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Help on the road: Effects of vehicle manual consultation in driving performance across modalities[☆]

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A B S T R A C T

The growing advancements of in-vehicle electronics and the intrusion of consumer electronics in the vehicle cockpit have increased the complexity of in-car experiences. Therefore, vehicle manuals are needed, now more than ever, to provide information and guidance. Automakers have extended user assistance through multimedia, integrated manuals, online services and telephonic assistance. However, no driver-centric interfaces have been created to provide vehicle documentation assistance effectively. Drivers are expected to interrupt the driving experience in order to find vehicle information in a paper manual. This paper compares the effects on driving performance and cognitive load when consulting a manual in a simulated driving environment through various conditions. These conditions consist of interacting with a voice activated vehicle manual called the Voice User Help, an on-board multimedia manual, a passenger, and a call center. Results suggest that any kind of interaction to access information while driving has an impact on the driver's attention based on a decrease in driving performance and increase of cognitive load. However, amongst all modalities, voice interfaces seem to be the better option for consulting information while driving. Also, and under some circumstances, interaction with a conversational manual system appears to be safer than human-to-human communication.

1. Introduction

Vehicle manuals provide drivers with the ability to search for a wide variety of information about their vehicle. These vehicle manuals are the only reference available when a problem occurs in the car. In recent years, automakers have been extending traditional printed manuals attempting to deliver rich-media documentation in electronic formats such as PDF, multimedia disk manuals and interactive multimedia systems incorporated in in-vehicle information systems (IVIS) (Zachry et al., 2001; Alvarez et al., 2010). In spite of these efforts, printed paper manuals are still the most dominant form of car manuals regardless of other electronic formats (Alvarez et al., 2010).

The advancement of vehicular technologies have increased the use of vehicle electronics, adding to the complexity of the driving experience and to the need for acquiring information about the vehicle. Along with the increased functionality to operate a car, vehicles have become a place for information access, media consumption and personal entertainment (Schmidt et al., 2010).

Furthermore, drivers and passengers are bringing smart consumer electronics into vehicles making them highly interactive spaces. With the inclusion of in-vehicle features, questions about how to operate them may arise when the automobile is in motion. These issues may range from a light that appears on the dashboard to setting the cruise control or selecting a song from the driver's personal music collection. Some matters may require an immediate response from the driver. Consulting a paper manual in these cases can be extremely complex and potentially unsafe while driving. This paper investigates the conditions under which current technologies allow the consultation of vehicle documentation while driving. The impact of modality is addressed in terms of cognitive load, system usability, and driver performance when consulting a vehicle's manual as a secondary task. This research aims to discover the best practice for finding vehicle information safely.

2. Distraction while driving

Distraction in this research is understood as the diversion of attention away from activities critical for safe driving toward a

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competing activity (Lee et al., 2008). Driver distraction occurs when a driver is delayed from recognizing obstacles that could threaten their ability to maintain safe driving (Klauer et al., 2006). The issue of driver distraction remains a serious problem today and is the main cause of road fatalities and accidents (Lee et al., 2008; Gordon, 2009). Many drivers find it difficult to resist the temptation of talking on the phone, texting, eating, or using electronic devices while driving. The "100 car naturalistic study" found that secondary tasks were performed during 40% of all trips (NHTSA, 2006a, 2006b). According to recent data collected by the US National Highway Traffic Safety Administration (NHTSA), 17% of the police-reported crashes that occurred in the USA in 2010 were the result of distracted driving (NHTSA, 2012).

Particularly, the rising trend of using technological gadgets in the vehicle is currently one of the main sources of driver distraction (Roberts et al., 2012). Text messaging has been studied for its effects on lateral control and reaction time while driving. It was found to decrease driving performance up to 35% (Reed and Robbins, 2008). Current in-vehicle driving environments have become increasingly complex and drivers are susceptible to cognitive and perceptual information overload (NHTSA, 2006a, 2006b). The amount of attention given to the use of IVIS has peaked considerably due to safety concerns (Oz et al., 2010). In particular, Ziefle et al. (2008) demonstrated that the use of IVIS's contributed to 25% to 30% of crash risk. In 2010, 26,000 police-reported crashes were found to be caused by an in-vehicle technology, which is 3% of all distraction related crashes (NHTSA, 2012).

Despite all effort, it has been evident that prohibiting drivers from texting while driving only causes more distraction and further accidents. Therefore, it was essential to find a solution that attends to drivers' immediate needs while keeping them safe and less distracted. The Dual-Task Paradigm states that humans have a limited amount of available cognitive resources (Goselin and Gagné, 2010). In driving conditions a great deal of those resources are allocated to the primary driving task, leaving little capacity to secondary actions. The multiple resource theory of attention explains, however, that humans are able to drive and perform secondary actions without fatal consequences. That latter is achieved by assigning pools of resources that can be used in parallel when they are allocated to different modalities (Wickens, 2002). This supported the design of eyes-free, hands-free vehicular interfaces.

Given that cross-modal attention happens constantly in real-life, different studies have addressed the effects of modality for dual-task performance in driving scenarios. Cao et al. showed auditory interfaces to be the preferred media for in-vehicle warnings (Cao et al., 2010). Research presented by Jeon et al. (2009) and Sodnik et al. (2008) showed evidence that favor auditory interfaces for menu navigation. Driving distraction has been proven to decrease when comparing the use of voice interfaces to manual interfaces (Maciej and Vollrath, 2009). Furthermore, the US Department of Transportation (DOT) recently released driver distraction guidelines that encourage the use of voice-activated interfaces for in-vehicle technologies as the least distracting modality (NHTSA, 2012).

The effects of conversing on cellular phones while driving have been studied for its effects on driver performance. Many studies attribute radical decrements in attention and elevation in cognition levels to texting and talking on the phone while driving (Bruyas et al., 2008; Just et al., 2008; Brumby et al., 2011). It has also been shown that the use of hands-free devices can be just as dangerous as the use of cell phones while driving (Horrey and Wickens, 2006; Iqbal et al., 2011). The latter implies that distraction originates at the cognitive demand level, rather than the interaction of the conversation itself.

Conversational phone interactions can diminish driver's attention to visual road inputs ahead due to necessary verbal cognitive processing of the conversation (Strayer and Johnston, 2001). This can cause longer reaction times, and worsen the driver's situation awareness (Gugerty et al., 2004). Although the nature of the interactions, whether texting or talking, is difficult to distinguish in most of the cases, 47% of the accidents related to driver distraction in 2010 in the USA were result of the use of cellular phones (NHTSA, 2012).

In his research, Charlton addressed driver distraction levels produced by engaging in conversations with a passenger versus engaging in conversations with a remote person via a cell phone. He estimated that interactions with a remote person are more susceptible to distract the driver because the telephonic partner lacks the context awareness to modulate the conversation in favor of the driver's road awareness (Samuel, 2009). Conversation modulation is a collaborative phenomenon that occurs when a passenger regulates the flow of the interaction with the driver as a result of identifying events ahead of the road that might affect the driver (traffic incidents, hazards, etc.). Even though conversation with a passenger still erodes the driver's performance, sharing that contextual awareness makes it less negative than telephone conversations. However, Charlton demonstrated that when remote partners are somehow informed of road events, driver distraction would only depend on the actual form and content of the conversation.

This research analyzes the effects of consulting vehicle documentation on driver performance and cognitive load when accessing different modalities. This study was conducted to compare and evaluate driving performance measures depending on the condition to which they are acquiring the information from. These conditions are (1) interacting with Voice User Help (VUH), (2) using iDrive to access a multimedia in-vehicle manual, (3) interaction with a passenger, and (4) interaction with a person who is physically absent via a cell phone (i.e. at a call center). In all the modalities studied, the goal of the interaction is identical; to find information about a vehicle feature for the purpose of solving an issue that arises while driving.

3. Measuring driver distraction

Researchers have tried to measure driver distraction in numerous ways using driving simulator environments. Driver eye glancing patterns have been a common metric to evaluate distraction effects with IVIS. Yulan et al. (2007), designed a method that uses support vector machines on the driver's eye movement observations to detect distractions in real time. Lateral and longitudinal vehicle control and object-and-event detection measures are now typically collected using driving simulator software. The software runs in the background collecting the driver's performance measures and can later be processed on a number of variables such as acceleration, reaction times, mean speed, steering angle deviation and lateral deviation. The Peripheral Detection Task (PDT) provides measures of driver distraction while performing in-vehicle tasks on real roads (Olsson and Burns, 2000). However, this research focuses on voice interfaces. Therefore, it opted for the Lane Change Test (LCT); a standard tool that does not require visual glance metrics (Mattes, 2003). In addition, a psychological metric of importance for evaluating driver distraction is the driver's self-reported cognitive workload. It assesses the level of stress that a secondary task produces on the driver. Cognitive workload has been typically collected using questionnaire tools, such as the NASA Task Load Index (TLX) (Hart and Stavenland, 1988), the Operator Workload Assessment (Wolf, 1978), or the Multitasking Difficulty Assessment (NHTSA, 2006a, 2006b).

4. Experimental design

This study investigates the effects of consulting vehicle documentation as a secondary task under various driving conditions.