



Effect of police mobile computer terminal interface design on officer driving distraction



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ABSTRACT

Several crash reports have identified in-vehicle distraction to be a primary cause of emergency vehicle crashes especially in law enforcement. Furthermore, studies have found that mobile computer terminals (MCTs) are the most frequently used in-vehicle technology for police officers. Twenty police officers participated in a driving simulator-based assessment of visual behavior, performance, workload and situation awareness with current and enhanced MCT interface designs. In general, results revealed MCT use while driving to decrease officer visual attention to the roadway, but usability improvements can reduce the level of visual distraction and secondary-task completion time. Results also suggest that use of MCTs while driving significantly reduces perceived level of driving environment awareness for police officers and increases cognitive workload. These findings may be useful for MCT manufacturers in improving interface designs to increase police officer and civilian safety.

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1. Introduction

In the U.S., there are three main categories of emergency services including: firefighting, emergency medical services (EMS), and law enforcement. According to [Karter and Stein \(2012\)](#) and [Reaves \(2011\)](#), there are 30,100 fire departments and 17,985 state and local law enforcement agencies throughout the Country that provide emergency services. A large number of firefighters, paramedics, and police officers at these agencies spend most of their work shift in emergency vehicles. The National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) and General Estimate System (GES) reports from 2002 to 2012 indicated that police vehicles are involved in significantly more fatalities in comparison to fire or emergency medical vehicles. One possible explanation for the greater numbers of crashes and fatalities for police might be the larger number of police cruisers in comparison to other emergency vehicles and the fact that police vehicles are more likely to be single-crewed ([Yager et al., 2015](#)). It is important to note that the number of reported crashes are in absolute terms and does not consider miles driven. Several studies identified in-vehicle distractions to be a primary cause of

emergency vehicle crashes (e.g. [Yager et al., 2015](#); [Abdelwanis, 2013](#)).

1.1. Effect of in-vehicle technology use for normal drivers

Driver distraction has been defined as “diversion of attention from activities critical to safe driving for performance of a secondary competing activity” ([Lee et al., 2009](#)). The effect of visual and cognitive distraction caused by in-vehicle technologies on civilian driver performance, and attention allocation has been examined through many studies documented in the literature. For example, [Liang and Lee \(2010\)](#) conducted an empirical study to investigate the combined effect of visual and cognitive distraction on driver performance caused by a secondary navigation task and made comparison with only visual or cognitive distraction effects. Results showed that visual distraction interferes with driving performance more than cognitive distraction, and visual distraction dominates performance decrements during combined distraction. In a more recent study, [Kaber et al. \(2012\)](#) also assessed the effect of visual, cognitive, and simultaneous distraction of an in-vehicle navigation aid on operational and tactical driver behavior. Their results showed that tactical behavior is more demanding in terms of cognitive distraction than operational behavior. In addition, they found that visual and cognitive distraction both increase driver workload but in different ways in terms of vehicle control and gaze behavior. Related to this, several studies have found the use of in-

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vehicle technology to increase driver distraction and compromise safety for normal drivers. For example, the findings of [Salvucci et al. \(2007\)](#) revealed that interaction with an iPod while driving significantly affects driving performance. More specifically, they found that selecting media using a portable music-player not only affects driving performance but the effect is comparable to previously reported effects of dialing on a cell-phone while driving.

Beyond this, several studies have found the characteristics of in-vehicle technology to have effects on the safety of normal drivers. For example, [Kim et al. \(2014\)](#) conducted a driving simulation study and found that increasing the size of touch-key increases both driver safety and usability of in-vehicle technology. In another simulation study, [Mitsopoulos-Rubens et al. \(2011\)](#) investigated the effect of layout of information in in-vehicle displays on driver performance. Although they found performance of a secondary task (music selection) to have a negative effect on driving performance, the layout of information did not have any significant effect on the magnitude of the effect.

Although several studies have found that in-vehicle technologies increase driver distraction and compromise safety for normal drivers (e.g. [Blanco et al., 2006](#); [Salvucci et al., 2007](#); [Kaber et al., 2012](#)), few studies have focused on distraction due to in-vehicle technologies in emergency vehicles. Given that the origin, type and magnitude of driver distraction have been found to be influential in driver performance and safety, there is a need to conduct additional research to map the effects of distraction on emergency vehicle driver behavior.

1.2. Emergency vehicle crashes due to in-vehicle distraction

Some prior research has observed that use of in-vehicle technologies in emergency vehicles might cause driver distraction and reduce attention to the driving task (e.g. [Hampton and Langham, 2005](#)). [Callander and Zorman \(2007\)](#) mentioned that vendors of patrol vehicle information systems state that such systems are not designed for use while driving. However, after interviewing a large sample of officers, they found that all respondents confirmed computer use while driving. Related to this, officer distraction/inattention was identified as an underlying factor in 1021 crashes of emergency vehicles in the State of Texas recorded from 2010 to 2014 ([Yager et al., 2015](#)). In another investigation, the South Carolina Department of Public Safety recorded 803 emergency vehicle crashes between 2001 and 2010 and driver fatigue and distraction were identified as primary causes of these accidents ([Abdelwanis, 2013](#)). Finally, the Austin (Texas) Police Department reported 48 patrol car crashes from 2010 to October 2014, which were attributed to distracted driving. It was found that in 25 of the 48 crashes, the police officer was interacting with a mobile computer terminal (MCT) while driving, and in 8 other cases, the officers were interacting with a cell phone or other on-board equipment ([Yager et al., 2015](#)). In general, these crash reports provide evidence that divided attention and driver distraction are growing problems for emergency vehicle drivers.

1.3. MCT usage rate in emergency vehicles

MCTs are computers inside emergency vehicles that have several functionalities including: map/GPS system, communication among responders, video recording modules, etc. Although MCTs were not originally designed to be used while driving, the interfaces can be used while driving and several police officers confirm using them frequently ([Callander and Zorman, 2007](#)). Among all in-vehicle technologies in police cars, MCTs are the most frequently used for officer performance of in-vehicle tasks ([McKinnon et al., 2011](#)). The [Yager et al. \(2015\)](#) study also included

an online survey of emergency responders from the Austin-Travis County EMS (TX) and found that the most frequently used in-vehicle technology was MCTs (about 10% of on-the-job time) followed by radio and cell phone use. Related to this, [Girouard et al. \(2013\)](#) found that officers make use of the MCT approximately 13% of their shift time during a typical workday.

1.4. MCT effect on distraction and driver performance

[Liu and Donmez \(2011\)](#) found that crashes involving police officer distraction due to in-vehicle sources are more severe than crashes involving similar civilian driver distraction. In addition, in-vehicle technologies used in emergency vehicles are more complex and demanding than normal cars. However, few studies have focused on visual and cognitive distraction caused by interaction with these high demand devices. [Hampton and Langham \(2005\)](#) conducted an on-road study of single and double-crewed police cars and officer distraction due to interaction with MCTs was identified as a primary safety concern. They used a survey/checklist called “The safety checklist for the assessment of in-vehicle information systems” and found that MCT use is incompatible with driving. On the basis of this work, follow-on studies have focused on the effect of different modalities of MCT interaction on distraction and driver performance. For example, after designing a new integrated MCT with speech recognition capability, [Kun et al. \(2004\)](#) conducted a field test to make comparison with an old system without speech capability. Results revealed that officers found the speech user interface (SUI) most useful while driving and the graphical user interface (GUI) most useful when parked. Related to this research, [Mitsopoulos-Rubens et al. \(2013\)](#) conducted a simulation study of voice-based input and output modalities towards reducing officer workload. Results showed the conventional visual-manual MCT interface to require more time and pose higher physical demand in comparison to visual-voice and audio-voice interfaces. The visual-manual condition was also reported as hardest to use. The authors also observed that the visual-manual interface was associated with significantly more eyes-off-road time than either of the two voice-based interfaces, and significantly more long, safety-critical glances. [Filtness et al. \(2013\)](#) also found that visual-manual and visual-voice interfaces resulted in significantly more glances to a MCT display than an audio-voice interface.

Although the above studies indicate benefits of using speech and voice based interaction styles with MCTs, [Lee et al. \(2001\)](#) assessed the effects of a speech-based email system on driver performance and found that reaction-time increased. In addition, they found that speech based interaction introduced a significant cognitive load for drivers. Although their study was not conducted in the context of emergency vehicle operation, their experimental task was similar to tasks that can be performed with MCTs in emergency vehicles. Therefore, this study supported the observation that using speech-based interaction may not always reduce driver distraction.

Besides studies focused on different modalities of information presentation in MCTs, some research examined the relationship between the use of in-vehicle technologies in emergency vehicles and the context of work. For example, [Streefkerk et al. \(2006\)](#) designed a personal attentive user interface (PAUI) for which the content and style of information presentation was based on user cognitive capacity, tasks, and context. In a more recent study, [Kurkinen et al. \(2010\)](#) developed a prototype called SUMO (Situational Updates from Mobile Officers) that recognizes the cognitive/attentional demands of officers while driving and that the user interface itself could adapt to expected user states and “optimize” interactions. The system worked based on gathering information from vehicle sensors to determine location, speed, and status (e.g.,

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