary. Rouzikhah, King, and Rakotonirainy (2013) conducted a study in a moving base simulator, in which they likened eco-driving to other secondary task execution and compared it with changing a CD as well as entering five digits in a navigation system. The eco-driving system consisted of a PDA displaying intermittent eco-driving messages with recommendations regarding braking, overtaking and over-speeding behaviour. It was mounted in a head-up position close to the centre console. Mental workload was assessed using a peripheral detection task (PDT) and the DALI mental workload questionnaire. It turned out that mental workload was slightly, but insignificantly higher for the eco-driving scenario than for baseline driving, and lower than for the other two secondary tasks. This result is consistent with findings by Birrell and Young (2011), who also reported that two prototypes of eco-driving aids did not significantly affect workload.

The potential of eco-driving systems to be distracting has also been discussed elsewhere (Barkenbus, 2010; Dogan, Steg, & Delhomme, 2011; Young et al., 2011), mostly with concern for the added visual load. However, it is rather obvious that a system that has some interest for the driver will also draw some attention to it. If "paying attention to the eco-driving system" is seen as equivalent with "being distracted from traffic", and if any glance directed at such a system is seen as one glance less towards a safety critical target, then each eco-driving system that is actually used by a driver is doomed to be labelled as "distracting". If it did not "distract" at all, then it would not need to be implemented (except if it is fully automated). So the question should not be whether an eco-driving system does attract any attention or not, but rather when, how and in which situations it does so. It should also be investigated which strategies drivers employ to sample this additional information in the context of solving the driving task as a whole.

In principle, eco-driving information can be presented continuously or intermittently. A continuous presentation shows the information all the time, allows the driver to monitor changes over time, and may aid in pre-planning if a look-ahead mode is used. Drivers can choose their own pace for consulting the display, without having to fear that information may disappear unseen. An intermittent presentation makes sure that the information only appears when it is really needed, such that it does not disturb unnecessarily. A certain pop-out effect is unavoidable since the information needs to be conspicuous enough for the driver to see it, however, without being completely capturing, as the driver has to be able to prioritise traffic.

As implied above, we assume that the human attentional resources are limited (James, 1890; Wickens, 2008). Attention can be redirected based on top-down decisions, that is, guided by expectations and internal processes, and also bottom-up, based on stimuli in the environment that attract attention (Theeuwes, 1991; Theeuwes, Kramer, Hahn, & Irwin, 1998). From a traffic safety perspective an information presentation format favouring top-down processing might be advantageous, as the driver can select opportune moments to look at the display. It is assumed that continuous presentation of information is conducive to top-down controlled glance behaviour, as the information is always present, and changes in the display will not be sudden. Bottom-up oriented presentation of information, manifested as an intermittent display on which the content can appear or change suddenly, is likely to produce more spontaneous glances, possibly in inopportune moments.

Not much research has been devoted to the question of whether the continuous or intermittent display of information while driving is better from a safety perspective, and none could be found for eco-driving support systems. Dijksterhuis, Stuiver, Mulder, Brookhuis, and de Waard (2012) conducted a simulator study on a lane keeping support system which was either completely deactivated, always activated, or intermittently activated when driving near the lane edges, driving over the lane edges, or weaving within the lane. Interestingly, more than one third of the participants reported that they tried to ignore the support displayed via a HUD as much as possible. Of the remaining participants, 79% used the information as a lane departure warning signal, and consequently the intermittent information display received the highest acceptance scores. Driving performance was slightly better with the intermittent system as well. In another simulator study a night vision system presented an enhanced view of the road ahead either continuously or intermittently, when a potential obstacle was detected (Alm, Kovordányi, & Ohlsson, 2006). All participants preferred the intermittent system to the continuous system, and NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988) values indicated a slightly lower workload for the