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Glance behaviours when using an in-vehicle smart driving aid: A real-world, on-road driving study ☆

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ABSTRACT

In-vehicle information systems (IVIS) are commonplace in modern vehicles, from the initial satellite navigation and in-car infotainment systems, to the more recent driving related Smartphone applications. Investigating how drivers interact with such systems when driving is key to understanding what factors need to be considered in order to minimise distraction and workload issues while maintaining the benefits they provide. This study investigates the glance behaviours of drivers, assessed from video data, when using a smart driving Smartphone application (providing both eco-driving and safety feedback in real-time) in an on-road study over an extended period of time. Findings presented in this paper show that using the in-vehicle smart driving aid during real-world driving resulted in the drivers spending an average of 4.3% of their time looking at the system, at an average of 0.43 s per glance, with no glances of greater than 2 s, and accounting for 11.3% of the total glances made. This allocation of visual resource could be considered to be taken from 'spare' glances, defined by this study as to the road, but off-centre. Importantly glances to the mirrors, driving equipment and to the centre of the road did not reduce with the introduction of the IVIS in comparison to a control condition. In conclusion an ergonomically designed in-vehicle smart driving system providing feedback to the driver via an integrated and adaptive interface does not lead to visual distraction, with the task being integrated into normal driving.

1. Introduction

1.1. Background

Driving can be described as predominantly a visual task (Kramer & Rohr, 1982; Spence & Ho, 2009). However, Hughes and Cole (1986) have suggested that drivers might have up to 50% 'spare' attentional capacity during 'normal' driving, with observations placed in the categories of the immediate road surroundings, general surroundings, vegetation and advertising being considered not relevant to the driving task. Green and Shah (2004) suggest that the goal of the distraction mitigation system should be to keep the level of attention allocated to the driving task above the attentional requirements demanded by the current driving environment, and that during 'routine' driving approximately 40% of attention could be allocated to

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non-driving tasks. This suggests that any increase in crash risk may be mitigated if the resources allocated to complete a secondary task are obtained from this spare capacity, compared to if they are reallocated from tasks critical for safe driving. For the crash risk to manifest itself other contributing factors also have to occur concurrently (Angell et al., 2006). Contributing factors may include the presence of a junction, urban driving or unexpected events. The presence of such driving situations occurring simultaneously as the driver is conducting a secondary task can impair the reactions of a distracted, or overloaded, driver since their spare attentional capacity has been absorbed by the secondary task. With the increasing prevalence and potential of new in-vehicle information systems (IVIS) coming to market, this spare capacity could soon get accounted for, thus creating workload issues if not carefully managed. The understanding of how drivers interact with these systems when driving is key to minimising distraction and workload issues while maintaining the obvious benefits to the user provided by Satnavs, infotainment and emerging driving related Smartphone applications.

The issue of driver distraction is a very difficult factor to quantify, firstly because it can take different forms (visual, cognitive, physical etc.), but also measuring distraction itself is almost impossible. We have certain techniques to infer distraction which range from self-completed questionnaire, peripheral detection tasks, or measuring the time taken to complete a cognitive task. One of the most effective ways to record driver distraction is by assessing glance behaviour, and recording the length of time that the driver spent with their eyes off the road. The introduction of an in-vehicle information system will inevitably lead to drivers spending some time looking at the display while driving. As described above this may not be a problem in itself; however, this allocation of visual resource should not be taken from the driving critical tasks such as looking at mirrors, the instrument panel and most importantly the road in front.

For this reason the 'Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices' proposed in 2012 were devised to help limit potential driver distraction associated with non-driving-related, visual-manual tasks (National Highway Traffic Safety Administration (NHTSA), 2012). Along with other factors aimed at limiting physical interaction with the IVIS (such as limiting manual text entry to 6 key presses or fewer or not requiring the use of two hands), they propose certain guidelines for limiting glance behaviours. Most relevant to this study, and paraphrased below, are:

- For all other secondary, non-driving-related visual-manual tasks, the NHTSA Guidelines recommend that devices be designed so that tasks can be completed by the driver while driving with glances away from the roadway of 2 s or less and a cumulative time spent glancing away from the roadway of 12 s or less. If a task does not meet the acceptance criteria, the NHTSA Guidelines recommend that in-vehicle devices be designed so that the task cannot be performed by the driver while driving.

1.2. Aims and objectives

The aim of this study and current paper was to evaluate the effects that on-road driving with a smart driving system has on glance behaviours over an extended period of time in real-world driving scenarios verses a control condition. The analysis will adopt a 'holistic' methodology rather than being 'event driven', by this we mean analysing a longer section of roadway rather than a specific period of time surrounding IVIS activity or complex driving situations (such as approaching junctions or overtaking). This offers the advantage of understanding IVIS use during comparatively normal or routine driving conditions, allowing us to make a better assessment of visual allocation. In addition the analysis of glance behaviours when using in-vehicle systems during a specific 'task' is well represented with the literature (see Dingus, Antin, Hulse, & Wierwille, 1989; Engstrom, Johansson, & Ostlund, 2005; Horrey & Wickens, 2007; Kaber, Liang, Rogers, & Gangakhedkar, 2012; Renge, 1980; Rockwell, 1988; Victor, Harbluk, & Engstrom, 2005; and summarised by Green & Shah, 2004). However, the impact of IVIS on normal driving is less well known, and hence addressed in this paper. Therefore data presented in this paper can be used as a reference for normal and extended periods of driving by future research to evaluate the use of IVIS.

Obviously placing an additional information source in the vehicle will attract the drivers' attention – particularly a highly visual display that changes in real-time as being evaluated here – this is clear from the literature cited above. What is unknown is whether this re-allocation of visual resource is taken from driving critical procedures such as glances to the mirrors, instrument panel or the road ahead, or from any 'spare' visual capacity (c.f Green & Shah, 2004; Hughes & Cole, 1986).

2. Methodology

2.1. The foot-LITE smart driving aid

This current study utilised a smart driving system developed for a UK project called Foot-LITE.[1] The system developed aims to bring information on safety and fuel efficiency together on a single, integrated, adaptive interface. Foot-LITE provides the driver with feedback and information on smart driving behaviours in the vehicle, in real-time via a visual interface presented on a Smartphone (HTC HD2). The smart driving advice offered is based on the analysis of real-time information related to vehicle operation and local road conditions, with data being collected via an adapted lane departure warning camera, the vehicles On-Board Diagnostics (OBDII) port, as well as 3-axis accelerometer and a Global Positioning Satellite (GPS) module.

[1] See foot-lite.net.