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Identification of task demands and usability issues in police use of mobile computing terminals

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ABSTRACT

Crash reports from various states in the U.S. have shown high numbers of emergency vehicle crashes, especially in law enforcement situations. This study identified the perceived importance and frequency of police mobile computing terminal (MCT) tasks, quantified the demands of different tasks using a cognitive performance modeling methodology, identified usability violations of current MCT interface designs, and formulated design recommendations for an enhanced interface. Results revealed that "access call notes", "plate number check" and "find location on map" are the most important and frequently performed tasks for officers. "Reading plate information" was also found to be the most visually and cognitively demanding task-method. Usability principles of "using simple and natural dialog" and "minimizing user memory load" were violated by the current MCT interface design. The enhanced design showed potential for reducing cognitive demands and task completion time. Findings should be further validated using a driving simulation study.

1. Introduction

1.1. Emergency vehicle crashes

According to the National Highway Traffic Safety Administration (NHTSA), in 2010, the total number of persons killed in crashes involving emergency vehicles was 31 for ambulances, 14 for fire trucks, and 84 for police vehicles. The NHTSA Fatality Analysis Reporting System (FARS) and General Estimate System (GES) reports from 2002 to 2012 also indicate that police vehicles are involved in significantly more fatalities in comparison to fire or emergency medical vehicles. The greater number of crashes and fatalities for police vehicles might be due to 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) than other emergency response vehicles.

Several studies have found that use of in-vehicle technologies in emergency vehicles might cause driver distraction and reduce attention to driving tasks (e.g. Hampton and Langham, 2005). Callander and Zorman (2007) noted that vendors of patrol vehicle information systems claim that such systems are not designed for use while driving. However, after interviewing police officers, the authors found that all of respondents confirmed computer use while driving. The Kansas City (Missouri) Police Department reported a total of 181 crashes from 2009 to November 30, 2014 and an average of over 30 crashes per year. They identified officer distraction as the main reason for these crashes (Yager et al., 2015). In another investigation, the Austin (Texas) Police Department reported 48 patrol car crashes from 2010 to October, 2014, which were attributed to distracted driving. They mentioned that in 25 of these 48 instances, a police officer was interacting with a mobile computing 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). Related to these statistics, Liu and Donmez (2011) found that crashes that involved police officer distraction due to in-vehicle sources are more severe than crashes involving civilian driver distraction due to in-vehicle sources, which might be due to the complexity of the technologies used in emergency vehicles as compared to normal cars. In an on-road study of single and double-crewed police cars, Hampton and Langham (2005) found distraction due to interaction with MCTs as a main safety concern. However, very few studies have focused on visual and cognitive distraction caused by interaction with these devices (e.g. Callander and Zorman, 2007).

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1.2. Mobile computer terminal

Police MCTs are also known as mobile data terminals (MDTs) or mobile digital computer (MDCs) and include a visual display with a keyboard and, in some cases, touch screen capability for data entry (Filtness et al., 2013). The general functionalities of MCTs include: providing information for the officer, serving as a portal for communication among responders, and providing auditory and verbal notifications. In more details, MCT software provides access to a map/GPS system, call notes (information relevant to a case), personnel assignment information, a video recording module, and several other functional capabilities, such as plate number checking (Yager et al., 2015). However, MCTs do not provide access to all available law enforcement data mainly due to screen size and cost of information retrieval from wireless networks (Hampton and Langham, 2005).

Among all in-vehicle technologies in police cars (e.g. radio system, video cameras, siren and control panel, etc.), MCTs are most frequently used in officer performance of in-vehicle tasks (McKinnon et al., 2011). In one study, Garrison et al (2012) found that officers spent approximately 7% of their time attending to a MCT display while a vehicle was in motion (i.e., while driving). Related to this, Girouard et al. (2013) found that officers use the MCT approximately 13% of their shift time during a typical workday. Response activities for Austin-Travis County EMS showed that the most frequently used in-vehicle technology was the MCT (about 10% of on-the-job time) followed by radio and cell phone use. Related to this, Anderson et al. (2005) conducted a field study with 121 police officers from British Columbia and observed their activities. Results revealed that 77% of officers used MCTs while driving. In addition, they found that 55% of officers used MCTs while performing at least one other task, and 11% used MCTs while performing at least two other tasks simultaneously.

1.3. Usability evaluation of MCTs

Usability is a general term concerning the effectiveness, efficiency and satisfaction with which users achieve goals with an interface (International Organization for Standardization, 1998). Molich and Nielsen (1990) identified a list of usability principles including: simple and natural dialogue, speak the user's language, minimize the user's memory load, be consistent, provide feedback, provide clearly marked exists, provide shortcuts, provide good error messages, and error prevention.

Although extensive MCT development has occurred, including integration of new technologies such as voice recognition systems and touchscreen capabilities, there remain concerns regarding the potential effect of these devices on officer driving distraction. High police car crash rates, attributed to officer distraction in use of MCTs, have motivated researchers to conduct usability analyses on these devices. Marcus and Gasperini (2006) conducted interviews with six police officers after receiving complaints from the San Jose police department about their new in-vehicle computer system. They found several usability issues with the system such as difficulty in completion of numerous important tasks while driving, reliance on indirect rather than direct controls, a user interface not optimized for touch screens, poor filtering of important information, poor information layout, problems with sending and receiving messages, and numerous issues with mapping and routing (e.g., confusing symbols, colors and text formats). They recommended user-centered design considering police officers as the end-users of these systems. They also recommended conducting task analyses as part of the design process for understanding what officers actually do in police cars. In another study, Branaghan et al. (2010) identified important information elements of different calls. They enhanced an MCT interface design by applying the proximity-compatibility principle (Wickens and Carswell, 1995) so that officers could easily recognize relationships between different pieces of information. The authors projected that the enhanced design would improve officer situation awareness. However, they did not objectively compare the enhanced design with the original interface.

Callander and Zorman (2007) conducted a usability study to assess police distraction as a result of in-vehicle technology. Combining a NHSTA workload assessment protocol and a cognitive modeling tool called Goals, Operators, Methods, and Selection Rules (GOMS), they compared the task of plate number check via radio with the same task via computer (MCT/MDC). The GOMS model results revealed the plate check via radio dispatch to require fewer steps with a minimum of zero and maximum of four off-road glances while the same task with a MCT/MDC required a minimum of eight and maximum of 27 off-road glances. After this assessment, they suggested use of a “project54” speech recognition system in patrol vehicles. There was only one reported accident after implementation of the new system and the reason was that the officer wanted to login to the system manually while driving and this task was not supported by the speech recognition system. Although Callander and Zorman found 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 when the speech-based system was used. In addition, they found that speech-based interaction introduces a significant cognitive load for drivers. Although Lee et al.’s study was not conducted in the context of emergency vehicle operation, the test task was similar to tasks that can be performed with MCTs in emergency vehicles. Therefore, this study supports the observation that using speech-based interaction may not actually reduce police officer distraction in in-vehicle task performance.

1.4. Problem statement

Given high crash rates for police vehicles attributed to in-vehicle distraction, and the fact that the most frequently used technology in these vehicles is the MCT, there is a need to understand perceptual, motor and cognitive demands associated with police officer MCT use. Such understanding may support design and development of additional interventions to reduce distraction and increase officer and civilian safety during police emergency operations.

On this basis, the objectives of this study were to: (1) identify the perceived importance and frequency of use of police in-vehicle technologies and different MCT tasks by decision tree analysis; (2) quantify the visual and cognitive demands of high importance and high frequency MCT tasks using cognitive modeling; (3) identify usability violations of the current MCT interface design and formulate design recommendations for an enhanced MCT using heuristic evaluation; and (4) ultimately introduce the enhanced MCT interface design concept and objectively compare it with the current interface design. In the following sections, we provide an overview of the research methods of the study, including knowledge elicitation, decision tree analysis and cognitive modeling.

1.5. Knowledge elicitation

Knowledge elicitation is defined as, “the process of explicating domain specific knowledge underlying human performance,” and is considered part of a knowledge acquisition process. There are four general categories of knowledge elicitation techniques including: observations, interviews, process tracing, and conceptual methods (Cooke, 1999). Observations can provide general