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Old habits die hard? The fragility of eco-driving mental models and why green driving behaviour is difficult to sustain

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ABSTRACT

Tangible incentives, training and feedback systems have been shown to reduce drivers' fuel consumption in several studies. However, the effects of such tools are often short-lived or dependent on continuous cues. Several studies found that many drivers already possess eco-driving mental models, and are able to activate them, for instance when an experimenter asks them to "drive fuel-efficiently". However, it is unclear how sustainable mental models are. The aim of the current study was to investigate the resilience of drivers' eco-driving mental models following engagement with a workload task, implemented as a simplified version of the Twenty Questions Task (TQT). Would drivers revert to 'everyday' driving behaviours following exposure to heightened workload? A driving simulator experiment was conducted whereby 15 participants first performed a baseline drive, and then in a second session were prompted to drive fuel-efficiently. In each drive, the participants drove with and without completing the TQT. The results of two-way ANOVAs and Wilcoxon signed-rank tests support that they drive more slowly and keep a more stable speed when asked to eco-drive. However, it appears that drivers fell back into 'everyday' habits over time, and after the workload task, but these effects cannot be clearly isolated from each other. Driving and the workload task possibly invoked unrelated thoughts, causing eco-driving mental models to be deactivated. Future research is needed to explore ways to activate existing knowledge and skills and to use reminders at regular intervals, so new driver behaviours can be proceduralised and automatised and thus changed sustainably.

1. Introduction

1.1. Background

A growing body of research suggests that the difficulty of changing drivers' behaviour towards more fuel-efficient driving practices is not simply overcome with organised training sessions (Delicado, 2012; Johansson, Färnlund, & Engström, 1999; Schall, Wolf, & Mohnen, 2016) and financial (Harvey, Thorpe, & Fairchild, 2013; Schall et al., 2016) or environmental motivations (Flynn, Bellaby, & Ricci, 2009; Stradling, Anable, Anderson, & Cronberg, 2008). Continuous feedback and feed-forward systems have the potential to encourage drivers to effectively eco-drive (Barkenbus, 2010; Birrell, Fowkes, & Jennings, 2014;

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Hibberd, Jamson, & Jamson, 2015), but these may be complex and potentially expensive to build. In contrast, simple prompts have been shown to effect reductions in fuel consumption (7–8% reduction), albeit to a lesser degree compared to support systems (10–16% reduction, van der Voort, Dougherty, & van Maarseveen, 2001; Waters & Laker, 1980). Nevertheless, prompts could be a cost-effective way to encourage drivers to utilise their existing knowledge and skills.

Several studies found that many drivers possess at least a certain amount of knowledge and skills to be able to reduce their fuel consumption. Drivers who use eco-driving support systems (EDSS) tend to adhere to the suggestions of support systems, but are also encouraged to apply existing knowledge based on their own understanding (i.e. mental models) of such behaviour. For example, an EDSS tested by Birrell and Young (2011) advised on gear changes and acceleration, but not on speed choice. Nevertheless, participants applied 'typical' eco-driving behaviours such as decreasing speed and the time spent speeding. Similar phenomena have been found with EDSS in the ecoDriver project (Saint Pierre et al., 2016). In a study by Tarkiainen, Peltola, Koskinen, and Schirokoff (2014) 39% of the participants reported that the presence of a support system alone led them to drive more safely and economically. Interestingly, drivers can apparently eco-drive without EDSS. Waters and Laker (1980) asked a convenience sample to drive normally and then eco-friendly around a specified course. The eco-driving session improved the average fuel efficiency by around 8%. This was achieved with slower speeds and higher gears. Pampel, Jamson, Hibberd, and Barnard (2015) explored eco-driving mental models further, and found that that drivers were able to effectively eco-drive, simply after being asked by an experimenter to 'drive fuel-efficiently'. Comparable effects were observed by Birrell, Young, and Weldon (2010) and van der Voort et al. (2001). An activation of eco-driving mental models could cause larger headways in order to prevent harsh braking (Boer, Ward, Manser, & Kuge, 2005), and lower speeds (Birrell et al., 2010). Drivers may keep longer headways during car-following (Birrell et al., 2014; Boer et al., 2005), but be temporarily tolerant when the headway becomes very short (Mensing, Bideaux, Trigui, & Tattegrain, 2013), e.g. when a front car is reducing its speed, to avoid stepping on the brake pedal. Hence, delivering prompts and reminders to eco-drive may have a similar function, effecting eco-driving mental models to be activated and applied.

One problem is that eco-driving is less familiar to many drivers compared to their usual driving style, and therefore less automated and habitual. Hence, behavioural changes may not be easy to sustain. In a related example, Allcott and Rogers (2014) demonstrated that the upkeep of household energy saving practices depended on a continuous provision of the prompt. The apparent fragility of sustaining new behaviours raises the question of what causes eco-driving mental models to be abandoned. In driving simulator studies with support systems, participants either worsened their eco-driving behaviours after the system was discontinued (Hiraoka, Nishikawa, & Kawakami, 2011), or they did not show improvements over repeated support system use (Jamson, Hibberd, & Jamson, 2015). Such studies show that eco-driving mental models may be deactivated over time, for example over the course of a journey, suggesting a lack of learning and internalisation. The deactivation may thus be occurring gradually over time. An additional cause may be that drivers encounter a variety of situations during their journeys, which may subject them to interruptions and elevated workload. Such interruptions are studied extensively as a cause for errors in aviation (Dismukes & Nowinski, 2007), due to the well-defined set of tasks in the field, but are applicable in the driving domain as well. In a driving simulator study with a simple display showing the amount of fuel left in the tank, Dogan, Steg, and Delhomme (2011) found that time- as well as safety-critical situations led to eco-driving behaviours being abandoned. Jamson et al. (2015) tested two EDSS advising on the gas pedal position. Despite the continuous signal, drivers largely prioritised safety in dense traffic conditions. In summary, it would appear that safety tends to be prioritised above eco-driving – as it should be – and, without constant reminders, previous driving behaviour may be resumed.

It could therefore be argued that mental workload is one of the causes for the abandonment of eco-driving. A possible explanation is that eco-driving on its own, when not supported by EDSS, can occupy mental resources (Birrell et al., 2010) and require more conscious effort. Hence, it is not an easy and intuitive task to accomplish over long periods of time. When other mental demands arise (such as safety-critical events or interventions), it may be necessary for drivers to attend to them temporarily. Once the event or intervention has passed, drivers may then revert to more familiar, and thus easier to adopt, driving styles. The current study is concerned with the stability of eco-driving mental models in the face of elevated workload and interruptions. The paper uses a workload task designed to challenge the strength of activated eco-driving models and to interrupt them.

1.2. Mental models

The theoretical underpinning for understanding drivers' eco-driving knowledge and skills in this research was based on mental models. Johnson-Laird referred to a mental model as a schema, "*a single representative sample*" (1983, p. 264) of a real entity. The idea that humans store representative schemas of the world is a central concept in the present study. In essence, it is assumed that humans possess a library of mental models, which comprise many aspects of the world, including objects, situations and events, but also sequences of events and actions (Garnham, 1997; Johnson-Laird, 1983; Rumelhart, 1980). As people perceive information, a matching mental model is retrieved and fed with the variables of the current situation. It then guides the person's perceptions and actions (Johnson-Laird, 1983).

Mental model theory is based on the understanding that the desired mental models need to be activated, and remain activated. In this example, eco-driving mental models need to take precedence over 'everyday' driving mental models. Rasmussen (1983) arranged mental models into hierarchical levels, knowledge, rules and skills. When humans learn how to drive and practise it regularly, the tasks are proceduralised, moving from the more conscious higher levels down to the

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