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Analysis of Law Enforcement Mobile Computer Terminal Interface

Maryam Zahabi[a], Taylor Shupsky[b], Adriana Lyman[b]
[a] Texas A&M University, College Station, TX, USA
[b]Wichita State University, Wichita, KS, USA

Abstract

Several crash reports have identified the mobile computer terminal (MCT) to be the main cause of police vehicle crashes. Prior MCT usability evaluations only focused on specific functionalities and might not be generalizable to all MCT modules. Eleven police officers participated in this study to assess the usability of an MCT interface and provide a comprehensive set of guidelines to improve its design. A combination of usability evaluation methods including hierarchical task analysis, think aloud, cognitive performance modeling, and heuristic evaluation were used. The findings revealed that some MCT tasks including warrant check and event query are more complex as compared to the other modules and should not be performed while driving. Several usability issues were identified including confusing abbreviations, inconsistencies in data entry format, heavy reliance on working memory, insufficient error messages, and unnecessary or redundant information. A set of usability guidelines was proposed to improve the effectiveness, efficiency and satisfaction of police officers in using the MCTs.

Keywords
Mobile computer terminal, usability, cognitive modeling, heuristic evaluation, police

1. Introduction
Police vehicles are equipped with several in-vehicle technologies including the mobile computer terminal (MCT), radio system, video cameras, and siren and control panel. Previous studies have found the MCT to be the most important and frequently used in-vehicle technology for police officers [1, 2]. The MCT is a laptop including a touch screen display and a keyboard that can be used for manual data entry. The MCT provides several functionalities for police officers such as accessing to case related information, serving as a patrol for communication, and providing navigation aids. In addition, MCTs provide safety critical information in real time and improve officer awareness of circumstances while on route.

Crash reports have identified in-vehicle distraction especially the MCT use to be the main cause of police vehicle crashes. For example, Austin (Texas) police department reported 48 patrol vehicle crashes from 2010-2014 that were caused by distracted driving. In 25 out of these 48 cases, the police officer was interacting with the MCT [3]. In another report from Kansas City (Missouri) police department from 2009-2014, the total of 181 crashes were reported and in-vehicle distraction was the main causal factor. In July 2012, NBC 5 (Arlington City, Texas) reported an investigation of the number of police vehicle crashes in the past 3 years and found 18 crashes involving officer interactions with the MCT [4]. The above crash reports have motivated several researchers to conduct usability evaluations on MCTs.

1.1. MCT Interface Usability Evaluation
The international organization for standardization (ISO) defines usability as a general term which is focused on the effectiveness, efficiency and satisfaction with which users achieve goals with an interface [5]. Prior MCT usability evaluation studies have used a combination of methods including interviews and ride-along with police officers, cognitive performance modeling, and user-testing. For example, Marcus and Gasperini [6] usability evaluation study with six police officers revealed that the MCT was not optimized for touchscreen usage, presented information with a poor layout, and had several problems on sending and receiving messages and finding routes. Hampton and Langham [7] conducted semi-structured interviews with seven police officers and found issues with network coverage, information content, and layout that need to be improved to have more efficient human-computer interaction. In our previous study [8], we conducted structured interviews and heuristic evaluation with five police officers and two human factors professionals to identify the usability issues in one of the MCT tasks (i.e., plate number check). Findings revealed that the plate number check module contains several irrelevant or rarely needed

information (e.g., sex offender, stolen vehicle) and the system was designed in a way that several pieces of information needed to be memorized from one page to another, which violated the usability principle of minimizing user memory load. We proposed an enhanced MCT design concept, provided a summary page for the officers, ranked the information based on the importance on each page, and enhanced the navigation among different information pages. However, the evaluation was only focused on one MCT task and might not be generalizable to other modules.

Another approach to assess the usability of an interface is using walkthrough methods such as cognitive performance modeling. Goals, Operators, Methods, and Selection Rules (GOMS) is one of the walkthrough usability analysis methods that have been used previously in assessing MCT interfaces. For example, by comparing the visual operators derived from the GOMS models of performing a plate number check task with the radio and the MCT, Callander and Zorman [9] found that using the radio is less visually demanding than the MCT. In our previous study [2], we used GOMS language (GOMSL) as a computational cognitive modeling tool to identify the visual and cognitive demands in performing some of the frequently used MCT tasks including plate number entry, reading plate information, and orientation on map. Results revealed that reading the plate information was the most visually and cognitively demanding task for the officers. Prior studies have also conducted user-testing studies to assess the usability of MCT interfaces. Findings of a driving simulation study suggested that visual-manual interfaces negatively affected physical demand as compared to voice-based interfaces and resulted in higher time pressure. In addition, voice-based interfaces were rated easier to use and more useful as compared to visual-manual interfaces [10]. Related to this, results of our prior driving simulation study comparing the task completion times of police officers using two MCT interfaces revealed that even basic MCT usability improvements (e.g., ranking the information and providing summary pages) improved police officer performance [8].

1.2. Problem Statement

Although MCT interfaces have been improved extensively in recent years by integration of new technologies and touchscreen capabilities, there are concerns about the potential effect of these devices on officer safety. Crash reports have shown the MCT to be the main cause of police officer distraction and have motivated researchers to conduct several usability evaluations. However, prior usability assessments had limited sample sizes or focused on specific MCT functionalities. In our previous investigation [2], we used cognitive modeling and heuristic evaluation to understand perceptual, motor, and cognitive demands associated with police officer MCT use. However, the study only focused on the task of reading plate information. Although this selection was based on the findings of decision tree analysis, there are other tasks that may be challenging for officers under specific circumstances (e.g., being dispatched to an unknown area for an emergency call). In addition, the sample size was limited to five police officers. Therefore, in the present study, we used a combination of methods including hierarchical task analysis (HTA), think aloud, cognitive performance modeling, and heuristic evaluation to conduct usability evaluations on all typical MCT tasks. In addition, we improved the generalizability of our findings by increasing the sample size and collecting data from two police departments using an MCT interface provided by another vendor as compared to our previous study. The main objective of this study was to identify the most demanding MCT tasks and a set of usability guidelines for enhancing MCT interfaces.

2. Method

2.1. Participants

Eleven police officers (9 males and 2 females, age: *M* = 33.82 yrs., *SD* = 5.13 yrs.) from two police departments in the Midwest with all having prior experience as patrol officers (*M* = 6.90 yrs., *SD* = 4.36 yrs.) participated in the study. All participants were identified as being expert in using the MCT (Experience level (0-100 scale): *M* = 86%, *SD* = 16%). The participants had 20/20 vision or corrected vision and were regularly driving police vehicles (*M* = 6.96 hrs. per week, *SD* = 1.58 hrs.). The study took approximately 2 hours to complete and the officers were paid $70 for their time. The Wichita State University Institutional Review Board (IRB) has approved the study procedure.

2.2. Data Collection Procedure

The study procedure was similar to the approach used by Zahabi and Kaber [2] in order to provide a fair comparison between the usability violations and the tasks identified in the previous investigation. Initially, the police officers were asked to complete the informed consent form and the demographic questionnaire. Upon completion of the forms, participants were asked to go through each MCT task using the concurrent think aloud protocol and describe "why" and "how" they are performing each step. This procedure was critical to create the HTAs and cognitive models (described in section 2.3). Subsequently, the officers were asked to perform each MCT task twice without any verbal protocol and with one-hand (similar to the use of MCT while driving) to get accurate task completion time estimates. At the end of each task, the officers were asked to fill-out the heuristic evaluation form (described in section 2.3). This procedure was repeated for all the MCT tasks.

2.3. Data Analysis

A combination of walkthrough and non-walkthrough usability evaluation methods were used to identify different usability issues with the MCT interface.

Hierarchical Task Analysis. Results of think-aloud protocol were analyzed by a researcher and was validated with an additional interview with an experienced police officer to create the HTAs [11]. The HTA trees were developed for each MCT task and the complexity of the trees were compared in terms of the number of steps to accomplish each task, the depth and breadth of the trees. Number of steps was determined as the maximum number of steps taken to complete each goal. Depth was determined by counting the total number of levels (number of tasks and subtasks) in each tree. Breadth was defined as the total number of sub-steps required at the lowest level of each tree.

Task Completion Time. Task completion time has been used previously as a primary indicator of efficiency [12]. In this study, task times were calculated based on the review of video recordings. A one-way analysis of variance (ANOVA) model and Tukey's Honesty Significant Difference (HSD) post-hoc test were used to identify the tasks with significantly longer task completion time than others. Prior to inferential statistics, diagnostics were conducted to ensure ANOVA assumptions are met.

Cognitive Performance Modeling. Harvey et al. [13] identified Critical Path Method GOMS (CPM-GOMS) as a method that could be used for usability evaluation in the context of driving. In this study, CPM-GOMS models were developed for all MCT tasks using a cognitive modeling tool called Cogulator [14]. The software has been used and validated previously as a task modeling tool to produce estimates of working memory load and task time [15].

Heuristic Evaluation. Police officers were provided with a list of usability heuristics and their definitions based on Molich and Nielsen [16] at the end of each MCT task. They were asked to identify the usability issues regarding the specific tasks and provide their recommendations to resolve the issues. In addition, the officers provided a rating (0-100%) regarding the extent that each usability heuristic was upheld in any specific MCT task. This procedure has been previously used in identifying the usability issues in police MCTs [2]. The sample size in this study was sufficient in terms of identifying 95% of usability problems [17]. The heuristic evaluation results from police officers were further validated by three usability experts for identification of usability issues based on human factors principles.

3. Results

3.1. Hierarchical Task Analysis

HTA trees were developed for all the typical MCT tasks performed by the police officers including message board, unit summary, activity log, gun remote query, driver license query, plate check, event query, and warrant check. As shown in Table 1, warrant check task was found to be the most complex MCT task (steps=21, depth=2, breadth=25) followed by the event query (steps=16, depth=2, breadth=23). The purpose of the warrant check task is to identify any individual potentially wanted by local or state police by inputting information into a formatted screen. Officers reported using this task either during a traffic stop or directly following a plate check. Therefore, the task is typically performed while driving. The event query task is designed to produce chronological activity, officer involvement, and dispatch and officer notes on a specific event. The user enters as much information as possible into the data entry page in order to retrieve the correct event information. Officers reported that this page was mainly used when dispatch was unavailable.

Table 1: Summary of Hierarchical Task Analysis

MCT Task	Number of Steps	Tree Depth	Tree Breadth
Unit Summary	6	3	15
Plate Check	13	2	14
Driver License Query	10	2	16
Warrant Check	21	2	25
Message board	5	2	8
Activity Log	7	2	11
Event Query	16	2	23
Gun Remote Query	8	2	9

3.2. Task Time Analysis

An ANOVA model was generated to identify the most time consuming MCT tasks. Results revealed significant differences in time among different MCT tasks (F (7,156) = 17.43, $p < 0.0001$). Post-hoc test revealed the event query and warrant check tasks to be significantly more time consuming (less efficient) as compared to other MCT tasks (Figure 1).

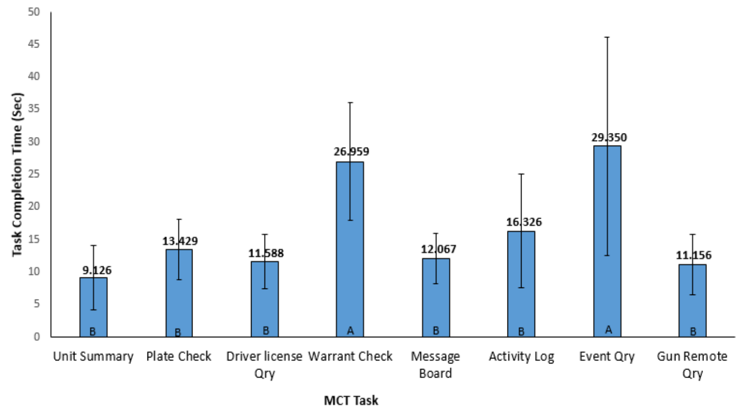

Figure 1: MCT Task Completion Time Analysis

3.3. Cognitive Performance Modeling

CPM-GOMS models were used to analyze each task in terms of perceptual, motor, and cognitive operators. The models were generated based on the video recordings of police officers performing different MCT tasks. In each task, there were several pathways to accomplish each goal. Therefore, selection rules have been used and the path with the longest duration was selected for analysis. It is important to note that the task time estimates using CPM-GOMS may not exactly match the actual officer task performance. First, CPM-GOMS uses normative operation time estimates based on a user population derived from the literature [18], which may not be representative of specific individual behavior. Second, defined scenarios (e.g., plate number=ABC1000) were used for preparing the CPM-GOMS models to have comparable time estimates among different MCT tasks. However, the officers used variety of input values for performing different MCT tasks. Third, GOMS models provide an estimate of task times for expert users without any error. However, it is possible that officers made mistakes in entering information during actual task performance. The results of CPM-GOMS models are summarized in Table 2. Warrant check was found to be the most cognitively demanding (cognitive operators=16, average WM chunks=4.4) and the most time consuming (CPM-GOMS time estimate=29.1 sec) MCT task. It also required the highest number of motor operators (i.e., 22) among all MCT tasks. However, the plate check was found to be the most visually demanding task for the police officers (perceptual operators=11). Although the number of cognitive operators for plate check and warrant check tasks are equal (i.e., 16), we believe the warrant check task was more mentally demanding since a majority of cognitive operators in this task were "recall" and "store" as compared to the plate check task which did not require as many items to be stored and retrieved from WM.

Table 2: Summary of CPM-GOMS Results

MCT Task	#Perceptual Operators	#Cognitive Operators	#Motor Operators	Average WM Chunks	CPM-GOMS Time Estimate (Sec)
Activity Log	4	9	21	1.7	16.9
Unit Summary	3	6	8	0.9	7.9
Driver License Query	4	11	13	1.2	14.8
Event Query	6	15	21	3.9	23.4
Gun Remote Query	6	11	11	2.4	13.5
Message Board	7	12	12	3.4	19.8
Plate Check	11	16	10	4.0	18.0
Warrant Check	9	16	22	4.4	29.1

3.4. Heuristic Evaluation

Heuristic evaluation identified the main issues across different MCT tasks as confusing abbreviations, inconsistencies in data entry format, heavy reliance on WM, insufficient error or warning messages, and unnecessary or redundant information. Although the officers were mainly satisfied with the usability of the device (i.e., all mean usability ratings were greater than 80%), the warrant check module was found to be the least user-friendly interface among all MCT tasks (M = 86.14%, SD = 6.86%).

4. Discussion

Results of HTA revealed the warrant check and event query tasks to be the most complex MCT tasks for the officers. Eight of the 21 steps in the warrant check involved going through different message pages received after submitting the required identification information. By combining the return pages into one page of information, the entire warrant check task could be reduced to 15 steps which is roughly 33% reduction in the size of the original HTA. Combining the return pages could also reduce or eliminate redundant information from each individual page to decrease the amount of time and cognitive load placed on the user. The officers mentioned that a majority of icons in the event query module are unnecessary, unfamiliar, or irrelevant. Removing the unnecessary icons could declutter the entry screen as well as reduce the amount of time spent tabbing or clicking into the necessary boxes.

Findings of task time analysis were also in line with the results of HTAs. It was found that the warrant check and event query tasks are the most time consuming MCT tasks for the officers. These results were also in line with the task time estimates from CPM-GOMS models. Prior studies have found that on-road task times are approximately 1.3 to 1.5 times the static times [19]. For the static task completion times, the maximum acceptable distraction time is less than 15 seconds, which is called the 15-second rule. Our study also revealed that on average, warrant check and event query tasks are significantly above the acceptable distraction time. Therefore, these tasks should not be performed while driving. In addition, the MCT interfaces need to be redesigned to improve the efficiency of police officers while performing these tasks.

Regarding the cognitive performance modeling, results also revealed the warrant check to be more cognitively demanding task as compared to other MCT tasks. In warrant check, the officer needs to recall from WM the driver's information, and memorize the returned information from one page to another to make a law enforcement action. Although the average WM chunk (i.e., 4.4) was less than the cognitive overload threshold [20], reducing the mental demand by providing a summary page or ranking the information could improve officer performance. Warrant check also required the highest number of motor operators. This was mainly due to several input values that needed to be manually entered. Once the information was received, the officers used the arrow keys to scroll through different pages. The findings are in line with prior studies that found visual-manual MCT interfaces to negatively affect motor performance [10]. One way to resolve this issue is to use voice recognition systems. Finally, the plate number check was found to be the most visually demanding MCT task since the officers needed to search for and read specific tag information such as vehicle status, insurance, and registration status. This finding is also in line with our previous investigation [2]. To reduce the visual demand, information needs to be organized such that the officers can quickly identify the violations. In addition, voice-based output system might reduce the visual demand as officers do not need to look at the MCT for searching specific information.

Regarding the heuristic evaluation, police officers identified several usability issues within each MCT task. The main concerns included confusing abbreviations, inconsistencies in data entry format, heavy reliance on memory, insufficient error or warning messages, and unnecessary or redundant information. Prior studies found similar results investigating the usability issues in reading plate information task using a different MCT interface [2]. Therefore, the results of current study further emphasize the need for providing a comprehensive MCT design guidelines for manufactures and software developers. To address the identified issues, we combined the recommendations from police officers with our evaluation of the system and provided eight recommendations to improve the usability of MCT interfaces, which includes: (1) remove all unused icons and redundant information across all queries and functions; (2) organize the information in return pages and present the information in consistent locations; (3) standardize all key words, abbreviations, and codes across all agencies, jurisdictions, and states; (4) provide error warnings for missed information or connection issues; (5) provide update messages when the system has software updates; (6) use machine learning algorithms to better identify warrant check matches; (7) use voice-based systems instead of manual data entry; and (8) use automation for the tasks requiring high mental demand.

5. Conclusion

The objective of this study was to assess the usability of an MCT interface and provide guidelines to improve the design. Results revealed that some of the MCT tasks including warrant check and event query are more demanding for the officer to perform as compared to the other modules. Police officers identified several usability issues with the current MCT design including confusing abbreviations, inconsistencies in data entry format, heavy reliance on WM, insufficient error or warning messages, and unnecessary or redundant information. General usability guidelines were proposed to improve the effectiveness, efficiency and satisfaction of police officers in using MCTs. Findings of usability evaluation will be useful for MCT interface designers and for police officers as users of these systems. Implementation of the usability guidelines are expected to ultimately increase officer and civilian safety during police emergency operations. One limitation of this study was that the task times were captured while the vehicle was in a stationary position. This procedure was followed to ensure the safety of both the officers and the researcher. Although prior studies found a high correlation between static and dynamic task performance times in driving [19], observation of officer performance of MCT tasks in police operations might be more realistic. Second, although the MCT system evaluated in this study is commonly used by different police departments in the area, the results might not be generalizable to other police departments using other technologies. Future research should assess the usability of MCT systems used by different police departments in order to validate the findings.

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