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Enhancing eco-safe driving behaviour through the use of in-vehicle human-machine interface: A qualitative study

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ABSTRACT

Background: The widespread reliance on motor vehicles has negative effects on both the environment and human health. The development of an innovative in-vehicle human-machine interface (HMI) has the potential to contribute to reducing traffic pollution and road trauma.
Aim: A qualitative study, using a driver-centred design approach, was carried out to test how best to provide ecological and safe (eco-safe) driving advice and feedback to drivers on their driving style via an in-vehicle HMI.
Method: A total of 34 drivers (*52.9% males*), aged 19–61 years, participated in focus groups which explored concepts from the Technology Acceptance Model (Davis, 1989).
Findings: Main themes emerging from the focus groups were: (i) perceived importance of eco-safe driving behaviour; (ii) perceived usefulness of eco-safe in-vehicle HMIs; (iii) intentions to use an eco-safe in-vehicle HMI; (iv) perceptions toward eco-safe in-vehicle HMI design characteristics; and (v) potential problems associated with using eco-safe in-vehicle HMIs.
Implications: This study provides the foundation to inform the design and development of an evidence-based in-vehicle eco-safe HMI with high levels of driver acceptance. Recommendations for future research are also discussed.

1. Introduction

Climate change and the impact of humankind on the environment is a prominent public health issue requiring immediate action (Gore, 2006). Ambient air pollution contributes to 3.7 million deaths each year worldwide, making it the single largest threat to environmental health on a global scale (World Health Organization, 2014). Our ever-increasing reliance on motor vehicles contributes to this problem by increasing gaseous and particulate pollution, which in turn has severe impacts on human health, such as increasing lung and heart disease. Moreover, 19% of all carbon dioxide (CO_2) emissions are caused by road vehicles, with such emissions intrinsically linked to rising global temperatures (Matthews et al., 2009).

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There have been a number of recent developments within the transportation industry aimed at, among other things, reducing the impact of motor vehicles on the environment, such as electric or automated vehicles (Fagnant and Kockelman, 2015; Wadud et al., 2016). However, improvements associated with these initiatives have been relatively incremental due to the typically higher costs to users associated with such options. On the other hand, eco-driving, which can broadly be defined as driving behaviours aimed at reducing fuel consumption and subsequent emissions, has been demonstrated as a promising and cost-effective approach (Barkenbus, 2010; Pampel et al., 2015). The general objective of the present study is to identify user requirements and perceived acceptability toward an in-vehicle HMI system for both eco-driving and safe driving behaviours.

This paper is divided into four main sections, the first of which has three sub-sections. The first section focuses on eco-driving as a climate change initiative, user-centred design and driver acceptance, and the aims of the present study. The second section outlines the study methodology, while the third section presents the results and discusses the findings. The final section outlines the conclusions of the research and its real-world implications.

1.1. Eco-driving as a climate change initiative

Prior research has identified three levels of decisions associated with eco-driving (Alam and McNabola, 2014): (i) strategic decisions (e.g., vehicle selection, maintenance schedules); (ii) tactical decisions (e.g., route selection, vehicle loading); and, (iii) operational decisions (e.g., driving style). While all of these decisions are important, improving driving style is associated with relatively immediate impacts on fuel consumption and emissions once the appropriate driving style is adopted (Martin et al., 2012).

Despite these advantages, many drivers do not adopt or practice eco-driving. Thus, Barkenbus (2010) described eco-driving as an underutilised initiative for battling climate change, reporting that improvements in eco-driving have the potential to reduce fuel consumption by up to 10%. As a result, governments in a number of highly motorised countries have begun to develop and implement eco-driving policies within the transport sector in a bid to reduce fuel consumption and subsequent emissions (Alam and McNabola, 2014).

However, a number of studies have argued that eco-driving behaviour may at times compromise safe driving. For example, maintaining a constant cruising speed and choosing the highest appropriate gear, may increase the likelihood that a driver will decrease headway to the vehicle in front and reduce their ability to brake appropriately, in turn increasing the risk of rear-end collisions (Young and Birrell, 2012; Young et al., 2011). In addition, such behaviour may also increase the likelihood of a driver manoeuvring at inappropriately high speeds, such as when cornering (cited in CIECA, 2007). These findings highlight that the development of any eco-driving initiative should be conducted with driver safety as a critical consideration. That is, the development of in-vehicle HMI systems should ultimately seek to address eco-safe driving behaviours, defined as those behaviours that reduce fuel consumption and subsequent emissions, while also considering the impact of system use on safe driving behaviours.

In recent years a number of guidelines (e.g. EcoDrivingUSA; ECOWILL, 2014), public education campaigns and driver licence training (ECODRIVEN; Graves et al., 2012 for examples) have been developed to encourage eco-driving behaviour among the driving population, with mixed results. An explanation for this may be that while many drivers are ultimately aware of the range of eco-driving behaviours that impact upon fuel consumption and subsequent emissions, they lack the technical understanding of how to appropriately perform these behaviours (Delhomme et al., 2013; Pampel et al., 2015), or may make conscious decisions to drive in a manner that is not fuel efficient or safe due to a variety of reasons they believe justify the behaviour in the given moment, such as (Harvey et al., 2013) running late or enjoying the feeling of driving fast. Alternatively, the complexity of the driving task might mean that drivers are not always aware of their actions, and in turn may not use their eco-driving knowledge and skills to their full potential (Pampel et al., 2015).

For this reason, the development of in-vehicle human-machine interfaces (HMI) represent a promising approach for providing relevant real-time advice and feedback to drivers to assist them to better adopt eco-driving behaviours. Previous research has highlighted the potential for eco-driving in-vehicle HMIs to have positive impacts on fuel consumption and vehicle emissions (e.g. Ecodriver, 2011; Jonkers et al., 2016; Larsson and Ericsson, 2009; Van der Voort et al., 2001). However, it is important that the development of such initiatives adopt a user-centred design approach and carefully consider the impact of issues associated with driver acceptance on subsequent system effectiveness.

1.2. User-centred design and driver acceptance

The effectiveness of an in-vehicle HMI is highly dependent on driver acceptance of the technology, and in particular on the perceived usefulness and intention to use the system. Driver acceptance has been defined as "the degree to which an individual incorporates the system in his/her driving" (Adell, 2009, p. 31). This concept has also been used to describe how much drivers would use the system and their willingness to pay to purchase a system (Jamson, 2010). Adopting a user-centred design approach can increase the likelihood of driver acceptance of an in-vehicle HMI and motivate greater usage, in turn enhancing the effectiveness of a system (Maguire, 2001).

The International Organisation for Standardization ISO (2010) has highlighted four key principles and recommendations for user-centred design. Overall, these principles characterise the process of user-centred design into a number of stages (see Fig. 1). Specifically, it is argued that system developers must (i) analyse and comprehensively understand the context of the