

Designing for Redundancy: Nurses Experiences with the Wireless Nurse Call System

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Abstract

Patients rely on the nurse call system when in need of nurses' assistance, while nurses rely on the nurse call system to coordinate work. In order to handle the highly mobile nature of nurses' work, a wireless nurse call system has been introduced at a Norwegian hospital. In light of findings from previous research that identify challenges associated with wireless nurse call systems, we have conducted qualitative and ethnographically inspired fieldwork, i.e. workshops including both ordinary and student nurses to describe nurses' present system use. We further identify challenges related to wireless nurse call system usage, in particular how nurses manage the interruptive nature of wireless nurse calls so as to ensure continuous patient support. Our analysis acknowledges that High Reliability Organization (HRO) principles are transferable to a hospital organization. Based on our data, we propose improvements for design that hopefully can help reduce disruptive interruptions, ensure quick responses to patients, and further improve quality of care and patient safety. Further, we suggest that technology should facilitate and strengthen the redundancy of function.

Keywords:

Communication, Collaboration, Safety, Qualitative research.

Introduction

A hospital is a safety-critical organization characterized by multiple information sources, moments of intense stress interspersed with long periods of routine activity, and often complex and confusing human-machine interfaces [1]. Regardless of hospital department type, whether a traditional ward, an intensive care unit or operating theatre, information exchange is of vital importance. Communication is therefore a key component for high quality care [2][3], patient safety being an important dimension to quality of care [4].

Health professionals prefer in-person and oral information sharing, communication that is context sensitive and detailed [5]. Still, hospital communication is often time consuming and disruptive. For example, synchronous communication is often associated with interruptions and breaches of communication [6]. Interruptions are shown to be one of the main reasons behind medication errors [7][8], thus influencing patient safety.

A High Reliability Organization (HRO) is an organization that handles unexpected and potentially harmful situations better than other organizations [9][10]. In order to cope with unforeseen events [10], HRO's have inherent varying forms of

redundancies so as to be *prepared* and *flexible* in order to ensure safe operations [1][11]. Redundancy means to organize and design for several 'defences in depth'. If one level fails, backup exists at the next level [11]. Redundancy is therefore associated with an organization's ability to minimize mistakes and generate optional action strategies [12].

There are distinct challenges to communication in traditional hospital wards because work is spatially and temporally distributed [13], and information often varies in complexity and degree of urgency. As health care workers are highly mobile [14], Coiera and Tombs propose the introduction of wireless devices (phones) for communication [5].

The nurse call system, in particular, enables patients to call for nurses when in need of assistance. Effective nurse call systems can improve patient care [2], yet introducing wireless nurse call systems where nurses receive and provide calls directly on personal wireless phones are still associated with challenges [15][16].

This paper reports results from a qualitative and exploratory study of three different wards' varying use of the wireless nurse call system. Our analysis assumes that HRO principles are readily transferable to health care environments [10]. We also acknowledge parallels between hospital organizations and high reliability industries when focusing on redundancy of function for increased safety [17]. The hospital departments are located in a large Norwegian university hospital where the wireless nurse call system is used by patients to communicate the need for assistance to the nurses. The wireless nurse call system is also used among the nurses to coordinate work, for example when several patients need assistance at the same time.

Through a qualitative analysis we start by describing nurses' present use and challenges pertaining to the wireless nurse call system. Thereafter, we aim to identify areas where novel technological functionality can improve the system's redundancy and hence patient safety, following which we put forth implications for the design of such functionality.

Background

Functional redundancy

In his study of team collaboration in marine vessels, Hutchins describes how a shared knowledge and competence level among operators in the navigation room means that each operator is able to follow colleagues' work [18]. Operators in medical emergency call (AMK) centers are similarly capable

of supporting one another by carrying out each other's tasks if necessary [19]. The term *redundancy of function* [13][18][19][20] implies that the level of knowledge and situational awareness are distributed [18] and overlapping [20] among team members. Functional redundancy is achieved by making visible one's own work to colleagues, such as when an incoming emergency call is made available to all operators in AMK centres via the listening-in-function on individual phones [19]. Functional redundancy means inherent flexibility to perform colleagues' work, an overlapping work responsibility and division of labor [18][19].

Interruptions

Interruptions are shown to be one of the main reasons that medication errors occur [7][8]. This implies that interruptions per se have a negative impact on quality of patient care [21], and therefore also patient safety. One example is when the wireless phone rings while the nurse is in a discussion with a patient, which results in an ended discussion [21]. Further, novel technology to support communication between health care workers should support unobtrusive communication [5]. For example, many of the received nurse calls did not require immediate attention and many calls were initiated unintentionally, according to a study on reasons behind nurse call use [22]. Generally, interruption research needs to be conducted in a real setting in order to fully understand its nature. Such research should also include the social context [23]. In order to handle unwanted interruptions mediated through mobile communication devices, McGillis Hall et al. argue that *awareness* needs to be provided to colleagues in order to reduce distractions [21].

Dourish and Belotti define awareness as "*an understanding of the activities of others, which provides a context for your own activity*", shared feedback being, for example, one aspect to support in order to further assist collaborative work [24]. Nevertheless, like interruptions [25], awareness is a diverse and often complex topic to study [26]. Further, designing technology that automatically manages interruptions is challenging [27]. However, there is research using pervasive technologies to provide contextual information to users [28][29], with the goal of enhancing awareness of colleagues' location and situation in order to reduce unwanted interruptions.

Methods

Research Design

First we conducted a qualitative observational study of nurses' work in three different hospital departments at a Norwegian University hospital in late 2011 and early 2012. Our aim during the initial observational period was to gain overall insight and understanding related to nurses' actual use of the wireless nurse call system. Our roles as observers were in line with that of *observer as participant* [30]. This meant occasional interactions with nurses, for example, when verifying ongoing observations. Thus we were participating in social encounters, yet avoiding taking any part in work related activities. Our observations were ethnographically inspired, in line with rapid ethnography [31].

Following the observational period, four workshops were held in early 2012 that involved both ordinary and student nurses¹.

The workshops included scenarios to illustrate specific aspects of present nurse call system use together with focus group interviews before and after the scenarios to further clarify nurses' experiences with the system.

The design of the scenarios and content of the focus group interviews were motivated by insights gained when we initially observed nurses' work at the three departments. The workshops were held inside the hospital at an empty bed area. Video cameras were used to ensure good quality data for later analysis. All authors performed initial observations at the departments and participated in the workshops afterwards as mediators. Departmental observations were conducted over several days totaling 22 hours while the later four workshops totaled 12 hours of data material.

Our study has been approved by the Norwegian Social Science Data Services. We have collected informed consent from all participants together with securing participants' confidentiality by de-identifying and securely storing the collected data material.

Case Description

The departments studied at the hospital were divided into several bed areas, each of which consists of seven to nine patient rooms and a nurse station. The nurse call system allows patients to issue an alarm from their room. The nurse call is not a voice call, but a signal that indicates that a patient seeks the attention of a nurse. The nurse call system consists of two integrated systems. The fixed part of the system consists of a wall-mounted panel and a drawstring in each patient room and toilet, as well as a display in the nurse station. The patient issues a nurse call by either pressing the button on the wall panel or using the drawstring. To respond to the call a nurse needs to enter the room and press the presence button on the wall-mounted panel. By doing so, the nurse marks her presence to the system. Pressing the nurse call button again, after the presence has been marked, issues an emergency alarm.

The wireless part of the system delivers nurse calls to a wireless phone with which each nurses has been equipped. To make the phones ready to receive nurse calls, nurses first need to authenticate themselves using the phones' user interface. Second, they need to register themselves as an available resource in the call plan, which is accessible through a computer in the nurse station. The call plan maps a room to one or several nurses. So when a nurse call is issued, the phone of the nurse registered with the room rings first. The nurse then has the option to either accept or dismiss the nurse call. Dismissing, or ignoring the nurse call for fifteen seconds, will forward the nurse call to the next nurse registered in the call plan in a round robin fashion. Further, a number of "available" roles can also be configured in the call plan. This role does not have the responsibility of a specific room, but act as a redundant resource when others are unavailable.

The room number, from which a nurse call is issued, is shown in the nurse station and on wall panels inside the rooms that have the presence buttons activated. According to documentation, the nurse call should be delivered to the responsible nurse, both effectively and precisely.

Results

The data presented are from both our observations and subsequent workshops, with the aim of illustrating how the

¹ In total there were twenty-one participants in the workshops.

technology is used at the different departments included in the study. Further, the way nurses typically organize themselves by continuously allocating and reallocating responsibility, focusing on meeting the needs of the patients, is also illuminated.

Responsibility Configuration and System Use

Despite the fact that the same system is implemented at the different departments, its usage differs. At both the thorax and orthopedic departments, the nurses authenticate and register themselves in the system and use the phones for both nurse calls and ordinary phone calls. This includes setting up responsibilities for the separate patient rooms in the call plan. One nurse at the thorax departments notes *"everyone is logged on (...) we notice quickly if someone is not"*. The nurse explains that they all take responsibility for making sure that everyone within the department is using the wireless system. Further, within these two departments, they wish to receive emergency alarms that are issued from other bed areas than their own (though still within the department) in order to act as backup. They achieve this by adding themselves in the call plan as available resources, or as primary or secondary contacts for one of the toilets in the other bed areas. As one nurse at the thorax department explains: *"...if we are unlucky then, we are assigned a very active toilet (laughter), then it keeps ringing all the time"*. The nurse is referring to the fact that nurse calls issued from the toilets will initially be routed to their phones, according to the ad-hoc configured call plan.

At the infection department, on the other hand, nurses report that they rarely use the wireless phones for receiving nurse calls. One nurse at the department mentions the isolation rooms as one reason behind the sparse use of the technology: *"...a difficulty for us at the infection department is that we have so many isolation rooms (...), it just doesn't work"*. Due to the infection risk, it is not appropriate to pick up the phone while in an isolation room. A nurse at the thorax department explains that this is an issue for them as well, when they occasionally need to dress in an infection control gown. The nurse explains: *"...when we insert CVC² then we do it [dress in an infection control gown] (...), then I put away the phone as I know that it can ring (...), so I never have it in my pocket (...), then I see what it's about if it rings by throwing a glance at it (...), then I see who is calling and then I assess whether to take it or not"*. Nurses at the infection department do not, on the other hand, bring the phone with them into the patient room.

Organization of Work and Responsibility Allocation

Nurses in these departments divide the responsibility of patients among them. In their everyday language they use the term "primary nurse" when referring to the one responsible for a patient³. Usually, the responsibility allocation takes place during a handover meeting, which occurs whenever a workforce is replaced, i.e. when the work shift changes. During this meeting, information about the different patients in the department is also shared orally. The responsibility allocation is also reflected in the call plan in the departments where the system is used.

A nurse at the orthopedic department tells us: *"...we distribute the [responsibility of] patients everyday, but we try to follow the patients that we are familiar with"*. A nurse from the thorax department mentions that they use a similar approach, where they try to keep the primary nurse for a patient as consistent as possible during the stay of the patient. They also agree that often a nurse is responsible for two to four patients during a working shift. Nurses at the infection department also affirm that they split the responsibility of patients. They mention that they also try to keep some consistency, but state that it is impossible that the same nurse is responsible for the same patient over several working shifts. The consensus at the department is that they try to respond to their assigned patients, which they are more familiar with, as much as possible. However, in practice they affirm that this is difficult to do consistently. As one nurse tells us: *"...we respond to all..."*, indicating that they make a common effort in responding to nurse calls from all patients at the department.

Responsibility Reallocation

The findings also illustrate that there is a continuous need to reallocate the responsibility during work hours. One example is the lunch routine, which different departments have slightly different ways of arranging. Common to all departments is to arrange the practice so that someone always is present at the department. These are then responsible for responding to nurse calls while the others are at lunch. As explained by a nurse at the infection department: *"we split the bed area, and tell the others when we go for lunch, and then the ones there [at the bed area] responds to nurse calls"*. Some nurses at the orthopedic department report that they respond to nurse calls while at lunch, if the ones working are unavailable.

At the thorax department they hand over the patients that they are responsible for to another nurse, and provide a short oral report on the relevant patients. They also make changes to the call plan so that the switch of responsibility is reflected in the system. This limits the risk of nurses being interrupted by nurse calls while on lunch. However, they do report that they cannot fully avoid receiving calls while on lunch, but that these then are dismissed. The nurses also agree that their practice of reallocating responsibility requires extra work in the form of reconfigurations of the call plan. By contrast, the nurses at the orthopedic department make no changes to the call plan. The nurses comment that this causes a lot of ringing in the lunchroom, as the nurses carry the phones with them.

Reallocations of responsibility were also made at other times than during lunch. A nurse at the infection department explains the procedure before changing a wound dress: *"... always, if you are going into an isolation room and you will be there for a while, you always tell the others (...), so that they can answer the nurse calls"*. The same nurse also notes: *"If I'm busy with changing a wound dress, I won't respond to a nurse call (...), unless I know that the others are busy with other things"*. Another nurse at the same department mentions that if she knew that the other nurses were busy, she wouldn't make herself unavailable during that time. Hence, nurses make informal arrangements during work to be able to act as backup for each other. A nurse from the thorax department also confirms that they make similar arrangements when they have planned for an activity that will take a longer time. The same nurse states: *"...if this [the procedure of changing a wound dress], was not planned [i.e. no arrangements made], I would have felt stressed to get out of the room as quickly as possible"*.

² Central Venous Catheter (CVC)

³ The departments seem to pursue a practice that Pontin refers to as 'primary nursing'. This mode of nursing is characterized as patient centered, where interpersonal relationships between the nurse and the patient are emphasized. The actual practice, however, tends to lean more towards the opposite of primary nursing, namely team nursing, which pursues effectiveness [32].

Another situation where nurses seek to transfer the responsibility of a patient to another nurse is when a nurse call is issued while they are attending another patient. One way to handle this is to press the dismiss button on the phone in hope that someone else will respond to the nurse call. When asked if she would leave the patient due to a nurse call, a nurse from the infection department answers: *"I would not have gone from the patient. I'd rather put out my head into the hallway and asked someone else to take it"*. This illustrates how nurses make ad-hoc maneuvers to utilize other nurses in order to ensure that both patients receive attention.

Discussion

Challenges and Implications for Design

One of the main challenges with the current wireless system is that when a nurse is unavailable with one thing or another at work, the nurse is still available in the system. Hence, the system state does not reflect reality. Examples of this presented in the results include times during which a nurse is at lunch, in an isolation room, or visiting a patient whom the nurse is reluctant to leave. Still, during these times nurse calls are delivered to the nurse due to her system status. Although it is possible to reconfigure the call plan, this requires a cumbersome procedure that is rarely carried out in practice.

A consequence of this is an increased number of disruptive interruptions. When receiving a nurse call, the nurse has the option to either abort the current activity by visiting the calling patient or to dismiss the nurse call. A nurse from the infection department tells us: *"[I] wouldn't have been able to (...), if you turn off the sound, you still hear the humming or vibration, and I wouldn't have been able to shut it out"*. The nurse explains if she had to dismiss the call repeatedly, that she then would be totally *"out of it"*, meaning that the focus on the current activity is lost. Although some nurses are able to mentally ignore the ringing, they however express concern that the patient will be affected by the noise; as one nurse explains, it *"takes out on the communication between her and the patient"*. Dismissing, ignoring, or asking a nurse in the hallway to take the nurse call, also implies that the patient that issued it has to wait longer than needed to receive attention.

Is it then possible to minimize these disruptive interruptions through system design? The findings reveal that some nurses either do not carry the phone with them or do not register as a resource in the call plan to prevent interruptions. We therefore suggest that nurses should be able to easily *"go off system"* [33]. This would prevent nurse calls being delivered to an unavailable nurse. The system should make sure that not all nurses within a bed ward could make themselves unavailable at the same time. Further, it would be preferable that the system *"reminds"* the nurse to make herself available again.

A future design should also make it easy to hand over the responsibility of one or several patients to another nurse. In today's practice nurses make oral agreements on the switch of responsibility. However, this is not reflected in the system. As a nurse explains: *"... when I make such an agreement where the responsibility of a patient is transferred from me to you, then also the phone responsibility should be transferred to you (...), but it doesn't work like that today"*. We propose that while this oral agreement is made, it should be possible to make this change in the system at the same time. This could be realized, for example, through near field communication technology or electronic tokens in the form of radio-frequency identification

(RFID) tags, which would represent the responsibility of a patient.

Finally, the system should allow for nurses to receive emergency alarms from the other bed areas within a department, by design. The following summarizes the proposed implications for design:

- Allow nurses to make themselves unavailable in the system by simply pressing a button
- Allow oral responsibility hand-over agreements to directly be reflected in the system
- Allow nurses to receive emergency alarms within the whole department by design

The Role of Redundancy

We have seen how nurses within three different hospital departments use the wireless nurse call system. Despite variety in nurses' departmental needs and work strategy, there is a common denominator across departments. *Redundancy of function* is a key resource in all three studied hospital departments. The nurses we observed rely extensively upon each other in order to unobtrusively handle patient needs that are signaled via the wireless nurse call system. The nurses are able to complete the same tasks [13], seen for example at the thorax department, where nurses make informal arrangements when they have planned for an activity that will take some time. Consequently they act as backup for each other.

As our data show, and in line with [15] and [16], wireless nurse call systems are challenging to use, particularly when one considers the mobile work of nurses [28] and that unexpected wireless nurse call signals may cause disruptions. Mobility is one thing, complexity another when considering preparedness for task eventualities. Handling the co-occurring and sometimes conflicting needs of several patients can be challenging. There are often many considerations that must be taken into account. The question is, can technology help? The answer, arguably, lies in another question: *"how can we involve nurses in each others work without causing disruptive interruptions for any of them?"* Our implications for design are based on the assumption that *traditional* technology-mediated awareness [28][24] is not necessarily relevant in order to ensure a well functioning and robust wireless nurse call system. What is relevant for this type of communication technology is to ensure technology-mediated real-time one-way communication. To this end patient needs/urgency must be added; automatically forwarding, for example, a patient signal without delay will ensure both a practical and effective handling of the signal by an available nurse as quickly as possible. Similarly, a nurse *"offline"* will not be disturbed during sensitive patient encounters, by patients or by nurses.

We identify the design and evaluation of the implications presented in this paper as future research. For this we seek to adopt a participatory design approach by involving the end users in the process [34], providing users with a sense of system ownership [35]. Evaluating a prototype system in a real setting might, however, require that it be deployed in parallel with the current system to satisfy hospital safety requirements.

Our concluding remark is that insofar as one aims to improve the robustness of the present wireless nurse call system, improve handling of nurse calls by minimizing disruptive interruptions, and ensure quick response to patients, *implications for the design of novel technology* must be rooted in the need to facilitate and strengthen the *redundancy of function*. Hence, increasing departmental robustness in line

with a major HRO principle [1] for improved patient safety and quality of care is vital.

References

- [1] Reason, J. Understanding adverse events: the human factor. In: C. Vincent, Ed.: *Clinical Risk Management: Enhancing patient safety*. London: BMJ Publishing Group, 2001.
- [2] Miller ET, Deets C, and Miller RV. Nurse Call and the Work Environment: Lessons Learned. *JNCQ* 2001; 15(3): 7-15.
- [3] Toussaint PJ and Coiera E. Supporting communication in health care. *Int J Med Inf* 2005; 74(10): 779-781.
- [4] Vincent C. *Patient Safety*. Edinburgh: Elsevier Churchill Livingstone, 2006.
- [5] Coiera E and Tombs V. Communication behaviours in a hospital setting: an observational study. *BMJ* 1998; 316(7132): 673-676.
- [6] Karlsten ES and Toussaint PJ. Peri-operative Communication Patterns and Media Usage-Implications for Systems Design. *Stud Health Technol Inform* 2010; 160(1): 294-298.
- [7] Ulanimo VM, OLeary-Kelley C, and Connolly PM. Nurses perceptions of causes of medication errors and barriers to reporting. *J Nurs Care Qua* 2007; 22(1): 28-33.
- [8] Mayo AM and Duncan D. Nurse perceptions of medication errors: What we need to know for patient safety. *J Nurs Care Qua* 2004; 19(3): 209-217.
- [9] Roberts KH. *New Challenges to Understanding Organizations*. New York: Macmillan Publishing Company 1993.
- [10] Weick KE and Sutcliffe KM. *Managing the Unexpected: Resilient Performance in an Age of Uncertainty*. San Francisco: Jossey-Bass 2007.
- [11] Reason JT. *Managing the Risks of Organizational Accidents*. Aldershot: Ashgate Publishing 1997.
- [12] Landau M. Redundancy, Rationality, and the Problem of Duplication and Overlap. *Publ Admin Rev* 1969; 29(4): 346-358.
- [13] Cabitza F, Sarini M, Simone C, and Telaro M. When Once Is Not Enough: The Role of Redundancy in a Hospital Ward Setting. In: *Proc GROUP '05, 2005*; pp. 158-167.
- [14] Bardram JE and Bossen C. Mobility work: The spatial dimension of collaboration at a hospital. *Comput Supported Coop Work* 2005; 14(2): 131-160.
- [15] Kristiansen L. Nurse calls via personal wireless devices; some challenges and possible design solutions. In: *Proc CBMS '11, 2011*; pp. 1-6.
- [16] Jensen C. The Wireless Nursing Call System: Politics of Discourse, Technology and Dependability a Pilot Project. *Comput Supported Coop Work* 2006; 15(5-6): 419-441.
- [17] Committee on Quality of Health Care in America, Institute of Medicine. Kohn L, Corrigan J, and Donaldson M, eds. *To Err Is Human: Building a Safer Health System*. National Academies Press 2000.
- [18] Hutchins E. The Technology of Team Navigation. In: Galegher J, Kraut RE, and Carmen E, eds. *Intellectual Teamwork*. New Jersey: Lawrence Erlbaum Associates, 1990; pp. 191-220.
- [19] Tjora A. Maintaining redundancy in the coordination of medical emergencies. In: *Proc CSCW '04, 2004*; pp. 132-141.
- [20] Morgan G. *Images of Organization*. CA: Thousand Oaks, CA: Sage Publications Inc, 2006.
- [21] McGillis Hall L, Pedersen C, and Fairley L. Losing the moment: Understanding interruptions to nurses' work. *J Nurs Adm* 2010; 40(4): 169-176.
- [22] Meade CM, Bursell AL, and Ketelsen L. Effects of nursing rounds: on patients' call light use, satisfaction, and safety. *Am J Nurs* 2006; 106(9): 58-70.
- [23] Harr R and Kaptelinin V. Unpacking the social dimension of external interruptions. In: *Proc GROUP '07, 2007*; pp. 399-408.
- [24] Dourish P and Bellotti V. Awareness and coordination in shared workspaces. In: *Proc CSCW '92, 1992*; pp. 107-114.
- [25] Magrabi F, Li SYW, Dunn AG, and Coiera E. Why is it so difficult to measure the effects of interruptions in healthcare. *Stud Health Technol Inform* 2010; 160(1): 784-788.
- [26] Schmidt K. The problem with 'Awareness': Introductory remarks on 'Awareness in CSCW'. *Comput Supported Coop Work* 2002; 11(3): 285-298.
- [27] Thomas Erickson. Some problems with the notion of context-aware computing. *Commun ACM* 2002; 45(2): 102-104.
- [28] Bardram JE and Hansen TR. The AWARE architecture: supporting context-mediated social awareness in mobile cooperation. In: *Proc CSCW '04, 2004*; pp. 192-201.
- [29] Hansen TR, Bardram JE, and Soegaard M. Moving out of the lab: Deploying pervasive technologies in a hospital. *IEEE Pervasive Comput* 2006; 5(3): 24-31.
- [30] Gold RL. Roles in sociological field observation. In: *Social Forces* 1958; 36(3): 217-223.
- [31] Millen DR. Rapid ethnography: time deepening strategies for HCI field research. In: *Proc DIS '00, 2000*; pp. 280-286.
- [32] Pontin D. Primary nursing, a mode of care or a philosophy of nursing? *J Adv Nurs* 1999; 29(3): 584-591.
- [33] Minnick A, Pischke-Winn K and Sterk MB. Introducing a two-way wireless communication system. *Nurs Manage* 1994; 25(7): 42-47.
- [34] Ehn P. *Scandinavian Design: On Participation and Skill*. In: D. Schuler and A. Namioka, eds. *Participatory design: principles and practices*. Lawrence Erlbaum Associates, 1993.
- [35] Miller SE. From system design to democracy. *Commun ACM* 1993; 36(6): 38.

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