

Sources of Cognitive Load in a Simulated Law Enforcement Patrol Task

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ABSTRACT

Unlike in civilian driving, law enforcement officers are required to multitask for effective job performance. In addition to the traditional radio and radar equipment, integrated mobile data terminals are finding their way into patrol vehicles, adding additional features, flexibility, and potentially cognitive load to the already demanding patrol task. Because of the working memory and attentional demands of patrol, it is imperative that the impact of in-vehicle technology interfaces be considered. For the current project, sworn law enforcement officers completed a simulated patrol task that required them to interact with a semi-automated dispatch system and an in-vehicle data terminal that either 1) visually presented dispatch information (working memory support) or 2) presented only a map of the environment.

Categories and Subject Descriptors

H.1.2. [User/Machine Systems]: Human factors, human information processing, J.4. [Social and Behavioral Sciences]: Psychology.

General Terms

Human Factors, Design, Experimentation.

Keywords

Law Enforcement, Driving Simulation, Driver Multitasking.

1. INTRODUCTION

When it comes to discussions of driver multitasking and performance, the primary focus is on the impact of in-vehicle and mobile technologies for the civilian driver (e.g., [1]). In most civilian situations, interactions with in-vehicle systems can be viewed as distracting the driver from the primary task of controlling the vehicle. As examples, a cellular phone conversation may reduce a driver's reaction time [2], or a

navigation display may capture the driver's attention (e.g., [3]). However, there are a number of professional driving domains that require vehicle operators to interact with technology for effective job performance. Many occupations require drivers to regularly navigate potentially unfamiliar areas, and to interact with technology while doing so, such as a logistics management system on a fleet of commercial vehicles or a mobile data terminal in a law enforcement patrol vehicle. The most visible and potentially most cognitively demanding of these domains is law enforcement patrol.

Law enforcement patrol requires officers to observe and monitor the activities of vehicles and individuals in the external environment while simultaneously maintaining control of the patrol vehicle. The observational skills of law enforcement officers are critical for their reports as well as for later legal proceedings. Although the traditional patrol vehicle may be imagined as including only a radio for communication to dispatch and a radar speed detection system, the current patrol vehicle includes far more (e.g., [4]). Video recorders, license plate readers, and computer-assisted dispatch interfaces restrict available space and range of motion and add visual complexity within the vehicle cockpit. These restrictions may result in increased cognitive workload for officers in the field. However, if designed well and integrated with the vehicle to minimize complexity and space demands, a mobile data terminal may also improve officer performance by leaving more attentional and working memory resources available for processing the current situation (i.e., situation awareness, [5]) rather than merely maintaining an acceptable level of performance.

2. METHOD

As part of a project funded by the National Institute of Justice, we brought officers from three regional municipal police departments to the Center for Advanced Vehicular Systems (CAVS) Driving Simulation Laboratory to perform a simulated patrol task.

2.1 Participants

Fourteen sworn law enforcement officers from three municipal departments volunteered for 2.5 hours in return for \$50 compensation. Depending on the distance traveled from the municipal department and CAVS, officers may have also received an additional travel allowance.

2.2 Materials and Apparatus

The CAVS Driving Simulation Laboratory includes a full-size vehicle cab mounted on a six degree-of-freedom motion base platform, designed and installed by Realtime Technologies, Inc. (RTI, Royal Oak, MI). Three large screens are located ahead of the vehicle to provide approximately 180-degrees of visual angle. An additional screen is located behind the cab and visible in the internal rear-view mirror. On-board LCD monitors act as side mirrors. The vehicle is controlled via the original steering wheel, accelerator and brake pedals, and automatic gear shift lever. The dynamics model is customizable, but for the current project, a standard full-size sedan model was used.

To simulate the in-vehicle mobile data terminal, an ultraportable notebook computer was mounted just above and to the right of the gear shift. In all drives, the computer presented a static map of the driving environment and a text box for the presentation of dynamic dispatch messages (see the following section).

2.3 Procedure

Officers completed five patrols (see Table 1) in a generic city driving environment, in one of four dispatch conditions: naturalistic language with a dynamic display, naturalistic language with a static display (map only), or coded language (ten-codes, e.g., 10-4 for “acknowledged”) with a dynamic display or a static display. The fifth driving condition was a ‘Baseline’ condition without dispatch information in which officers only responded to environmental events. The order of conditions was counterbalanced for all participants. Each drive took between fourteen and twenty minutes to complete.

Table 1. Drive conditions for simulated patrol task

Drive	Communication Format	Display Type
1	Naturalistic	Dynamic
2	Naturalistic	Static
3	Coded	Dynamic
4	Coded	Static
5	Baseline	Static

During the four dispatch conditions, participants monitored and responded to calls for service via an automated dispatch system. Participants were assigned a call sign. The simulated dispatcher assigned calls to the participant and three other simulated officers. The participants were expected to monitor the status of other (simulated) officers, since in actual patrol operations they may be called on as backup.

During all five drives, eye movements and in-vehicle MDT interactions were recorded via video. The in-vehicle MDT always presented the environment map; in the dynamic display conditions, additional information including the current call for service and location address was presented in either coded or naturalistic language. This information was presented in a simple sentence format, nearly identical to the auditory message provided by the dispatch recording.

When participants either arrived on scene in response to a call for service via dispatch or witnessed an event that required a response from them, they were to put the vehicle into ‘Park’ and then press the Space bar on the mobile data terminal (MDT). At this point, the view of the environment was obscured by presenting a black screen, and participants answered three questions presented in a four-alternative forced-choice format about the current event and related radio chatter for other ‘officers’ on patrol. These questions examined participant’s memory for the characteristics each event, such as how many individuals or vehicles were involved, where the call for service was located, and whether a specific officer was currently responding to a separate event or ‘in-service’ (i.e., patrolling the environment).

2.4 Data Analysis

Data was collected from three primary sources: the driving simulator, the eye tracker, and the video recording system. All sources were integrated using SimObserver [6] and annotated using Data Distillery [7]. Eye movement recording was overlaid onto the video, and both the video and the eye movements were independently coded by at least two experimenters prior to compilation and analysis. Driver performance data (e.g., control inputs, lane position) were recorded by the simulation system and were available in a spreadsheet format in Data Distillery.

Two approaches to coding the data were taken by experimenters. Initially, eye glances to the MDT and the external environment (e.g., other vehicles, pedestrians, street signs, etc.) were coded. This approach was used to code data for six of the fourteen participants, with inter-rater agreement ranging from 74% to 95%. Given the substantial time requirements of this coding approach, we shifted focus to only coding glances to the MDT. When coding only the MDT, inter-rater agreement ranged from 95% to more than 99%. Regardless of which approach was used for a particular participant, only the MDT glance data were considered for the following analyses.

3. RESULTS

Figure 1 shows the percentage of time while driving spent attending to the in-vehicle MDT (including the environment map). In all but the Baseline condition, participants spent roughly 7% of the time attending to the MDT display while the vehicle was in motion (i.e., while driving). A repeated measures ANOVA was conducted, and found a significant difference across conditions, $F(4, 44) = 5.56, p < .01$.

Upon further inspection, we found that the only statistically different condition is the Baseline condition, in which there was no radio dispatch communication and therefore no calls for service that required navigation to a given location. As anticipated, there were no significant differences among the drive conditions once the Baseline condition was excluded, $F(3, 36) = 2.20, p = .10$.

Another potentially interesting statistic is what percentage of time spent looking at the in-vehicle MDT occurs when the vehicle is in motion compared to when it is stopped (e.g., at a traffic light or stop sign, or along the side of the road). Figure 2 gives the percentage of time spent attending to the MDT while the vehicle was in motion as a ratio to total time spent on the MDT across the drive. This is distinguished from the data in Figure 1, which is the ratio of time spent on the MDT while in motion over total drive time (i.e., not only time spent on MDT).

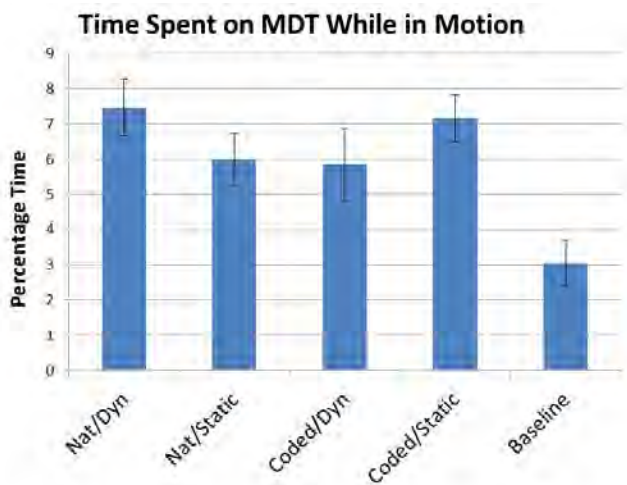


Figure 1. Percentage of time spent on MDT while vehicle was in motion, by condition. Error bars indicate standard error of the mean.

With the exception of the Baseline condition, participants were driving for between 25% and 30% of the time spent attending to the MDT. This is likely an underestimation of the actual time spent looking at the MDT while driving since this number also includes the time participants were completing the situation awareness assessment (during which the driving environment was replaced with black screens and the vehicle was “parked”).

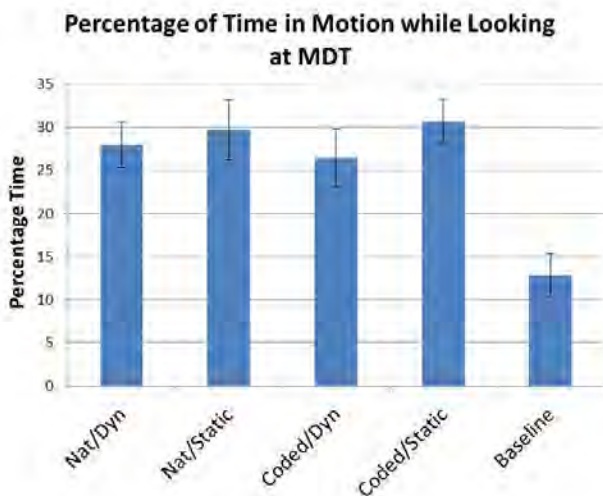


Figure 2. Time spent on MDT while vehicle in motion as a percentage of total time on MDT, by condition. Error bars indicate standard error of the mean.

As was the case with the overall percentages of time spent attending to MDT while driving, the only condition that differed significantly was the Baseline condition (with Baseline, $F(4, 44) = 5.25, p < .01$, and excluding Baseline, $F(3, 36) = 0.31, p = .82$).

More broadly, results from the situation awareness measures have been presented previously [8]; these results indicated that the

coded language conditions were most sensitive to the presence of the dynamic display conditions compared to the naturalistic language conditions in which there were no significant differences. Figure 3 shows the error rates for the situation awareness assessment by condition.

4. IMPLICATIONS

The previous situation awareness results [8] indicated that the coded language conditions were most sensitive to the presence of the dynamic display conditions compared to the naturalistic language conditions in which there were no significant differences. Because naturalistic language is processed automatically, participants may have found retaining this information in memory less challenging than in the coded language conditions, leaving more attentional resources available for processing the current situation. In contrast, the use of coded language may be more concise for communicating across the radio, but it also requires more active interpretation by the individual receiving it; in those situations, the additional memory support provided by the displayed dispatch information may have allowed participants to process the current situation more effectively, resulting in improved performance.

Situation Assessment -- Error Rates

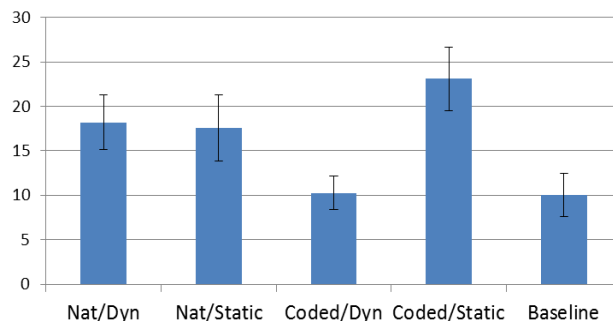


Figure 3. Error rates for situation awareness assessment questions, by condition.

Although the only statistically significant difference in viewing of the MDT is that participants spent less time looking at the MDT in the Baseline condition (given that there was no requirement or necessity to do so) compared to the conditions with radio dispatch, the trend toward an interaction across communication and display type is potentially interesting. Time spent looking at the display increased when additional information was presented for the naturalistic conditions, but decreased (non-significantly) in the coded language conditions. Participants also spent slightly (i.e., not significantly) more time attending to the MDT when the vehicle was in operation in the conditions with no dispatch information displayed.

Considering the MDT results (Figure 2) with the situation awareness results (Figure 3), it appears that participants may have been able to offload some of the cognitive demands of maintaining information presented in coded language to the MDT without requiring substantial attention to the MDT. The additional display information did not seem to have any significant impact on the naturalistic conditions, which are roughly equivalent.

Although the dynamic display condition does trend higher in total time (see Figure 1), the proportion of time spent on the MDT while in motion is comparable across the two conditions (Figure 2).

Considering the task of law enforcement officers on patrol, the observed 25-to-30% of attention to the MDT occurring while the vehicle is in motion is potentially problematic. Patrol officers tend to spend a substantial portion of their shift driving, and much of the information that they must attend to will be presented on the in-vehicle display. Although the information presented can alleviate cognitive demands, the fact that the officers looked away from the forward roadway for a substantial amount of time could create a dangerous driving situation [9]. Follow-up analyses will include the duration of individual glances in order to compare the current data to the current in-vehicle interface standards of avoiding glances longer than 2 seconds [10].

The current project is limited by the small sample size, which inevitably is reflected in the lack of clearly significant results. This is a product of multiple factors: a specialized population and a challenging simulation that increases the potential for simulator adaptation syndrome (simulator sickness). Given that the original intent of the project was to simulate the experience of law enforcement officers on patrol, these limitations were necessary. Future work in this area should leverage current law enforcement driver training programs that use simulators to both improve statistical power and simplify scenario development. In addition, a second (or perhaps even primary) eye tracking and/or video recording system should be located near the MDT to more directly observe attentional shifts to the display and thus away from the forward roadway.

5. ACKNOWLEDGEMENTS

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