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Interface design of eco-driving support systems – Truck drivers' preferences and behavioural compliance

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ABSTRACT

The aim of the study was to investigate the perceived usefulness of various types of in-vehicle feedback and advice on fuel efficient driving. Twenty-four professional truck drivers participated in a driving simulator study. Two eco-driving support systems were included in the experiment: one that provided continuous information and one that provided intermittent information. After the simulator session, the participants were interviewed about their experiences of the various constituents of the systems. In general, the participants had a positive attitude towards eco-driving support systems and behavioural data indicated that they tended to comply with the advice given. However, different drivers had very different preferences with respect to what type of information they found useful. The majority of the participants preferred simple and clear information. The eco-driving constituents that were rated as most useful were advice on gas pedal pressure, speed guidance, feedback on manoeuvres, fuel consumption information and simple statistics. It is concluded that customisable user interfaces are recommended for eco-driving support systems for trucks.

1. Introduction

Reducing greenhouse gas emissions is a great challenge which requires actions on several fronts. Fuel efficient driving or *eco-driving*, is a way for drivers to reduce their carbon footprints by applying certain strategies and behaviours while driving. Pilot studies with trucks have demonstrated fuel savings in the range of 0–27%, decreases in gear changes and a reduced number of brake applications (Parkes and Reed, 2005; Symmons and Rose, 2009). In-vehicle driver support systems may encourage and help drivers to adapt eco-driving strategies. So far, most research on eco-driving support systems has considered private car drivers and passenger cars. Although the underlying eco-driving principles are similar for all vehicle types, there are some aspects that are specific for heavy vehicles and professional drivers. The large weight, the high aerodynamic drag and the slow acceleration of heavy vehicles make the topography, the speed and the use of the brakes particularly relevant. In addition to the differences in vehicle characteristics, the motives and incentives may differ between private and professional drivers. While a private driver will save money by applying a fuel efficient driving style, the situation is more complex for truck drivers who operate on a commercial basis and often are under time pressure. Unless the haulage contractor requests or rewards fuel efficient driving, there may be no reason for a truck driver to save fuel. On the other hand, increasing competition and rising fuel prices may make it necessary for hauliers to apply eco-driving in order to reduce costs. For companies, eco-driving may be part of a green marketing strategy.

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The aim of the present study was to evaluate three different advice strategies for eco-driving systems for trucks for perceived usefulness and compliance: continuous or intermittent advice, or a user-selected combination of both. The study was conducted in a driving simulator. Additional results on gaze behaviour were presented in a separate paper (Kircher et al., 2014).

1.1. Eco-driving as a means of reducing emissions

Eco-driving means driving smoothly, anticipating the traffic, maintaining a constant speed, shifting gears early, decelerating by releasing the accelerator (engine braking) rather than applying the brake, and taking advantage of slopes (Gouvernment of Québec, 2011; TREATISE, 2005; Young et al., 2011). In addition to driving behaviour, the concept of eco-driving may also include trip planning, idling avoidance and vehicle maintenance (Roth et al., 2012; Rutty et al., 2013; Sivak and Schoettle, 2012). Barkenbus (2010) claims that eco-driving perhaps is the most overlooked action for reducing CO_2 emissions from personal transportation, with estimated savings of 5–10%. A great advantage is that savings can be immediate across the entire vehicle fleet, in contrast to the slow increase in fuel efficiency that can be expected as the fleet is gradually replaced.

Eco-driving training is offered by automobile associations and driving schools, and there are a number of web pages that provide guidance to interested drivers. Eco-driving training has been shown to give fuel consumption reductions in the range of 5–15% (Andrieu and Saint Pierre, 2012; Beusen et al., 2009; Hiraoka et al., 2009; Roth et al., 2012), but it has been observed that without support or positive reinforcement, the effects of training may wane over time (af Wåhlberg, 2007; Beusen et al., 2009; Luther and Baas, 2011). From that perspective, in-vehicle driver support systems that give continuous feedback and guidance have a potential to be more efficient than eco-driving training. Several such systems have been presented and evaluated in the literature. The majority of eco-driving support systems display information on fuel consumption (Boriboonsomsin et al., 2010; Hiraoka et al., 2009; Jenness et al., 2009; Manser et al., 2010; Meschtscherjakov et al., 2009; Stillwater and Kurani, 2013), but there are also systems that are targeted at giving advice or feedback on driving behaviour, such as accelerations and decelerations (Graving et al., 2010; van der Voort et al., 2001), speed (Trommer and Höltl, 2011), throttle pedal pressure (Azzi et al., 2011; Jenness et al., 2009; Larsson and Ericsson, 2009; Meschtscherjakov et al., 2009) and gear shifting (van der Voort et al., 2001). Another type of eco-driving system evaluates the overall driving performance and presents it to the driver for example as an "eco-index" (Jenness et al., 2009), a changing colour (Azzi et al., 2011; Jenness et al., 2009; Meschtscherjakov et al., 2009; van der Voort et al., 2001) or as a symbol (Jenness et al., 2009; Meschtscherjakov et al., 2009). Yet another type of eco-driving support system uses real-time data on traffic conditions in order to give drivers advice on speed (Barth and Boriboonsomsin, 2009). In addition to in-vehicle systems, there are post-trip systems that provide fuel economy statistics and tailor-made advice on how to drive more fuel efficient (Jenness et al., 2009; Trommer and Höltl, 2011). Eco-driving support systems have been reported to reduce fuel consumption by 0–16% (Azzi et al., 2011; Boriboonsomsin et al., 2010; Hiraoka et al., 2009; Larsson and Ericsson, 2009; van der Voort et al., 2001), but there is still a lack of long-term studies under real-world driving conditions that can confirm the hypothesis that eco-driving support systems will have a lasting effect on fuel use.

The present simulator study is part of the human machine interface (HMI) development in the ecoDriver project (ecoDriver, 2013), that aims at encouraging a fuel efficient driving behaviour by giving advice and feedback via in-vehicle devices.

1.2. Human–machine interfaces for eco-driving support systems

Eco-driving support systems are designed for voluntary use and thus, the penetration of such systems and the compliance with their advice depends largely on the perceived usefulness. The HMI plays a central role in this context. In contrast to other gauges and symbols on the dashboard, there are no standardised user interfaces for eco-driving systems. Since eco-driving systems may give advice and feedback on a variety of driving behaviours the design options are almost endless, but today there is limited knowledge on how to design these systems in order to gain user acceptance and to obtain fuel savings. Yet another very important factor when discussing driver support systems is safety. A poorly designed system may draw too much attention from the driving task, or it may even cause unsafe driving behaviour if the advice or feedback is misunderstood or followed too strictly.

There are a few studies on HMIs for eco-driving systems reported in the literature. Most of these studies consider visual information, which has been found to be preferred to auditory information, haptic feedback and direct intervention (Fricke and Schlissl, 2011; Meschtscherjakov et al., 2009). A variety of eco-driving interface concepts have been investigated in interview and questionnaire studies, where participants have been asked to rate and give their view on various examples. High ratings were obtained for colour-coded consumption rate (Fricke and Schlissl, 2011; Jenness et al., 2009), a consumption display based on driver profile, advice on optimal gear choice, traffic adaptive navigation and route suggestions (Fricke and Schlissl, 2011), a speedometer that glows green when the driver drives eco-friendly (Meschtscherjakov et al., 2009), post-trip analysis and feedback (Jenness et al., 2009; Trommer and Höltl, 2011), speed guidance at traffic lights (Trommer and Höltl, 2011), text and analogue displays and social comparison (Jenness et al., 2009). Complex graphical information such as flow diagrams, fuel economy bar charts, game-like displays and growing plants were seen as excessive, distracting or confusing (Jenness et al., 2009).