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Effects on driving performance of interacting with an in-vehicle music player: A comparison of three interface layout concepts for information presentation

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ABSTRACT

Interface design is an important factor in assessing the potential effects on safety of interacting with an in-vehicle information system while driving. In the current study, the layout of information on a visual display was manipulated to explore its effect on driving performance in the context of music selection. The comparative effects of an auditory–verbal (cognitive) task were also explored. The driving performance of 30 participants was assessed under both baseline and dual task conditions using the Lane Change Test. Concurrent completion of the music selection task with driving resulted in significant impairment to lateral driving performance (mean lane deviation and percentage of correct lane changes) relative to the baseline, and significantly greater mean lane deviation relative to the combined driving and the cognitive task condition. The magnitude of these effects on driving performance was independent of layout concept, although significant differences in subjective workload estimates and performance on the music selection task across layout concepts highlights that potential uncertainty regarding design use as conveyed through layout concept could be disadvantageous. The implications of these results for interface design and safety are discussed.

1. Introduction

The distracting potential of in-vehicle information systems (IVIS) has raised concerns regarding their ultimate effects on road safety. This concern is well-justified given that IVIS are ubiquitous, and given estimates that engaging in an additional task in general while driving can increase driver's risk of a crash or near-crash by up to three times relative to baseline driving (Klauer et al., 2006). While voluntary guidelines exist to assist manufacturers in designing and developing systems that are minimally distracting to drivers (e.g. Alliance of Automobile Manufacturers, 2006; Commission of the European Communities, 2008; Society of Automotive Engineers, 2004; see Green, 2009 for an overview), continued research is necessary to explore the nature and magnitude of effects on driving performance and safety across the IVIS range.

IVIS include fixed, original equipment manufacturer supplied or retrofitted entertainment systems/music players and navigation systems, and nomadic or portable devices, such as mobile phones, navigation systems and music players. That mobile phone use while driving can result in impaired driving performance and heightened crash risk has been well established (e.g. Caird et al., 2008; Horrey and Wickens, 2006; Hosking et al., 2009; McEvoy et al., 2005). Nonetheless, the range of IVIS available (e.g. in terms of data structure, functionality, and interface design) highlights the potential for IVIS interaction while driving to have varied effects on driving performance and safety across the range. The significance of the issue is further reinforced when the potential influences of other, non-system based factors (e.g. person-based, and driving task-based) are also taken into account.

Menus constitute a common data structure for many currently available information and communication technologies, including IVIS. Hierarchical menus are a common structure for many small screen devices (Ziefle, 2010). However, while menus are intended to provide structure and guidance to users (Jacko et al., 1995; Norman, 1991, 2008), they have the potential to be cognitively loading (Jacko et al., 1995; Maciej and Vollrath, 2009; Ziefle, 2010) – an effect which may be exacerbated through poor design of the supporting interface (Speier, 2006). An important component of the design of interfaces, visual interfaces in particular, is information presentation format or layout (e.g. text, graphics), as this will impact how efficiently and effectively a user can access the desired functions of the device (Chen et al., 2009; Singleton, 1971; Speier, 2006; Ziefle, 2010). According to Ziefle (2010), there are two mechanisms at play here. One mechanism is more visual/perceptual in nature as it relates to how quickly and accurately menu items can be processed. The more visible and readable the menu

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item, the quicker and more accurately it can be encoded. The second, more cognitive, aspect relates to the requirement that the way in which the information is presented help users to effectively and efficiently navigate through a menu whose structure may not be transparent. That is, the layout should aid users to understand what menu options are available to them, thus facilitating the decision-making process.

Despite the importance assigned to presentation format in the information and communication technology domain more generally, IVIS interface layout has been the subject of little systematic investigation for its effects on driving performance. Yet, delays or difficulties in accessing the desired information due to issues in presentation layout could have implications for driving performance and safety (Blanco et al., 2006). More generally, information presentation format or layout has a long history of research in safety-critical domains other than road safety (e.g. Singleton, 1971; Kirwan and Ainsworth, 1992).

Music players are an example of IVIS for which presentation format can vary. Research already exists into the effects on driving performance of interacting with a music player while driving, with decrements in driving performance observed in every case (Chisholm et al., 2008; Garay-Vega et al., 2010; Maciej and Vollrath, 2009; Salvucci et al., 2007). For example, relative to a baseline driving condition, Chisholm et al. (2008) reported a significant increase in response time to hazardous events and greater steering wheel variation when participants drove while also manually interacting with a visual display to perform music selection tasks of five to seven steps. Nonetheless, to date, no studies have been conducted that explore whether the way in which information is presented on a display has a moderating influence on the effects of menu item selection, in this case the selection of music, on driving performance.

The current research aims to address this gap by comparing the effect on driving performance of three different prototype presentation layout concepts for music selection. All three concepts use a hierarchical menu structure, but differ in the layout of visual information on the display. In every case, navigation through the menu structure in order to achieve the music selection goal requires manipulation of controls and buttons.

The three layout concepts chosen for study represent common ways of displaying menu information. The first concept, labelled 'Classic', comprises a linear listing of menu items and is a format common to more traditional music players. The second layout, 'Modified fisheye', is based on the fisheye distortion concept. Fisheye menu interfaces show part of the menu in focus, with gradually shrinking menu items positioned above and below the focus region. Thus, in a limited amount of screen space, fisheye menus can accommodate more menu items than a traditional linear list. The potential benefit of fisheye menus to users is that users can scrutinise the region that is in focus while also being able to maintain an overview of the menu (Bederson, 2000; Hornbæk and Hertzum, 2007). The third concept, 'Cover Wheel', is a 3D graphical layout based on the cover flow concept most commonly associated with iTunes™ (Apple Inc.), and typical of the format used in several iPod™ models. The use of the 3D metaphor for displaying graphical information represents a currently popular way of presenting data graphically on an interface. Aside from enhancing user satisfaction (Cockburn and McKenzie, 2001), interfaces of this sort aim to facilitate use by drawing on users' spatial and visual recognition of images (Broy et al., 2006).

Driving performance was assessed using the Lane Change Test (LCT; Mattes and Hallén, 2008). The LCT method currently exists as a Draft International Standard (DIS) developed by International Organisation of Standardisation (ISO) Technical Committee 22 Subcommittee 13 (ISO/DIS 26022, 2009). Essentially, the LCT is a laboratory-based method for estimating the effects on driving performance associated with concurrent operation of an in-vehicle device. Previous research has demonstrated the LCT to be sensitive to variation in the demands of the additional task (e.g. Bruyas et al., 2008; Burns et al., 2005; Engström and Markkula, 2007; Harbluk et al., 2009; Maciej and Vollrath, 2009), and as such, was considered suitable for use in the current study.

To explore the impact of presentation layout on driving performance, the three layout concepts were compared with two types of 'baseline': driving only, and driving while also performing a cognitive task with no visual-manual component. Several previous studies have reported no adverse effects on lateral control associated with concurrent performance of a task that was designed to be cognitively loading in the absence of any visual-manual load (e.g. Engström et al., 2005; Jamson and Merat, 2005). In these studies, the cognitive task that was used served as a surrogate for the cognitive demands that might be imposed by a 'real' IVIS with no visual-manual load. Given these findings it was considered worthwhile to include a cognitive task in the current study to serve as a further frame of reference.

2. Method

2.1. Participants

Participants in the study were 30 drivers with a full car driver's licence. All participants were in the age range of 24–55 years ($M = 31.5$ years; SD = 8.1 years). A similar proportion of males (53%) as to females (47%) took part in the study, and all participants had held a car driver's licence for at least five years (Mean = 11.5 years; SD = 7.7 years). Approximately two-thirds of participants (60%) reported driving between 5001 and 20,000 km in a given year. Just under one-third (30%) reported that they drive more than 20,000 km in a given year. All participants reported that they listen to music at least 'some of the time' while they drive a car. All participants reported having normal or corrected-to-normal vision for driving.

Participants were mainly staff and students of Monash University (about 80%) and had responded to recruitment notices posted on University-based electronic noticeboards and distributed through University email bulletins. Participants were offered AUD20 for their involvement in the study.

2.2. Layout concepts

Three layout concepts for music selection were examined in the current study. In every case, music information is arranged as a hierarchical menu, in which available options for selection are increasingly restricted and refined as users progress through the structure. The critical difference between the three concepts is the way in which information is presented visually on the IVIS display. A schematic of each of the design concepts is given in Fig. 1.

The first concept labelled 'Classic', can be described as providing information through a simple linear, scrollable list. In general, within a given list, the items are arranged alphabetically. The lists are circular and can be scrolled through in either direction – that is, either up or down. A status bar on the right-hand side of the display is intended to signify how much of the list is shown on screen and how far through a given list the user has scrolled. The highlighted item at the top of the list is the item which would be selected were the user to depress the main rotary control (not shown). The main rotary control is also the principal device used for scrolling through the lists.