

Context-Aware Notification for Mobile Police Officers

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Abstract. To minimize unwanted interruption and information overload during surveillance, mobile police officers need to be supported by a mobile, context-aware notification system. This system adapts message presentation to message priority and context of use. A prototype is designed and evaluated in a simulated surveillance task, requiring users to attend to videos while handling messages on a mobile device. Adaptive notification led to better performance and less intrusive messages than non-adaptive notification, especially in high workload situations. Subjective judgments showed a positive user experience with the adaptive notification system. These empirical findings are used to improve the design of mobile notification support systems for police officers.

Keywords: Mobile device, notification, context-aware computing, Wizard-of-Oz, police.

1 Introduction

Police officers on surveillance need to be aware of task-relevant information. For these mobile users, both the interaction possibilities with devices and the momentary user needs for information continuously change over time and place [1]. Location-based and context-aware services on mobile devices offer new possibilities for supporting the police officer's task such as providing up-to-date information in the relevant context (i.e. at a specific location). Both theory and police practice show a clear need for interfaces that attract and guide the attention of individual officers to relevant, high priority information in a mobile setting [7].

Designing such interfaces should take into account divided attention during surveillance. An intrinsic part of police officers' task is dividing their attention between detecting incidents in their environment and attending to incoming messages on a mobile device. Two potential risks to effective surveillance are unwanted distraction by low priority messages and information overload in high workload situations. These situations are caused by monitoring and integrating complex information from the environment, while simultaneously performing tasks on a mobile device [6]. Imagine a police officer on surveillance handling an argument between two individuals. During this intervention, his mobile device interrupts him with a message. He has to attend to and read the message to perceive its urgency and content. Focusing his attention on his device distracts him from the argument, which could have serious consequences. When he can perceive the urgency of a message by

its presentation, i.e. by auditory signals, unwanted distraction will be minimized. Similarly, when the message content on the mobile device is presented concisely instead of elaborately, information presentation is optimized for the situation. Thus, message presentation on a mobile device must be matched to message priority and user workload.

1.1 Adaptive Notification Systems

Context-aware notification systems can provide this match by adapting information presentation based on a model of relevant use context factors. For example, the information provided by a context-aware mobile device is tailored to the user's location or resources [2]. No such support system has yet been developed for mobile police officers [7]. In earlier research, context-aware support for firefighters was designed to generate user alerts on a (Personal Digital Assistant) PDA based on sensor information, such as location, temperature, toxicity etc. Results of a formative user study showed that firefighters found the application useful [3]. In the police domain, a context-aware communication system was designed on a mobile device to support handling criminal incidents. Based on incident characteristics, contact details of colleagues who could assist with the incident were presented together with the message [9]. Results from a preliminary user study suggested that police officers found this application useful for efficient handling of incidents. Despite these promising results, there is still a lack of experimental evaluation of context-aware applications in task-relevant settings [10].

Our approach is designing a context-aware notification system on a mobile device that presents messages in the appropriate notification style, given message priority and user workload. The notification style determines message presentation, i.e. the auditory and visual signals and text in the user interface. For example, in a high workload situation, a medium priority message will be presented with another type of auditory signal than a high priority message. A semi-functional prototype of this context-aware notification system is implemented on a mobile device and evaluated in a simulated surveillance task. In this paper, first the design and implementation of the context-aware notification system is described. Then, the evaluation results are discussed and implications for design of notification systems are presented.

2 Design of Notification System

From the discussion above, we concluded that a context-aware notification system that adapts the notification style to context factors can support mobile police officers. In this section, we specify the notification styles, match these to the context factors of message priority and user workload and describe the implementation of a prototype.

2.1 Designing Notification Styles

The general goal of a notification system is to successfully prompt the user to attend to another task. Successful notification systems should facilitate 1) successful interruption, 2) comprehension of the notification and 3) quick user reaction [5].

Users should be able to perceive a notification, understand the message and act on the notification quickly and efficiently.

The notification styles were determined by two important aspects of notification: *salience* and *information density* [4]. We matched message priority to salience, because highly salient notifications are perceived more easily. Thus, high priority messages were presented highly salient (with visual flashing effects and loud auditory signals) and medium and low priority messages less salient. This was expected to benefit interruption and comprehension of notifications.

Information density is the amount of information conveyed by the notification, for example the amount of text in a display or the richness of an auditory signal. We matched user workload to information density, because the amount of information that has to be processed is an important factor in determining the speed of the response. Thus, more condensed information was presented in high workload situations. This was expected to benefit response time to notifications.

Concluding from these design considerations, the adaptive behavior of our notification system was dictated by two rules:

1. *If message priority is high, then use highly salient warning signals.*
2. *If user workload is high, then present more condensed information.*

2.2 Implementation of Prototype

A semi-functional prototype of this adaptive notification system was implemented on a mobile device (PDA) for evaluation. High priority messages were presented with red visual flashing bars and icons and a sharp sound (🔊) (see Table 1). Medium priority messages were presented with a soft sound (🔊) and low priority messages without sound. In low workload situations the full message text was presented at once, but in high workload situations first a summary of the message was presented. To avoid interruption while users were interacting with the device (e.g. reading a message), in these situations an icon signaled a new message (right column in Table 1). An exception to the rules was made for a high priority message in high workload situations. Because we assumed that all relevant information is necessary to take action on high priority messages, the entire message was presented instead of a summary. The evaluation compared the context-aware prototype to a non-adaptive prototype presenting the full message text with a sharp sound for all messages.

3 Evaluation of Context-Aware Notification










This lab study evaluated the prototype in a Wizard-of-Oz setup that simulated the adaptive system behavior [8]. This setup allowed varied system behavior between conditions and accurate measurements without the need to implement a fully functional system. By comparing context-aware notification to a non-adaptive prototype (i.e. uniform notification style), participants experienced the dynamics of this system. A representative participant group was used in the evaluation, because adaptive notification is expected to address general instead of police task-specific abilities.

A simulated, mobile surveillance task was created in which participants had to perceive, read and remember messages on a mobile device, while attending to videos. We expected that adaptive notification lead to better task performance during high workload situations, less interruption by low priority messages and higher preference compared to non-adaptive notification. Furthermore, we examined whether adaptive notification was recognized easily by users and whether the underlying rules for adaptive notification were appropriate.

3.1 Method

Participants. 20 participants (10 male and 10 female) between 22 and 45 years old ($M=29.1$; $SD=6.8$) completed all tasks in the experiment. All used a PC and the Internet on a daily basis, 17 participants used a cellular phone daily and most of them ($N=19$) had never before used a mobile device. None had working experience in the police domain.

Table 1. Matching notification styles to message priority (vertical) and context of use (horizontal)

		Attention on environment		Attention on device
		Low Workload	High Workload	
High priority				
				
Low priority				

Experimental Design. A within subjects, repeated measures design was used with an adaptive notification condition (notification style adapted to context of use and message priority) and a non-adaptive condition (uniform notification style). In both conditions, similar surveillance scenarios were used with similar messages and videos. The order of conditions and scenarios was counterbalanced.

Manipulation. In the adaptive notification condition, notification styles of messages were adapted to the context of use and the message priority. Context of use was characterized as low workload or high workload (determined by the location of the participant) or interacting with the device (taking notes or reading a message on the PDA). Workload (WL) was induced by videos shown in two “districts” represented by two adjacent rooms. Low workload videos (district 1) showed only bicyclists riding through a shopping street, whereas high workload videos (district 2) showed fights, arguments and attacks on police officers (see Figure 1). These videos required focused attention from the participant to accurately remember perpetrator and situation characteristics. When participants physically moved from one district to the other, prompted by the messages, this constituted a switch in the context of use.

All messages were relevant, however the priority of the messages differed between high, medium or low priority. High priority messages, such as a colleague in need of backup, were considered urgent and needed immediate attention. Medium priority messages (e.g. about an outstanding warrant) did not require immediate attention. Low priority messages, such as questions from colleagues on past events, were not classified as urgent.

Tasks. The mobile surveillance task consisted of moving between both districts, watching the videos and reporting targets from the videos. In district 1 (low workload) the number of bicyclists that rode into a shopping street had to be counted. In the other district (high workload), participants took notes on the PDA about the perpetrator and situation characteristics in the videos. In total 18 targets had to be identified from these videos. One scenario consisted of alternating three low workload videos and three high workload videos and took about 25 minutes to complete.



Fig. 1. Video stills from the low workload (left) and high workload district (middle and right)

The second task was handling the messages. A total of nine (three low, four medium and two high priority) messages were sent to the participants, spread evenly over the three different contexts. High priority messages had to be read as fast as possible and prompted participants to move from district 1 to district 2. Medium and low priority messages could be read when possible. To read the whole message on the PDA, scrolling was required.

Measures. In this experiment, we measured efficiency and effectiveness of task performance, mental effort, message intrusiveness and preferences for adaptive notification. Prior to the experiment, a questionnaire was filled out concerning gender, age, education, computer experience and use of mobile devices. During each scenario, task performance was measured as the *number of targets* reported from both the high and low workload videos. In addition, *message handling time* was measured in seconds. After each scenario, *mental effort* was measured with the Rating Scale Mental Effort [10] and *number of messages* recalled correctly with six multiple choice questions.

After each message, participants were asked to rate the *message intrusiveness* using a small, 7-point rating scale on the PDA. After each scenario, subjective judgments are measured with a 5-point rating scale on the ease of the surveillance task, difficulty in directing attention, interruption and irritation experienced by the messages. In addition, *recognition of adaptation* was measured with open questions after the adaptive condition asking participants which differences they noticed between the messages and contexts. Finally, after the experiment participants stated *preferences* by comparing both conditions and offered improvements to the prototype.

Apparatus. The adaptive notification system was simulated using a HP 5550 PDA. A Wireless LAN connected the PDA to a message server, used by the test leader to send the messages. The server kept an event log with time codes of all events on the PDA (messages received, messages opened, etc.). Videos were projected full-screen on the wall of the two rooms using two beamers controlled by a desktop PC. The rooms, PDA screen and the video images were videotaped as back-up.

Procedure. At the start of the experiment, participants were instructed they had to perform two surveillance scenarios by watching videos and handling messages on a mobile device. In one session, the notification style of the messages on the PDA would be adapted to their context of use, either “relaxed” (district 1, low workload), “busy” (district 2, high workload) or “working with the device”. Also, the style would be adapted to the message priority. In the other session, all notification styles would be uniform. Participants could decide for themselves when to read a message.

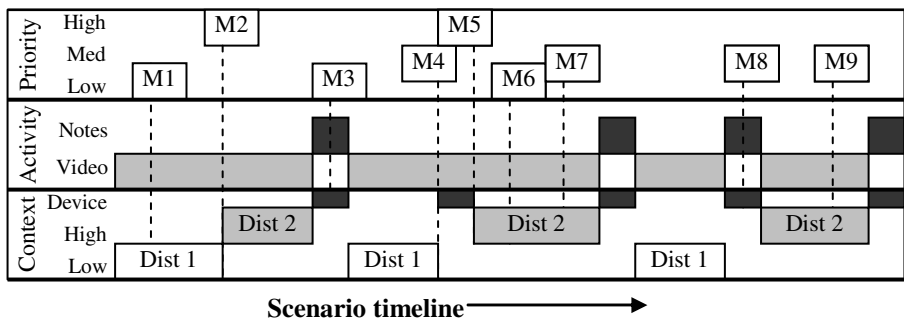


Fig. 2. Timeline of both scenarios with the presentation moments of the messages

After training with the PDA, messages and notification styles, participants performed both sessions with a short break in between. The timeline of the session is presented in Figure 2. After each session, they filled out the multiple choice questionnaire, recognition questionnaire and subjective rating scales. After both sessions, they were asked which session they preferred (session 1 or 2). After this, they were debriefed and paid for their participation.

Statistical Analyses. Repeated measures ANOVA with factors condition (2 levels) and context (3 levels) or message priority (3 levels) and Bonferroni post-hoc comparisons analyses were performed on message handling time and message intrusiveness. Number of targets and messages and mental effort are analyzed with separate t-tests for dependent samples. Finally, the questionnaires and rating scales were analyzed with non-parametric tests (Wilcoxon Matched Pairs). In the adaptive condition, message M6 (low priority, high workload) was only perceived and read by 4 participants and therefore excluded from the analysis.

3.2 Results

Number of Targets and Messages. Results indicate that there was no difference in the number of targets in the low workload context ($t(19)=1.04$; $p=.31$). However, significantly more targets were recalled in the high workload context ($t(19)=2.15$; $p<.05$). There was no difference in number of messages recalled correctly ($t(19)=0.21$; $p=.84$). Thus, task performance on the surveillance task profited from the adaptive system in high workload situations.

Message Handling Time. Message handling time was significantly different between conditions ($F(1,19)=35.1$; $p=.000$) and between contexts of use ($F(2,38)=18.4$; $p=.000$) (see Figure 3). The significant interaction effect ($F(2,38)=5.37$; $p<.01$) showed that message handling time was varied across conditions and contexts. Post-hoc comparison of MHT in low and high workload situations showed significant differences in the adaptive condition ($p=.000$) but not in the control condition ($p>.05$). Thus, message handling time was more varied in the adaptive condition.

Message handling time was also significantly different for different message priorities ($F(2,38)=29.3$; $p=.000$) (see Figure 3). Again, post-hoc comparison of MHT for low, medium and high priority messages showed significant differences in the adaptive condition (all $p=.000$) but also in the control condition ($p<.05$ and $p<.005$). However, differences were greater in the adaptive condition.

Table 2. Averages for the performance measures message handling time (*MHT*), message intrusiveness (*MI*), mental effort (*ME*), number of messages (*#M*), and number of targets (*#T*)

Condition	Context	MHT	MI	ME	#M	#T low	#T high	Priority	MHT
Adaptive	Low WL	27.3	1.9	46.7	3.3	12.4	13.1	Low	50.0
	High WL	64.3	4.0					Med	52.3
	Device	36.0	2.0					High	16.5
Control	Low WL	23.8	2.0	50.9	3.2	11.4	11.6	Low	14.9
	High WL	39.3	5.1					Med	31.2
	Device	14.8	3.3					High	18.0

Message Intrusiveness and Mental Effort. The messages were experienced as more intrusive in the control condition ($F(1,19)=17.6$; $p=.000$). In addition, post-hoc comparison showed that messages in the adaptive condition were experienced as less intrusive, especially when the device was in use ($p=.000$) and in high workload situations ($p=.000$). Thus, with the adaptive system, the intrusiveness of messages is lower. No significant differences were found for mental effort between conditions. However, a trend towards lower mental effort in the adaptive condition could be observed ($t(19)=1.93$; $p=.06$).

Subjective Judgments and Preferences. Results indicated that participants did not find the surveillance easier in one of both conditions ($Z(20)=1.48$; $p>.05$). However, in the adaptive condition they found it significantly easier to direct their attention between the messages and the videos ($Z(20)=2.56$; $p<.05$), were less interrupted and irritated by the messages ($Z(20)=2.28$; $p<.05$ and $Z(20)=2.82$; $p<.01$ respectively). Their preference was almost unanimously for the adaptive condition (90%) because they could distinguish message priority (50%) and the messages were less interruptive (25%). These results show high preference and positive judgments for adaptive notification.

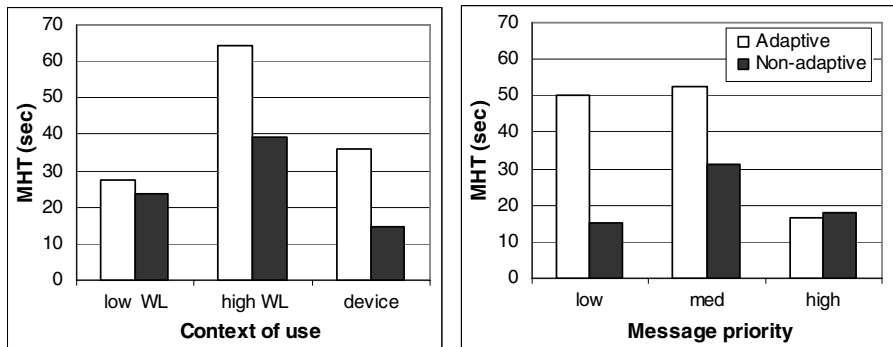


Fig. 3. Message handling time (*MHT*) for context of use (left) and message priority (right)

Recognition of Adaptation. In total 22 remarks were made about the differences in message presentation between the districts. Of these, only 23% identified the correct differences (district 1: whole message, district 2: summary). 36% of the answers were wrong or did not state any differences. The rest (41%) of the remarks did not concern message presentation. When asked about the differences in message presentation between the conditions, 25 correct remarks were made. Of these, 20% stated all differences, 24% were only about differences in priority, 24% only about visual aspects and 20% only about the auditory signals.

3.3 Discussion and Conclusions

This study evaluated adaptive notification compared to non-adaptive notification in a simulated surveillance task. Results showed that with the context-aware notification system, task performance was better than with the non-adaptive system, especially in

high workload situations. In these situations, more targets were reported from the high workload videos and message handling times were longer, showing participants postponed reading messages. Furthermore, with the adaptive notification the intrusiveness of messages was rated lower than the intrusiveness of the same messages presented with a non-adaptive system. When using the adaptive system, users could direct their attention better and felt less interrupted by the messages than with the non-adaptive system. The preference was almost unanimously in favor of the adaptive notification system. These empirical findings support the anticipated usefulness of context-aware notification systems and positive subjective judgments found in earlier research in other domains [3].

Overall, the notification system allowed users to quickly perceive, comprehend and act on messages, suggesting the notification system was appropriately designed for this task. The variance in message handling time (short for high priority, longer for low and medium priority) showed participants could recognize message priority correctly from the notification style. The correct answers on the recognition questionnaire support this conclusion. Participants did remark that low priority messages should also be announced by an auditory signal. In addition, the current prototype uses the visual modality heavily, keeping visual attention away from the environment. Instead, the auditory modality could be used to provide more information-rich signals, for example with synthesized speech.

Many participants did not notice and recognize the differences in message adaptation between contexts. It was not clear to participants that the appearance of a summary or icon depended on their location or activity. However, participants found the summary before a message useful and task performance was better than with full-text messages. This shows that the matching between user workload and information density was intuitive and appropriate. The adaptive system behavior supported the users' task flow, even though users may not actively notice it. Thus, the adaptation of information density is useful for notification systems.

The Wizard-of-Oz setup was successful in creating the illusion of a functioning adaptive system. In addition, using videos and messages successfully created a divided attention situation, characteristic of a surveillance task. However, participants only needed to remember the content of the messages and the videos and were not required to participate actively in the situations. A more elaborate and immersive task environment, such as a game-based environment, can also take into account the task flow, situation awareness and the dynamics of the user experience.

In conclusion, this study provided empirical data on the impact of a context-aware notification system in a task-relevant setting. When using this system, task performance was better in high workload situations and users felt less interrupted than with a non-adaptive system. We continue this ongoing research by designing and testing these systems in game-based environments and in field studies with end-users. By relating these results back to the design process, usable and innovative support concepts for police officers are realized.

Acknowledgements. The MultimediaN project is sponsored by the Dutch Ministry for Economic Affairs. We thank Bert Bierman for programming the prototype and Natasha Weitenberg and Cirquest for the video material.

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