Using Speech, GUIs and Buttons in Police Vehicles: Field Data on User Preferences for the Project54 System

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ABSTRACT
The Project54 mobile system for law enforcement developed at the University of New Hampshire integrates the control of disparate law enforcement devices such as radar, VHF radio, video, and emergency lights and siren. In addition it provides access to state and national law enforcement databases via wireless data queries. Officers using Project54 are free to inter-mix three different user interface modes: the device native controls; an LCD touchscreen with keyboard and mouse; and voice commands with voice feedback. The Project54 system was utilized by the New Hampshire State Police agency wide for a period of seven years spanning 2005 through 2011. This paper presents an analysis of user preferences in regard to user interface modes during the three years 2009 through 2011, obtained through logs of daily system use in approximately 200 police cruisers. Results indicate that most officers chose to use the touch screen controls frequently instead of the device native controls, but only a minority chose to use the speech command interface.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Evaluation/methodology.

General Terms
Measurement, Performance, Human Factors

Keywords
Case study, user preferences

1. INTRODUCTION
Typical police cruisers contain specialized aftermarket devices such as police voice and data radios, radar, video recorders, and emergency lights and siren systems. The devices in a single cruiser often were manufactured by different companies with totally different user interface designs. The device control heads tend to be small, to avoid overcrowding in the vehicle cabin, and often have a large number of small buttons with small indicator lights or alphanumeric displays in order to support the control of diverse functionalities. Taken together, the collection of disparate control heads presents a user interface which conforms to few, if any, principles of good interface design.

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The objective of the Project54 mobile embedded computer system for law enforcement, developed at the University of New Hampshire, was to integrate the control of these disparate law enforcement devices in order to provide convenient touchscreen and voice interfaces with a common look and feel across all devices [1]. The case study presented here introduces the Project54 human-machine interface, and discusses data on user interactions with the HMI collected over a 3-year span between 2009 and 2011. Specifically, we are interested in answers to the following questions regarding officer use of the in-vehicle Project54 system's HMI:

1. Did officers use the system's HMI?
2. Did officers use the system's speech input capability?
3. If officers did use the system's speech input capability, what task or tasks did they use it for?

2. BACKGROUND
As Kern and Schmidt pointed out, the number of functions available to vehicle operators has increased greatly in recent years [2]. While this phenomenon is evident for "civilian" vehicle operators, it also affects police officers operating vehicles: the number of in-vehicle electronic devices in police cruisers is increasing, and their functionality is becoming more complex. For many years in-vehicle HMI (civilian and police) utilized buttons, knobs and levers for input, while output relied on dials and indicator lamps. Today's vehicles retain these modes of interaction, but also utilize GUIs and speech for input/output.

The use of speech, GUIs and various buttons and levers for in-vehicle HMI has been explored by a number of researchers. Some of these efforts focused on exploring specific interaction styles, either on the road or in the laboratory. For example, in a recent road study, Fröchlich et al. compared three presentation styles for presenting safety information to drivers [3]. Results indicated that speech-only presentation was highly efficient; however participants also valued visual displays. In our own work we compared speech and manual-visual interaction with a police radio. We found that speech interaction allows for better driving performance in a simulated environment [4].

In addition to exploring specific in-vehicle interactions, researchers have also worked towards understanding the underlying mechanisms of these interactions. In these efforts the concept of cognitive load has been used to represent the effects of in-vehicle interactions (as well as driving) on the vehicle operator. For example, Lavallière et al. conducted a field study to assess how drivers change lanes under different levels of cognitive load [5]. They found that an increase in cognitive load results in decreased lane changes – a finding with potential applications in the design of in-vehicle interfaces.

Figure 1. A typical Project54 system installation in a New Hampshire State Police cruiser. The user interface includes three parallel modes of operation: a noise canceling array microphone with steering wheel mounted push-to-talk; a 10 inch diagonal touch screen display with keyboard; and the original device control head controls.

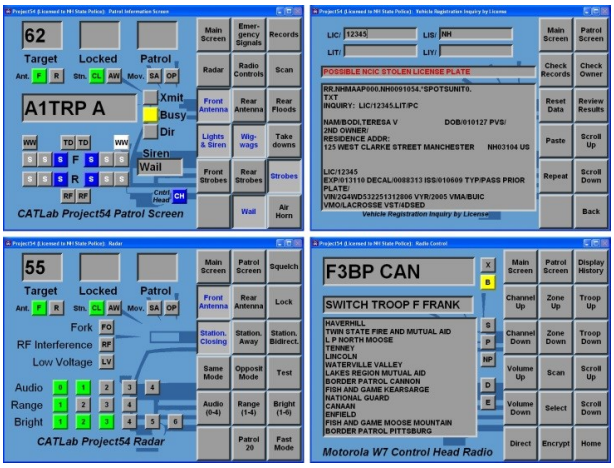

Figure 2. Four separate touchscreen displays, of four different Project54 application modules, are shown for comparison to illustrate the common look and feel.

However, as Lo and Green pointed out, there is almost no field data on who uses speech interfaces, for what, and how often [6]. Moreover, to the best of our knowledge, there is almost no field data on how police officers use in-vehicle interfaces. We explored this question in prior work in which we argued that officers are most likely to utilize interfaces that allow safe and fast interactions [7]. The work in the current paper provides further data on how police officers interact with in-vehicle electronic devices and supports our prior findings.

3. PROJECT54

3.1 System Design and Deployment

Design and testing of the Project54 system began in the year 2000. Large scale deployment for routine use within the New Hampshire State Police began in 2003 and was largely completed during 2005. The full deployment within the NHSP included approximately 230 police cruisers and 20 auxiliary vehicles. In subsequent years, an additional 750 Project54 systems were also deployed in police cruisers operated by city and town police departments in New Hampshire. However these systems are not considered in this paper.

The Project54 system remained in use agency wide within the NHSP until the end of 2011, after which time the use of the integrated Project54 systems was phased out to be replaced by conventional laptop computers with cellular data connectivity, which are not integrated with the in-vehicle devices. The typical lifetime of an NHSP cruiser is three to four years, so by 2011 the deployed embedded systems had been migrated to new cruisers at least once, and in many cases twice. During these system migrations, the embedded computers were upgraded to newer processors (three different processors were used for installations during the time interval 2003 until 2011). In addition, Project54 software updates were distributed to NHSP cruisers periodically via a statewide system of high speed wireless data hotspots [8]. However, the basic look and feel of the Project54 user interface, and the operation of the voice command system remained constant.

During the three year period from 2009 through 2011, system use metrics from all NHSP cruisers were logged automatically via the mobile data system used for wireless data queries. This logged data provides the basis for the case study to follow in this paper. Unlike a well-controlled laboratory study, no supporting information is available in this case study to provide definitive explanations for the results of the analyses. However, the case study has the advantage that the data to be presented is free from behavioral bias that could be introduced by the design of a laboratory study. The data to be presented comes from a set of experienced users (all NHSP officers) whose sole concern was to carry out their day-to-day law enforcement assignments. Officers were generally aware that certain computer system use parameters were being monitored in order to assist in identifying and remedying computer system problems. However, they were also aware that NHSP administrators had no bias towards particular system interface modes, and as such officers received no feedback (negative or positive) about their individual system usage preferences either before or during the three year period.

3.2 The Project54 User Interface

All devices controlled by the Project54 system can also be controlled directly from their native control heads (Figure 1). This generally involves activating mechanical buttons, or rotational or slide switches. When using the Project54 system, the three modes of control (physical control head buttons, touchscreen buttons and speech commands) can be intermixed arbitrarily. It is not necessary for the user to select a single preferred mode of control.

The Project54 run-time software system consists of a collection of separate software modules implemented as dynamic link libraries. Some service modules support standard functionalities (data logging, speech recognition, text to speech, and so forth) common to all installations. Other application modules support the various items of equipment in each specific police cruiser.

Each application module has a module specific user interface screen with a common look and feel (Figure 2). The left portion of the screen contains large text fields, status lights, and so forth as needed to reflect the current status of the associated device. The right portion of the screen contains columns of large touch activated buttons as needed to control the functionality of the device. Some application modules integrate information from multiple devices. For example, the interface shown in the upper left of Figure 2 (the "patrol" application) combines status information and limited control functionality for the radar, voice

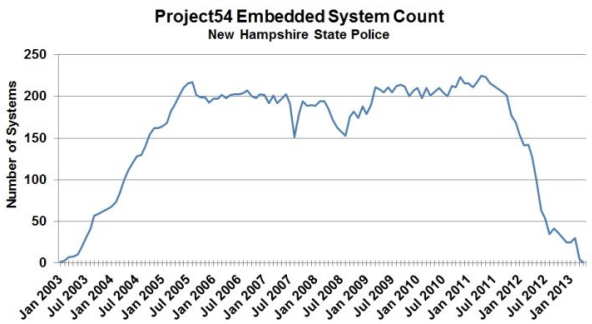

Figure 3. The number of Project54 embedded systems in use by the NH State Police during the interval January 2003 until April 2013.

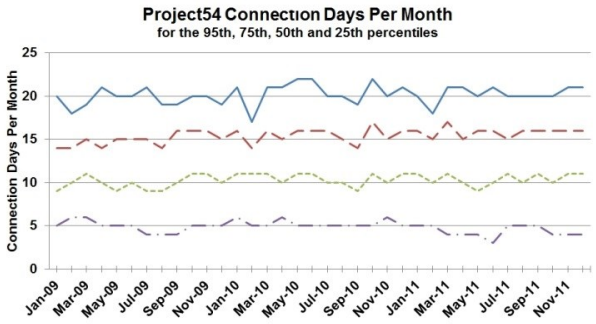

Figure 4. The number of Project54 mobile system connection days, per user per month. The four lines represent the 95th, 75th, 50th and 25th percentiles of system usage for about 200 users.

radio, and lightbar. Generally, touchscreen buttons can be pressed (by touching the button) to activate a function, and released (by touching the button again) to deactivate the function. For example, touching the "Strobes" button would activate or deactivate the lightbar flashing blue emergency lights.

Speech command input, triggered by a push-to-talk button, provides another form of control of the Project54 system (Figure 1). Each Project54 application module has a fixed command grammar associated with its visible GUI. At any time only a single application module display is visible on the touchscreen and only the corresponding application grammar is loaded in the speech system. Generally, the available speech commands match the labels on the touchscreen buttons. For example, the "Strobes" button in the patrol application (upper left quadrant of Figure 2) can be pressed by issuing the "Strobes" speech command and can be released by issuing the "Strobes Off" speech command. Thus, in most cases, the speech commands in the current grammar are visible as button labels, which facilitates learning the grammar of each application.

The application used to perform data queries (upper right quadrant of Figure 2) has a more complex grammar since it is necessary to fill out alphanumeric form fields as well as to press and release buttons. For example, the speech command "License Number" followed by the string "One Two Three Four Five" would place the string "12345" in the license number form field. The speech command "Check Records" (or pressing the "Check Records" touchscreen button) would then submit a query for processing using the current form field information.

4. DATA COLLECTION

The Project54 system uses a single module to provide speech recognition services in the background to all other modules. Each module can define a module specific speech grammar as a combination of fixed commands or alphanumeric strings. When a module's screen becomes visible, as a result of the user selecting the module, the module's speech grammar is activated by the background *s*peech recognition module. Any speech recognition results obtained are then delivered as corresponding text from the background speech module to the visible application module.

The background speech module is thus in a position to observe which application modules are activated by the user, and to count the number of speech commands delivered to each application module. In an effort to obtain basic monitoring of system usage, without unduly impacting system performance, a basic logging system was introduced via the speech recognition module. This module logged the number of times that the active foreground application module was changed by the user (the number of times the user changed from one command screen to another). It also logged the total number of times that speech recognition results were delivered to any module, and the total number delivered individually to each of several key application modules. This information was delivered to the central Project54 server automatically each time a mobile Project54 system connected. It was also possible to track, using server side logging, the number of mobile data queries submitted from each Project54 system.

5. RESULTS

5.1 System use

Figure 3 indicates the number of mobile systems which connected to the corresponding Project54 central data server at least once in each month, as a measure of the number of systems in actual use within the NHSP rather than the total number of deployed systems. Note that the anomalous declines seen in 2007 and 2008 reflect upgrades in the radio equipment at the state communications headquarters and the state wide system of repeater sites, which resulted in regional rolling blackouts of wireless data connectivity. The number of deployed systems was essentially constant during this time period.

Figure 4 shows the number of days on which individual NHSP officers connected to the central Project54 server each month. The line representing the 95th percentile indicates that 5% of users connected at least that many times (about 20 times) per month, while 95% of users connected fewer than that many times. Note that usage of the system, by this measure, was consistent over the entire 3 year period represented. The remaining data to be presented is normalized on a per day of use basis, and does not distinguish more frequent users from less frequent users.

Figure 5 shows the number of user directed changes from one Project54 application screen to another on a per day of use basis, averaged over each month. It can be seen that the top 25% of users changed from one screen to another about 40 or more times per day, while only the lower 25% of users changed screens less than about 20 times per day. Such changes from one application screen to another can only occur in response to corresponding speech command input or touch screen button presses. Use of the traditional controls on a device may impact the current touchscreen display by changing the device status, but cannot

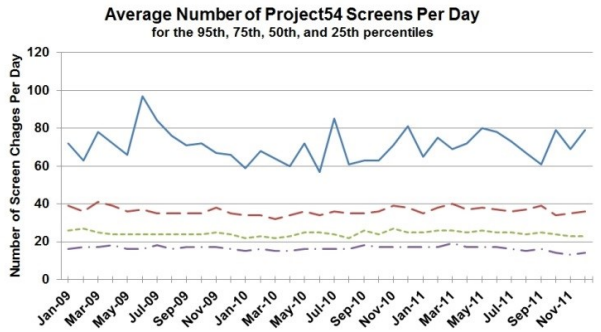

Figure 5. The average number of Project54 mobile system screen changes per day on a per user basis. For each month, the number of screen changes by each user was averaged per days of use, and the 95th, 75th, 50th and 25th percentiles were plotted.

cause the display to switch to a different application screen. Thus, the touch screen interface (or voice command input) was used fairly frequently by most of the roughly 200 users. Note that usage of the system, by this measure, was consistent over the entire 3 year period represented.

Another available measure of the frequency of Project54 system usage is the number of mobile data queries submitted per day of system use (Figure 6). The only way to submit such queries is via the Project54 touch screen or by speech command input. Officers can also solicit query results via requests to the dispatcher using the voice radio, but such queries would be processed through separate headquarters data server connections. It can be seen that the top 25% of users submitted more than 10 queries per day, while only the lower 25% of users submitted fewer than 4 queries per day.

5.2 Using speech

Figure 7 shows the number of speech commands entered by each user on a per day of use basis, averaged over each month. It can be seen that only the top 5% of users entered about 20 or more speech commands per day of system use, while 90% of users entered fewer than 10 speech commands per day, and 70-80% of users essentially did not use speech command input at all. Thus, the much more frequent application context changes shown in

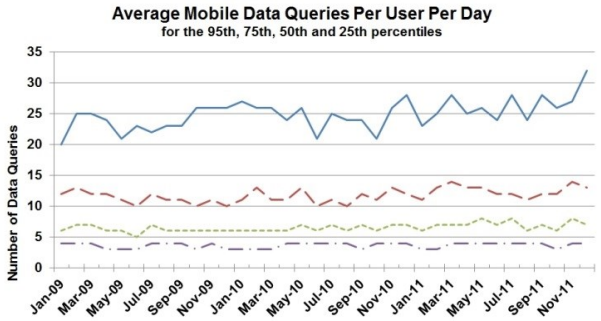

Figure 6. The number of mobile data queries submitted per day on a per user basis. For each month, the number of data queries submitted by each user was averaged per days of use, and the 95th, 75th, 50th and 25th percentiles were plotted.

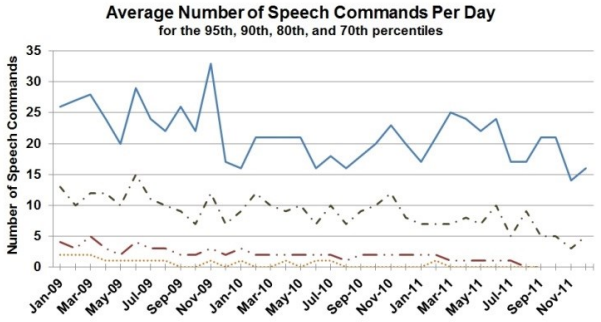

Figure 7. The average number of Project54 mobile system speech commands entered per day on a per user basis. For each month, the number of speech commands processed by each system was averaged per days of use, and the 95th, 90th, 80th and 70th percentiles were plotted.

Figure 5 must have resulted largely from touch screen input. Also, each mobile data query requires 3 or 4 commands to complete when using speech input alone, so many of the data queries indicated in Figure 6 must have been submitted partially or fully via touchscreen/keyboard input.

Figure 8 shows the percentage of the total speech command input directed to specific Project54 application modules. It can be seen that 70-80% of the speech commands were directed to the application used for submitting mobile data queries, 10-20% were directed to the "patrol" application which combines radar, radio and lightbar control functionalities, and the remaining speech commands were distributed across various other modules.

6. DISCUSSION

In this paper we set out to find answers to three questions. We now discuss each of these in light of our results.

1. *Did officers use the system's HMI?*

The focus of this case study is the analysis of user (NHSP officer) preferences in the selection of interface modes when using the Project54 integrated system in police cruisers. It is important to recognize that officers could complete their assigned tasks during a shift without even turning the Project54 system on. All devices in the cruiser which were controllable by the touchscreen and voice interfaces were also controllable by the standard device control heads. Similarly, all data queries, which could be

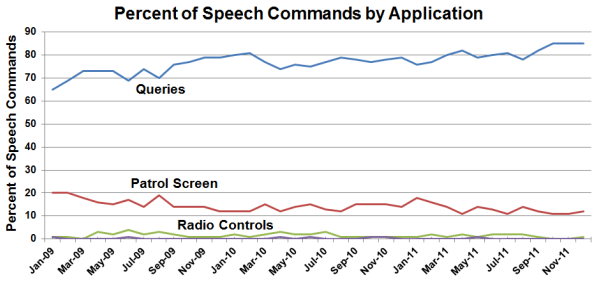

Figure 8. The percentage of the total speech commands issued each month while using different Project54 applications.

submitted via the touchscreen/keyboard and voice interfaces, could also be submitted via a request to the dispatcher using the voice radio. The choice of interaction mode was entirely at each officer's discretion, and the only benefit to using the Project54 system was to obtain access to the alternative UI modes that it offered.

The data clearly indicate that the Project54 system was utilized regularly by NHSP officers during the interval analyzed. The number of days per month that the system was used varied across officers from only a few days each month to 20 or more days each month. The possible reasons for this variation in frequency of use are several, and are largely unrelated to interface preferences. Many officers are assigned periodically to non-patrol tasks such as office assignments at headquarters or remote troop stations, investigative tasks, training assignments, and so forth. It is reasonable to assume that officers who preferred using the Project54 interfaces would use them every day they were assigned to patrol duty, whereas officers who preferred not to use the Project54 interfaces would consistently avoid using them. The fact that the distribution of the frequency of use across all officers (Figure 4) was consistent across 3 years of analysis suggests that this distribution mostly reflects the typical distribution of patrol assignments within the agency.

When considered on a per day of use basis, it is clear that the Project54 interfaces were utilized frequently by officers. 50% of the officers changed from one application screen to another more than 20 times in a day, some as many as 60-80 times in a day (Figure 5). It is reasonable to assume that officers wouldn't change from one screen to another unless they intended to utilize some aspect of the new application screen. It is difficult to interpret the distribution of the number of screen changes per day of use without more detail on the time distribution of these changes. An officer assigned to spend the entire day patrolling a major highway would certainly be likely to use the system more in that day than another officer who used the cruiser to drive to the site of an incident and was subsequently out of the cruiser for a large part of the day.

2. *Did officers use the system's speech input capability?*

Speech was not the preferred interface when using the Project54 system. Many officers chose not to use speech input at all, and even the most active speech users (the top 10%) issued only 10 to 20 speech commands per day (Figure 7). Thus, for most tasks the touchscreen/keyboard interface was preferred over speech.

One explanation for the lack of use of the speech command system could be that the system performed poorly, or was difficult to use. However, analyses of over 49,000 speech commands issued by 27 officers in 2003 and 2004 [9, 10] revealed a speech recognition rate of 94% after the elimination of out-of-grammar utterances (about 8% of the total utterances). The recognition rate for simple commands was the highest, while the recognition rate for longer alphanumeric strings was lower. Thus, the basic speech recognition system used by Project54 (based on the Microsoft SAPI version 5.1 engine and using the Andrea DA-350 noise canceling four element array microphone) performed comparably to other speech command systems. In addition, in a survey of 68 officers carried out in 2004, 25% of respondents characterized the speech input system as "seldom if ever failed", 31% as "sometimes failed", 11% as "often failed" and 33% as "not used" or no response. While it is reasonable to assume that better speech recognizer performance would have a positive impact on the frequency of use of the speech command interface, it seems likely that recognizer performance was not the major factor influencing the observed low usage of speech input.

Another explanation for the relatively low usage of speech command input is that while speech input provided an alternative to touchscreen use, in many cases it was not a more convenient alternative. For example, the blue strobe lights on the lightbar could be activated by holding down the push-to-talk button on the steering wheel and saying "strobes". They could also be activated by touching the button labeled "strobes" on the touchscreen. For such simple on-off operations, voice command provided an "eyes off" command alternative, but not necessarily a more convenient alternative.

3. *If officers did use the system's speech input capability, what task or tasks did they use it for?*

Of all of the Project54 application modules used by NHSP, the data query application required the most complicated user interactions using touchscreen and keyboard input (filling out form fields). Over 70% of all speech commands that were issued were directed to this application, even though the speech commands required (involving entry of alpha-numeric strings) were more prone to error than those of other applications. This supports the notion that the speech input option was more likely to be selected in situations which otherwise required more complex manual interactions.

7. CONCLUSIONS

In this paper we presented a case study of user interface preferences for a particular mobile environment (police cruisers). The novel aspects of this case study are that:

1. Users had the option to freely intermix the use of three different interfaces for all operations: traditional buttons/switches, touchscreen and keyboard, and voice command input.

2. Background data collection was transparent and automatic. There was no bias in the selection of interface suggested either by the nature of the study or imposed by the agency (NHSP).

3. There were no imposed study tasks. Rather, officers were in their police cruisers carrying out their normal law enforcement assignments.

4. Subjects were not "selected". The study group included all active duty NHSP officers, every time they used the system, over a period of three years.

The fundamental conclusion of the analysis is not surprising: officers tended to pick the interface that was most convenient. Most often this was the touchscreen interface. Officers used speech input relatively infrequently, and mostly in the application which otherwise required the most complex touchscreen/keyboard interactions.

A secondary conclusion is that behavioral patterns were consistent over the three year study period. Over that fairly long time period officers did not use the Project54 system more or less frequently, or substantially modify their preferred uses of the available interfaces. This suggests the importance of training to establish "preferred" behaviors (if any) early on in the deployment of a new system.

While our data comes from police officers, we believe that the conclusions we reached are also important for consumer applications. Specifically, in-vehicle HMI designers should carefully examine how drivers might use HMI features with overlapping functions (e.g. speech and dial input for music selection): drivers might quickly decide which one is more

convenient, and they will likely not give the other one a chance throughout the life of the vehicle. Thus, investing significant resources in designing multiple overlapping HMI features might not be an effective use of designer time.

Furthermore, while a number of researchers have found evidence that speech-based HMIs can provide for better driving performance [6], it is clear that speech input/output is not always a good match to in-vehicle tasks, especially if for tasks that are simple, such as flipping a switch. On the other hand, drivers are likely to be open to using speech interfaces for complex tasks, which are exactly the tasks where good design can improve driving safety.

8. ACKNOWLEDGMENTS

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