Evaluation of a Context-Specific Communication System Based on Smartphones

A field study of use and nurses' expectations

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Abstract—**This project evaluates a context aware communication system designed for use in hospitals. This communication system aims to increase and improve the communication and information exchange between nurses, between nurses and physicians, and between physicians. In this paper, we focus on nurse-to-nurse communication. Nurses in the oncology department at the University Hospital of North Norway tested the system. The aim of this field study is to investigate the expectations, consequences and experiences of using the phone system in a clinical setting. The study uses a multi-method research approach including both quantitative and qualitative data. We use a before-and-after study design, with data from questionnaires, interviews and logs as well as step count measurements. In this paper, we describes the phone system and how it can be used. We also report on the nurses' expectations and presents some preliminary findings on system usage and the before-and-after step count assessment.**

Keyword- hospital communication systems; context awareness; nursing; e-health; work practices; ICT in hospitals; work effinecy

I. INTRODUCTION

Working in a hospital environment requires highly mobile personnel. Health care personnel depend on effective modes of communication and information exchange to provide high quality services [1][2][3]. In a clinical setting, gathering the right information can be complex, requiring frequent conversations and discussions [4]. However, research has shown that communication in hospitals suffers due to poor practices and inefficiency; caused by an insufficient infrastructure, such issues emerge particularly when the need for communication is urgent [4][5][6].

Most hospitals rely on a mobile communication infrastructure with devices dedicated for each role, with pagers being the most common mobile communication device. Generally speaking, mobile phones are not widely used in hospitals, with personnel using wired/wireless phones and personal digital assistants (PDA) in addition to their pagers [7]. To ameliorate communication issues, more extensive use of mobile phones could offer a solution by improving accessibility and communication [4][6][8]. Compared to pager use, important advantages can be achieved with texting and voice services. Decreasing communication delays may lead to improved patient care while reducing the risk of medical errors [6]. Studies have shown that wireless phones can overcome most of the limitations of pagers, thus facilitating communication within hospital settings [9].

Despite the advantages of mobile phones, there are also well-known downsides to the usage of such devices. For instance, the increased availability and accessibility can overload key human resources, such as senior physicians and on-call staff [2][9]. Only a few staff members carry wireless phones due to the assumption that phones are more interruptive than pagers [2][7]. Therefore, before introducing wireless phones as standard hospital equipment, it is important to evaluate usability and user satisfaction and to assess impacts on work practices.

Our study investigates how the use of one such system, the CallMeSmart (CMS) system, influences nurse-to-nurse communication and affects work practices at the Oncology Department (OD) at the University Hospital of North Norway (UNN). In this paper, we describe the technology, present the pilot study and report on preliminary results. We discuss results regarding nurses' expectations towards the phone system, patterns of use and time use, as measured by step count.

The paper now proceeds into Section II, which provides background information and includes an overview of the local context as well as the use of phone systems in clinical work. Section III outlines the materials, research setting and methodology of this study. Section IV provides an overview of our results. Section V discusses implications and limitations. Finally, conclusions and future work are detailed in Section VI.

II. BACKGROUND

CallMeSmart is a context-sensitive mobile communication system developed for hospital use. The system aims to reduce unnecessary interruptions from

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mobile devices in situations where disruptions should be avoided. These situations include, for instance, times when health personnel is involved in surgery (dressed in sterile clothing), doing patient examinations at outpatient clinics, or having conversations with patients/relatives in designated rooms.

Context-sensitive systems for hospitals represent a promising application domain. Hospital staff depend on a wide and reliable communication infrastructure for the exchange of different types of data, such as patient reports, lab tests and work shifts. They also depend on this infrastructure for text, voice and alarm services. Management of this information is difficult and requires avoidance of a wide variety of problems in order to properly meet the needs of hospital professionals. Context-sensitive applications for mobile communication seem to promise a valid solution that could also move some workers' activities over to computers.

The phone system focuses on context-sensitive interfaces, middleware and new interaction forms for mobile devices that support multi-modal communication in hospitals. These devices support media, such as voice services, text-messaging and paging services, in an efficient and non-interruptive manner. They also enable support for individual and role-based contact on a single device. That is, users only need to carry one device for both personal and role-based communication, which enables other users to, for example, contact someone assigned to "on-call" duty in a specific department, even if they do not know the identity of that person. At the same time, the system seeks to balance between availability and interruptions while enabling acute calls and alarms to go through.

The phone system senses the context automatically from different sensors, calendar information and work schedules. It makes changes to the health care worker's availability and the phone's profile according to the collected contextual information. At the same time, the caller is given feedback about the health care worker's availability, thereby making it possible for the caller to force through an emergency call or to forward the call to another available health care worker at the same level. The system is based on ideas from earlier studies on interruptions in combination with ideas from Solvoll (2013) [10]. A first version of the system is ready and has been tested in lab settings with physicians/nurses as test users. The tests were performed as scenarios derived from real situations. The feedback was mostly positive, and the input was used to improve and further develop the system, moving from prototype to production [10]. A more detailed description of the system, including figures that itemise the functionality, architecture, interruption reduction and compatibility with other existing systems can also be found in Solvoll (2013) [10].

Management at the Oncology Department at the University Hospital of North Norway has decided to invest in mobile communication devices to save time and improve patient care. Currently, all phone communication at the department occurs through wired/wireless landline telephones. People on call also carry pagers. The nurses have no mobile devises to help them exchange information. To ease the situation in the department, management has decided to invest in the CallMeSmart system. As part of this initiative, we proposed a study to investigate the expectations, consequences and experiences of using the phone system in a clinical setting.

The purpose of this evaluation is to assess the impact and experiences of using a context-aware communication system at a hospital department (the Oncology Department). The main research question can be put as follows: Will work practices at a hospital ward be improved by using local smart phones? We will investigate these aspects:

- System usage
- Nurses' expectations
- Changes in time use
- Changes in work practices
- Nurses' experiences

In this paper, we report results from the three first aspects outlined above. Changes in work practices and nurses' experiences are reported in a separate paper [11].

III. Materials and Methods

In this section, we present details on the materials and methods used to investigate system usage, nurses' expectations and changes in time use. It also provides detailed information regarding how to use the phone system and the research setting.

A. Using the phone system

Users are provided personal accounts that they can access from any phone connected to the system. Users log on using personal login credentials. Configuration and personal data (like contact lists, messages and phone logs) are temporarily stored on the phones – only as long as the user is logged into the system. All personal data are stored on the user profile. The profile is downloaded to the phone when the user logs on and deleted from the phone when the user logs off. In all cases, the user's data are stored in the system and protected so that other users cannot access this information. Authentication is based on Lightweight Directory Access Protocol (LDAP) and is compatible with Active Directory (AD), meaning that each user can potentially use his or her ordinary username and password from the hospital information system to log in to the phone system. The users can make and receive calls in a one-to-one configuration, or in a one-to-many configuration for conference calls. A user cannot receive or start a second call without hanging up the first one.

The system silently offers 'delivered' and 'read' acknowledgement for each message. Messages are stored on the users' profiles, which means that whenever the user is logged on, his or her messages are available on the phone through the profile.

Before the nurses started to use the phone system, they were provided an introduction and training lasting approximately five minutes. The phone system's inventor visited the ward for the first two days after the first nurses

started using it to provide more support if needed. The only support required involved creating accounts for new users.

B. *The setting*

The study site was the Oncology Department at the UNN. The department offers chemotherapy, radiation therapy, hormone therapy, other symptomatic treatment and palliative care. Nurses follow national guidelines for treatments with the goal of curing as many people as possible of their cancer or to prevent or delay the development of the disease.

The Oncology Department includes a ward with 25 beds and about 120 employees, including nurses, nurse assistants and medical doctors. The ward treats and cares for patients between the ages of 16 and 95 years old. Most of these patients are seriously ill and in need of heavy care. In addition, about ten patients stay at the patient hotel connected to the hospital. The nurses' work schedule is organised in three shifts: the day shift includes 10 nurses, the afternoon shift has 5 or 6 nurses, and the night shift has 3 nurses.

C. *Methods*

This evaluation study follows a multi-method research approach using both quantitative and qualitative data. We recognise that randomisation is the most robust method of avoiding systematic bias, but this method was not possible for this evaluation. To randomise the nurses into two groups would require the nurses to switch between their usual mode of communication and the new phone system. Such a switch between the intervention and usual care is unlikely to succeed [12].

We have collected data before and after the introduction of the phones. The data were collected from phone logs and we registered the nurses' step count. We utilised an anonymous survey to explore the nurses' expectations of the system. The survey was made accessible to the nurses on duty prior to implementing the communication system. The survey included a one-sided questionnaire and was placed in a cardboard box in the main corridor close to the nurses' station. The questionnaire included questions about their expected changes in work practices as a result of using the phone system. They were first asked to name three changes they anticipated in their own work. Then, they were asked to specify which of the changes they thought were most important and why. The questionnaire included questions about when they expected the phone system device to be most used (during the day or night shift) and in which situations. Furthermore, the nurses were asked if they expected the phones to be used inside or outside the ward location. All questions in the questionnaire were open ended. Two of this paper's authors categorised the answers.

To analyse if the phone system saved time for the nurses, we measured the step counts before and after introducing the phone system. Twenty-five nurses received the Fitbit step count, carrying it in their uniform pockets during their shifts. Different nurses used the step count before and after. It was not possible to measure the step count for the same nurses before and after the phone system

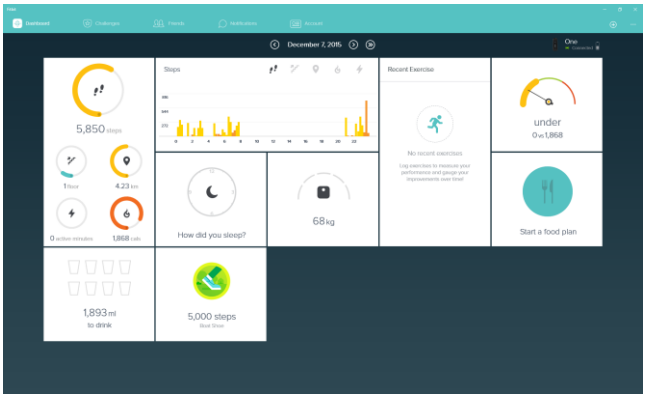

Figure 1. Screen dump from Fitbit One for a nurse working two consecutive night shifts

was introduced. The main reason for this limitation was that the shift plan for the study period was already made.

The steps were monitored one week before and one week after the introduction of the phone system (in December 2016).

Fitbit One tracks all steps taken, stairs climbed, calories burned and distances travelled (see figure 1). The results from each day were stored digitally and displayed as an activity from midnight one evening until the following midnight. This feature implies that if a nurse was working the night shift, data from two different data collection screen dumps had to be summarised to measure the steps over the whole shift. Likewise, data from one screen dump sometimes had to be divided if the nurse had two consecutive night shifts. Data from the step counts were reported in an Excel sheet. Data regarding calories burned was considered irrelevant and not reported.

We also collected logs of the system usage, including how many messages and phone calls were sent/performed on which date and at what time of day.

IV. RESULTS

In this section, we report on the nurses' expectations and presents some preliminary findings on system usage and the before-and-after step count assessment.

A. *Expectations*

A total of 11 nurses completed the questionnaire. All respondents answered the first part of the questionnaire, except one who did not specify the change perceived to be most important. All respondents expressed positive expectations. No one voiced any concerns. Expectations revolved around two main themes: phone use would save time and reduce disruptions and interferences in daily tasks. As reasons for these expected benefits, the nurses pointed to improved information and communication flow in their work practices. They expected changes in time use as a result of spending less time walking around and searching for colleagues. Furthermore, they noted that fewer paper messages and a more "orderly" information flow would improve their work practices. They seemed to assume that fewer messages would be lost or forgotten; instead of having to use several stages to deliver messages, the process of

sending questions and receiving answers/feedback would be streamlined. They expected that the system would make it easier to get in contact with colleagues and cause fewer interruptions during reports and rounds. The nurses could also "mark themselves as busy" when in a sterile setting or working with a patient, for instance.

All respondents envisaged situations where they expected to use the phone system. This response applied both when the nurse would be with 'their own patients' (patients for whom they have a special responsibility) and with other nurses' patients. They also reported that they believed the system would be useful in the following situations: during patient admittance, patient examinations, shift handovers, and while sending and receiving messages from secretaries, medical doctors and other colleagues.

Several nurses expected to use the phone system especially in the daytime, but some assumed that they would benefit most from the phone system during night shifts. Most nurses estimated that they would use the system inside the ward location, not outside.

B. Phone logs

We also collected phone log data regarding the use of both the message and phone services. Figures 2 to 5 show the total usage of the system since implementation, from December 16th to January 21st. Figure 2 shows the total usage during the day from zero (midnight) until 23:59. Figure 3 shows the total number of messages sent during the day. Nurses send messages on all shifts, with a peak during the day shift between 9 and 10 am. Figure 2 compared with Figure 3 reveals that nurses only use the message function during the night shift, omitting the call function. Figure 4 shows the total number of phone calls during the same period. We can see that there were almost no phone calls between December 19th and January 3rd. Figure 5 shows the number of messages sent per day from December 16th to January 21st. A few messages were sent on December 21st due to a false alarm, but this error was fixed the following day. The system was not used during the Christmas holidays.

C. Step count

Before the phone system was introduced, we measured the steps of 21 nurses from 80 shifts, 24 afternoon shifts and 56 day shifts. The day shift resulted in 369,589 steps over 446 hours, and the afternoon shifts in 150,600 steps over 171 hours. After the phone system was introduced, we collected steps from 13 nurses on 82 shifts, 27 afternoon shifts and 55 day shifts. The day shift resulted in 334,017 steps over 411 hours, and the afternoon shifts led to 174,445 steps over 197 hours.

We found no significant difference in step count after implementing the phone system. Using a t-test, the mean number of steps per hour before and after was 838 and 830, respectively ($P = 0.82$).

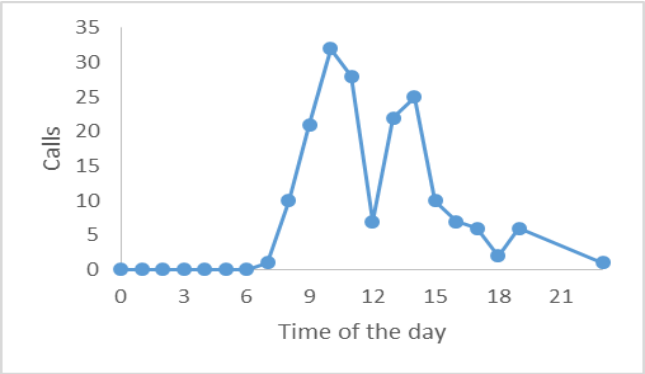

Figure 2. Total number of actual calls at certain times of the day from December 16th to January 21st

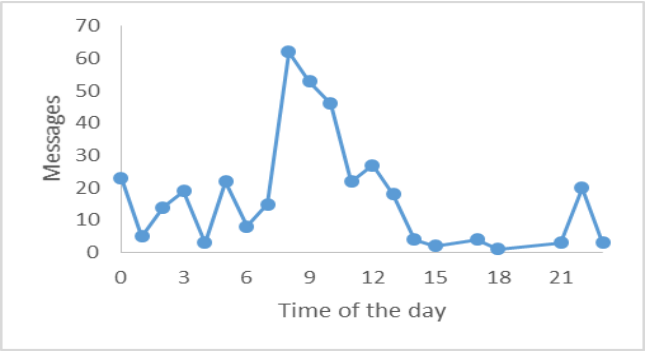

Figure 3. Total number of actual messages divided by time of the day from December 16th to January 21st

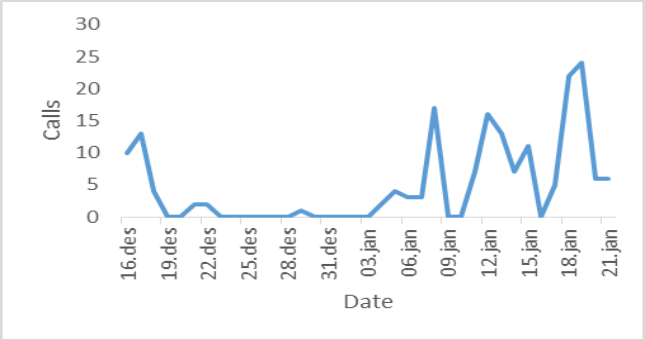

Figure 4. Total number of actual calls for each day from December 16th to January 21st

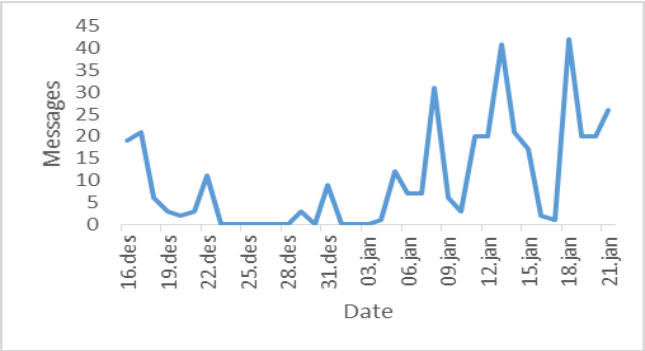

Figure 5. Total number of actual messages for each day from December 16th to January 21st

V. DISCUSSION

In this paper, we have evaluated a hospital phone system at the Oncology Department at the main hospital in Northern Norway. We found that the nurses believed that phone use would save time and reduce disruptions and interferences during their daily work. They also envisaged fewer paper messages and a more "orderly" information exchange. The logs show that phone use increased over time and that the system was most frequently used during the day shift with a peak at 9 and 10 am. However, we did not find that nurses spent less time walking around looking for colleagues.

The results of the survey suggest that the nurses believed the phone system would make the information and communication flow more efficient while improving work practices. Furthermore, they emphasised that this improvement would not only benefit the nurses themselves by saving time and reducing disruptions, but it would also improve patient care. The nurses believed that they would spend less "unnecessary time" on getting messages and questions to the right people. Fewer interruptions might also reduce stress according to the nurses. Furthermore, they noted the stress they felt when they had "to run after" people or when they "must remember" things. They also expressed frustrations over "not finding" or "forgetting to pass on a message". It seems logical that when nurses spend less time and energy on getting and passing on information, it benefits the patients. The patients would have easier access to the nurses who would experience fewer interruptions during patient treatment and care. The nurses suggested that the phone system would make them more time efficient and thereby improve patient care.

However, we found no significant difference in step count after implementing the phone system, a result that must be seen in light of several methodological limitations. The step count was measured over a short period, one week before and one week after the system was introduced. Steps were measured in December. Perhaps more importantly, the “after” measurements were collected the last week before the Christmas holidays, which might have affected the results as normal workloads are reduced around the holidays. Furthermore, collecting the measurements right after the phones’ introduction might have been too soon to capture an effect. It is reasonable to assume that the users need more time and practice to learn how to use the phone system before we can expect a change in work habits.

It should also be noted that a few messages were sent on December 21st due to an alarm going off. Caused by a bug in the system, the issue caused the nurses stop using the system for a day. The bug was fixed the same day, but due to the upcoming holidays and less activity at the department, several of the nurses were not aware that the system was up and running again. This situation might explain the system’s lowered use during the holidays.

We did not record the nurses’ exact workload for these two weeks; such information would include how many patients each nurse had in his or her care and how much care these patients needed. In addition, the nurses were given very little training in using the system. The phone logs show that system use has increased over time since we measured the steps, which might indicate that the nurses did not know the full functionality of the system at the time. When the nurses become more experienced in using the system, a change in work habits and practices may follow. Another possible explanation for the low use and the lack of difference in step count is that the nurses will run as much as possible independent of any technological system due to their eagerness to help as many patients as possible [13]. This finding could imply that more patients might receive better treatment and care due to the new phone system.

Another limitation is that it was not possible to measure the step count for the same nurses before and after the phone system was introduced. The main reason for this limitation was that the shift plan for the study period was already made. Some of the nurses working the first week (before data) were off work during the second week (after data). Another reason for this limitation is the short time period allotted for this pilot study.

Therefore, **future studies** are necessary. Data should be collected in different departments, and over longer periods, both before and after introducing the new system. Before the “after” data is collected, the nurses should be given time to become familiar with the phones and their functionalities. The data collected should be from periods with equal workloads, and data on step counts should be collected from the same nurses before and after. These changes would improve the validity of the results.

VI. CONCLUSION AND FUTURE WORK

In this paper, we have reported some preliminary results from a pilot study evaluating the introduction of a phone system in one hospital department. We found that the nurses believed that phone use would save time and reduce disruptions and interferences in their daily work. The logs show that phone use increased over time and that the system was most frequently used during the day shift with a peak at 9 and 10 am. However, we did not find any time savings, as measured by reduced step count.

The next step in this evaluation is to collect interview data and measure use and step count over a longer time period. Future research questions will also investigate if the phone system influences the quality of patient care as well as the nurses’ perceived safety of information exchange and productivity at the hospital ward.

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