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Alarm Fatigue vs User Expectations Regarding Context-Aware Alarm Handling in Hospital Environments Using CallMeSmart

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Abstract. Surveys and research show that mobile communication systems in hospital settings are old and cause frequent interruptions. In the quest to remedy this, an Android based communication system called CallMeSmart tries to encapsulate most of the frequent communication into one hand held device focusing on reducing interruptions and at the same time make the workday easier for healthcare workers. The objective of CallMeSmart is to use context-awareness techniques to automatically monitor the availability of physicians' and nurses', and use this information to prevent or route phone calls, text messages, pages and alarms that would otherwise compromise patient care. In this paper, we present the results from interviewing nurses on alarm fatigue and their expectations regarding context-aware alarm handling using CallMeSmart.

Keywords. Alarm Fatigue, context awareness, mobile communication, hospital systems, CallMeSmart

Introduction

Due to serious consequences with malfunctioning equipment, hospitals, and the health care sector in general, are moving slowly in terms of utilization of new technology. Medical personnel deal daily with life and death situations, and they cannot spend valuable time and attention on learning to use new gadgets. It is also essential that they must be able to have complete confidence in new gadgets' functionality and stability.

Previous studies [1-3] have shown that physicians and health care personnel in general, are carrying multiple electronic communication devices, each device performing a crucial role in the departments' communication networks. The most frequently used devices are pagers and phones. As a consequence, physicians and nurses at the University Hospital of North Norway (UNN) are using a combination of pagers and phones for internal communication. Each of these pagers or phones are related to specific areas of responsibility for that particular day. These devices are almost always on, and can cause interruptions while health care workers are e.g.

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explaining serious consequences of a patient's illness to the patient or next of kin. At the Oncology department at UNN they have since April 2014 been testing CallMeSmart [4], a context sensitive mobile communication system, to prevent unnecessary interruptions from calls and alarms.

Currently, a common way to handle bed and toilet alarms in Norwegian hospitals is a one-to-many relationship network where pagers are subscribing to alarm information, and alarm signals are broadcasted to every pager associated with a department. Nurses have to pick up their pager, look at the room and bed information and remember if the care of this patient is their responsibility. Finally, to turn off the alarm, nurses have to push a button inside the room of the patient.

In a small hospital department, such as the Oncology department at UNN, alarm bells ring up to as much as 2800 times during a one week period. Most of these alarms are related to patients asking for small favors, like opening a window, saying that they are ready to take their medicine, ask for a glass of water and similar. Even though many of these messages are meant for a specific nurse, and also quite frequently are of a little time sensitive character, signals are sent to everyone using a pager within the department, making pagers ring quite frequently. Moreover, alarms are interruptive by nature, and they are designed to catch the attention of the receiver. Furthermore, several patients explained that they get stressed of continuous alarm rings, because they feel like the nurse that visits them is needed somewhere else. It is clear that desensitization to alarm signals is a serious concern in hospital environments [5], and multiple nurses have told us that after being at work for a while, they no longer hear their pager. Sound produced by pagers are considered background noise, and their way to check for running alarms is to make it a habit to often check the pager display. Another nurse continued and said that blocking and ignoring the sounds, quote: "is the only way to get something done, and not constantly lose focus".

Alarm fatigue appears when someone has been surrounded by a high frequency of alarms throughout a substantial period of time. These alarms are very interruptive in their behavior, and as such our human body desensitize our perception of these particular sounds and light signals, making us less aware of them. Studies like [6] try to prevent alarm fatigue by reducing false positives. They accomplish this by customizing some settings to levels that are less likely to trigger an alarm, while they are still ensuring safety for the patient.

While the AAMI/IEC 60601-1-8 standard suggests three severity levels for alarms:

- High - Requires immediate response from hospital staff, and where it is assumed that delayed reaction will result in injury or death in the interval from seconds to a couple of minutes,
- Medium - Requires prompt response from hospital staff, where it is assumed that delayed reaction will result in injury or death if not attended within "several to many" minutes, and
- Low - Requires awareness of clinicians, no acute danger,

it is argued by [7] that some committees do not recognize that not all alarms generated from equipment should have the maximum priority level. They continue with the claim that clinicians control their own workflow and that there are no human or electronic system that sets priority levels to different work tasks. Hence, health care personnel are responsible to undertake additional work and weave it into their already tight schedule. They conclude with a clarification of the already stated severity levels for alarm:

- High - Requires an interruption in the caregiver's current workflow
- Medium - Requires replanning of the caregiver's current workflow
- Low - Requires planning of the caregiver's current workflow

According to [8], a forthcoming book by Frank Block, one of the authors of [7], claims that broadcasting of alarms will be replaced by systems that designate alarms to individual caregivers, resulting in a drastic decrease in interruptions caused by alarms. Today however, most middleware platforms available provides these types of functionality:

- Only create sound when it is high priority
- That are distinct, vocal and explanatory
- Notify the caregiver in a reasonable time
- Notify the caregiver on urgency

In this paper, we present the results from interviewing nurses on alarm fatigue and their expectations regarding context-aware alarm handling using CallMeSmart.

1. Materials and Methods

CallMeSmart (CMS) is a context-sensitive communication system developed at the Norwegian Centre for E-Health Research (NSE), and has been in use at the Oncology department at UNN since 2014. The system was primarily intended to be used by health care professionals in hospital environments. Physicians' and nurses' workflow are constantly interrupted by events [6, 9]. Phone conversations, meetings, patient consultations, messages from test results and similar, force them to constantly plan and re-plan their workflow. By enforcing filtration on phone calls based on availability, CMS try to prevent unnecessary interruptions and increase productivity. A particular user's availability is determined by examining calendar events, tracking a user's location, user action responses to events and any context information available regarding the user's availability. Examples include, but are not limited to, scheduled patient consultations, being within a surgery room or rejecting a phone conversation.
To understand the situation about alarm fatigue and thereby be able to design and develop a system that balances the interruptions from alarms and thereby, by our belief, reduces the alarm fatigue, we decided to involve the users themselves. Thus, in close collaboration with potential users, we developed a set of user requirements. The user requirements were set collaborating with nurses at the oncology department at UNN. A set of questions were asked verbally to a set of nurses. The interviews were of ad-hoc character and took place during the nurses' break periods, asking questions and following up on their replies. Nurses were also asked if it was OK to record the conversations, and while some of them did, far from all of them were OK with it. In fact, after overhearing sensitive patient information, some recordings were withheld from submission, and deleted. The interviews/discussions was performed over two days, during the fall 2016, at the department. Two representatives from the CMS team were sitting at the lunchroom interviewing the nurses coming by, in total 13 nurses were involved in this interview/discussion session. The discussions were transcribed and analyzed after the sessions. The following questions were asked:

General questions:

1. How much do you use CMS during a work session?
2. How much do you use your old DECT phones and pagers?
3. What's positive with CMS?
4. What's negative with CMS?
5. Do you miss anything from the old system?
6. Have you ever thought of something that you'd like to be there?

Alarm specific questions (i.e., primarily related to bed and toilet alarms):

1. How do they work today?
2. How do you specify who's in charge of specific rooms?
   a. Nursing officer continues to provide an overview of rooms and designated nurses. Every nurse then inputs which beds they are responsible for.
   b. Nursing officer marks in a suite which nurses are responsible for which beds.
   c. The system regulates what beds are designated to which nurses dependent on availability.
3. Are there any setbacks to being set as busy when you are assigned to an alarm?
4. How long would you like to automatically be set to busy after handling an alarm?
5. Is there anything you expected to be asked? (I.e., have we missed something?)

2. Results

Interviews at UNN's Oncology Department revealed that almost everyone interviewed preferred CMS over their old system, and that the old system was only used when they could not get a response within a reasonable time on CallMeSmart, which happened very seldom. This never happened because of stability issues or functionality problems with CMS, but rather that they for some reason didn't want to use the phone. One nurse said that she couldn't use CMS because the weight of the phone along with the pager pulled her jacket down and caused pressure on her neck. For the average user, their user pattern showed about 40-50 messages and roughly 10 calls per 8-hour shift.

The unanimously most appreciated feature was the ability to easily send messages to one another, and verify that these had been read. Use cases presented included their ability to finish their lunch break because they knew how important and how time sensitive the issue explained in the message was, and that only by reading it they acknowledged to the sender that it was read and understood.

Previously, messages would be given verbally, either after calling on a pager or after physically searching the ward for the person to deliver the message in person. In either case, precious time was spent on walking and administration – time that could otherwise have been used on a patient. As a result, their work flow improved tremendously because they had less interruptions caused by messages that had a low time sensitivity, and less time was spent searching, walking and acquiring information.

The most surprising comments however were related to alarm balancing. We proposed alarm handling based on location and availability tracking, but most nurses saw major drawbacks to that design. While balancing alarm calls efficiently and correctly were one of the primary ideas, most nurses were very reluctant to this change. Their primary concern was that it would prevent consistency for both nurse and patient. This inconsistency would lead to confusion because it would be very hard to keep track of a patient's treatment when handled by multiple nurses.

However, there was a clear consensus among those interviewed that they wanted a hierarchy with three levels:

1. The first layer consisted of primary nurses assigned to a patient. Normally up to two people.
2. The second layer consisted of all nurses in the same team as those found in layer one.
3. The third layer consisted of every nurse in that ward.

There was also strong consensus that they didn't want to be automatically marked as unavailable for further alarms after accepting one. They presented multiple reasons:

1. Accepting an alarm did not necessarily mean that they were too busy to accept another one in close proximity in time.
2. Patients are prioritized diff erently based on their personality, illness(es) and situation.
3. They didn't want to increase complexity by losing patient history after missing an alarm while they were busy.

Nurses also established that, more often than not, they were assigned individual beds, and not entire rooms. It was therefore decided to design the user interface in a way that made this as easy as possible.

3. Discussion and Conclusion

Open ended discussions and interviews, similar to what Solvoll describes in [9] were very effective. Even though the questions we prepared were designed to give the users room for interpretation and creativity, they actually shaped the feedback. When users were presented with a question, they tried to give an answer to that particular question and move on. In contrast to open discussions, where they were able to extract multiple scenarios from their workday regarding the questions/discussion, by following their own line of thought.

Most users interviewed were very happy with the current system. One nurse in particular expressed that she is hostile to technology in general, and that she was very skeptical to CMS when they were first presented to it. After getting instructed on how to use the system, however, she became extremely satisfied. She continued with "Now, I dig it!".

As the interviews at oncology department at UNN revealed, almost everyone interviewed used CMS over their old system. As mentioned earlier, the old system was only used when they could not get a response within a reasonable time using CMS, which happened very seldom. This never happened because of stability issues or functionality problems with CMS, but rather that some users for various reasons didn't want to use the phone. This means that if we are able to design and implement an

intelligent alarm handling system within CMS, the nurses can stop using the pager and thereby only carry the CMS-Smartphone. We also believe that handling the alarms in an intelligent way by only involving the necessary nurses, it will reduce the alarm fatigue.

Since user satisfaction and adoption is a crucial concern to any system, huge importance has to be given to any feedback handed to us directly by clinicians. Their wishes, needs and requirements have to influence both the user interface and the alarm handling intelligence of the system. The idea is to first use context-aware techniques to decide how alarms should be handled. However, conversations and planning with health care personnel revealed that this was not how they wanted it to be implemented. Instead of using location, availability and statistics to balance the workload, they preferred to assign patients to specific nurses.

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