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Safe driving in a green world: A review of driver performance benchmarks and technologies to support 'smart' driving

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ABSTRACT

Road transport is a significant source of both safety and environmental concerns. With climate change and fuel prices increasingly prominent on social and political agendas, many drivers are turning their thoughts to fuel efficient or 'green' (i.e., environmentally friendly) driving practices. Many vehicle manufacturers are satisfying this demand by offering green driving feedback or advice tools. However, there is a legitimate concern regarding the effects of such devices on road safety – both from the point of view of change in driving styles, as well as potential distraction caused by the in-vehicle feedback. In this paper, we appraise the benchmarks for safe and green driving, concluding that whilst they largely overlap, there are some specific circumstances in which the goals are in conflict. We go on to review current and emerging in-vehicle information systems which purport to affect safe and/or green driving, and discuss some fundamental ergonomics principles for the design of such devices. The results of the review are being used in the Foot-LITE project, aimed at developing a system to encourage 'smart' – that is safe and green – driving.

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1. Introduction

Driving is a highly complex task, comprising over 1600 separate tasks over five behavioural levels (Walker et al., 2001). Drivers simultaneously control the vehicle, adjust speed and trajectory, deal with hazards, evaluate progress towards their goal, and make strategic decisions such as navigation. Groeger (2000) suggests that driver behaviour is very much goal-directed, and drivers may have multiple goals (safety, speed, economy etc.), which at any one point in time might be in conflict. Drivers appraise these conflicts and plan their driving accordingly.

With climate change becoming increasingly prominent on social and political agendas, many drivers have a new goal in mind – 'green', or environmentally friendly, driving. Whereas to date the key focus of ergonomics research in transportation and other applied domains has – quite properly – been to enhance vehicle safety and performance efficiency, it now behoves the ergonomics community to contribute to the development of systems which encourage green driving behaviour. Road transport is a significant source of both safety and environmental concerns, accounting for 2.1% of global mortality (Peden and Sminkey, 2004) and nearly 20% of total greenhouse gas emissions (EEA, 2007). Clearly, then, this is an area where ergonomics can have a meaningful impact.

'Foot-LITE'[1] is a multidisciplinary consortium project aimed at developing a system which will encourage drivers to drive in a safer and greener manner through on-board advice and post-drive feedback. The system comprises two aspects: an in-vehicle interface, which delivers real-time feedback on driving style, and a post-drive component for longer-term advice and information. The in-vehicle module is connected to the on-board diagnostic system and uses additional monitoring sensors to provide feedback on elements such as speed, acceleration, gear use, lane position and headway. Journey data are then downloadable to the off-line, web-based system for more detailed analysis and links to driver coaching modules. Foot-LITE is above all an advisory system, providing information and feedback without intervention, on how the driver's behaviour relates to aspects of safe and green driving, with the aim of modifying such behaviour to improve both aspects – encouraging what has come to be known as 'smart' driving. In order to achieve this goal, the first objective is to ascertain the driver behaviours pertaining to both safe and green driving, to determine whether there are any conflicts between these goals, and to establish the information requirements for the driver. In other words, before we can develop a specification

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[1] For more information on the Foot-LITE project, see www.foot-lite.net.

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for the Foot-LITE system, we need to define what we mean by 'smart' driving.

In this paper, written at the outset of the Foot-LITE project, we aim to establish such benchmarks for smart driving, laying the basis for further development and specification work for the Foot-LITE system – or, indeed, any such system. We first review the components of safe and green driving independently, before examining where the two goals overlap and where they compete. We then close with a discussion of the driver's information requirements for smart driving, including a summary of the positive and negative aspects of in-vehicle information systems (IVIS), such as satellite navigation, congestion assistants, intelligent speed adaptation, and other prototype green driving tools which are relevant to Foot-LITE. With 'green ergonomics' growing in popularity as an important research field (as evidenced by the recent formation of the special interest group within the UK Institute for Ergonomics and Human Factors), we hope this paper serves as a useful reference in a domain of key relevance to environmental and ergonomics issues.

2. Safe driving

Throughout the literature, excessive driving speed consistently emerges as the single biggest predictor of both crash risk and crash severity (Haworth and Symmons, 2001; Taylor et al., 2002; af Wahlberg, 2006; Aarts and van Schagen, 2006). Exceeding the speed limit or driving too fast for the conditions were identified as contributory factors in 15% of all accidents on UK roads in 2005 (Robinson and Campbell, 2006). Conversely, similar research indicates that for every 1mph reduction in speed, a 5% drop in accidents is observed (Taylor et al., 2000). It has further been suggested that accident frequency (whether fatal, serious or minor) increases with driving speed to the power of approximately 2.5 (Taylor et al., 2002). In other words, a 10% increase in mean speed would result in a 26% increase in the frequency of all injury accidents. This increases to 30% when considering just KSI (killed or serious injury) accidents (Taylor et al., 2002). When considering the severity of an accident in crash statistics, speed factors contributed to 26% of fatal accidents – which in turn accounted for 28% of all road fatalities (Robinson and Campbell, 2006).

It is worth noting that absolute speed is not necessarily the problem – the emphasis is on excessive speed, or inappropriate speed for the road and/or conditions. Indeed, many roads traditionally associated with higher speeds (such as motorways) are actually safer in terms of road traffic accidents (COM, 2006; Taylor et al., 2002). Nonetheless, it is well established that speeding (i.e., breaking the speed limit) is dangerous, particularly in urban environments (Haworth and Symmons, 2001; Aarts and van Schagen, 2006) where the number of vulnerable road users is greater. Haworth and Symmons (2001) cite evidence that '…the risk of a pedestrian receiving fatal injuries at an impact speed of 50 km/h is approximately ten times higher than at an impact speed of 30 km/h'. Likewise, the tipping point between a survivable and fatal collision for a pedestrian occurs between 50 and 60 km/h.

Various parameters of speed (i.e., average speed, speed distribution, speed profile, cruising speed, standard deviation, and free speed) are commonly used when considering accident frequency or prediction. Related measures such as acceleration/deceleration behaviour (af Wahlberg, 2006) and driver headway (Brackstone and McDonald, 2007) have also been used. These will become pertinent as we go on to discuss and contrast safe driving techniques with the components of green driving.

Whilst speed has been identified as a major factor for unsafe driving, it is by no means the sole contributor; others may include aggressive driving behaviours or risky driving manoeuvres. In a review of published literature on aggressive driving, Tasca (2000, p. 2) proposed a formal definition of aggressive driving: 'A driving behaviour is aggressive if it is deliberate, likely to increase the risk of collision and is motivated by impatience, annoyance, hostility, and/or an attempt to save time'. Similarly, a report published by the National Highway Traffic Safety Administration (NHTSA) states that aggressive driving '…is generally understood to mean driving actions that markedly exceed the norms of safe driving behaviour and that directly affect other road users by placing them in unnecessary danger' (NHTSA, 2004). Tasca (2000) further outlined some specific driving behaviours that meet the proposed definition, including tailgating, weaving in and out of traffic, failure to yield the right of way to other road users, preventing other drivers from passing, driving at speeds "far in excess of the norm," running stop signs or red lights, and several others.

Whilst definitions for aggressive driving have been established, the actual effect that it has on accident statistics is more difficult to establish. A research update completed for the American Automobile Association Foundation for Traffic Safety on aggressive driving (AAA, 2009) suggested that 56% of fatal accidents between 2003 and 2007 involved one or more actions typically associated with aggressive driving, with excessive speed being the number one factor. The report does recognise that these statistics may overstate the actual effect, as ideally an estimate of the prevalence of aggressive driving would include only instances in which such actions were performed intentionally. A more accurate measure may be when an accident was coded as having two or more of these potentially-aggressive actions, as the report suggests that '…it is more likely that a driver's actions were committed deliberately, as opposed to accidentally, when a driver was coded as having committed multiple potentially-aggressive driving actions.' (AAA, 2009, p. 8). When taking these accidents into consideration they account for 8.4% of crashes. Interestingly, in 2004 the US database of fatal vehicle crashes (NHTSA's Fatality Analysis Reporting System, or FARS) added a new code for 'Road Rage/Aggressive Driving'. The identification of a fatal accident using this code is very rare, accounting for only 0.2% (AAA, 2009) of crashes.

Although it may be argued that there are many other facets to safe driving, in this review we have focused on those most prominent in the literature (and it is notable that speed emerges conspicuously throughout, even as a consequence of aggressive driving), as well as those which have most relevance for green driving behaviours. As we shall see in the next section, speed and aggressive driving have effects on eco-driving as much as they do on safe driving.

3. Green driving

Surprisingly, in our review we found relatively more scientific literature on the effects of driving style on fuel economy and emissions than on how driving style affects safety outcomes. Whilst there are several facets to the concept of green driving, for the private driver the key controllable factors are fuel consumption and emissions. Studies suggest that simply asking drivers to drive economically can reduce fuel consumption by 10–15% (van der Voort et al., 2001; Waters and Laker, 1980). When drivers are asked to drive more efficiently, they generally interpret this as to drive slower. Indeed, Anable and Bristow (2007) estimated that enforcing the 70mph speed limit on dual carriageways and motorways in the UK could save around one mega-tonne of carbon per year. Reducing the speed limit to 60mph would almost double the saving to 1.88 mega-tonnes. Generally, though, it is thought that fuel efficiency is at its maximum between 60 and 80 km/h, as this optimises the trade-off between overcoming rolling road resistance and increasing wind resistance (Andre and Hammarstrom, 2000; Haworth and Symmons, 2001; El-Shawarby et al., 2005).

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