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A design science approach

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Norwegian University of
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Doctoral thesis

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To Tanja,
Emma, Hugo, and Isak

Abstract

A nurse call system allows patients in a hospital department to remotely call for a nurse's assistance when required. Commonly, a nurse call system notifies nurses about an issued call through strategically placed alarm displays. Recently, nurses have also been equipped with wireless phones through which they receive nurse calls. However, nurse call systems have been accused of being a source of continuous interruption that further complicates nurses' work. In particular, interruptions have been found to negatively affect human cognition and are considered a possible cause to medical errors in this type of working milieu.

Through a design science approach, effort is aimed at designing technology that addresses nurses' struggles to handle interruptions in the form of nurse calls at a Norwegian university hospital. The research is divided into three distinct yet interdependent phases. In the first phase, the nature of these types of interruptions and nurses' strategies to handle them are explored using a qualitative case study strategy. In the second phase, engineering methods are applied to develop prototypes that support nurses' strategies. Finally, during the third phase, nurses are involved in co-design exercises that utilise socio-technical design approaches to further refine the prototypes as well as evaluate their possible implications on practice.

The results indicate that nurse calls are a complex phenomenon that cannot easily be distinguished as having negative or positive effects on nurses' work. In particular, these calls are an inherent and central part of nursing work, which is supported by the finding that several factors influence nurses' decision to respond to a nurse call. Nurses were found to adopt four main strategies to both restrict unwanted nurse calls and facilitate the reception of wanted ones, and prototypes were developed to more efficiently support three of these strategies. The evaluation of the prototypes suggests that these could make existing sub-optimal workarounds redundant, improve work efficiency, and facilitate nurses' decision making. Further, using this technology to support nurses' everyday practices

that result in successful outcomes could enhance patient safety by strengthening the socio-technical system's resilience.

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Joakim Klemets,
Ytteresse, August 2016

Contents

PART I

THESIS INTRODUCTION

CHAPTER 1

Introduction

1.1 Motivation

Nurses constitute one of the largest healthcare components, making them an indispensable resource for providing care to hospitalised patients. Nurses' work ranges from managerial duties and delegated tasks, such as medication administration, to central nursing activities, such as planning and providing care to patients. Studies have demonstrated that increasing the time nurses spend on a patient has significant benefits for patient outcomes (Aiken et al. 2002; Kovner et al. 2002; Needleman et al. 2002). However, growing patient load (Aiken et al. 2001), nurse shortage (Chan et al. 2013), and cuts to public health costs make it difficult for nurses to spend as much time as they would like with their patients. Therefore, it is increasingly important that nurses prioritise their time wisely to maintain a good quality of care.

In addition, nurses' work in hospitals requires complex cognitive efforts that involve continuous organisation, prioritization, and decision making (Ebright 2010) in the midst of systems that often fail to deliver timely, accurate, and reliable information or services (Tucker and Spear 2006). The many complex human-machine interfaces that healthcare personnel are exposed to present yet another challenge to nurses' work (Reason 1995).

Interruptions have previously been identified as a major part of nurses' daily challenges, in particular, as these disrupt nurses' attention, require them to shift focus, and aggravate nurses' ability to remain mindful (Ebright 2010; Potter et al. 2005; Tucker and Spear 2006). A distinct type of interruption that nurses are recurrently exposed to in a hospital department are nurse calls. A nurse call is a request issued by patients through a nurse call system, which communicates a call for attention to nurses. Depending on the system in place, a notification about the patient's request is delivered to nurses (e.g., through public displays, pagers, or wireless phones) (Figure 1.1).

Figure 1.1: Illustration of the general principles of a nurse call system. The patient pulls a draw-string to communicate the need of assistance. Nurses get notified through a receiving device and respond by visiting the calling patient. (Left upper photo by Tony Webster, right upper photos form Mathiesen (2005))

Nurse call systems have existed for decades and are commonplace in any modern hospital (Nightingale, Vicinus, and Nergaard 1990, pages 66-68) (not surprisingly), as these systems provide a 'lifeline' for patients, allowing them to communicate their need for nurse assistance (Meade, Bursell, and Ketelsen 2006). However, previous studies have pointed to nurses' struggles to handle the interruptions these systems cause (Deitrick et al. 2006; Kristiansen 2011; Meade, Bursell, and Ketelsen 2006; Torres 2007).

Interruptions in the form of nurse calls are also relevant with regard to patient safety. First, there is an increasing concern that interruptions in hospital milieus could cause patient harm (Coiera 2012). There is also some evidence that points to the causality between medication errors and interruptions (Prakash et al. 2014; Westbrook et al. 2010a,b). Second, as mentioned, the time a nurse is allowed to spend on a patient has consequences on the patient's recovery and well-being. As not all nurse calls or nursing activities may be equally important, nurses need to prioritise whether to respond to a nurse call immediately or remain focused on the task at hand. However, except for interventions aiming to reduce the number of nurse calls, little attention has been devoted to support nurses to efficiently handle nurse calls, in particular, from a perspective that acknowledges that these are an inherent, unavoidable, and central part of nurses' work.

1.2 Research questions

The thesis approaches the challenge of interruptions in the form of nurse calls through a design science methodology with the objective to design artefacts that address the issue. However, as there is a lack of literature describing how nurses handle nurse calls and what strategies they use, the first research question aims at exploring this phenomena. The associated challenges that nurses need to overcome to employ these strategies are also scrutinised. The second research question is a follow-up question that aims to utilise the findings of the first question as an input to design supporting technologies for the identified strategies. Further, how the technology could be designed to ensure patient safety is also addressed. The two main research questions and associated subquestions have been formulated as:

RQ1: What strategies do nurses employ to handle nurse calls?

- RQ1.1: What are the associated challenges in employing these strategies?

RQ2: How could technology be designed to support nurses' handling of nurse calls?

- RQ2.1: How can the design support nurses' strategies?
- RQ2.2: How can the design ensure patient safety?

The objectives of the thesis are to identify practices that nurses adopt to handle nurse calls and to design technology that supports these practices. Further, another objective is to co-design and evaluate these solutions together with domain experts (i.e., nurses). Finally, the work aims to demonstrate how the solutions supporting nurses' practices and strategies facilitate the socio-technical system's resilience and, effectively, enhance patient safety.

To enable a deep investigation within the restricted time frame, the case is limited to hospital departments and does not include other healthcare settings where nurse call systems could be deployed (e.g., care homes). There has been little focus on designing technological nurse call innovations. Therefore, the focus of this thesis is on designing information and communications technology (ICT) to support nurse call handling rather than designing care models, organisational structures, or workflow changes. An underlying assumption is that nurses are a highly professional and skilled workforce that know how to do their job efficiently and safely while coping with complexity, multiple goals, and organisational pressure (Rankin et al. 2013). Hence, the role of the ICT designer is to discover the strategies and mechanisms that constitute everyday work and design adequate support.

1.3 Research context and design

This thesis adopts a design science approach that aims to solve problems through the design of artefacts. To produce effective artefacts, design science emphasises the importance of identifying and understanding the problem (Hevner et al. 2004). Thus, this project adopts a design science strategy that focuses on a particular case (Iivari 2015), where the issue of interruptions in the form of nurse calls has been previously identified (Kristiansen 2011). The selected research setting is a Norwegian university hospital, where an integrated fixed and wireless nurse call system is deployed in different departments. The system allows nurses to receive nurse call notifications on fixed displays as well as on wireless phones that they carry around.

The research has been divided into three main phases. The first phase is mainly exploratory and addresses the first research question by studying nurses' use of the nurse call system. In particular, the focus is on nurses' work practices related to their handling of nurse calls and associated strategies. A qualitative case study research strategy has been adopted to explore the phenomenon in its natural environment, including utilising data collection methods, such as observations and interviews. The second phase seeks to develop prototypes based on the findings from the first phase. Engineering methods, such as the SPACE methodology (Kraemer 2008), are utilised in this phase to produce artefacts. The designs of these prototypes are further refined and evaluated in the third research phase (together with nurses) in an attempt to respond to the second research question. Research strategies adopted include role-play simulation and socio-technical systems design methods. Table 1.1 provides an overview of the different phases and how they are linked to the papers included in this thesis.

Table 1.1: Research phases and the resulting papers

Phase	Purpose	Paper
Phase 1	To explore nurses' strategies in handling nurse calls and their use of a nurse call system	P1, P3, P6
Phase 2	To design prototypes that support nurses' strategies to handle nurse calls	
Phase 3	To evaluate and refine the prototype designs produced in the previous phase	P2, P4, P5

1.4 Included papers

The six research papers listed below have been produced as a result of the research. Three of these have been published in journals, two have been published in conference proceedings, and the final paper has been submitted for review to a journal. The full papers are included in the second part of the thesis.

Paper 1 Joakim Klemets, Tor Erik Evjemo, Lill Kristiansen. *Designing for redundancy: nurses' experiences with the wireless nurse call system*. Studies in Health Technology and Informatics. 2013;192.

Paper 2 Joakim Klemets and Katrien De Moor. *Patient responsibility reallocation: a user-centred approach to support nurses' handling of nurse calls*. Personal and Ubiquitous Computing. 2015;19.

Paper 3 Joakim Klemets and Tor Erik Evjemo. *Technology-mediated awareness: facilitating the handling of (un)wanted interruptions in a hospital setting*. International Journal of Medical Informatics. 2014;83(9).

Paper 4 Joakim Klemets and Pieter Toussaint. *Availability communication: requirements for an awareness system to support nurses' handling of nurse calls*. Studies in Health Technology and Informatics. 2015;216.

Paper 5 Joakim Klemets and Pieter Toussaint. *Does revealing contextual knowledge of the patient's intention help nurses' handling of nurse calls?* International Journal of Medical Informatics. 2016;86

Paper 6 Joakim Klemets and Tor Erik Evjemo. *Understanding nurses' strategies to handle (un)wanted nurse calls: a resilience perspective*. Submitted to CIN: Computers, Informatics, Nursing.

1.5 Contributions

The main contributions of this thesis are twofold. First, related to the first research phase, it identifies four strategies that nurses employ to handle nurse calls, the factors influencing nurses' prioritisation, and the nature of these types of interruptions. Second, it contributes to the design of technology supporting nurses' efforts to handle nurse calls.

The nature of nurse call interruptions. Whether a nurse decides to respond immediately to a nurse call or prioritise the current activity is influenced by several factors. These include the patient's condition, the nurse's situation or ongoing activity, the nurse's relationship with the calling patient, awareness of colleagues'

availability, and the patient's intention. Hence, these identified factors determine whether a nurse call is wanted or unwanted in a particular context. For example, a nurse call from a seriously ill patient whom is the nurse's primary responsibility is regarded as a wanted nurse call in a situation where the nurse is not doing anything of high importance. Thus, the nurse would want to respond immediately to such a nurse call.

Strategies to handle nurse calls. Four main strategies that nurses employ to handle interruptions in the form of nurse calls have been identified. Two of these are applied to facilitate the reception of wanted nurse calls, while the other two strategies are utilised to facilitate the handling of unwanted nurse calls.

The strategy 'staying connected' facilitates the reception of wanted nurse calls, where nurses (through different means) ensure the reception of nurse calls by exploiting various system configurations and flexible system use. For example, the strategy allows nurses to receive nurse calls from other bed areas during night shifts when there are fewer staff at work. The strategy 'discerning the urgency of a call' is another strategy to facilitate wanted nurse calls, which include various techniques that nurses apply to receive cues about a call's urgency.

Strategies named 'formally sharing responsibilities' and 'informally sharing responsibilities' involve means to manage unwanted nurse call interruptions. Nurses formally share their patient responsibilities with colleagues to avoid having to abort an important procedure. This includes making agreements in advance to temporarily shifting the responsibility while undertaking a planned activity. Nurses also informally share the patient responsibility by maintaining an awareness of colleagues' activities. The knowledge is utilised when, for example, the nurse is in a situation that he/she does not want to leave. Knowing that colleagues are able to respond to nurse calls allows the nurse to remain focused on the task at hand.

Technology support. Three different prototypes have been co-designed and evaluated (together with nurses) to support three of the above mentioned strategies. PANIC (PAtient iNtentIon Communication) is designed to help nurses discern the urgency of a call by allowing patients to communicate a more contextualised message. AWAY (AvailabilitY AWareness) supports nurses to remain aware of colleagues' availability also when not co-located. Finally, the PatientRhover (Patient Responsibility handover) prototype allows nurses to quickly hand over patient responsibilities, supporting the 'formally sharing responsibilities' strategy.

An overview of the contributions is illustrated in Figure 1.2. The figure includes the four different strategies, categorised into 'wanted' and 'unwanted', and the developed prototypes associated with the strategies. The balance scale at the bottom aims to illustrate how there are various factors that influence whether a nurse call is wanted or unwanted.

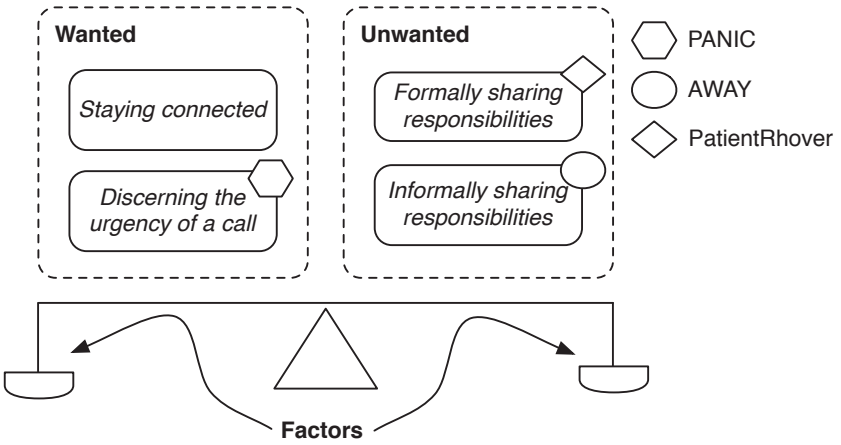

Figure 1.2: Illustration of nurses strategies to handle wanted and unwanted nurse calls, their relation to various factors, and the supporting prototypes

1.6 Overview

The thesis consists of two independent parts. Part I is structured as follows: Chapter 2 presents the background, including previous work, concepts, and relevant frameworks; Chapter 3 describes the research setting, methodology, and a description of the research activities in the various phases; Chapter 4 presents the results; and Chapter 5 discusses these in light of previous work, how they relate to the research questions, and their implications. Part II includes the research papers.

CHAPTER 2

Background

2.1 Previous nurse call studies

Florence Nightingale provided one of the earliest accounts of a nurse call system in a letter to Lady Charlotte Canning in the mid-nineteenth century. The system described in the letter allowed patients to use draw-strings attached to call bells to notify nurses about the patient's request for attention. A particular characteristic of the system is that the bells consisted of valves that were opened whenever the bell rang, identifying the patient even after he or she had stopped pulling the string (Nightingale, Vicinus, and Nergaard 1990). Although the literature within this topic is not overwhelming, there have been a number of studies of nurse call systems. Although there are variations of how the researched nurse call systems are designed, they all embody the fundamental principles of Nightingale's call bells.

2.1.1 Reasons behind nurse calls

One of the aspects that has been investigated is reasons behind nurse calls. A study found that about 30% of all calls were serious medical concerns and around 20% were secondary medical concerns. However, almost 30% were for no specific reason, 14% were non-serious, and the rest were due to room amenities (Meade, Bursell, and Ketelsen 2006). Torres (2007) identified that the most frequent nurse calls were due to positioning (48%), pain medication (18%), and toileting requests (11%). Calls for toileting assistance were also found to be most frequent by Van Handel and Krug (1994). Accidental requests and calls that could be classified as less serious constituted 15 % of all recorded nurse calls (Torres 2007). A survey focusing on nurses' perspectives on the reasons behind nurse calls by Tzeng (2010) found that toileting assistance, pain medication, and intravenous problems were most frequent.

The same study also revealed that only about half of the nurses surveyed thought nurse calls mattered to patient safety and a similar number did not think nurse calls required the attendance of someone with nursing skills. Altogether, 53 % responded that they thought nurse calls prevented them from doing more important work (Tzeng 2010, 2011b). Further, a study conducted by Miller, Deets, and Miller (2001) in a medical/surgical unit found that 75% of the calls did not require a nurse's expertise and could, therefore, be handled by less skilled personnel. In an earlier study, that figure was found to be 60% of all recorded nurse calls (Sheedy 1989), while Miller, Deets, and Miller (1997) found the number to be between 70-80% depending on the hospital studied.

2.1.2 Nurses' and patients' perceptions

The high volume of nurse calls of a non-critical nature might be one of the reasons why researchers found that nurses perceive nurse calls 'as an interruption to their work rather than a means of patient communication with unit staff' (Deitrick et al. 2006). A further contributing factor to nurses' dissatisfaction with nurse calls is that most nurse calls are reported to be initiated during busy moments, such as meal and medication times (Torres 2007; Van Handel and Krug 1994). Nurses' perspectives on nurse calls have also been highlighted in other studies. Miller, Deets, and Miller (1997) described nurses' dissatisfaction with a system, where nurse calls were dispatched to a pager of the assigned nurse, especially in situations where the nurse was not able to respond to the nurse call (e.g., when administering patient care), that could not be interrupted. Nurses reported that this 'created a sense of recurrent frustration and helplessness' (ibid.). The nurse call notification sound generated by the system was also something nurses found disturbing (ibid.). Through a qualitative approach, Kristiansen (2011) found similar results while studying a wireless nurse call system that allows nurses to receive nurse calls on their wireless phones. Although the system enhances nurses' availability, a major challenge was that nurse calls were often received during 'bad' times, e.g., during an ongoing conversation with a patient (ibid.).

Nurse calls and their impact on patient satisfaction is another aspect that has been investigated in the literature. Deitrick et al. (2006) interviewed patients and family members with regard to their experience with the nurse call system. The authors reported that patients were dissatisfied with the long waiting times, which varied between two and 20 minutes, before anyone attended to them after initiating a nurse call. Similarly, patients had to wait even longer for their request to be met once a nurse had visited them (ibid.). An analysis of patient satisfaction scores and nurse call response times in another study did, however, not find a correlation between the two (Roszell, Jones, and Lynn 2009).

Lasiter (2013) interviewed patients at intensive care units and found that the nurse call system was an important aspect in making them feel safe, which is important for a successful recovery (Lasiter 2011). The nurse call system provided patients with a sense of control of their situation, and they expected their call to be attended to quickly (Lasiter 2013). Similarly, a study investigating patients' perceptions of their nurse call usage found that 53% of the participants thought that most of their calls mattered to their safety (Tzeng 2011a).

2.1.3 Interventions to manage nurse calls

A few studies reported on interventions that aim to reduce the number of nurse calls. By introducing one- and two-hour nursing rounds at 14 different hospitals, Meade, Bursell, and Ketelsen (2006) found that the number of nurse calls reduced significantly. Actions taken during a nursing round were informed by previous studies on the reasons of nurse calls, which included, among others, offering toileting assistance and assessing the patient's position. Patient satisfaction improved and fall rates dropped during the two-week trial (ibid.). A similar effect with regard to a reduced use of nurse calls was also observed by Torres (2007). In their study, a two-hour nursing round was introduced in addition to a number of anticipatory strategies (e.g., offering pain medication in advance) (ibid.).

New technological interventions have also been proposed to improve nurse call handling. Miller, Deets, and Miller (1997) compared two different nurse call systems. The first system dispatches nurse calls automatically to a pager worn by the nurses. In the other system, patients make voice calls to a secretary whom, if necessary, pages a nurse about the patient's request. The authors discovered that the latter system saved time, as calls were screened, which allowed the nurse to prepare for the visit in advance. The latter system also seemed to reduce the number of interruptions to nurses' work for the same reason, as not all calls had to be forwarded to a nurse (ibid.).

Vocera is a voice communication system that provides hospital staff with wireless communication through a voice-controlled badge (Breslin, Greskovich, and Turisco 2004). The system has also been integrated with a nurse call system in which a nurse call is routed directly to the appropriate nurse's Vocera badge. The nurse can then decide to either forward the call to another nurse, initiate a voice call with the patient, or visit the patient face-to-face. A study of the Vocera-integrated nurse call system found it to reduce response times by 51% compared to a system through which patients made phone calls to a central station. This required the nurse (or a secretary) to pick up the phone and decide whether to contact a nurse about the patient's request or respond to the request (Kuruzovich et al. 2008).

Galinato et al. (2015) investigated (through a qualitative study) nurses' and patients' impressions of a nurse call system concept that allowed, except for voice communication, patients to communicate their need to the nursing staff through symbols. Nurses found the prototype easy to use and appreciated that the additional information (in the form of a symbol) could help them prioritise and anticipate patient needs. Although nurses were concerned as to whether patients would be able to use such sophisticated technology, the patients included in the study did not share the same concern (ibid.).

Further technological interventions to improve nurse call handling were suggested by a research group in Belgium that developed an ontology-based nurse call system through a user-centred design approach (Ongenae et al. 2012, 2011). The system provides patients with a wearable gadget through which nurse calls can be issued. Nurses receive nurse calls on PDAs. An ontology (developed together with domain experts) contains context information, such as staff and patient profiles, as well as patients' risk factors. The priority of a nurse call is determined by the system through these risk factors. When a nurse call is initiated, the system determines the best nurse to handle the call based on information contained in the model, which includes location of the patient and nurses, call priority, and nurses' ongoing activities. For example, the system seeks to avoid contacting a nurse that is busy with a high priority task. The system was evaluated through simulation based on log data captured from a hospital. The evaluation showed faster response times to nurse calls and a more balanced workload among nurses (Ongenae et al. 2011).

2.2 Interruptions

2.2.1 Interruptions in the healthcare domain

Interruptions are a mundane element of a staff's busy working day in a hospital environment (Alvarez and Coiera 2005; Coiera and Tombs 1998; Ebright et al. 2003; Grundgeiger and Sanderson 2009; McGillis Hall, Pedersen, and Fairley 2010; Rivera and Karsh 2010). Interruptions have been previously studied intensively within the fields of psychology and human-computer interaction, where their negative effects on human cognition and task performance have been the focus (Adamczyk and Bailey 2004; Coiera 2012; Li, Magrabi, and Coiera 2012; McFarlane and Latorella 2002; Trafton and Monk 2007). The Institute of Medicine's (IOM) report on patient safety, which pointed to interruptions as a possible reason behind medical errors (Linda T. Kohn and Molla S. Donaldson 2000), partially fueled the interest in interruptions within the healthcare domain. Although the empirical support for this claim was initially rather vague, later re-

search has strengthened the evidence for a causality between interruptions and medical errors (Prakash et al. 2014; Westbrook et al. 2010a,b). However, whether such a clear causality exists is still questioned (Grundgeiger and Sanderson 2009; Sanderson and Grundgeiger 2015).

While various interventions, such as marked quiet zones and wearing vests during medication preparation, have been proposed to reduce the number of errors induced by interruptions, their effects remain questionable (Raban and Westbrook 2013). For example, while wearing red vests did reduce the number of interruptions from patients, it did not hinder colleagues from interrupting (Tomietto et al. 2012). The same intervention has also been criticised by nurses to harm the patient-nurse relationship (Raban and Westbrook 2013; Weitz 2011). Further, a closer investigation of nurses' medication preparation procedures revealed that not all medication tasks are equally sensitive to interruptions and that nurses' interruption handling strategies in these situations depend on several factors (Colligan and Bass 2012), highlighting the significance of the context in which the interruption takes place.

2.2.2 Technology-mediated interruptions

While aiming to support a highly mobile workforce, the introduction of wireless communication devices has also further exposed healthcare workers to interruptions (Coiera and Tombs 1998; McGillis Hall, Pedersen, and Fairley 2010; Scholl et al. 2007). Scholl et al. (2007) found that wireless phones introduced more frequent and harmful interruptions than pagers and that such devices can lead to staff becoming 'over-available'. The Vocera hands-free communication device, described earlier, allows staff to initiate voice communication through a wireless badge using speech recognition. While the benefits of the system have been documented (Breslin, Greskovich, and Turisco 2004; Kuruzovich et al. 2008), there are also more critical voices directed towards the technology. Yang and Rivera (2015) compared interruptions mediated through the hands-free communication device with interruptions made face-to-face. The authors illustrated how face-to-face interruptions contain affective cues that the technology is not able to mediate, making it harder for the interrupter to discern the interruptibility of a person and for the interruptee to anticipate the importance of the message. Rivera (2014) also illustrated how nurses carefully weigh various environmental cues with their own needs before deciding to interrupt.

To handle technology-mediated interruptions, a number of strategies have been suggested in the literature. Grandhi and Jones (2010) provided an overview of different strategies incorporated into various communication technologies, including:

1. interruption prevention, e.g., blocking an incoming interruption;

2. interruption dissuasion, e.g., using status information to persuade someone not to interrupt;

3. notification modification, e.g., changing how the interrupted is notified;

4. interruption preview, e.g., providing further information about the interruption; and

5. automation of interruption management, e.g., using sensors and software to determine if the interruptee can be interrupted in the current context.

One example of a system implementing the automation of interruption management strategy is the work carried out by Solvoll (2013). A context-sensitive communication system is proposed to reduce harmful interruptions caused by communication devices in a hospital environment. The system design has been shaped through a participatory design process involving end-users. In the proposed system, health care workers carry their own mobile phones. Calls are routed through a system that decides whom to forward the call to and if the time is appropriate. The system makes the decisions based on location, availability of the callee, and predefined rules.

An interruption dissuasion approach is taken by Bardram and Hansen (2004), where the authors do not provide a system that tries to act 'intelligently'. Rather, they argue that, by distributing context clues through the use of technology, nurses and physicians can become socially aware of persons that are not in the same location. They introduce a wireless phone, which provides context information, such as location and status, about the persons listed in the phone's address book. Through extended social awareness, it is assumed that the caller selects not to interrupt in an inappropriate situation. A more thorough discussion of the notion of 'social awareness' is provided in section 2.4.

With regard to nurse call systems, few projects have looked to enhance these systems with similar interruption management functions. However, the previously described ontology-based nurse call system adopts the automation of the interruption management strategy (Ongenae et al. 2012, 2011). The Eloquence nurse call system presented by Galinato et al. (2015) (also described earlier), which allows patients to press a symbol to communicate their need, incorporates the interruption preview strategy (Grandhi and Jones 2010). Although Galinato et al. (2015) did not explicitly discuss the system's ability to support nurses' interruption management, the more nuanced nurse call message could inform a nurse's decision to respond to a request.

2.2.3 The complexity of interruptions

Much of the research on interruptions, i.e., the ones mentioned earlier, focuses merely on the negative effects of interruptions on task performance. Hence, assuming that all interruptions are bad, the target of the various interventions suggested to manage these has been generally to reduce the number of interruptions. However, there are multifaceted aspects to interruptions, which are part of the complex socio-technical healthcare system. Simply aiming to reduce these might not have the desired effect, as some interruptions are an integral part of a functional system (Rivera 2014; Rivera and Karsh 2010).

For example, when Harvey, Jarrett, and Peltekian (1994) studied the paging patterns to medical interns, they found that most of the calls made were due to medication prescriptions and that, although interruptive, two thirds of these calls resulted in new medication orders. Similarly, a qualitative study focusing on the nurse initiating the interruption rather than the one being interrupted found that interruptions allow for timely information transfer, increase the timelines of patient care, enhance problem solving abilities, and facilitate teamwork (Rivera 2014). The information provided through an interruption can also prove to be valuable for the one being interrupted (Potter et al. 2005). Further, (McGillis Hall, Pedersen, and Fairley 2010) found that 11% of all interruptions in four paediatric units at a teaching hospital during a 13-month study had a positive outcome.

These studies suggest that interruptions can also have positive effects that outweigh the potential negative effects. This is an equation carefully evaluated by nurses before deciding to interrupt (Rivera 2014). Colligan and Bass (2012) further reinforced the view that interruptions are of a complex nature by investigating nurses' interruption handling strategies during medication administration. Although interruptions during a medication administration procedure have been linked to increased medical errors (Prakash et al. 2014; Westbrook et al. 2010b), the study revealed that there are a number of factors that play a role in nurses' selection of interruption handling strategy, and that all interruptions should not (even in this context) be assumed to be 'bad'. For example, the authors wrote that the intervention to wear a red vest during the procedure assumes that all interruptions should be avoided while administering medication. However, if a patient's parent asks for help moving their child to the bathroom, the nurse willingly aborts the medication work (Colligan and Bass 2012). Therefore, a workplace design that is sensitive to these nuances is proposed (Colligan et al. 2012).

Whether it is possible to distinguish 'bad' interruptions from 'good' ones remains an open question (Grundgeiger and Sanderson 2009; Sanderson and Grundgeiger 2015). However, the studies mentioned above do hint that a clear

distinction cannot easily be made. Further, outside the healthcare domain, Harr and Kaptelinin (2007) illustrated how interruptions can cause 'ripple effects', which have implications on the social context as well. Grandhi and Jones (2010) demonstrated (through a field study) that not only the cognitive and social contexts are of importance in interruption management but also the relational context. The authors argued that instead of looking at how to reduce the impact of an interruption, focus should be directed towards how to provide useful information to the interruptee so that an informed decision can be made when handling technology-mediated interruptions. The previous section highlighted interruptions as one of the issues that nurses experience with nurse calls. Just as Sasangohar et al. (2012) concluded that not all interruptions are equal, perhaps this also holds for interruptions in the form of nurse calls. The question of how to facilitate the reception of wanted nurse calls while reducing harmful ones remains an open issue upon which socio-technical approaches could shed further light (Rivera and Karsh 2010).

2.3 Patient safety and resilience engineering

Although modern medicine rose in the 19th century, patient safety gained general acceptance as a central issue in healthcare as late as the 21st century (Wears, Sutcliffe, and Rite 2014), even though Nightingale (1863) emphasised that the hospital 'should do the sick no harm' long ago. Patient safety is defined by Charles Vincent as:

> 'the avoidance, prevention, and amelioration of adverse outcomes or injuries stemming from the process of healthcare'. (Vincent 2010)

The traditional approach to safety has, therefore, focused on how to minimise the occurrence of errors and adverse events. The system approach to safety assumes, in essence, that humans are fallible and prone to make errors, and that there is little we can do about the human condition in this respect (Reason 1995). However, contrary to the person approach, which blames individuals, the system approach seeks to improve the working conditions mainly through a system of defences (Reason 2000). This approach, also referred to as the Swiss cheese model, focuses on creating several layers of defences or safeguards, involving management processes, sharp end activities, and technologies, to prevent accidents from occurring (Reason 1990; Reason 2000).

Hence, the traditional approach to safety thinking, also known as Safety-I (Hollnagel 2014) focuses on instances where things go wrong. Through mainly a reactive effort, attempts have been made to find and eliminate the underlying cause. Again, a central assumption within this tradition is that humans are

prone to err and that, through standardisation, rules, and regulations, performance variability can be constrained and risk for error can be limited. The root of this assumption lies in the fact that systems are transparent and well understood (Hollnagel, Woods, and Leveson 2006; Hollnagel 2014).

A complementary and emerging perspective on safety known as resilience engineering, or Safety-II (Hollnagel 2014), acknowledges that our socio-technical systems are becoming increasingly complex, where advanced information and communication technology is tightly intertwined with sophisticated problem-solving work practices. It is argued that, to better deal with the complexity, focus should be directed towards things that go right instead of things that go wrong. Peoples' ability to adapt and adjust their work under varying conditions is at the core of what constitutes a resilient system. To ensure a high number of acceptable outcomes, one should aim to understand everyday work and how adjustments are made proactively to prevent errors from happening (Hollnagel, Woods, and Leveson 2006; Hollnagel 2014; Hollnagel, Braithwaite, and Wears 2013). Hence, through a Safety-II approach, safety is increased by improving the things that go right, which will also reduce the things that go wrong. In improving safety, the focus is, therefore, to study ordinary work, or the performance variability that results in successful outcomes rather than failures (Pariès, Wreathall, and Woods 2012). The resilience engineering approach, therefore, subverts the traditional definition of safety from 'avoiding that something goes wrong' to 'ensuring that everything goes right' (Hollnagel, Braithwaite, and Wears 2013). In this context, resilience is defined as:

> 'the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances so that it can sustain required operations under both expected and unexpected conditions'. (Pariès, Wreathall, and Woods 2012)

Four factors have been identified as central in the system's effort to achieve resilience or adjust its functioning, i.e., responding, monitoring, anticipating, and learning. Responding involves knowing what to do under changing circumstances, which can include adjusting to both regular and irregular disruptions. Monitoring involves knowing what to look for and discerning what can become a near-future threat. Anticipating involves knowing what to expect in a more distant future in terms of changes or disruptions. Learning involves knowing what has happened and building off of experience. For this thesis, the ability to respond is relevant, as the analysis explicitly explores nurses' responses to interruptions in the form of nurse calls. Responding proactively to a situation also involves anticipating what is about to happen, assessing the situation, and executing the appropriate actions (Hollnagel 2009).

2.4 Collaboration and computers: the awareness concept

Computer-supported cooperative work (CSCW) is an interdisciplinary research field defined by Bannon and Schmidt (1991) as 'an endeavor to understand the nature and characteristics of cooperative work with the objective of designing adequate computer-based technologies'. Hence, the authors stated that, 'the focus is to *understand*, so as to *better support*, cooperative work' (ibid.). Computer-supported cooperative work emerged in the late 80s from the two fading research programmes: computer mediated communication and office automation (Schmidt 2009). An important influence was the ethnographical studies of how office work was actually carried out (Blomberg and Karasti 2013; Suchman 1987). The preceding office automation effort aimed to regulate and model procedures and workflows in typical office work in a technological deterministic fashion, which appeared to be more difficult than presumed (Schmidt 2009). Hence, research on computer-supported cooperative work is not technology-driven but begins with a thorough examination of the workplace (Bannon and Schmidt 1991).

One of the core dimensions to cooperative work that has emerged from computer supported cooperative work studies is the concept of awareness. In cooperative work, awareness has been found to be a key component in achieving effective coordination and collaboration (Gross 2013). An early definition of awareness is 'an understanding of the activities of others, which provides a context for your own activity' (Dourish and Bellotti 1992). Although the topic is complex and the research has taken various paths, Schmidt (2002) stated that the concept was initially conceived through ethnographic studies of cooperating actors in centres of coordination (Suchman 1997). In particular, work carried out at the London Underground control room (Heath and Luff 1992), and within air traffic control (Harper, Hughes, and Shapiro 1989), were instrumental in forming our understanding of awareness in these contexts. These studies highlighted the fine-tuned social interactions that take place almost unconsciously between collaborating partners to achieve a mutual understanding of activities as a basis for coordinating cooperative work. Central to achieving and maintaining awareness is the practice of *displaying* one's own actions and *monitoring* others' actions (Schmidt 2002).

The study of the London Underground's control room illustrated how the Divisional Information Assistant (DIA) monitors his colleague's action by passively listening when the controller calls the train driver to request a longer stop at a platform to even the intervals between the trains. The DIA, who was responsible for making public announcements to passengers about train delays, etc., then went on to announce the delay without that information being explic-

itly exchanged between the two actors (Heath and Luff 1992). Another example from the London editorial office of Reuters demonstrated how a journalist made a joke about his story in progress as to render it selectively available to colleagues for whom the story might have been relevant (Heath et al. 2002).

In this regard, 'awareness is an integrated part of practice' (Schmidt 2002) that 'arises in and through social action and activity' (Heath et al. 2002). A particular characteristic of participants' monitoring and displaying practice is that its obtrusiveness is carefully adjusted according to the situation, referred to as 'appropriate obtrusiveness' (Schmidt 2002). Similarly, the coordinative practice is carried out in an effortless and seamless manner concurrently with other activities (Gross 2013; Schmidt 2002).

Due to the wide diversity of awareness research that exists and because the notion of 'awareness', itself, is rather ambiguous, it needs to be understood as an awareness of something (Schmidt 2002). Bardram and Hansen (2004, 2010) used the term 'social awareness' to describe the previously discussed monitoring and displaying practice. Bardram also noted that, while social awareness is directly maintained through verbal and visual cues from person to person when cooperating actors are co-located, this is not possible when co-workers are spatially and temporally distributed (Bardram and Hansen 2010), which is often the case in a hospital setting (Bardram and Bossen 2005). In this setting, the authors argued, social awareness is instead mediated through social artefacts such as whiteboards (Wears et al. 2006). Further, people draw upon context cues in the environment, e.g., an empty office desk indicates that the person is not at work, to maintain social awareness (Bardram and Hansen 2004). Bardram presented an approach that aimed to allow healthcare workers in a hospital to maintain a social awareness even while not co-located through computer support. A part of this work introduced the AwarePhone, which provides context cues about colleagues listed in the contact list. The cues include personal status, activity, and location. The status can be set by the user, while the activity is fetched from a calendar. The location is automatically inferred through an indoor positioning system (ibid.). Discussed in section 2.2.2, an aim with the technology is to support 'distributed appropriate obtrusiveness' by allowing users to monitor and display their status and, thereby, not choosing to interrupt, for example, by making a voice call when not appropriate (ibid.).

2.5 Technology and society

2.5.1 Technological determinism

Societies and cultures tend to change and evolve over time, and scholars have tried to identify the underlying factors that cause these changes. A particular view holds that technological innovations are the main drivers that form society, including its structures and cultural values (Sismondo 2009). As expressed by Karl Marx, 'the hand-mill gives you society with the feudal lord; the steam-mill society with the industrial capitalist' (Marx 1935). This theory is often referred to as technological determinism, a term believed to be coined by the Norwegian-American sociologist and economist Thorstein Veblen in the late 19th century. A well-known example of scholarly work that supports the view of technological determinism is the work of Alvin Toffler, presented in his book, The Third Wave (Toffler 1980). Toffler argued that human history can be divided into three main 'waves' of technological innovations that dramatically impacted our society. The first substantial innovation was agriculture, which moved us from being hunter-gatherer nomads to farmers that stayed in one place. The industrialisation accounted for the second wave, in which technological innovations such as the steam engine and the ability to exploit electricity were revolutionary. Centralisation, which involved people moving into cities and fast economic growth, was also a key trademark of these societies. Finally, the third wave was the information society, in which we now live in, driven by computer technology that, for example, decentralises society and changes work practices and communication (ibid.).

Ogburn (1947) wrote that 'technology changes society by changing our environment to which we, in turn, adapt', and provided a number of examples where technology had social effects. For example, there is a clear correlation between the invention of the automobile and the development of suburbs. Although there are various strands within the technological determinism camp, at the extreme end of the spectrum, technology is described as an agency or force that is more or less unstoppable (Wyatt 2008). A prime example would be Moore's law (Moore 1965). Our role in shaping the society is then merely reduced to adapting to the technological force. Hence, 'resistance is futile', as uttered by the Borg before 'assimilating' their victims in the Star Trek series.

2.5.2 Social constructivism

Technological determinism has been criticised on a number of points. One problem is that it does not account for social factors in the development and use of technology. Further, if technology is an irresistible force that we cannot do

much about, it implies that humans do not have the free will to choose otherwise, which absolves us from any kind of responsibility (Wyatt 2008). Within science and technological studies (STS), technological determinism has been to a large degree dismissed in favour of social constructivism, which challenges the assumption that technologies, themselves, have any intrinsic features and, therefore, cannot affect social structures (Sismondo 2009). Rather, the case has been made for a social shaping of technology, where the features of technology are tightly intertwined with social processes. Pinch and Bijker (1984), who developed the social construction of technology (SCOT) approach, illustrated how the development of the 'ordinary' bicycle, which had a large front wheel and a small back wheel, to the 'safety bike', a design adopted by modern bikes, did not follow a straightforward path where the superior design was simply triumphed. Instead, there were different social groups (women cyclists, elderly men, sport cyclists, etc.) connected to the bicycle, each with their own problems, and suggested design solutions; the solutions to one group's issues were not appreciated by another group (ibid.). Rather, 'the success of an artefact depends upon the strength and size of the group that takes it up and promotes it' (Sismondo 2009). A central aspect stemming from the social construction of technology approach is the notion of 'interpretive flexibility', which states that technology's meaning and use can be interpreted in various ways among different social groups. Further, the notion incorporates the idea that technology can be designed in a number of ways and that there is not 'one way of best designing an artefact' (Pinch and Bijker 1984).

2.5.3 The affordances of technology

Although there are a plethora of social constructivist views, of which some to various degrees acknowledge technology's participation in the interaction with society [1], the logical conclusion of the constructivist position outlined by Grint and Woolgar (1997) was questioned by Hutchby (2001). In essence, Hutchby analysed that an anti-essentialist position was being portrayed, where technology is merely a *tabula rasa* that can adhere itself to (more or less) any interpretation. He asked the question, 'does the aeroplane lend itself to the same set of possible interpretations as the bridge; and, if not, why?' (ibid.). Rather, Hutchby suggested that technologies should be seen as possessing different *affordances* that constrain how they can be interpreted as a middle ground between social constructivism and technological determinism.

The notion of affordances was initially formulated by Gibson (1979), who wrote that 'the affordances of the environment are what it offers the animal, what

[1] For example, the actor-network theory involves both technical and non-technical actors as units of analysis (Callon 1986).

it provides or furnishes, either for good or ill'. As an example, Gibson discussed how a horizontal, rigid surface affords support for a terrestrial animal, making it 'walk-on-able' (Gibson 1979). In particular, Hutchby (2001) emphasised four aspects of affordances to highlight its relevance to our understanding of technology and society. First, Hutchby noted, there are many types of affordances, including affordances of the natural environment, artefacts, other species, and other members of our own specie. Secondly, affordances have a relational aspect in that an object affords different things for different species. For example, water does not afford support for heavier animals, which is the case for, e.g., water bugs. Hence, what capacities an object affords might not have to be immediately perceived. Thirdly, the affordances of objects are also sometimes intertwined with complex social expectations or rules guiding their use. For example, a child has to learn that one should not open the camera door and expose the film to light in order to avoid the photos being destroyed. Finally, affordances can be designed into artefacts so that their use is easily perceived by the users (a property referred to as perceived affordance) (Norman 2002). As an analytical tool, the concept of affordance encourages one to be observant to how an artefact allows certain interpretations while, at the same time, restricting others (Hutchby 2001).

2.6 Concluding remarks

Previous studies of nurse calls revealed that these are a source of interruptions and disturbances to nursing work, as not all needs called for are of an urgent nature or even require the skills of a nurse to be met. In line with the interruption research tradition originating from psychology, most work has looked at interventions aimed to reduce nurse calls. Despite the importance of restricting harmful interruptions in certain contexts, one should not disregard the argument that the phenomenon of interruptions is a part of a larger system and that it is not straightforward to discern whether an interruption has a negative or positive outcome. For example, in the case of nurse calls, the majority of patients' calls are, indeed, important. Hence, there is a lack of research that investigates interruptions in the form of nurse calls from a perspective that assumes the possibility that these can have both positive and negative effects. In particular, what interruption management strategies do nurses employ to handle nurse calls, and what factors play a role in the strategy selection?

In aiming to design technology that supports nurses' handling of nurse calls, influences have been drawn from the theoretical frameworks presented in this chapter. The dual perspective on interruptions, the notion of awareness, the affordance concept, and the resilience engineering perspective all emphasise the significance of studying the phenomena in context. Instead of developing solu-

tions in a technological deterministic fashion, the work of this thesis aims to first understand work practices through a qualitative approach. By studying the ways through which nurses deal with nurse calls and utilising the presented frameworks as analytical vehicles, the aim is to better support the means of working through novel technology. In particular, the adopted approach includes developing prototype systems based on a sound understanding of the context of work done and inviting end-users to co-design and evaluate these systems.

CHAPTER 3

Research design

3.1 Research context

The starting point for this project was a study (Kristiansen 2011) of a recent (at the time) implementation of a wireless nurse call system at a Norwegian university hospital. As a part of a major rebuilding, the hospital had invested in a new communication infrastructure that also included a new wireless nurse call system. A nurse call system already existed in the different hospital departments that consisted of fixed artefacts, such as draw-strings to issue nurse calls and public displays mounted throughout a department on which active nurse calls are displayed. In the implementation process, the wireless nurse call system was integrated with the existing, fixed, nurse call system. The wireless nurse call system introduced wireless phones that nurses are supposed to carry around, on which nurse calls are delivered, in addition to the fixed displays. Nurses are able to configure a call plan, where the patients are assigned a primary and secondary nurse. Nurse calls are then routed, according to the call plan, to the primary nurse's wireless phone. If the primary nurse is not able to answer, the nurse call is forwarded to the next nurse in the call plan.

Most departments in the hospital are divided into smaller units called bed areas, where each bed area consists of seven to nine single patient rooms and a nurse station. An instance of the described nurse call system is deployed in each bed area. Nurses are assigned to a bed area, and the call plan can be configured so that nurse calls from patients within a bed area are routed to these nurses.

3.2 Philosophical presumptions

Any scientific undertaking is shaped by the philosophical assumptions held by the scientist. In the information systems research paradigm, there are two main distinct epistemological positions: positivism and constructivism. Positivism

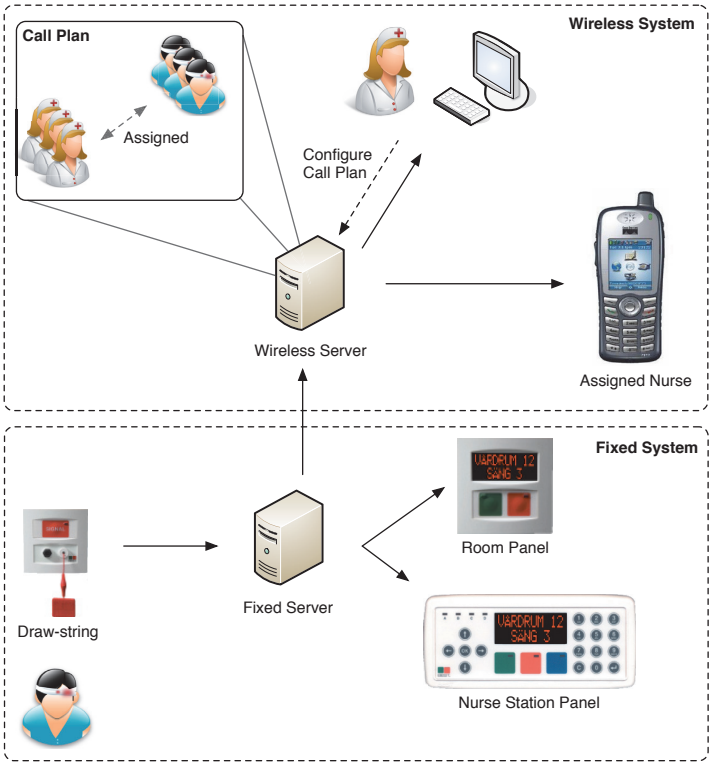

Figure 3.1: An overview of the deployed nurse call system. The patient (left lower corner) uses the drawstring to issue a nurse call. The call is then delivered to fixed displays and to the primary nurse's wireless phone (Klemets and Evjemo 2014).

dates back to the 16th century and has been the dominating position since. Although there are several definitions of positivism, some main characteristics are usually shared. Positivism assumes that all forms of science can use the same methodological approach. It also seeks to find causal relationships through the use of reductionism and implies a belief in empiricism, which states that the only valid data is that which can be observed and measured though the senses. This excludes things such as human thought and subjective experiences. Further, it states that science is value free, i.e., independent of moral or ideological beliefs, and that mathematics provides the foundation for science (Hirschheim 1985).

Although science has enjoyed great success under positivism, it has been criticised, in particular, by scholars in psychology and social sciences (Robson 2002).

The positivistic approach seems to have limited success in generating general laws for these sciences and, thus, is unable to adequately deal with research involving people in a real-world context. Constructivism or interpretivism, resulting from the critique of positivism, rejects the idea of science being value free and takes the stance that human values influence the scientific process. Further, the position holds that it is not possible to develop general rules on human behaviour through the study of man by using methods of the natural sciences, as 'man is not subject to the law in the physical sense, but is free...' (Hirschheim 1985). To gain access to the meanings and values that people ascribe to things, a different methodological approach is required, i.e., a qualitative approach, which dismisses the idea of empiricism.

Constructivism has been criticised to embrace the view that no part of reality is objective but rather the product of the meanings and values that humans ascribe to it. Thus, if reality only exists in our minds as a perception, 'we can redefine the world in any way we choose' (Murphy et al. 1998). Hutchby (2001) offered a similar critique of social constructivism in developing the concept of affordances (section 2.5.3). The ontological position that reality is subjectively constructed presents a problem in scientific inquiry, as there is no way to disclose legitimacy among different accounts (Andrews 2012). Further, it can be argued that this is not how the world is usually perceived (Robson 2002).

Andrews (2012), however, argued that critics confuse claims about epistemology and ontology. In essence, constructivism is (first and foremost) an epistemological position that does not infer any particular ontological view. For example, Andrews (ibid.) argued that, although our understanding and naming of a particular disease is socially constructed, it might very well exist outside of language.

This work largely adopts a constructivist view on epistemology. The implications are that the study focuses on unveiling shared values and ascribed meanings within the context of nurse call handling through a qualitative approach. At the same time, it also implies that the researcher needs to be sensitive and reflective about his or her own preconceptions and theoretical preferences. However, the adopted ontological position leans more towards realism rather than relativism. In particular, how technological artefacts are designed is assumed to affect their interpretation (or social construction), which is in line with the concept of affordances (section 2.5.3).

3.3 A design science endeavour

Natural, social, and other traditional sciences' main concern is with how things are. The facilities provided by these sciences allow researchers to study the mechanisms and structures behind a phenomenon, i.e., natural or social, to produce

theories that describe, explain, and predict. In his influential work, Simon (1996) questioned the ability of traditional sciences to bring about knowledge of things that do not yet exist. He, therefore, called for a new science, i.e., the 'science of design', that provided the proper tools to investigate how to design artefacts with desired properties. This new science is motivated by the fact that most things around us are artificial, or designed, rather than natural (Dresch, Pacheco, and Antunes 2014; Simon 1996). Other criticism of traditional science, which has sparked interest in what is often referred to as design science, is the gap that sometimes exists between theory and practice, i.e., solely understanding a problem is not always sufficient to solve it (Dresch, Pacheco, and Antunes 2014).

Arising from the arguments put forward by Herbert Simon, design science has evolved into an important research paradigm within information system research, complementary to the behavioural science paradigm stemming from the natural science methodology (Hevner et al. 2004). It focuses on the design of artefacts to solve problems and generates knowledge about the designed artefacts, their use, and context of use (Johannesson and Perjons 2014). Wieringa (2014) wrote that 'design science is the investigation of artefacts in context' and that artefacts are 'designed to interact with a problem context in order to improve something in that context'. Artefacts include novel constructs, models, methods, and instantiations (Hevner et al. 2004; Johannesson and Perjons 2014). In contrast to other information system research approaches, design science generates a distinct type of theory that states 'how to do something'. The 'theory for design and action' produced by design science is closely interrelated with the 'theory for explaining and predicting' in that the latter can be used to inform the design of an artefact and provide the means to investigate the impact of an artefact on, for example, an organisation or society (Gregor 2006).

This project adopts a design science approach, and some outcomes of the work are artefacts in the form of new system functionality designs that aim to solve issues experienced by nurses in handling nurse calls. Iivari (2015) discussed two different strategies for conducting design science research. The first strategy proceeds from a general problem with a vague link to a specific problem in practice, as this strategy does not have to include a client. The starting point for the second strategy is an existing problem experienced in practice by a client that the researcher aimed to solve through the means of novel artefact design. While the outcome of the first strategy is generalisable due to its general problem statement, the outcome of the second strategy, which is heavily linked to a certain context, needs to demonstrate how it can be generalised to other contexts. By looking at a particular system instance, i.e., the nurse call system at a particular hospital, this project adheres to the second strategy, which is not as common in design science research as the first strategy but leads to a contribution that is highly relevant for practice (ibid.).

There are a number of frameworks and guidelines proposed in literature on how to carry out design science research (Fischer and Gregor 2011). For example, the seven guidelines by Hevner et al. (2004), the design science research process advocated by Peffers et al. (2006), or the framework by Wieringa (2014), which relies upon the framework of Hevner et al. (2004) with some modifications. All of these suggested ways of approaching a design science endeavour in a rigorous and relevant manner suggest an iterative approach, which includes the core activities: problem identification, solution design, and evaluation (Offermann et al. 2009).

3.4 A method framework for design science research

Johannesson and Perjons (2014) presented a method framework inspired by Peffers et al. (2006) that includes both activities and guidelines for how to undertake a design science research project. The method framework is used here to illustrate how the activities undertaken in this project map to such a process, as seen in Figure 3.2. The figure depicts the different design research activities, dividing them into three main project phases, and shows which strategies are employed in each phase. Although the figure seems to present a sequential process, this is not the case. Rather, the project adopts an iterative process, which is also supported by the framework (Johannesson and Perjons 2014). The following activities are included in the method framework:

Explicate problem The initial activity aims to gain a good understanding of the problem within the situated context. In particular, the activity aims to answer the question, 'what is the problem experienced by some stakeholders of a practice, and why is it important' (ibid.). The problem is clearly formulated, and its importance beyond the local practice should be justified.

Define requirements The requirements outline a solution to the explicated problem that informs the design and development of an artefact.

Design and develop artefacts Based on the outlined requirements, an artefact is designed and developed in the third activity. A number of approaches exist to accomplish the activity, e.g., creative thinking. One particular approach to development adopted in this thesis is the SPACE engineering method (Kraemer 2008).

Demonstrate artefact This activity aims to demonstrate how the developed artefact could solve the experienced problem. e.g., applying the artefact to a use case. The demonstration helps in communicating how the concept works.

Evaluate artefact While the goal of the previous activity was to show how the artefact could solve a problem, the purpose of the evaluation activity is to show how well it solves the problems and why. Two distinct evaluation strategies are *ex ante evaluation* and *post ante evluation*, where the former is performed before the artefact is fully developed to further inform the design. Ex post evaluations are usually carried out with a fully developed artefact with real users (Johannesson and Perjons 2014).

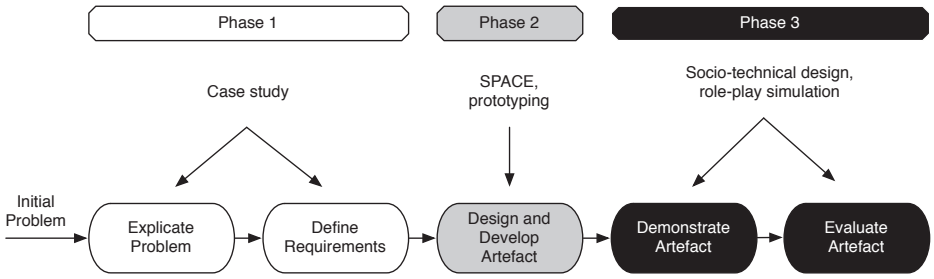

Figure 3.2: Selected research strategies and phases mapped to the design science research process proposed by Johannesson and Perjons (2014)

3.5 Research strategies

A number of research strategies and data collection methods can be used in each activity in the method framework to reach its goal. Johannesson and Perjons (ibid.) defined research strategy as 'an overall plan for conducting a research study' and distinguished research strategies from research methods as describing how to collect and analyse data at a more technically detailed level. The research undertaken adopts different research strategies in order to answer the research questions, including case study, role-play simulation, and socio-technical system design methods.

3.5.1 Case study

A case study aims to generate in-depth information about a particular phenomenon in a certain context. Distinctive for the strategy is its focus on a case, e.g., a situation, individual, group, or organization (Robson 2002). Case studies are appropriate when aiming to find answers to how and why questions or when the

examined phenomenon cannot be easily detached from contextual conditions. Hence, the study is carried out in a real-world setting in which all complexity of reality is present, e.g., organisational and social structures, as well as personal relationships that may influence the phenomenon under study. Due to its tendency to become immersed in details, a case study is often limited to a single instance, although multiple-case designs are possible (Yin 2003). A case study can either be explorative, in which the aim is to generate research questions or hypotheses, or descriptive. A descriptive case study aims to bring about a detailed description of the phenomena under scrutiny and the context in which it occurs. Usually, a case study utilises several data collection methods, e.g., document studies, interviews, and observations (Johannesson and Perjons 2014; Yin 2003). Case studies have also been used in information systems research, i.e., the use of an information system (Oates 2006).

3.5.2 Role-play simulation

Unlike case studies, a role-play simulation study takes place in an environment that aims to replicate the real world. Such an approach allows for more control and focus, similar to a laboratory experiment, while retaining some of the characteristics of a real-world setting (Johannesson and Perjons 2014). In this approach, scenarios are prepared in which participants take on various roles, performing tasks related to the investigated phenomena (Svanaes and Seland 2004). As an approach to usability testing, role-play simulation has been advocated in the design and evaluation of mobile ICT systems for hospitals due to the environment's complex working arrangements, as usability evaluations in the field are not always feasible due to safety reasons or security concerns. The approach has been found to help uncover important usability aspects, including ergonomic, social, and contextual aspects, in addition to graphical user interface issues usually focused on in traditional usability approaches (Svanaes, Alsos, and Dahl 2010).

3.5.3 Socio-technical system design

Several system design approaches have been influential in the design and evaluation of the technology presented in this thesis. Some of the methods originate from different research communities and can, perhaps, be best classified as socio-technical system design methods (Baxter and Sommerville 2011). According to Baxter and Sommerville (ibid.), socio-technical systems design methods are 'an approach to design that consider human, social, and organisational factors, as well as technical factors in the design of organisational systems'. The main rationale in embracing such methods is that they are considered to produce solutions

that are more sensitive to the context in which the developed system will be deployed and more likely to be accepted by end users.

Participatory design

The participatory design approach originated out of the industrial democratisation in Scandinavia during the 60s and 70s as a political argument that people should be able to influence their working conditions. Through early pilot projects, this developed into a method allowing end users to participate and influence the shaping of computer systems developed for their workplace. A fundamental aspect of participatory design is that the craftsman's expertise in his own field is imperative when designing new tools. This is a view also referred to as the tool perspective (Ehn 1992). During participatory design workshops involving different stakeholders, 'mutual learning' is emphasised, which is another cornerstone of participatory design (Kensing and Greenbaum 2012).

User-centered design

User-centred design shares many of the characteristics of participatory design in that it emphasises the importance of recognising the human's role in the sociotechnical system. Ritter, Baxter, and Churchill (2014) described that 'being user-centred means considering human characteristics and capabilities during system design'. In particular, the approach seeks to understand how and why people do what they do and predict when people are likely to do things (ibid.). A central distinction of participatory design is, perhaps, that 'user-centred design does not mean asking users what they want and then giving it to them' (Endsley 2011). Rather, it is the designer who is ultimately in charge of making design choices. The International Organization for Standardization (ISO 9421-210) suggests an iterative model for conducting user-centred design, which includes the steps: 'understand and specify the context of use', 'specify user requirements', 'produce design solutions to meet user requirements', and 'evaluate designs against requirements' (ISO 2010).

Scenario-based design

Scenario-based design is another approach that encourages the involvement of users in the system design process. In this method, scenarios play a central role. Scenarios can be described as 'stories about people and their activities' (Carroll 1999). Through the stories, users envision the future use of a system in various situations. Scenario-based design has also proved its usefulness in the design of collaborative systems, where the approach is proposed to bridge the gap between system design and understanding the work context (Bardram 2000; Haynes et al.

2009). The scenario-based approach to design not only provides a platform for understanding how new technology could support certain aspects of work but also identifies possible issues with the changes that a system could bring about and what effect it could have on the context in which it is to be deployed (Bødker 2000).

3.5.4 Data collection

Observations

During an observation, the researcher directly observes a phenomenon in its natural setting. In particular, the approach allows the researcher to observe what people actually do, as such observations allow researchers to study complex phenomena without reducing possible influencing factors. This is fundamental in organisational studies aiming to understand actual work practices (Tjora 2010) and, therefore, also a central data collection method used in computer supported cooperative work (Randall, Harper, and Rouncefield 2007).

Gold (1958) distinguished four different observation approaches, including complete participant, participant-as-observer, observer-as-participant, and complete observer. The first three are also referred to as participant observation (Robson 2002). In this type of observation, the researcher gets involved (to various degrees) with the social world of the observed group. To do so, the researcher needs to take on a role in the group being observed. Immersing oneself into the subjects' social world helps to interpret and understand the meanings that participants attach to various phenomena and their individual experiences. One way of conducting participant observation is participant-as-observer, where the researcher is known to the group as an observer. Hence, the researcher is able to connect with the group members and ask questions to clarify observed events. This mode of participant observation differs from complete participant, where the researcher's intent to observe is concealed and the researcher acts as a complete group member (ibid.).

Interviews

Interviews are useful when aiming to study opinions and attitudes or to get an insight into the experiences and emotions of the subjects (Tjora 2010), i.e., to understand how the world is perceived from the subject's perspective. In case studies, interviews often complement observations in order to get a more in-depth insight on how and why subjects think and act in a certain way. Interviews can either be structured, semi-structured, or unstructured. Semi-structured or unstructured interviews are usually associated with case studies and qualitative designs, while structured interviews are more related to survey studies (Yin 2003).

A semi-structured interview allows participants to more freely elaborate and discuss things that they feel are of importance, although a central theme and key questions guide the interview (Robson 2002).

Focus groups are a form of interview that usually takes place in a group, which can also be either structured, semi-structured, or unstructured. A distinctive feature of focus group interviews is the focus on a certain topic while the researcher guides the discussion. Focus groups provide advantages over ordinary interviews, e.g., a large amount of data can be collected at once, and group dynamics can help participants express their viewpoints. However, some participants might be reluctant to convey their views in front of others, and others might dominate the discussion (ibid.).

Document study

Document study is an unobtrusive data collection method where no subject is involved. Rather, data collection is comprised of the use of documents related to the object of study as qualitative data. Documents are often used to acquire background information about a case before utilising other data collection methods, such as interviews or observations (Tjora 2010). Documents can include, for example, letters, written reports, administrative documents, or newspaper clippings. In case studies, documents are also used to further support evidence from other sources (Yin 2003). However, Yin (ibid.) stressed that, in case studies, one should not rely on documents as the main source of data or assume that documents contain the complete truth.

3.6 Research phases

Due to the similarities in some of the activities in the design science research process, it is difficult to distinguish what category a performed activity belongs to. To utilise available resources as efficient as possible, several activities were carried out during the same data collection. For example, interviews with nurses were carried out to gain a better understanding of the context and current practices and elicit system requirements that could support these practices. Therefore, some activities included in the process model have been more broadly divided into three phases, as illustrated in Figure 3.2. The first phase constitutes the activities 'explicate problem' and 'define requirements', while system development took place during the second phase. The third phase includes the activities 'demonstrate artefact' and 'evaluate artefact'. The selection of research strategies and methods in each stage is further described below. Figure 3.3 provides a temporal perspective on when the different phases were executed.

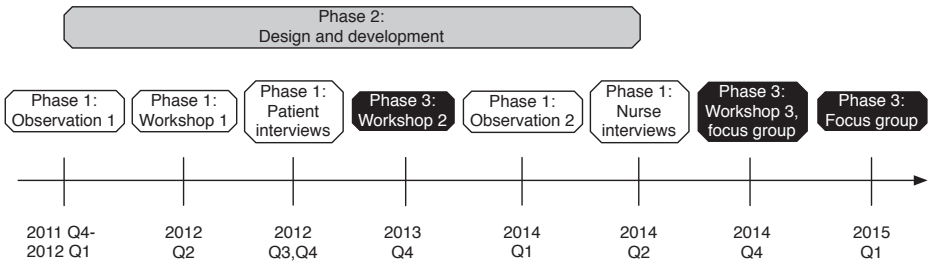

Figure 3.3: Data collection activities from different phases proceeded in a non-sequential way.

3.6.1 Phase 1

The first research phase aimed to make the problem concrete by thoroughly investigating the issues related to nurse call handling. Further, through an analysis of the collected data, requirements for various solutions to address the identified problems were defined. The selected research strategies for this phase included both case study and role-play simulation. In the early stages of the research phase, the case study could be classified as an exploratory case study, in which the aim was to get a general understanding of the research context and come up with relevant and interesting research questions. As the research progressed and a decision was made to explicitly focus on identifying nurses' strategies to handle nurse calls, the study formed into a more descriptive case study. Hence, the focus was to provide an elaborated description of how nurses experience and tackle interruptions in the form of nurse calls in order to design new technology that could ease their struggle. An overview of the data collection periods is presented in Table 3.1

Initially, to acquire an understanding of the deployed nurse call system at the hospital and how it was supposed to operate prior to doing observations, documents, including system manuals and system requirement specifications, were studied. Afterwards, as a part of the explorative phase, observations were carried out in different hospital departments with the intention to gain an initial insight into nurses' work practices and their interaction with the nurse call system. For this purpose, a total of 22 observation hours were conducted over several days in late 2011 and early 2012. The approach can be classified as participant observation, as the hospital staff were aware of the researcher's presence and intentions. The researcher did not participate in the activities carried out by the staff but interacted occasionally to clarify observed events with the personnel.

Table 3.1: Data collection periods conducted in the first research phase

Approach	Participants	Period
Participant as observer	Four hospital departments	Several days in late 2011 and early 2012. 22 hours in total.
Role-playing workshop with focus group	21 ordinary and student nurses from the infection, thorax, geriatric, and orthopaedic departments	4 workshops in early 2012.
Semi-structured interviews	Eight patients admitted at the hospital	Late 2012.
Participant as observer	Infection, thorax, and orthopaedic departments	Observations carried out at 18 different occasions in early 2014. 33 hours in total.
Semi-structured interviews	9 ordinary and head nurses from the infection, thorax, and orthopaedic departments	Spring 2014

Based on the initial observation study, a workshop was designed to gain a further understanding of the interruptions that the wireless nurse call system caused. The workshop began with a focus group interview, in which participants were asked more general questions about their use of the system and working practices related to nurse call handling. Afterwards, a role-play session was held, where participants got to act out the various scenarios in which they were interrupted by a nurse call. The workshop took place in an empty bed area within the hospital, which allowed us to use the nurse call system deployed at the hospital in the role-play. The scenarios reflected situations that had been previously observed, in which nurses received a nurse call while doing something else, e.g., talking to a patient or taking a blood sample. Afterwards, a focus group discussion was held where nurses got to reflect on how and why they handled a certain situation in a particular way and how it could be done otherwise. In total, 21

regular and student nurses from the infection, thorax, geriatric, and orthopaedic departments participated in four workshops held in early 2012.

To complement nurses' perspectives of the nurse call system, eight interviews were held with patients admitted to the hospital in late 2012. During the semi-structured interviews, patients were allowed to reflect on their experiences with the system. In particular, the study aimed to understand how interruptions in the form of nurse calls are perceived by the patient, i.e., when a nurse is visiting the patient and receives a nurse call. Further, what the patients consider before issuing a nurse call and whether it could be done in any other way were also explored.

After analysing the previously collected data material, a second observation study took place at three different hospital departments in early 2014. Eighteen observations were made that lasted 33 hours in total. The approach was similar to the earlier observation study, i.e., participant observation, but with a more targeted focus. The purpose was to identify strategies adopted by nurses in their handling of nurse calls. The study could be classified as both explorative and descriptive, in which the aim was to provide a description of the strategies nurses utilised. The observations were explorative in the sense that the observations were sensitive to discovering previously unknown strategies.

Data collected through these observations was complemented with semi structured interviews of nurses working in the same departments in which the observations took place. Interviews were held with nine nurses, including both ordinary and head nurses, from the three departments. Each interview lasted for about 30 minutes and aimed to clarify nurses' rationale behind certain previously observed strategies and behaviours. Hence, the interviews facilitated the collection of in-depth insight about the various previously observed events related to nurses' strategies in handling nurse calls.

3.6.2 Phase 2

The second phase, which (to a certain extent) runs parallel to the other two phases (Figure 3.3), is mainly concerned with the design and development of artefacts. Three different prototypes (Table 3.2), which were developed based on the requirements acquired in the first phase, are presented. These have been named *PatientRhover*, *AWAY*, and *PANIC* in this thesis for reading purposes. However, the same naming scheme is not apparent in the research papers presenting the prototypes. Initially, the ambition was to build a prototype system that would be deployed and used in real practice. Through the use of an engineering approach referred to as SPACE, work was undertaken early on in the project to build a similar but modifiable solution found at the hospital based on the Android platform.

SPACE (SPecification by Activities, Collaboration, and External state machines) is a Model-Driven Architecture (MDA) (OMG 2003) influenced methodology that focuses on building reactive systems (Kraemer 2008; Kraemer, Bræk, and Herrmann 2009). The name, to some degree, entails, that the method uses UML Collaboration and Activity diagrams to specify a system. Collaboration diagrams are used to model the structural aspects of a system, while the system behaviour is captured in an extended UML activity diagram. An activity that can be composed of other activities is referred to as a building block. The external behaviour of a building block is described by something called an External State Machine (ESM). As illustrated in Figure 3.4, the buildings blocks, which encapsulate some functionality or service, can be reused and composed into a system using the Arctis [1] tool. The same tool provides facilities to transform the specification into state machines that can be used to generate executable code. The Arctis tool, which is provided in the form of an add-on to the popular Eclipse IDE, also performs model-checking to ensure that the specified system fulfils certain properties.

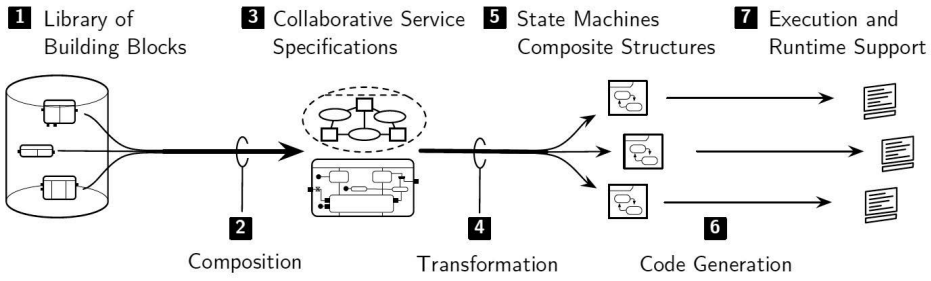

Figure 3.4: The SPACE engineering approach (adapted from (Kraemer 2008))

Even if the enterprise of deploying the developed nurse call system in real practice never materialised, one of the distinct features of the working prototype was eventually evaluated in a role-play simulation study. Hence, the PatientRhover system is implemented on a fully functional nurse call system running on Android devices engineered using the SPACE approach. The prototype implements a functionality that allows nurses to hand over their patient responsibilities to a colleague during a working shift.

Although there was early optimism in the project, the goal of system development in this research changed after realising that building a complete system that

[1] The tool has recently been commercialised and now goes under the name Reactive Blocks SDK (www.bitreactive.com).

passes the rigid quality assurance validations required by the health care domain was not a viable option. Rather, the research is concerned with building proof-of-concept systems, or prototypes, that illustrate the viability of a design. Prototyping, itself, can be classified as a system engineering method used to quickly obtain a working artefact that generates a new understanding. The prototype is then refined thorough a number of analysis, design, and implementation cycles (Oates 2006).

As the aim to evaluate new system functionalities in a real setting was abandoned, it was regarded as not necessary to implement a fully functional prototype to meet the research objectives. Hence, in the development of AWAY and PANIC, the SPACE methodology provided too much overhead to the development process and was, therefore, not adopted. In designing the AWAY system, a tool to design interactive mobile user interfaces was used to create a prototype that could be deployed on an iPhone. Although users could interact with the user interface, communication between devices was not possible for PatientRhover. Three different PANIC prototypes were developed using a simple user interface drawing tool that did not produce interactive prototypes. Instead, the user interfaces were printed on paper and presented as such to the users.

Table 3.2: Prototypes

Prototype	Supported strategy	Fidelity	Paper
Patient-Rhover	Formally sharing responsibilities	A fully working nurse call system running on the Android platform	Paper 2
AWAY	Informally sharing responsibilities	An interactive prototype of the graphical user interface running on an iPhone	Paper 4
PANIC	Discerning the urgency of a call	Paper prototypes representing three non-interactive graphical user interfaces	Paper 5

3.6.3 Phase 3

The final two activities in the design science method framework took place in the third phase of the research, where the prototypes (Table 3.2) were demonstrated

and evaluated. For this purpose, the role-play simulation strategy and socio-technical design methods were adopted.

In Fall 2013, two workshops were arranged to evaluate the AWAY prototype. Nine female student nurses currently having their internship at the hospital were recruited for the study. The workshop began with an initial group discussion. Afterwards, participants were presented the prototype and the proposed scenarios. The scenarios were based on earlier studies of nurses' use of the wireless nurse call system in practice (see section 3.6.1). After the role-play session, discussions were held with the participants where they got to express their experiences with the prototype, propose design enhancements, and discuss the possible impact of the solution on their practice. The workshops were carried out at the NSEP usability lab (Figure 3.5), which is designed to reassemble a hospital department (for a detailed description of the lab, consult (Dahl, Alsos, and Svanæs 2010; Svanaes, Alsos, and Dahl 2010)). The lab was equipped with video and audio recording facilities, through which data was collected.

Figure 3.5: NSEP usability laboratory.

A year later, in Fall 2014, another evaluation study was set up to examine the design of the PatienRhover prototype. Initially, semi-structured interviews were held with eight nurses from seven different departments. The interviews aimed to verify the validity of the scenarios proposed to be used in a later role-play simulation phase. Further, during the interview, the nurses got to use the prototype and were encouraged to talk aloud (Jaspers 2009) during the task and share their thoughts and reflections.

As a second phase in the study, 15 student nurses conducting their internship at the hospital were recruited to a role-play workshop. During the workshop, role-play scenarios were acted out by the participants in which they used the developed prototype. A focus group interview was held after the session with all participants, allowing them to reflect on their experiences with the system.

In total, six workshops were held that all took place at the NSEP usability lab, similar to the previous workshop.

The third and final study within the last phase of the research investigated the PANIC prototypes by adopting a scenario-based design approach. This approach is commonly used in the evaluation and design of computer systems, where potential users are encouraged to envision the use of a proposed system in pre-defined scenarios (Bardram 2000; Bødker 2000; Go and Carroll 2004). Seven focus group interviews were held with 2-3 nurses participating in each interview, yielding a total of 18 nurses. The three variations of the prototype were envisioned during the session in five different scenarios. A semi-structured interview guide led the discussion.

Table 3.3: Prototypes were evaluated in the third phase

Prototype	Approach	Participants	Period
AWAY	Workshop with role-play simulation and focus group	Nine student nurses	Two workshops in Fall 2013
Patient-Rhover	Phase 1: Semi-structured interviews Phase 2: Role-play simulation and focus group	Phase 1: Eight ordinary nurses Phase 2: 15 student nurses	Eight interviews and six workshops held in Fall 2014
PANIC	Focus groups adopting scenario-based design	18 ordinary nurses	Seven focus groups in late 2014 and early 2015

3.7 Research quality

At first sight, design science could be accused of being nothing more than ordinary design, relevant only for a local practice. However, Johannesson and Perjons (2014) presented three criteria that distinguish a design science research project from a design project, including

1. applying rigorous research methods,

2. correlating generated knowledge to an existing knowledge base to ensure originality and consistency, and

3. communicating results to both the research community and professionals.

Commonly, when discussing research quality, the terms reliability, validity, and generalisability are used (Robson 2002). However, what these imply varies depending on the underlying philosophy. Quantitative studies are often influenced by a philosophy of science known as positivism. It has been argued that similar quality measures are not relevant for qualitative studies, which usually adopt an almost orthogonal philosophy (ibid.). Therefore, these need to be defined to suit the particular research tradition.

Validity is concerned with the research carried out being 'accurate, or correct or true', hence, credible (ibid.). Valid research should ensure that the answers found through the research are actually answers to the pursued research questions (Tjora 2010). Robson (2002) discussed a number of validity threats to qualitative research, including description, interpretation, theory, researcher and respondent biases, and reactivity.

Description refers to not being able to accurately portray what has been seen or heard. The threat of interpretation mainly lies in trying to impose an inappropriate framework for interpreting the data. The threat of theory, again, is not to consider alternative explanations of the studied phenomena. Further, the threat of research bias suggests that the researcher might bring his or her own preconceptions or assumptions, which could influence the selection of informants or data to be analysed. Likewise, another threat is that the informant could be biased towards the research by providing information that he/she thinks the researcher might 'want' or by withholding information. Another threat is reactivity, which suggests that the researcher's presence could influence the behaviour of those studied, e.g., the Hawthorne effect. A number of strategies have been suggested to deal with validity, including prolonged involvement, triangulation, and audit trail (ibid.). How these have been applied in the research project is further discussed in section 5.4.

Although qualitative research does not have to be as concerned with the use of standardised research instruments, which are able to produce consistent results to the same degree, as quantitative studies, the researcher needs to be thorough, honest, and careful for the results to be reliable (ibid.). In essence, *reliability* is concerned with the replicability of the research, i.e., whether the same results would be obtained if another researcher carried out the same work (Yin 2003). Tjora (2010) also stressed the importance of reporting how the researcher's position and engagement might possibly characterise the research to maintain high reliability.

A design science project that starts with a problem experienced in a local practice should contribute to a global practice and the scientific body of knowledge (Iivari 2015). *Generalisability*, sometimes also referred to as external validity (Yin 2003), is concerned with how the findings can be generalised beyond the studied case. Generalisation based on case studies differs from a survey research, which relies on statistical generalisation using a correctly selected sample. By using qualitative measures in case studies, analytical generalisation can be used to generalise the results beyond the immediate case. The approach involves situating the findings within a broader theory (ibid.).

CHAPTER 4

Results

4.1 Research publications

The results from the research carried out in the three different research phases described in section 3.6 have been published as six research papers. This chapter presents an overview of the papers and their main contributions. The paper presentations include the title, a short description, authors' contributions, and publication details. An overview of the papers, how they relate to each other, the research questions, and the research phases are illustrated in Figure 4.1.

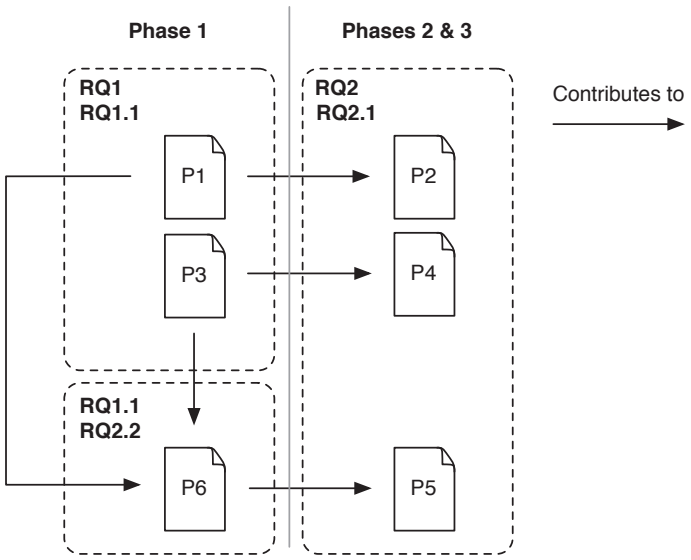

Figure 4.1: Illustration of how the different papers relate to each other, the research questions, and the research phases

4.1.1 Paper 1: Designing for redundancy

Authors: Joakim Klemets, Tor Erik Evjemo, and Lill Kristiansen

Title: Designing for redundancy: nurses' experiences with the wireless nurse call system

Published in: Proceedings of MEDINFO 2013, IOS Press

Authors' contributions: All authors were involved in the research design and data collection. The data material was analysed by Klemets and Evjemo, who also wrote the paper. Klemets wrote the methods and results sections and parts of the background and discussion. Evjemo wrote the introduction and parts of the background and discussion. Kristiansen provided feedback and comments.

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, i.e., 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 can hopefully 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.

4.1.2 Paper 2: Patient responsibility reallocation

Authors: Joakim Klemets and Katrien De Moor

Title: Patient responsibility reallocation: a user-centred approach to support nurses' handling of nurse calls

Published in: Personal and Ubiquitous Computing. 2015;19, Springer

Authors' contribution: Both authors contributed to research design, data collection, analysis, and writing.

Abstract: A central part of nurses' work at a hospital department is to respond to nurse calls issued by patients in need of assistance. In the highly dynamic work environment, where nurses need to continuously shift focus and handle interruptions, managing nurse calls presents a challenge. Previous studies of nurses' use of a wireless nurse call system deployed at a major Norwegian university hospital point to how nurses apply various strategies to handle nurse calls efficiently. These strategies involve a high degree of collaboration and coordination among nurses. By means of a user-centred approach, a system prototype has been designed. This system aims to support nurses in their continuous reallocation of patient responsibilities through the utilization of ubiquitous computing principles. Thus, we present results from the evaluation of the system prototype, for which a qualitative methodology was adopted. More concretely, we combined interviews and role-playing workshops with nurses and student nurses in order to: (1) evaluate usability- and acceptability-related aspects and (2) evaluate the feasibility of the system to be used in real practice. The results indicate that the prototype design would further reinforce an already existing practice, allowing nurses to reallocate the patient responsibility more easily. Further, the system could support and improve communication among nurses and reduce the number of unwanted interruptions. The paper concludes by describing how applying a user-centred approach in designing a pervasive computing system is vital in order to make the technology seamlessly blend in with the context of use.

4.1.3 Paper 3: Technology-mediated awareness

Authors: Joakim Klemets and Tor Erik Evjemo

Title: Technology-mediated awareness: Facilitating the handling of (un)wanted interruptions in a hospital setting

Published in: International Journal of Medical Informatics. 2015;83(9), Eslevier

Authors' contribution: Both authors contributed to research design, data collection, analysis and writing.

Abstract: *Introduction*. Nurses' work in hospital departments is highly collaborative and includes communication with a variety of actors. To further support nurses' communications, wireless phones, on which nurses receive both nurse calls and general calls, have been introduced. However, while they ensure high availability among the mobile nurses, these phones also contribute to an increased number of interruptions.
Purpose. This paper aims to discover whether all interruptions caused by the wireless phones are unwanted. Further, it investigates how nurses handle these interruptions in a hospital setting in order to construct a foundation for guidelines to use in designing these types of systems. *Methods*. Qualitative and ethnographically inspired fieldwork, including workshops with both ordinary and student nurses from a Norwegian hospital, was undertaken. Patients from two hospital departments were interviewed.
Results. Nurses struggle to handle interruptions caused by the wireless nurse call system. Deciding whether or not to abort an activity or respond to an interruption is regarded as stressful. The decision is further complicated by the complex nature of the interruptions. At the same time, patients anticipate that nurses are able to make these judgements with limited information. Nurses' work is highly collaborative, and nurses depend on one another to carry out their work and manage interruptions.
Conclusion. The dual nature of the interruptions is complex, and whether or not an interruption is wanted or unwanted depends on many factors. Nurses manage interruptions mainly by making their own activities visible and monitoring colleagues' work. Therefore, nurses' awareness of colleagues' activities is a key factor in how they handle interruptions in the form of nurse calls.

4.1.4 Paper 4: Availability communication

Authors: Joakim Klemets and Pieter Toussaint

Title: Availability communication: requirements for an awareness system to support nurses' handling of nurse calls

Published in: Proceedings of MEDINFO 2015, IOS Press

Authors' contribution: Klemets contributed to research design, data collection, analysis, and writing. Toussaint provided feedback and comments throughout the whole writing process.

Abstract: The recent development of mobile technologies allows nurses to receive different types of requests anywhere. However, the interruptions generated by these devices often present a challenge for nurses in their daily work in a hospital department. In previous inquiries, we investigated nurses' strategies to managing technology-mediated interruptions in the form of nurse calls. However, this study reports on an effort to co-design a system that supports an important strategy employed by nurses. Through the involvement of domain experts, the study elicits requirements for an awareness system to support nurses' collaborative effort in handling nurse calls.

4.1.5 Paper 5: Patient intention communication

Authors: Joakim Klemets and Pieter Toussaint

Title: Does revealing contextual knowledge of the patient's intention help nurses' handling of nurse calls?

Published in: International Journal of Medical Informatics. 2016;86.

Authors' contribution: Both authors were involved in research design, data analysis, and writing. Klemets carried out the data collection and wrote the paper. Toussaint provided feedback and comments throughout the whole process.

Abstract: *Objectives*. An inherent part of nurses' work is handling nurse calls, which often interrupts ongoing activities. In situations when nurses are interrupted by a nurse call, they need to decide whether to continue focusing on the task at hand or abort and respond to the nurse call. The difficult decision is often influenced by a number of factors and can have implications for patient safety and quality of care. The study investigates how technology could be designed to support nurses' handling of nurse calls by allowing patients to communicate a more contextualised message, revealing their intention to the nurse when issuing a nurse call.
Methods. Through a qualitative methodology employing a scenario-based design approach, three different nurse call system concepts were evaluated by nurses from different departments of a Norwegian university hospital.
Results. Nurses find the uncertainty of not knowing the reason behind a nurse call stressful in situations where they are required to prioritise either the calling patient or a patient they are currently nursing. Providing information about a patient's intention behind a nurse call influences the nurse's decision to various degrees depending on the situation in which they find themselves and the information that is communicated. The nurses' reflections suggested that the message communicated should be designed to contain neither too little nor too much information about the patient's needs.
Conclusions. A nurse call system that allows nurses to discern the reason behind a nurse call allows them to make a more accurate decision and relieves stress. In particular, the information communicated would reduce uncertainty and lessen nurses' dependence on other factors in their decision. The design of such a system should, however, carefully consider the needs of the department in which it is deployed.

4.1.6 Paper 6: Designing for resilience

Authors: Joakim Klemets and Tor Erik Evjemo

Title: Understanding nurses' strategies to handle (un)wanted nurse calls: a resilience perspective

Published in: Submitted to CIN: Computers, Informatics, Nursing.

Authors' contribution: Both authors contributed to research design, data analysis, and writing.

Abstract: *Background*. Nurse calls in a hospital can constitute either positive or negative (wanted or unwanted) interruptions depending on various factors. This study aims to understand nurses' strategies in facilitating the reception of wanted and restriction of unwanted nurse calls. Applying a resilience engineering perspective, nurses' performance variability is investigated as a basis to design appropriate computer support to enhance efficiency and patient safety.
Methods. A qualitative case study was conducted for a period of four years with a focus on nurses' use of a wireless nurse call system at a Norwegian university hospital. The study involved various data collection methods, such as observations, interviews, and workshops. The collected data were then transcribed and analysed using a combined inductive and deductive approach.
Results. Nurses employ four main strategies, involving a large degree of collaboration, to allow or avoid interruptions in the form of nurse calls depending on situations and circumstances. However, these strategies are not supported by the wireless nurse call system, which requires nurses to employ sub-optimal workarounds to enable the necessary performance variability.
Conclusion. Interruptions have been largely perceived as a threat to patient safety. However, nurses' handling of calls illustrates that, when aiming to introduce interventions to manage interruptions, a detailed understanding of work that has been done is important. Nurses continuously make appropriate adjustments to cope with challenges that characterise hospital work to ensure efficient and safe operations. Hence, technology, in terms of a nurse call system, needs to be designed to afford the adjustments made to support a resilient practice, and as such, leverage patient safety.

4.2 The nurse call challenge

One of the challenges of the nurse call system is the sound generated to notify nurses about issued nurse calls. Nurses explain that they are not always able to focus on the task at hand while the phone keeps ringing and vibrating in their pockets, i.e., the ringing has been accused to cause communication breaches between the nurse and the visited patient (*Paper 1*). Further, the nurse call notification also creates discomfort for other accompanying parties, e.g., another nurse, doctor, or patient.

Another dimension to these types of interruptions, reported in *Paper 5*, is that nurses also worry about the calling patient. Nurses revealed that the calling patient is sometimes even more occupied in their thoughts than the current task. The issue of not knowing what lies behind the call creates both anxiety and stress. However, nurses admit that it is not optimal to leave an unfinished task behind and are, therefore, often reluctant to do so, complicating the decision to respond.

Effectively, a nurse call requires a decision where the nurse has to assess his or her availability towards an issued nurse call. *Paper 3* and *Paper 5* identify a number of factors that influence nurses' decisions to respond to a nurse call in a given context. The factors include:

- *patient's condition*, where patients that are seriously ill are prioritised,
- *nurse's situation*, or the importance and urgency of the on-going activity,
- *relationship with the calling patient*, as nurses tend to prioritise their responsible patients,
- *awareness of colleagues' availability*, or knowing whether someone else is able to respond, and
- *call intention*, i.e., the underlying reason behind the issued nurse call (if it can be known or assumed).

The duality of these kinds of interruptions, i.e., that nurse calls can be both wanted and unwanted depending on various factors, is further discussed in *Paper 3*. Nurse calls that are responded to immediately can be regarded as wanted under the particular circumstance. However, under other circumstances, e.g., when the nurse prioritises their current activity, the nurse call is regarded as unwanted. A wanted nurse call provides awareness about an important request that should be attended to immediately, e.g., a patient in serious pain when the nurse is carrying out non-urgent administrative work. Conversely, unwanted nurse calls disturb the nurse and can prevent them from effectively carrying out an important activity.

The wireless nurse call deployed at the hospital also presents a challenge in its limited affordances. Reported in *Paper 1* and *Paper 3*, some departments have been more eager to adopt the technology than others. For example, in the infection department, one reason to not use the wireless nurse call system is that the wireless phones do not afford use within isolation rooms due to the strict hygiene regime. Similarly, the wireless system has been found to not afford fast enough configuration at the start of a working shift, leaving nurses to abandon its use, e.g., during busy mornings, as further discussed in *Paper 6*.

4.3 Nurses' strategies to handle nurse calls

Nurses employ different strategies to facilitate the reception of wanted and restriction of unwanted nurse calls. These strategies are illustrated in Figure 1.2 and summarised in *Paper 6*. In particular, two strategies have been identified to handle unwanted nurse calls, and two other strategies have been identified to facilitate wanted nurse calls.

4.3.1 Managing unwanted nurse calls

Informal sharing of responsibilities

Paper 3 describes how nurses continuously monitor colleagues and display their own activities through observation and small talk to maintain awareness of availability. Nurses utilise this awareness in deciding whether or not to respond to a nurse call as a strategy to handle nurse calls. The knowledge of colleagues' activities is foremost advantageous in unplanned situations, i.e., everyday occurring situations in which a nurse enters without having planned the procedure long in advance, e.g., assisting a patient after responding to the patient's nurse call.

An example situation is when a nurse has responded to a nurse call and the patient visit unexpectedly requires the nurse's full attention. In these cases, nurses' awareness of colleagues' availability to respond to nurse calls in the meantime relieves stress in the situation and allows the nurse to remain focused on the current task. Correspondingly, if a nurse is aware that colleagues are unavailable, this influences the nurse to be more inclined to respond to an issued nurse call, allowing the unavailable nurse to remain focused on his or her task.

Formal sharing of responsibilities

Before planned activities, which usually include time-consuming undertakings, such as sterile procedures or certain patient conversations, nurses usually hand

over their patient responsibilities to another nurse before engaging in the activity. In accordance with the primary nursing model (Pontin 1999), nurses at the hospital are assigned the main responsibility for a few of the patients at their bed area, which includes receiving and responding to nurse calls from assigned patients. Nurses are assigned patients at the start of each working shift (a responsibility that is supposed to remain throughout the shift).

However, this responsibility usually shifts temporarily whenever the primary nurse has to undertake a longer procedure that should not be interrupted. Before the planned activity, the nurse asks one of his or her colleagues if they could take over the patient responsibilities in the meantime. During the handover meeting, the nurse taking over the responsibility is informed about the patients and any particular arrangement or special needs the nurse should know about. The practice allows the nurse to remain fully focused throughout the planned procedure, knowing that someone else is responding to nurse calls from their patients. The strategy is further described in *Paper 1* and *Paper 2*.

4.3.2 Managing wanted nurse calls

Discerning call intention

The strategy, which is described in *Paper 6*, entails staging nurse calls in ways that enable nurses to receive cues about the underlying intention. One example is to tie the draw-string, which releases a nurse call when pulled, onto patients with high fall risk. Consequently, if the patient falls to the floor, a nurse call is automatically issued. As nurses know to what patients the additional safeguard has been applied, it gives them a hint of the call's urgency.

Another example of an arrangement in levering the discernment of call intention is to make agreements with patients about when they should issue an alarm, e.g., when a patient's IV-drip finishes or when a patient needs help with repositioning. The practice allows nurses to receive a bit of foreknowledge of what to expect and helps them prioritise appropriately.

Staying connected

This strategy further stresses how nurses find it important to receive nurse calls and stay connected with what is happening in the department. The strategy, which includes the adoption of system workarounds, allows nurses to receive nurse calls they otherwise would not receive and is further described in *Paper 6*. There are two main variations of this strategy.

First, in circumstances when the wireless phone is not used to receive nurse calls, e.g., in departments with many isolation rooms or when there is not enough time to configure the wireless system, nurses rely on the fixed nurse call system

as a backup system to receive nurse calls. A second variation is to make ad-hoc system configurations that allow nurses to receive nurse calls from all bed areas in a department. This is important during night shifts when there are fewer nurses at work, increasing the possibility that all nurses in a bed area are occupied at the same time.

4.4 Technology support for nurses' strategies

The design science approach seeks to change the current state of affairs to a more desirable state through the design and introduction of artefacts. The work carried out in the first research phase explored ways in which nurses employ various creative strategies to handle interruptions in the form of nurse calls. However, while these are well developed strategies, they are not nearly as effective as they could be if the technology provided adequate support. Instead, nurses are required to work around, and at times even against, the current nurse call system to enable these strategies. Therefore, three different prototypes have been developed and evaluated (together with nurses) in an attempt to support these existing practices.

4.4.1 AWAY: AvailabilitY AWareness

Maintaining awareness of colleagues' availability is made cumbersome by the fact that nurses are highly mobile and not always co-located (Bardram and Bossen 2005). For example, as reported in *Paper 3*, nurses sometimes monitor the situation while situated in a patient room by looking out in the hallway to see whether there are available nurses to respond to an issued nurse call. However, except that such a practice takes the focus away from the current task, the practice is not well suited while located in an isolation room.

To find a solution to these issues, a prototype was designed that provides facilities for nurses to monitor and display availability statuses through a mobile phone. The prototype allows nurses to set their status to either available, busy, or unavailable. Whenever a nurse call is received on the phone, colleagues' availability statuses are displayed to inform the decision to respond (Figure 4.2). The prototype was used both as a trigger to further elicit system requirements in a participatory design workshop with nurses and to evaluate whether it could be used in real practice to support nurse call handling. Nurses expected that such a system would able them to be more fully focused on the visited patient and that the response time to nurse calls could be reduced. The evaluation has been published in *Paper 4*, which suggests the following system enhancements:

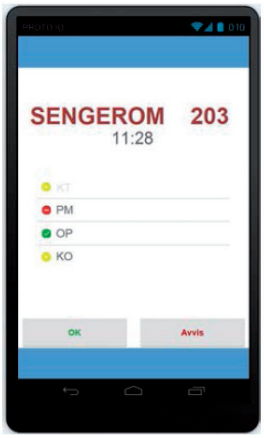

Figure 4.2: The AWAY prototype

- nurse calls should not be blocked, even if the status is set to yellow or red, so that nurses can remain aware of what is going on in the department;
- the notification for nurse calls should be modified according to set availability status and how long the calling patient has waited;
- status should be set automatically when entering or leaving a patient room;
- a timer should remind the nurses to update their status if it has been set to yellow or red; and
- the system should allow nurses to interact with wall mounted displays instead of the phone (monitoring and displaying availability).

4.4.2 PatientRhover: Patient Responsibility handover

Although nurses hand over their patient responsibilities before undertaking a planned procedure, the responsibility reallocation is not updated in the wireless nurse call system. This means that the unavailable nurse is still listed as the patient's main contact and receives nurse calls accordingly, which is a source of unnecessary and unwanted interruptions. At the same time, the nurse, who is temporarily responsible, might not receive any nurse calls from the reallocated patents. The main reason why the system is not updated after a handover is the time it takes to make appropriate changes, which include walking over to a stationary computer, logging in, and scrolling through a long list of nurses.

The prototype designed to overcome these issues allows nurses to reallocate patient responsibility by handing over a token during the handover meeting.

The token, a near-field communication (NFC) enabled chip, represents a nurse's patient responsibilities. When the receiving nurse touches the token to his or her phone, the system is automatically updated. Afterwards, nurse calls are routed to the nurse carrying the token.

Figure 4.3: Nurses using the PatientRhover prototype to hand over patient responsibility during a role-session act.

The design and evaluation of this prototype is further described in *Paper 2*, which outlines two objectives. With regard to the first objective, namely to evaluate usability- and acceptance-related aspects of the prototype, the following findings were identified:

- nurses found the prototype easy to use and intuitive;
- the token presented a problem, as it could be contaminated or easily lost;
- the prototype works best for planned situations; and
- the system behaviour is highly context-dependent.

The second objective was to evaluate the feasibility of the system to be used in real practice, including its possible impact on the current workflows and practices. These are the key finding of the second objective:

- the prototype reinforces an already existing practice,
- the prototype improves communication and clarifies accountability,
- the prototype reduces unnecessary interruptions and response time to nurse calls, and
- the prototype reduces the need for a suboptimal workaround that jeopardises patient safety.

4.4.3 PANIC: PAtient iNtentIon Communication

The third strategy presented involves making various arrangements to receive cues about the context of a nurse call. The cues allow nurses to more precisely assess the urgency of a nurse call and prioritise their activities. The study presented in *Paper 5* proposes a system that allows patients to explicitly communicate their call intention as an attempt to support nurses' decision making. Three prototype alternatives were designed that afford different levels of intention richness to be communicated (Figure 4.4).

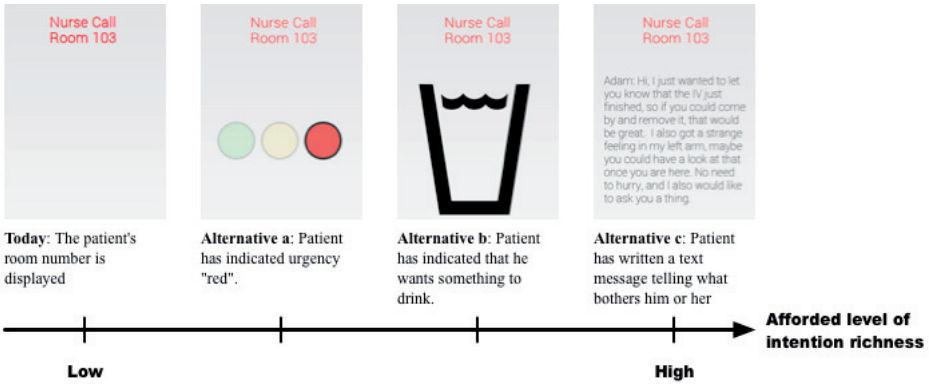

Figure 4.4: Three different alternatives of the PANIC prototype allow patients to convey their intention to various degrees.

Results indicate that whether or not a nurse decides to respond to a nurse call is (to various degrees) influenced by the communicated intent, message design, and nurse's situation. Situations in which the nurse was undertaking an important procedure, the information communicated did not affect the decision, while in other situations, it did. However, the design of the communicated message also has an impact to what degree the communicated intent influences nurses' decisions. Nurses suggested that the message should allow nurses to objectively assess the urgency of the call. The message should also be easily accessible in the sense that little cognitive effort is required to understand its meaning.

Nurses found the alternative that represents the patient's intention through a symbol (alternative b) the most promising candidate, as it allowed them to objectively assess the urgency by quickly glancing at the communicated symbol. This message design was also found to relieve nurses' reliance on other factors when discerning the urgency of a nurse call. Hence, a nurse call system that allows the patient's intention to be revealed reduces uncertainty and facilitates nurses' ability to make a more informed decision.

CHAPTER 5

Discussion

5.1 RQ1: What strategies do nurses employ to handle nurse calls?

In previous studies, nurse calls have been found to be a source of interruption that causes frustration and stress for nurses in their work (Deitrick et al. 2006; Kristiansen 2011; Miller, Deets, and Miller 1997). Interventions aim to manage these interruptions by reducing the number of nurse calls (Meade, Bursell, and Ketelsen 2006; Torres 2007) or through artificially intelligent call handling systems (Ongenae et al. 2011). However, no study has investigated how nurses actually manage these interruptions in practice (at least from a perspective that not all nurse calls are unwanted).

Influenced by a traditional view of interruptions, *Paper 1* approaches nurses' abilities to handle nurse calls from a similar perspective, i.e., primarily viewing nurse calls as unwanted interruptions. The study highlights how nurses utilise colleagues' overlapping skills and awareness about what is going on in the bed area to share the responsibility of responding to nurse calls. In accordance, what is needed to ensure rapid responses and reduce unwanted nurse calls is a system that affords quick responsibility handovers.

However, the proceeding evaluation study of the PatientRhover prototype presented in *Paper 2* reveals that this strategy is only suitable for certain situations, i.e., planned procedures or undertakings that require the nurse to become unavailable for a long period of time. A more nuanced view of interruptions in the form of nurse calls is portrayed in *Paper 3*, where the dual nature of these are highlighted. This is a position that is further developed in *Paper 6* and is central to the thesis. Hence, part of its novelty lies in acknowledging that nurse calls are not merely unwanted interruptions to nurses' work but also an important mechanism to facilitate the awareness of wanted nurse calls, which is an intrinsic necessity of nursing work in a hospital department. Therefore, the approach was

to identify nurses' strategies in handling these in various circumstances. This exploration has identified a highly collaborative practice, including both nurses and patients, which strives to handle nurse calls safely and efficiently given limited resources, competing demands, and management's pre-expectations on workflow.

The identified strategies contribute to a greater understanding of how nurses' actual practice helps in handling nurse calls and the challenges they are faced with in daily work. As such, they should have implications for the design of future nurse call systems (cf. RQ2). In particular, each nurse call requires the receiving nurse to make a decision on what to prioritise, i.e., the calling patient or the current activity. This is a decision that is based on several underlying factors. The complexity of the decision reveals that automating such a decision is not a straightforward task, if even possible. However, a step in the right direction would be to support the decision in ways that reduce uncertainty by efficiently revealing relevant information without compromising too much focus from the current activity.

The results could also have implications for how nursing care is organised. The primary nursing model is currently regarded as the preferred way for organising nursing work (Mattila et al. 2014), where a one-to-one relationship between the nurse and the patient is emphasised (Pontin 1999). By always delivering the nurse call to the assigned primary nurse, the investigated wireless nurse call system supports such a model of work. However, the partly collaborative practice that underlies nurses' efforts to handle nurse calls suggests that enforcing a strict adherence to the primary care model might not be the most efficient way to organise work.

In response to the subquestion (RQ1.2), *what are the associated challenges in employing these strategies?*, several challenges were identified that provide difficulties for nurses. In particular, as discussed more thoroughly in *Paper 6*, nurses had to adopt sub-optimal workarounds to make use of their strategies to handle nurse calls. These workarounds neither contributed to work efficiency nor patient safety. An example is the wireless nurse call system's inadequate support for spontaneous patient responsibility reallocations. To avoid unnecessary interruptions after handing over their patient responsibilities, nurses often leave their phone behind before undertaking the planned activity. In this case, e.g., a nurse call from a patient whose primary nurse had shifted, the call would first be routed to the unoccupied phone and, afterwards, possibly to other nurses' phones before finally reaching the nurse that was currently responsible and, as a result, possibly delaying the response time while generating unnecessary interruptions.

5.2 RQ2: How could technology be designed to support nurses' handling of nurse calls?

5.2.1 RQ2.1: How can the design support nurses' strategies?

The identified strategies that serve as a response to RQ1 have been used to inform the re-design of the wireless nurse call system. This initially resulted in three different prototypes with functionalities that were designed to afford support for nurses' practices. Influenced by socio-technical approaches (Baxter and Sommerville 2011; Mumford 2006), such as user-centred design (Ritter, Baxter, and Churchill 2014) and participatory design (Simonsen and Robertson 2012), nurses were involved in refining the design and evaluating the prototypes. The purpose of adapting such an approach is motivated by the fact that it often leads to solutions which are more responsive to user needs that better fit the context of use and the particular tasks they are supposed to support. The choice of method is further rooted in the view that people interpret technologies within the range of their affordances (Hutchby 2001). As affordances can be designed into technology to make them easily perceivable, affordances can differ between people, which motivates the inclusion of actual end-users in the process. For example, the PANIC prototype alternatives were developed to possess different affordances, as perceived by the researchers. However, in the evaluation reported in *Paper 5*, the nurses found technology to embody affordances that initially were not anticipated. Another example is the token designed to represent patient responsibility, which is a part of the PatientRhover prototype. Although the design was inspired by the tangible user interface concept, which aims 'to make computing truly ubiquitous and invisible' (Ishii and Ullmer 1997), the design did not convince the nurses. Rather, the token presented a problem, as it could be contaminated or easily lost.

The AWAY prototype, which was developed based on the study presented in *Paper 3*, was influenced by the concept of awareness within the field of computer supported collaborative work. Even if awareness systems are nothing new (Markopoulos, Ruyter, and Mackay 2009), these have not previously been designed for use within the context of nurse call handling. Awareness information has previously been used to reduce unnecessary interruptions in the form of phone calls by facilitating appropriate obtrusiveness (Bardram and Hansen 2004). However, interruptions in the form of nurse calls are distinct, as they are expected to be responded to more or less immediately, which is not always the case with phone calls.

Galinato et al. (2015) presented a solution that allows patients to communicate a more contextualised message by selecting an appropriate symbol. How-

ever, whether or not such a solution could support nurses in their handling of nurse calls is not further discussed in the paper. The PANIC prototype was designed and evaluated for the purpose of finding out how such a message would leverage nurses' decision to respond to a nurse call (*Paper 5*).

Likewise, there are no known solutions similar to the PatientRhover, which aims at supporting nurses' handover practices during a work shift. The evaluation of these novel technologies contributes to the design of functionalities when aiming to support nurses' nurse call handling strategies as well as an analysis on their possible impact on existing practices.

5.2.2 RQ2.2: How can the design ensure patient safety?

The underlying assumptions of Safety-I are that systems are well understood and causes to failures can be traced (Hollnagel, Braithwaite, and Wears 2013). The safety approach in case of a failure has, therefore, largely been to track down the possible cause and constrain performance variability through rules and regulations.

For example, studies that have found a causality between interruptions and medical errors (Prakash et al. 2014; Westbrook et al. 2010a,b) have triggered the introduction of various interventions to reduce the number of interruptions. However, interventions, such as nurses wearing red vests during medication administration, have not always been well received. There are also indications that the act of interrupting is a part of nurses' strategy repertoire to prevent failures (Rivera 2014). Further, Colligan and Bass (2012) demonstrated that, during medication administration, there are several factors that influence whether an interruption is regarded as wanted or unwanted. The conception that interruptions can be both beneficial and harmful resonates with the findings of this thesis that there are several factors that determine whether a nurse call is wanted or unwanted.

An overarching goal of the developed solutions is to not only achieve better work efficiency by supporting practice through system design but also to enhance patient safety. However, if it is the case that humans are prone to err (Reason 1995) and that workarounds are merely an expression of the staff's incompetence or unwillingness (Debono et al. 2013), why study how nurses handle nurse calls in practice as a basis for designing interruption interventions (cf. RQ1)? The answer, arguably, lies in recognising the underlying assumptions of Safety-II, i.e., that performance variability, or everyday work, results in both unacceptable and acceptable outcomes. Restraining the performance variability in order to eliminate errors will, therefore, also constrain work that results in success. From a Safety-II perspective, safety is achieved by trying to make sure that things go right through understanding and strengthening the variability of

everyday work that results in acceptable outcomes. As outlined in *Paper 6*, the approach of establishing a link between novel technology in terms of nurse call handling and improved patient safety analytically demonstrates how supporting nurses' performance variability through design can facilitate the system's resilience.

In particular, nurses' adoption of strategies that enable the reception of wanted and restriction of unwanted nurse calls is what constitutes a resilient practice in the context of nurse call handling. To maintain focus on an important activity that requires a nurse's full attention, nurses anticipate future interruptions in the form of nurse calls and take appropriate actions to prevent these. Strategies include both the formal and informal sharing of responsibilities by maintaining an awareness of colleagues' availability and handing over patient responsibilities, respectively. Similarly, nurses adjust to circumstances by employing strategies that facilitate the reception of wanted nurse calls, e.g., the strategy described in section 4.3.2, where nurses make arrangements that provide cues about a nurse call's urgency, and even explicitly tell patients when to call them. These proactive strategies constitute a response repertoire that has not been formally trained on but developed at the sharp end to deal with reoccurring situations in a department.

However, to enable these strategies, nurses need to work around a system that reflects work-as-imagined in ways that can threaten patient safety. By aligning computer support to facilitate these strategies, one could overcome these challenges. Therefore, as acknowledged by others (Cabitza and Simone 2013), workarounds can constitute 'drivers for change' and act as a vehicle to identify inadequate designs rather than deviations from an ideal workflow, i.e. work-as-imagined (Debono et al. 2013), and, as such, indicate where effort is needed to support performance variability (Rankin et al. 2013). Through exploring the mundane strategies that nurses employ to handle nurse calls, demonstrating that these are part of the performance variability that ensures successful outcomes, and supporting these through the means of novel technology, the socio-technical system's resilience should be fostered. Hence, the prototypes presented, arguably, enhance both work efficiency and patient safety, as they are designed to support resilient practices. However, there is always reason to be cautious when introducing new technology, which could also have unexpected consequences.

5.3 Reflections on technology-mediated interruptions

To generalise the contributions of this thesis beyond the context of nurse call handling might be a bit far stretched. However, I would like to make a short reflection on how these results also could contribute to a more general discus-

sion, i.e., changing interaction patterns seem to go hand-in-hand with an increasing amount of technology-mediated interruptions. For most of the computer's history, this fascinating piece of machinery has been used to carry out batch-like processes or respond to information queries. In these types of systems, the user is the one who usually initiates the interaction to which a response can be expected, mostly, within a certain timeframe. However, recent developments of computing technologies, which often fall under the Internet of Things (IoT) umbrella, including sensor-based systems utilising a publish-subscribe design pattern, have shifted the interaction initiator towards the computing agency. We are constantly being reminded of upcoming birthdays, changes in the stock market, sport results, or shopping opportunities. Similarly, within the field of telecommunication, besides a plethora of asynchronous messaging services, the uprising of social media platforms provides a continuous stream of updates and notifications.

All of these technologies provide great opportunities to support our social engagements and keep us aware of what is happening in the world around us. Thus, it is arguable that clinical work could benefit from the same type of technology by supporting communication among colleagues or providing constantly updated information about patients. However, all of these generated events also interrupt our daily activities and call for our attention. Similar to nurses receiving a nurse call, the recipient has to evaluate their availability towards such an event. As for nurse calls, these are probably mostly either wanted or unwanted. To avoid being overloaded with irrelevant interruptions, management techniques are required to handle an ever-increasing amount of interruptions mediated through various technological mediums. A good amount of these can probably be handled automatically through intelligent software, but, as this work demonstrates, one should take great caution when aiming to automate such decisions. Knowing that these types of decision are often made based on various factors, e.g., social (Harr and Kaptelinin 2007) and relational (Grandhi and Jones 2010), indicates that a thorough understanding of the context is essential. In some cases, it will be necessary to support the interruption management strategy semi-automatically, as illustrated by the examples in this thesis.

5.4 Research evaluation and limitations

Section 3.7 identified a number of research quality indicators, including validity, reliability, and generalisation. To deal with threats to *validity*, a number of strategies have been utilised. To minimise the threat of description, the data collection of interviews and focus group interviews have been audio recorded. Workshops including role-play sessions and focus group interviews have, in ad-

dition to audio, also been video recorded. Notes have been made during each data collection opportunity. In dealing with the threat of interpretation, theories or frameworks have always been applied in a later stage of the data analysis after initial categories have emerged from the transcribed data in accordance with the stepwise deductive-inductive (SDI) approach (Tjora 2010). The frameworks identified to aid the interpretation of the data have been carefully selected after reviewing the literature with the previously developed categories in mind.

To further enhance the validity, the triangulation strategy has been applied (Robson 2002). Firstly, multiple data sources, including observations, interviews, and documents, have been used. Secondly, more than one observer has been involved in the study (observer triangulation). Theory triangulation has also been applied in the sense that several frameworks, or theories, have been employed by looking at the data from different perspectives. For example, *Paper 1*, *Paper 3*, and *Paper 6* all examine the same phenomena from different perspectives (functional redundancy, awareness, and resilience engineering, respectively).

An audit trail is another strategy to reduce the threat of researcher bias (ibid.). All recorded data material, including transcribed audio, video recordings, and field notes, have been securely stored. The data analysis has been carried out using a computer assisted qualitative data analysis software (CAQDAS) named HyperRESEARCH. It is, therefore, possible to trace the concepts presented in this thesis back to the underlying categories, codes, and text excerpts.

With regard to respondent bias and reactivity, prolonged involvement is a strategy that could reduce this threat (ibid.). As data has been collected on different occasions over a four-year period, this has enabled me to get familiar with many of the people in the different departments. Surely, there have been occasions when the respondent has clearly had an underlying agenda e.g., repeating more or less the same answer or opinion regardless of what questions have been asked. However, the threat is reduced through the prolonged involvement, diversity, and large number of respondents, including regular, student, and head nurses from different departments.

In assuring that the research is *reliable*, Yin (2003) proposed the use of a case study database similar to the audit trail suggested by Robson (2002). Recording interviews and reporting verbatim citations in the research papers also enhance the study's reliability (Tjora 2010). Tjora (ibid.) urged the research to convey his or her position to enhance reliability, which also helps reduce the researcher bias threat (Robson 2002). Within the interpretive research traditions, complete objectivity is regarded as an unachievable utopia. The researcher's knowledge and engagement is rather regarded as a resource (Tjora 2010). Hence, my engineering background has definitely instilled a technological deterministic view that characterises the initial work of my research. In particular, I was initially more occupied with trying to find solutions that would be technically interest-

ing than would be useful for nurses' work. However, in realising that such an approach would be rather ineffective in solving nurses' issues, my position developed towards a socio-technical stance, well expressed by the notion of affordances (Hutchby 2001). Progress has obviously been influenced by the strong socio-technical tradition of our research group, yet my background also ensures that the analysis does not lean towards 'a form of socio-ludditism' (Coiera 2007). It has, therefore, been important to involve study participants from departments that both endorse and oppose the wireless nurse call system to gain a balanced picture of what the underlying problems really are. Further, throughout the study, I found that experienced nurses tend to be more critical and resistant towards new technology (an attitude that possibly could be ascribed to the many failings of technology in theses settings (Kaplan and Harris-Salamone 2009)). Less experienced nurses, on the other hand, tend to be more open towards new technology and often see opportunities rather than problems. Involving a mix of both extremes, and all in-between, has allowed the research to remain balanced.

Concerning *generalisability*, the approach of generalising from theory is applied (Yin 2003). By focusing on the problem of interruptions, which has been identified as a major issue in previous nurse call studies, the research is made relevant also for other clinical settings employing a nurse call system. In particular, the thesis develops a theory of how nurses resiliently handle nurse calls and ways in which technology can be designed to support this effort. Further, the thesis demonstrates how the theoretical frameworks of awareness and resilience engineering are relevant in nurse call interruption handling. However, as the theory has not yet been tested in another setting (replication logic, see (ibid.)), whether similar results would be achieved is not possible to say.

A major limitation of the work is that the prototype evaluations are only made in a lab setting. The next step would be to test these in a real setting to see whether they stand up to scrutiny. Further, the fidelity of the AWAY and PANIC prototypes are rather immature. This means that issues related to, for example, usability and security have been overlooked in these studies. There are also several other technical challenges in developing a finished product of the prototypes.

CHAPTER 6

Conclusion and future work

Adopting a design science approach, the main objective of this thesis is to design technology that supports nurses' handling of interruptions in the form of nurse calls. To come up with effective solutions, nurses' strategies adopted to handle nurse calls were initially investigated through a qualitative case study. The exploration unveiled that several factors determine whether a nurse call is wanted or unwanted in a given context, and that strategies are adopted to both restrict and enable the reception of nurse calls. Most of these strategies involve a high degree of collaboration among nurses and patients (practices that are not well supported by current technology). In the investigated departments, the inadequate systems support results in nurses adopting sub-optimal workarounds that can have negative consequences on both work efficiency and patient safety.

To address these challenges, the thesis presents the design and evaluation of three different prototype systems that aim to support nurses' strategies. These include: AWAY (Availability Awareness), PatientRhover (Patient Responsibility handover), and PANIC (PAtieNt Intention Communication). The prototypes have been developed and evaluated (together with nurses) through the use of socio-technical design approaches. AWAY allows nurses to maintain awareness of their colleagues' availability as a means of informing their decision making whenever a nurse call is received. PatientRhover ensures quick reallocation of patient responsibility between nurses and supports a strategy adopted by nurses to restrict the reception of nurse calls during certain planned activities. PANIC allows patients to communicate a nuanced message to nurses, revealing the patient's intention to aid nurses in discerning the urgency of the call. Further, by adopting a Safety-II perspective on safety, the thesis demonstrates that supporting nurses' mundane work practices and adjustments through technology could further enhance the socio-technical system's resilience and, therefore, also improve efficiency and patient safety.

The theoretical framework developed in this thesis describing how nurses handle both wanted and unwanted nurse calls and how technology could be de-

signed to support these should, as part of future work, be verified in other hospital contexts to strengthen its analytical generalisability. Further, the developed prototype systems have not been tested and evaluated in a real setting. To develop systems out of the suggested prototypes that are dependable, from an engineering perspective, and mature enough to be deployed at a hospital is not a trivial task and, therefore, also considered as future work. A few master projects have also explored the possibility of augmenting parts of the proposed prototypes with location sensing (Arteev 2014; Jørgensen 2015) and artificial intelligence (Wei 2014). Although these ideas need further development, they present a promising path for future explorations.

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PART II

INCLUDED PAPERS

PAPER 1

Designing for redundancy: nurses experiences with the wireless nurse call system

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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 because 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 where 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 nurses[1]. 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 technology is used at the different departments included in the study. Further, the way nurses typically organize themselves by continuously allocating and reallocating responsibility,

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

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*". Here 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 CVC*[2] *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 asses 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 patient[3]. 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 such 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 in order 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"*.

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

[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].

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 that appears in the results 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 status in the system. 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 often unexpected wireless nurse call signals causing disruptive interruptions. 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 also 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.

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PAPER 2

Patient responsibility reallocation: a user-centred approach to support nurses' handling of nurse calls

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PAPER 3

Technology-mediated awareness: facilitating the handling of (un)wanted interruptions in a hospital setting

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Technology-mediated awareness: Facilitating the handling of (un)wanted interruptions in a hospital setting

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ABSTRACT

Introduction: Nurses' work in hospital departments is highly collaborative and includes communication with a variety of actors. To further support nurses' communications, wireless phones, on which nurses receive both nurse calls and ordinary phone calls, have been introduced. However, while they ensure high availability among the mobile nurses, these phones also contribute to an increased number of interruptions.
Purpose: This paper aims to discover whether all interruptions caused by the wireless phones are unwanted. Further, it investigates how nurses handle these interruptions in a hospital setting in order to construct a foundation for guidelines to use in designing these types of systems.
Methods: Qualitative and ethnographically inspired fieldwork, including workshops with both ordinary and student nurses from a Norwegian hospital, was undertaken. Patients from two hospital departments were interviewed.
Results: Nurses struggle to handle interruptions caused by the wireless nurse call system. Deciding whether to abort an activity or not to respond to an interruption is regarded as stressful. The decision is further complicated by the complex nature of the interruptions. At the same time, patients anticipate that nurses are able to make these judgements with limited information. Nurses' work is highly collaborative, and nurses depend on one another to carry out their work and manage interruptions.
Conclusion: The dual nature of the interruptions is complex, and whether an interruption is wanted or unwanted depends on many factors. Nurses manage interruptions mainly by making their own activities visible and monitoring colleagues' work. Therefore, nurses' awareness of colleagues' activities is a key factor in how they handle interruptions in the form of nurse calls.

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1. Introduction

The work of nurses in a hospital department is highly complex and characterized by a high degree of communication, coordination and collaboration with various actors. To ensure the delivery of high-quality care with limited resources, nurses must continually re-prioritize activities and make quick decisions, often based on limited information [1]. In this quest, communication is vital [2]. The effective and robust sharing of information in hospital departments is crucial if health professionals are to handle their various work challenges, which involve multiple sources of information and many complex human-machine interfaces [3].

One aspect of nurses' work is the handling of nurse calls. A nurse call system allows patients to call for a nurse when in need of assistance. The system also enables nurses to coordinate work with one another. To support spatially distributed work [4] and the mobility of nurses [5], some nurse call systems provide nurses with wireless phones. However, such wireless nurse call systems are associated with challenges in the nurses' daily work, such as an increased number of interruptions [6–8].

Other previous work that has studied nurse call systems[1] also highlights the issue of the additional interruptions to nurses' work that the systems create. The focus in those studies has included, for example, the reasons for nurse calls [9,10], system usage and its correlation to patient satisfaction [9,11–13], nurses' perspectives on system usage [9,13] and how to reduce nurse call usage by implementing new practices, such as additional nursing rounds [10,14]. However, while previous studies have covered various aspects of the problem, only limited research has been performed on factors that influence nurses' decisions about responding to a nurse call and the strategies nurses use to manage these interruptions. This paper investigates these factors and strategies.

It has been shown that interruptions further complicate nurses' work, increasing the number of times that they need to shift focus. For example, Tucker and Spear [15] report that nurses are interrupted in the middle of a task eight times during a typical working shift. Hedberg and Larsson [16] find that nurses are most frequently interrupted when involved in direct patient care. This distracts the nurses' attention from the patients that they are nursing [17]. Furthermore, the reduced amount of time nurses are able to spend on a given patient can have negative implications on patient outcomes [15]. Interruptions also create an additional cognitive load for nurses [1,17]. At any moment in time, nurses may have several tasks that they must attend to. Therefore, nurses must continually make trade-offs in terms of choosing what deserves their attention [1].

This paper is based on an observational and exploratory study of four hospital departments' varying use of and reliance on a wireless nurse call system. The departments are located in a major Norwegian university hospital. A qualitative methodology is applied, with which we seek to identify and describe nurses' uses of and challenges with the system and the associated wireless phone. In particular, we raise the following research questions:

1. What are the nurses' main challenges associated with the interruptions that the deployed wireless nurse call system causes?
2. What strategies do nurses use to deal with these challenges?
3. How can technology be designed to support and enhance these strategies?

We examine how nurses handle distinct interruptions, discussing in particular *the duality of interruptions* in this type of working milieu. We conclude by identifying how technology could improve the handling of unwanted interruptions via designing with nurses' awareness in mind.

2. Background

2.1. Interruptions

Due to the complexity of healthcare settings and the tight coupling between elements in this type of working environment, the exact reasons behind failures to deliver care are difficult to determine [18,19]. However, interruptions have been singled out as one possible link in the chain of events that ends in failure [15,20–24]. Interruptions have received much attention not only in healthcare but also in other similar research domains.

While there are many voices expressing the negative impact of interruptions [25], other studies show that interruptions also have positive effects [25,26]. For example, can an interruption provide new information that is valuable to the one being interrupted [17]. Harr and Kaptelinin [25] suggest that interruptions research must include the social context involved in order to determine the effects of interruptions. By social context, the authors refer to how interruptions create "ripple effects" that can have implications beyond the interrupted activity. To further understand people's strategies in handling interruptions, these effects should be considered [25].

Similarly, Grandhi and Jones argue in [27] that the relational context must be considered, that is, who is interrupting and what the interruption is about. The authors divide research on interruption management into two paradigms: *the impact reduction paradigm* and the *interruption value evaluation paradigm*. Whereas the former seeks to reduce the impact of interruptions by using, for example, prevention or dissuasion techniques, the latter acknowledges that not all interruptions are unwanted and holds that they should therefore be evaluated by the interrupted. One approach typically adopted in the interruption value evaluation paradigm is interruption preview. The approach seeks to provide useful information about the interruption to the individual being interrupted. By having access to, for example, the caller's intention in the case of a phone call, the interrupted party can make a more informed decision regarding whether to respond or not [27]. Thus, to discover whether an interruption is wanted or not, one must look beyond the effects it has on the interrupted activity to

[1] Sometimes also referred to as a call light or call bell.

include the social and relational contexts of the interruption as well.

While there are various techniques to use in managing interruptions [27], some have argued that interruptions could be handled through an increased awareness among colleagues [21,28]. Also, Ebright mentions that nurses' awareness of changes to unit activities and colleagues' work is an important factor in leveraging the decision-making process. The author writes, "*increasing support for nurses' decision making, or decreasing those factors that complicate nurses' ability to be mindful and make sense of changes, will result in decisions that lead to safe practice and quality care*" [1].

2.2. *Awareness*

The concept of awareness is defined by Dourish and Bellotti as "*. . .an understanding of the activities of others, which provides a context for your own activity*" [29], or, to put it another way, "*. . .knowing what is going on around you*" [30]. However, it is perhaps Mica Endsley who has had the greatest influence on how we traditionally understand the phenomenon of awareness, particularly situational awareness. Endsley defines situation awareness in the following way: "*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future*" [31].

The concept of awareness has become a central part of studies of computer-supported cooperative work, or CSCW [32,33]. Studies that also have influenced collaborative systems in health care [34]. Importantly, researchers within CSCW have explored "*. . . how computer-based technologies might facilitate some kind of awareness among and between cooperating actors*" [32]. However, the concept of awareness within CSCW has tended to be used in increasingly contradictory ways, hence its equivocal meaning [32]. Acknowledging that the concept of awareness sparks discussions due to its arguably ambiguous conceptualizations [32], the use of, for example, "peripheral awareness" [35], "workspace awareness" [36], "goal and decision-making awareness" [37], together with "social awareness" [38], nonetheless inform us that social processes and their immediate contexts are highly relevant when we discuss the phenomenon of awareness. Accordingly, awareness must be understood in terms of an "*awareness of something*" [32], meaning being or becoming aware of specific aspects of work. Hence, awareness is a property *of action* and an integrated aspect *of practice* [32].

In relation to the above, the challenge regarding awareness in nurses' work is to understand how nurses experience what is relevant to their own work, as well as to make sense of this information for practical use. Therefore, Schmidt, in relation to the field of "workplace studies" [39], advocates the following definition of awareness: "*. . . the practices through which actors align and integrate their distributed but interdependent activities*" [32]. Two complementary factors are crucial to this way of thinking: participants' *monitoring* of colleagues' activities and simultaneously *displaying* their own activities. This means that the phenomenon of awareness, in relation to facilitating unobtrusive work among nurses in hospital departments, must be grounded in *how* the nurses manage monitoring and displaying. Exploring and identifying nurses' mundane strategies in this regard is therefore of vital importance.

For example, how awareness is *configured* in various workplace milieus is illustrated by Heath et al., who show how awareness is produced and sustained "*. . . in and through social interaction with others*" [40]. Heath et al. point specifically at the skilful ways in which participants in milieus similar to Lucy Suchman's "centres of coordination" [41] render own activities selectively available so that others who are not directly involved in the interaction can contribute when needed. For example, when controllers at the London Underground speak out loud (display work) using the radio with train drivers, the information assistant is able to coordinate his own activities without explicitly having to ask the controller for an update (monitor work). Making work visible and monitoring work are thus two complementary aspects of controllers' coordinative and collaborative work practices.

In this paper, we choose to focus on aspects of awareness related to action, i.e., the strategies nurses rely on to make their own work visible to colleagues and how these nurses simultaneously monitor what their colleagues are doing. By understanding awareness in terms of what nurses' actually do, we aim to propose new functionality in today's wireless nurse call system. We argue that this new functionality will contribute to reduce unwanted interruptions, facilitate wanted

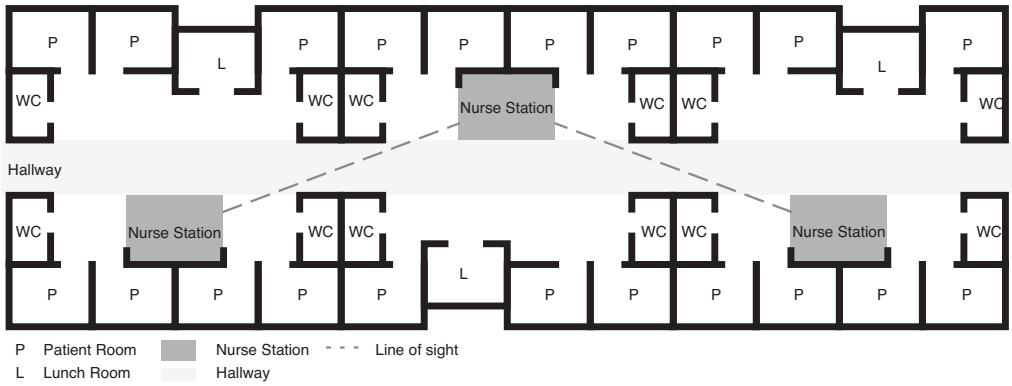

Fig. 1 – Floor plan of a typical hospital department, separated into smaller bed areas.

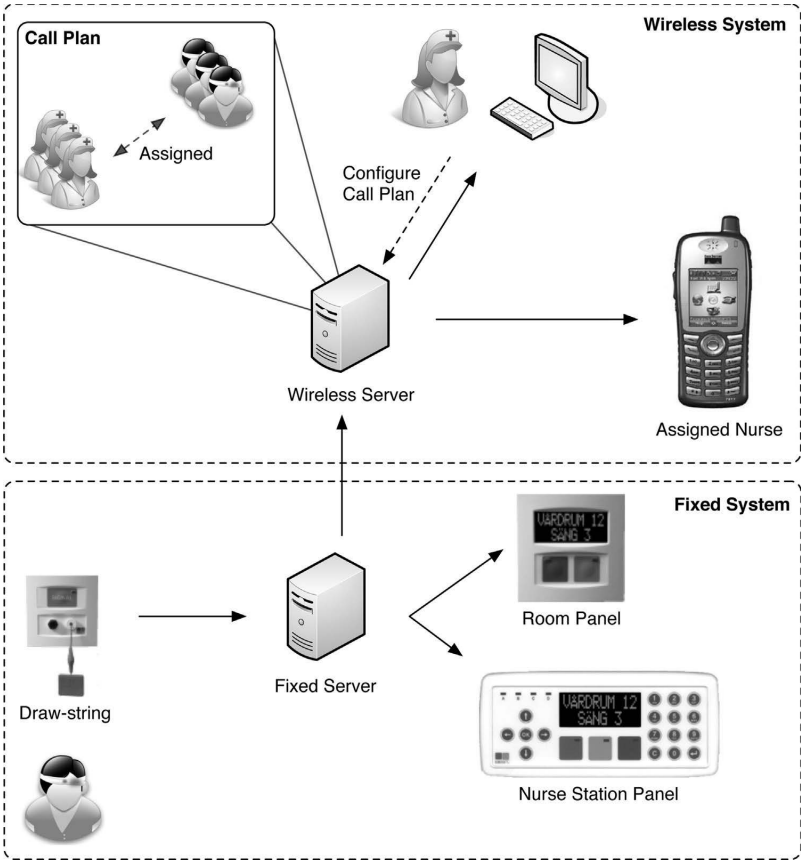

Fig. 2 – An overview of the deployed nurse call system. The patient (left lower corner) uses a drawstring to issue a nurse call. The call is then delivered to various fixed displays and to the wireless phone of the nurse assigned the responsibility of the calling patient.

interruptions and hence improve the wireless nurse call system.

3. Research setting

We studied a wireless nurse call system that had quite recently been introduced at a major Norwegian University hospital, where the system had been deployed in various departments. A typical department is separated into smaller logical units called bed areas. Each bed area consists of seven to nine patient rooms, all of which can accommodate one patient, and a nurse station, where nurses carry out administrative tasks. Nurses are usually assigned to one of the bed areas in a department. The floor plan of a typical department is illustrated in Fig. 1.

The wireless nurse call system allows patients to call for nurses' assistance by pressing a button or using a drawstring inside a room. The nurse call is then delivered as a signal that carries the room number from which the nurse call originated to both public displays and a nurse's wireless phone. The system overview in Fig. 2 illustrates how a nurse call signal is sent from the patient to various devices so that the nurses become aware of the nurse call.

The overall nurse call system consists of two subsystems (Fig. 2). A new wireless nurse call system has been integrated into a previous, fixed nurse call system. The fixed system delivers nurse calls on public screens placed inside each room and in the nurse station. The wireless part of the system includes a wireless phone for each individual nurse. In addition to phone calls, the nurses also receive nurse calls on the wireless phones. A server in the wireless system handles each nurse call and decides, based on a call plan, which nurse should receive a given nurse call. A distinct feature of the wireless component of the system, if the call plan is properly configured, is that the primary nurse of the calling patient will always receive the nurse call on his or her wireless phone first. However, if the nurse is busy, the nurse call can be dismissed via the phone's user interface. The nurse call is then forwarded to the next nurse in the call plan.

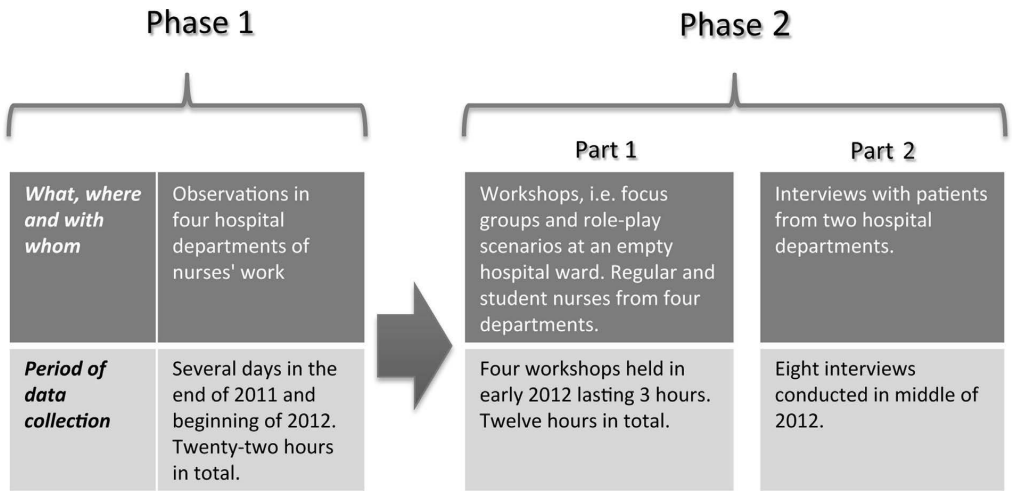

Fig. 3 – Overview of the data material.

Whenever a nurse attends to a nurse call, he or she must enter the room from which the call originated and press a green button on the room panel mounted on a wall inside this room. This de-activates the nurse call and marks the nurse's presence in the room within the system. Nurse calls and emergency alarms are displayed on the room panel after the nurse's presence has been marked.

4. Research methods and analytical approach

A qualitative methodology was applied in our study of the wireless nurse call system. The data were collected over several periods in two main phases. Fig. 3 illustrates the two main data collection phases. In the first phase, the aim was to establish a general understanding of the nurses' work at the hospital and the overall nurse call system in daily use. To do so, we conducted participatory observations and document studies that were in line with rapid ethnography [42]. Previous studies were also re-examined, as suggested in [43], to discover more about the domain (e.g., [6,44,45]).

The observations in phase one were held in four departments at a major Norwegian University hospital. By taking on the role of *observer as participant* [46], we occasionally interacted with nurses to verify ongoing observations. The observations were conducted over several days in the end of 2011 and in the beginning of 2012 and lasted for 22 h in total. The information gained from phase one was then used to design workshops with nurses (part one, phase two) from the following four departments: Infection, Thorax, Geriatric and Orthopaedic.

Four workshops were held in early 2012 with a total of twenty-one regular and student nurses from the four hospital departments mentioned above. We participated in the workshops as mediators and acted as patients in the role-play scenarios. The workshops were recorded using video cameras to enable a detailed analysis afterwards [47,48]. Each workshop lasted for 3 h, yielding a total of 12 h of videotaped data material. The workshops began with a focus group interview that discussed the general work practices related to the wireless nurse call system in the four hospital departments. Thereafter, a number of scenarios [49] were played out using role-play [50]. The decision to use scenarios and role-play, i.e., an experimental simulation, was made in an attempt to increase the precision of the study while retaining some realism [51]. To further increase the realism of the study [51], the workshops were held at an empty bed area inside the hospital, allowing us to use the deployed system in a setting familiar to the nurses. The scenarios were designed to highlight problematic situations related to the use of the wireless nurse call system, particularly interruptive situations identified during phase one of the study. For example, in one of the scenarios, the acting nurse in the role-play was instructed to discuss a serious matter with a patient. While the acting nurse was talking to the patient, a nurse call was issued to the acting nurse from another patient with a serious heart condition. Discussions then arose regarding the implications of the nurse call and how the situation would have been handled, as well as how it could have been handled differently. After the role-play scenarios, another focus group interview was held, in which the nurses reflected on matters that were brought up during the role-play session.

Finally, in part two of phase two, interviews were conducted with eight patients admitted to two of the four departments included in the study. The design of the semi-structured interview was based on findings from both phase one and part one of phase two. The interviews focused on issues relating to the use of the wireless nurse call system in general and challenges with patients' use of this system in particular. Each interview lasted approximately 30 min and was recorded on an audio recorder. The age of the patients varied from below 20 to 80 years old. The patients had been admitted to the hospital for 48 h or more before the interview.

The video material gathered from the workshops and the audio recordings from the interviews have been transcribed and analysed in line with the stepwise deductive-inductive (SDI) approach [52]. Acknowledging that a combination of several analytical strategies are beneficial [53], the SDI approach combines inductive and deductive approaches. The analysis of the transcribed material was conducted by first coding transcriptions in an open coding fashion. The codes were then categorized, and a few main concepts were ultimately derived. During the later stages of the analysis, established theoretical concepts identified in the literature were applied as a sensitizing tool.[2]

The study has been approved by the Norwegian Social Science Data Services. In addition to collecting an informed consent form from all participants, the participants' confidentiality has been secured by de-identifying and securely storing the collected data material.

5. Results

5.1. *System use: support for department diversity*

The wireless nurse call system described earlier has been deployed at several departments in the hospital. While the need for the patients to be able to call for a nurse is similar in all these departments, the context in which this is done can differ dramatically. To illustrate this, the thorax and infection departments are used as examples. These two departments are presented because they represent the two extremities of the departments included in the study with regard to wireless nurse call system use.

The thorax department most often nurses patients with severe heart injuries. Many of these patients are either waiting for a surgery or are recovering from a recent surgery. A nurse call from any of these patients is therefore treated as a high priority. Therefore, the nurses at this department always carry the wireless phones with them. Nurses at this department told us that they take collective responsibility for ensuring that everyone in the department has activated their wireless phones and is receiving nurse calls on them.

At the infection department, on the other hand, there are several infection rooms, where patients are contained to minimize the risk of spreading disease. While an isolation room looks like a normal patient room, the entryway includes a gowning room, where nurses dress in sterile clothes before they enter the patient room. Due to the infection risk, it is not appropriate to use wireless phones inside isolation rooms. During a workshop, a nurse from the infection department informed us about the nurses' usage of the wireless phones: "*One difficulty for us at the infection department is that we have so many isolation rooms. It doesn't work*." The nurse mentioned this as being one of the primary reasons for the nurses' sparse use of the wireless phones in the infection department. Instead, they rely on the fixed part of the nurse call system to become aware of nurse calls (Fig. 2).

5.2. *System challenges*

This section focuses specifically on the issues and challenges related to the wireless nurse call system with regard to the interruptions it creates. The system allows nurses become aware of a nurse call, and the nurses must then decide whether to respond to the call or not. In certain situations, due to the complexity of the context, this presents a major challenge for the nurses.

5.2.1. *Interruptions require a decision*

Based on the observations carried out in phase one of the study, we identified a number of situations in which the wireless nurse call system caused more disruption than in other situations. We therefore designed a number of scenarios for the workshops with the aim of replicating these problematic situations. One such scenario depicted a situation in which the acting nurse was to change a wound dressing of a patient and therefore needed to dress in sterile clothing. In the middle of the procedure, a nurse call was issued to the acting nurse. In this situation, the acting nurse had to decide whether to leave the patient to respond to the call or continue with the present activity. The reply from one of the nurses at the thorax department when she was asked how such a situation is experienced summarizes the nurses' reflections: "*I think it is stressful (.), then I need to decide whether to leave or not*." Another nurse in the thorax department expressed having felt irritation when a nurse call was issued in a similar situation: "*If I'm inserting a CVC*[3] *(.), which can take a long time (.), the alarm keeps ringing all the time because I have pressed the green button [marked presence] (.), and you really need to concentrate on what you are doing (.), then you have to look away to the wall display (.), wondering if no one is going to take that alarm (.), and you are there in the middle of a sterile procedure that takes a long time (.), it is very irritating when the alarm just keeps ringing*."

5.2.2. *The complexity of context*

In general, nurses from all the departments are reluctant to leave a patient that they are nursing. However, there are circumstances in which they wish to do so. In the discussions after the role-play scenarios, it became evident that there are a number of factors that play a part in making the decision regarding whether to leave or not.

5.2.2.1. *Current situation (activity)*. The situation that the nurses find themselves in plays a significant role in deciding whether to abort an ongoing activity. One example of such a situation is when the nurse is in the middle of changing a wound dressing in an isolation room and a nurse call is issued. A nurse from the infection department reflected on this situation during the workshop: "*If I'm in the middle of changing a wound dressing I won't go out to answer it (.), but if I'm just talking to the patient then I'd go out to take it*." While this nurse claimed that the phone would have been answered when talking to a patient, other nurses mentioned that it depends on the nature of the discussion. If it was an anxious patient that the nurse

[2] For the analysis, the qualitative data analysis program HyperRESEARCH was used.

[3] Central venous catheter.

is discussing a serious matter with, the nurses reported that they would be more reluctant to leave the patient.

5.2.2.2. *Call context*. In the case of a phone call, nurses also expressed that their reactions depend on who is calling and what the call is about. When the nurses were asked what they would do if they were expecting a call from the laboratory regarding a blood sample, a nurse in the infection department answered, "*If I was expecting a call then I would most probably go to answer it*." Similarly, the nurses mentioned that if the phone call was from someone that they had been trying to reach for some time, then they then would likely answer the call. Otherwise, it might be difficult to get into contact with the person afterwards.

5.2.2.3. *Patient relationship*. Another deciding factor is the nurse's relationship with the patient calling. At all departments included in the study, each nurse is assigned to one or several patients that the nurses has the main responsibility for during a work shift. In some departments, this responsibility is also reflected in the system, which means that the call plan is configured so that the responsible nurse will receive nurse calls from his or her assigned patients first on the wireless phone. The nurses said that they feel primarily responsible for visiting their assigned patients, whereas nurse calls from other patients are more easily ignored. A nurse from the thorax department explained, "*It depends on who you have the responsibility for (.), in practice you have one, two or three patients that are your responsibility (.), or those that you attend to first (.), and then you go immediately (.), but if any of the others are calling then you wait (. . .), there is an emphasis on the fact that they are your patients (.), if it wasn't my patient calling then I'd waited (.), but if it was my patient I would respond to the call*."

In the interviews, some of the patients reported that various nurses often responded to their nurse calls, although they were assigned a primary nurse. However, most patients were happy to receive attention from different nurses, pointing out that the important thing was that they received assistance in a timely manner. However, patients also reported that it could sometimes be difficult to relate to many different nurses. A patient in the infection department who had ten nurses visiting him explained, "*. . . it's a lot (.), then you don't have the energy to tell much about yourself (.), you think that next time it might be someone else (.), you might have asked about something (.), but then you don't have the energy to do so.*" Other patients also reported that they would have felt more secure if they had only one primary contact to relate to. This could also have reduced misunderstandings, the patients reported.

Furthermore, patients reported that there are certain situations in which they prefer their primary nurse to attend to the nurse call. When asked whether it matters who actually responds to a nurse call that relates specifically to one's own illness, one patient answered, "*I would say that it does (.), there is one that should follow up on me (.), so I would like to turn to that nurse with these types of questions*." During the workshops, nurses also explained that in certain situations, such as when a patient needs to be followed up on by the same nurse, an agreement is made so that everyone is aware of the situation. The nurses then plan the day so that the primary nurse for that patient responds to all nurse calls. Thus, in these situations, it is important that it is the primary nurse who receives the nurse call.

5.2.2.4. *Patient condition*. The nurses mentioned that if they believe the condition of the patient calling to be serious, they are also more likely to attend to the nurse call, even if they are occupied with another patient. A nurse from the infection department explained, "*If it is a seriously ill patient (.), or if the patient is very anxious (. . .), then I might have to tell the patient I'm currently visiting that I have to go and respond to the call*." Similarly, when asked under what circumstances they would leave a visited patient, a nurse from the orthopaedic department responded with the following: "*If I know what patient is calling (.), and that it is highly probable that the patient has fallen to the floor.*"

With regard to how well nurses know the patients who are not their primary responsibility, a nurse from the orthopaedic department explained, "*That varies from little to no knowledge at all (.), to just the things that you picked up during the handover meeting.*" Nurses in the thorax department also revealed that they had limited knowledge of patients who were not their primary responsibility.

Nurses reported that it is stressful when they do not know the patient calling very well and that in these cases, they in these cases often make guesses on the urgency of the call. A nurse from the infection department explained: "*If I know it is a patient that calls for minor things (.), if you know the patient (.), I'm not psychic (.), but I assume that he can wait for a while (.), but if I didn't know the patient I would become a bit stressed and would have had to tell the patient: sorry I'll come back later (.), and gone out and responded to the nurse call*"

In contrast, when the patients were asked, most of them were confident that the nurses knew the patients well and were updated regarding their conditions. Patients therefore assumed that the nurses were well-equipped to judge the urgency of their calls and able to prioritize accordingly. When asked how a nurse would be able to know whether a matter was urgent or not, one patient responded, "*I had a conversation with the nurse (.), so they know my condition and therefore know whether it is urgent or not when I'm calling.*"

5.2.3. *An overview of existing system challenges*

The following highlights summarize the main challenges that nurses and patients face with the deployed wireless nurse call system:

- Being interrupted in the form of a nurse call or a phone call while caring for a patient creates additional stress for nurses. Nurses must then decide whether to ignore the call or to leave the visited patient.
- A number of contextual factors play a role in deciding whether to leave a patient or not, further complicating the nurses' situation.
- Nurses are less equipped to assess the urgency of nurse calls from patients that are not their main responsibility. Still, patients expect them to do so successfully.
- Patients prefer to be in contact with as few nurses as possible. In some situations, they expect their primary nurse to respond to the nurse call.

5.3. *Nurses' strategies to manage interruptions*

The previous section brought up challenges associated with the wireless nurse call system. This section examines the various strategies that nurses rely on to manage these challenges.

5.3.1. *Interdependent collaboration among nurses*

The deployed wireless nurse call system allows the nurses to become aware of contact requests in the form of nurse calls and phone calls through public displays and the wireless phones. Although these notifications are useful in learning about an event, nurses also have strategies they use to inform one another about what is going on. For example, nurses explain that they try to maintain an overview of what their colleagues are doing through both observation and small talk. One nurse explained, "*You talk to your colleagues (.), this is going to take some time can you? (.), you make agreements (.), so communication is important regardless of the system*." Another nurse stated, "*Usually I know where the other three nurses are (.), in my bed area (.), so if I'm busy changing a wound dressing I don't go out and answer a nurse call (. . .), unless I know that the others are busy with something*." Nurses explain how they prioritize their own activities based on what their colleagues are doing. If, for example, another nurse is busy, a nurse explained, "*. . . then we are a bit more out (.), in the hallway (.), so that we don't make ourselves unavailable*." The nurse explained that during situations like these, they avoid taking on activities that would presumably require a great deal of time in order to be prepared if something unexpected occurs.

5.3.2. *Activities made visible*

During the workshops, nurses reported that they try to let their colleagues know in advance when they have planned an activity. As one nurse from the thorax department told us during one of the workshops, "*Often if you know that you'll be away for a while changing a wound dressing you usually tell someone else about it*." By informing the other nurses about an activity, the nurses hand over the responsibility of answering nurse calls from their assigned patients to the other nurses while they are busy. This strategy, the nurses reported, relieves stress in situations in which a nurse becomes aware of a nurse call while attending another patient because he or she knows that a colleague will care for the calling patient. A nurse from the orthopaedic department explained, "*It might be that there is a need to change a wound dressing (.), if someone has bled through the dressing (. . .), then I just have to tell the others before I'm going to change it (.), that I need to be able to finish so they have to respond to the nurse calls (.), so they don't make themselves unavailable (. . .), I don't want to go into a situation where I risk having to leave in the middle of the procedure*." They sometimes have complex wound dressing changes at the orthopaedic department. These require a long time, and they do not want to abort such procedures.

However, there are times when nurses do not tell the other nurses that they will be busy. After playing out a scenario in which the acting nurse received a nurse call while visiting an insecure patient, the acting nurse explained, "*If I'm talking to a patient, it's not always the case that I have told anyone about it (.), we don't do that every time we visit a patient*." A nurse from the thorax department also informed us that it is difficult to anticipate the time required when entering a patient room, "*You cannot know how the patient is before you enter the room (.), often you think that you are just making a short visit and then you end up there for quite a while (.), the patient might be contact seeking or afraid*." The nurses expressed concern that in such a situation, in which no one has been told about the prolonged visit, there might not be anyone available to answer nurse calls from other patients.

5.3.3. *Monitoring the situation*

In situations in which the nurse has not told anyone about his or her activities, nurses employ alternate strategies to ensure that the patients receive attention. A nurse from the thorax department reported the following during the workshop when discussing how to handle a nurse call while busy with another patient: "*You may have put your head out in the hallway to see if there is someone who can answer the call*." A nurse from the geriatric department added, "*And give a shout if you didn't see anyone*." Because the nurses are reluctant to leave their patients in these situations, they try to get a better understanding of the situation at the bed area by having a look into the hallway. If no other nurses can be seen, the nurses infer that their colleagues are busy as well, making them more inclined to decide to visit the calling patient and abort the current activity. However, as acknowledged by nurses from the infection department, in isolation rooms, it is not as easy to "*have a look in the hallway*", because of the risk of spreading diseases.

According to the nurses, they also decide whether colleagues are busy or not on the basis of how many times a nurse call rings. When asked during one of the workshops how many times the nurses would let the call ring before answering a nurse call from a patient who was not their primary responsibility, one nurse from the orthopaedic department answered, "*Before I came here [to the workshop] a room was calling but I didn't see any of the responsible nurses for that room (.), and then I responded after it had rung for a couple of times (.), if I don't see the other nurses then I assume that they are in another room or doing something else*." Another nurse from the same department also reported the following, reflecting on a workshop scenario in which the nurse was busy with a patient: "*I just thought that I'd let it ring for a couple of times (.), but after a while I felt that it would be best to go out and then come back again because there was no one else taking the call (.), so I would have told the patient that I needed to go out (.), and maybe gotten someone else to attend to him*." Because the nurses do not always have an understanding of what their colleagues are doing, they make assumptions based on various sources of information. Fig. 4 illustrates a scenario that was played through during one of the workshops, in which the acting nurse dismissed an incoming nurse call three times before finally aborting the current activity to visit the calling patient.

5.3.4. *An overview of nurses' strategies to manage interruptions*

This section has presented varying strategies that nurses rely on to manage interruptions caused by the wireless nurse call system. The following list summarizes the strategies:

- Nurses inform colleagues about the activities that they plan to undertake. They do so to ensure that someone else

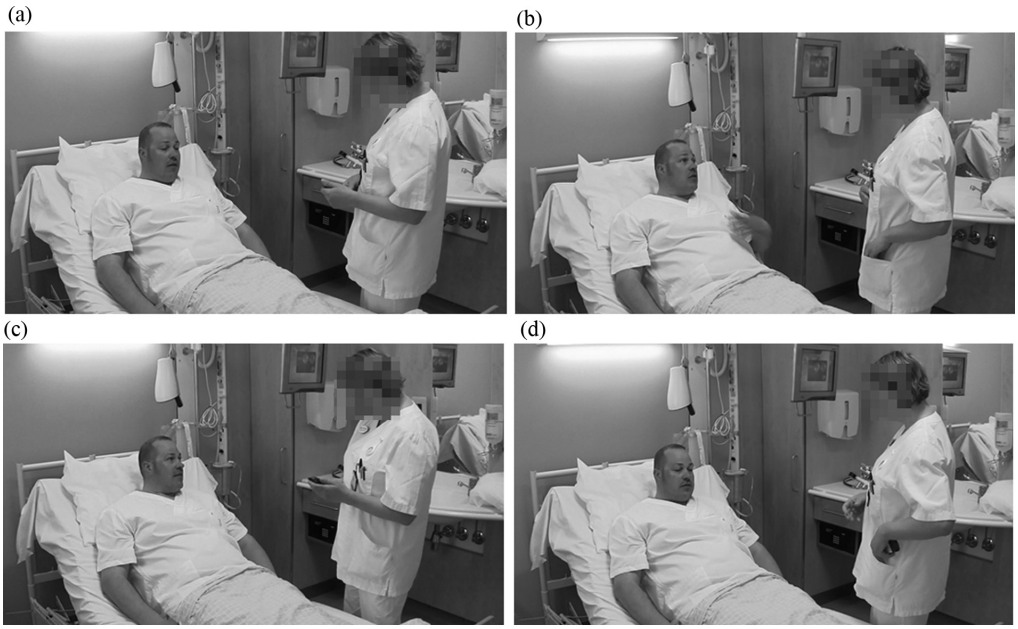

Fig. 4 – Nurse picks up the ringing phone to dismiss an incoming nurse call while talking to a patient. Because no other nurse responded to the nurse call, the call kept coming back to the acting nurse. The nurse dismissed the call three times before deciding to abort the discussion and visit the calling patient.

is aware of their situation so that these individuals can respond to nurse calls during that time.
- Nurses monitor the situation in the department to find out whether they need to respond to the call or someone else is able to.
- Nurses prioritize their own activities based on colleagues' availability.

6. Discussion

6.1. *The duality of interruptions*

Let us recap Section 5. Nurses rely on various strategies, both formal and informal, to obtain and provide information with regard to one another's availability. However, the use of the wireless nurse call system leads to explicit interruptions related to nurses' ongoing work. This particularly affects coordination and collaboration. However, it is important to note that interruptions are to be expected given the type of nurse work we have observed in the departments. Nevertheless, today's wireless nurse call system sometimes causes more harm than benefit, particularly for the nurses themselves. For example, we have seen that nurses do not want to have to deal with nurse calls or calls through the wireless phone when they are dressed in sterile equipment. This is regarded as stressful. Furthermore, nurses do not wish to be interrupted by a nurse call via the room panel when they are visiting a patient. Nurses feel that this removes their focus from the current procedure. On the other hand, interruptions are sometimes desirable, even though the nurses may have to stop their current activities. This can be the case when waiting for a specific test result that the nurse considers more important than the current activity, such as a mundane conversation with a patient inside the patient's room. We have also seen that nurses want to prioritize nurse calls from the patients they themselves have primary responsibility for over other nurses' patients. On special occasions, for example, when a patient needs to be followed up on by a specific nurse, nurse calls must reach that nurse regardless of the situation. Hence, the social and relational contexts tied to an interruption [25,27] are undoubtedly significant, as seen in these examples.

Like Grundgeiger and Sanderson, we must therefore distinguish between interruptions that are desirable or valuable and interruptions that are unwanted or unnecessary given the situation the nurse is in [26]. This duality regarding interruptions thus indicates the complexity of the context the system is operated in. It is the desirable interruptions we want to facilitate, and it is the latter we want to limit or possibly even exclude. Indiscriminately designing novel functionality for enhanced awareness among nurses via the wireless nurse call system in order to reduce interruptions must be approached with caution. As we have seen in Section 5, this is extremely context-dependent, and subtle nuances sometimes determine whether an interruption is regarded as unwanted or not by a particular nurse. Consequently, the complexity inherent in departmental work [1–3] makes it particularly challenging to

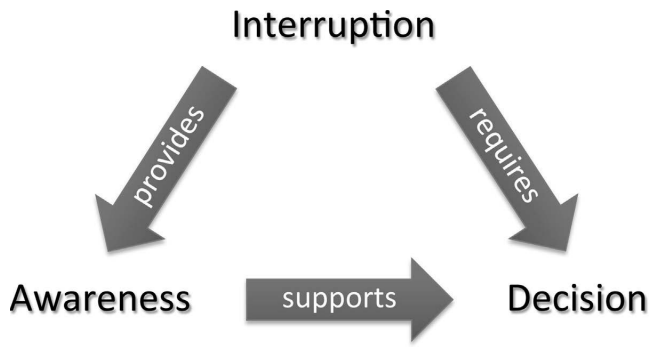

Fig. 5 – An illustration of the relationship between interruption, awareness and decision in the context of the wireless nurse call system.

design novel functionality aimed at facilitating "good interruptions" [26].

6.2. *Designing for awareness*

As the results indicate, in line with Schmidt [32], nurses' awareness of their colleagues' activities is an integrated aspect of their work practice. They continually *display* their activities through interactions with one another, for example, before they are about to make a wound dressing change. Similarly, nurses *monitor* the situation in the department to know what their colleagues are doing. Examples of this, as described in Section 5.3.3, occur when nurses check the hallway to search for available colleagues or infer their colleagues' availability based on the number of times a nurse call rings. Hence, nurses' awareness of one another's activities is mainly arrived at through social interaction, as discussed by Heath et al. [40].[4] Therefore, instead of restricting the analysis to the purely cognitive side of awareness, that is, situational awareness [31], we have sought to understand the social processes that nurses engage in to maintain an awareness of their surroundings. We argue that a system should not seek to replace these social strategies through which awareness is achieved, but rather provide support for and strengthen these strategies.

As already discussed, the wireless nurse call system mediates awareness through the interruptions that it generates in the form of nurse calls. While these interruptions enhance nurses' awareness of the situation, they must also be handled more-or-less instantly. Hence, nurses must decide whether to respond to a nurse call or not. As the results hint at, nurses' awareness of colleagues' activities supports this decision. If they know that someone else can respond to a nurse call while they are busy, this relieves the stress of the situation and allows them to focus on the task at hand. This relationship between interruption, awareness and decision is illustrated in Fig. 5.

The decision to leave the current situation to respond to the call is not trivial, because many factors play a role in this decision. One key factor, however, is the knowledge of the availability of colleagues. However, in some instances, if, for example, a patient visit takes an unanticipated turn that requires the nurse to spend more time with the patient, colleagues will most often be unaware of this. In line with research that seeks to support awareness through computer systems [54], we suggest that technology could allow nurses to communicate their availability to colleagues, for example, when no agreement has been made in advance, so as to strengthen nurses' awareness in order to support their decisions (Fig. 5). Furthermore, this availability status could be distributed to all nurses in a bed area. Nurses' statuses could be inferred automatically by the system whenever the nurse enters a patient room or be neatly integrated with the current practice of marking a nurse's presence when entering a patient room. Thus, whenever a nurse receives a nurse call, the statuses of the other nurses at the bed area would also be visible on the phone and the room panel. This information could then help the nurse to make a more informed decision regarding whether to accept or reject the request and, in doing so, making the interruption less stressful.

On the basis of the result, we suggest that changing a nurse's availability status from "available" to something else should not block the incoming request to the nurse. Rather, in line with the *interruption value evaluation paradigm* [27], we propose that the nurse at the receiving end should make the ultimate judgement about whether to accept or reject a request. Instead, the notification through which nurses become aware of a request could be modified based on their current status [8]. When a nurse is not "available", the system could use a less intrusive notification to make nurses aware of this in order to reduce the impact of the interruption on, for example, an ongoing discussion with a patient. This approach would utilize the notification modification technique to manage interruptions and provide the nurses with information about the request that is available "at a glance" [27,55]. For phone calls, this information could include the name of the caller and perhaps some cue regarding the matter at hand [8].

[4] Although our analysis utilizes the concepts of Heath et al., our analysis differs in that we have not carried out the same type of detailed interaction analysis.

Table 1 – An overview of proposed system behaviour when designing to reduce the impact of unwanted interruptions and facilitate wanted interruptions for nurses.

Request type (to a nurse)	Unwanted interruption	Wanted interruption
Nurse call	Notify the nurse about the nurse call using a less disruptive notification. Provide information about colleagues' availability and urgency cues.	Route the nurse call first to the patient's primary nurse. If the nurse is unable to respond, forward the nurse call to an available nurse based on the nurse's availability status.
Phone call	Notify the nurse about the call using a less disruptive notification. Provide information about who is calling and what the call is about "at a glance".	Always try to make nurses aware of a phone call.

In this way, nurses would be notified about requests that they indeed wish to receive, regardless of their situation, but in a less disruptive way.

A distinct feature of the studied wireless nurse call system is that it always routes a nurse call to the calling patient's primary nurse first. This approach is supported by the results, which suggest that the primary nurse knows his or her patients best and should therefore be provided the opportunity to assess whether his or her presence with the calling patient in needed, especially because patients wish to stay in contact mainly with their primary nurse. However, if the primary nurse is not able to respond, the interruption should be made as non-disruptively as possible and forwarded to an available nurse. Because nurses who do not have a given patient as their main responsibility are less capable of assessing the urgency of the nurse call, urgency cues about the call could be communicated [8,56]. An overview of system behaviour when designing to manage interruptions by providing relevant information is illustrated in Table 1.

7. Conclusion

Our study has not only shown how nurses struggle with interruptions caused by the wireless phone but also how interruptions have a dual nature. Depending on a number of factors, including both the context of the nurse being interrupted and the context associated with the interruption, interruptions are either wanted or unwanted. In some contexts, interruptions create stress for the nurse, who must decide whether to remain focused on the current activity or abort the activity to respond to the interruption.

The study also investigated nurses' strategies in managing these interruptions. It shows how important nurses' awareness of one another's activities is when determining whether to abort an activity due to a call. Nurses maintain this awareness by actively making activities visible and monitoring the situation in their own bed area. Therefore, we suggest that technology should be designed to support nurses' awareness. The wireless nurse call system also allows nurses to become aware of requests made by patients who are their main responsibility. As the relationship between a nurse and a patient is important when evaluating an interruption, we suggest that the system should always try to make the responsible nurse aware of nurse calls from his or her assigned patients, irrespective of that nurse's availability status.

Summary points

What was already known on the topic:

- Wireless phones are suggested to support nurses' mobility and enhance availability.
- Interruptions caused by these devices have a negative impact on nurses' work and can lead to a decreased level of patient safety and quality of care.
- Little is known about how these technology-mediated interruptions are handled by nurses.

What this study added to our knowledge:

- Interruptions caused by the wireless phone have a dual nature, and several factors determine whether nurses wish to respond to an interruption.
- Nurses manage interruptions from nurse calls by maintaining an awareness of one other's activities.

8. Future work

Our findings show how nurses utilize their awareness of colleagues' activities and availability when deciding whether to respond to a nurse call. Similarly, they decide whether to take a phone call based on who is calling. However, as also discussed, the context surrounding an interruption is complex, and many factors play a role in this decision. Future work should further investigate nurses' strategies in handling these interruptions, especially what contextual information would be relevant for the nurses to receive, further facilitating their decision-making. Discovering how such contextual information could be gathered and communicated to the interrupted nurse should also be a part of future work.

Author contributions

Joakim Klemets and Tor Erik Evjemo contributed to the design, data collection, data analysis and writing.

Conflict of interest

The authors declare they have no conflict of interest in terms of the research or the development of the manuscript.

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PAPER 4

Availability communication: requirements for an awareness system to support nurses' handling of nurse calls

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Availability Communication: Requirements for an Awareness System to Support Nurses' Handling of Nurse Calls

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Abstract

The recent development of mobile technologies allows nurses to receive different types of requests anywhere. However, the interruptions generated by these devices often presents a challenge for nurses in their daily work in a hospital department. In previous inquires we have investigated nurses' strategies to managing technology-mediated interruptions in the form of nurse calls. This study reports on an effort to co-design a system that supports an important strategy employed by nurses. Through the involvement of domain experts, the study elicits requirements for an awareness system to support nurses' collaborative effort in handling nurse calls.

Keywords:

Awareness; Interruptions; Collaboration; Nurse Calls.

Introduction

Nursing work in a hospital department is characterized by complex cognitive work that involves continuous organisation, prioritisation and decision making [1]. Nurses can have multiple clinical and administrative tasks that simultaneously compete for their attention. To manage these challenges in order to provide high quality care, communication among nurses is fundamental [2, 3].

One important aspect of nurses' work is responding to nurse calls. Nurse call systems provide a means for patients to communicate their need of assistance to a nurse. Regardless of how the nurse calls are communicated to the nurse, they are likely to interrupt an ongoing task. This requires the called nurse to assess her availability for the nurse call and perhaps yet again re-prioritise and re-organise work. Therefore, nurse call systems have often been accused to be a source of interruptions that not always are appreciated, as they often disturb ongoing work [4-6]. Interruptions in these environments are also associated with reduced quality of care [7] and patient safety [8].

The intentions behind a nurse call can vary greatly, from toileting assistance or pain medication to information requests [9]. As most nurse call systems do not provide urgency clues, nurses need to decide, with sometimes limited information, whether they should abort an activity to respond to the nurse call or not. A decision that often is regarded as stressful [4, 6].

To date, limited literature exists that describes nurses' handling of nurse calls. Instead, previous research on nurse call systems investigated aspects such as patient satisfaction [10], reasons behind nurse calls [11], and attempts to limit nurse calls [9, 11]. Through ethnographical fieldwork, we previously investigated nurses' strategies in managing interruptions in the form of nurse calls [6, 12]. As a next step, the aim is to discover how a system could be designed to support these strategies.

Nurses assess their availability towards a nurse call based on a number of contextual factors, including their current activity, the relationship to the calling patient and the patient's condition [6]. A strategy employed by nurses to handle nurse calls is to hand over their patient responsibility in certain situations [12]. However, another important strategy identified in our previous studies is maintaining an awareness of colleagues' activities. The decision of whether to respond to a nurse call is highly influenced by this awareness [6].

Therefore, the main objectives in this study were to (1) co-design a system with end-users that supports nurses in maintaining awareness of colleagues' availability, and (2) to analyse the possible effects the proposed system could have on current work. Based on data from our previous studies, we developed a prototype system. The prototype was used as a trigger for further requirement elicitation and analysis in participatory design workshops [13] to achieve the study objectives.

Background

Awareness

Awareness is a central concept within the field of computer-supported cooperative work (CSCW) that is essential when one aims to support efficient coordination and collaboration among team members [14]. The perhaps most commonly used definition of awareness within CSCW is *"…an understanding of the activities of others, which provides a context for your own activity"* [15]. Schmidt discusses the problem that the notion of awareness is indeed ambiguous and that it needs to be understood as a person's awareness of *something* [16]. One relevant example would be activity awareness that is an essential part of collaboration between medical personnel in a hospital. Here, the awareness of colleagues' activities has direct influence on their own activity [17]. Further, Heath et al. discuss how awareness is achieved and sustained through social interaction that involves participants' sensitive monitoring and displaying of actions and activities [16, 18]. A key aspect is that the monitoring and displaying process can occur simultaneously as its own activity, requiring very little effort [19].

There has been extensive research into how technology could support awareness [14]. Within the healthcare domain, one

example is the AwarePhone approach that seeks to minimize interruptions by mediating context cues about the callee to the caller through the phone's address book [20]. The main focus in their study is how the mediated social awareness can enhance collaboration among health care workers who are not co-located. For example, allowing a nurse to consult a doctor more easily. Our focus, however, is to investigate how such an awareness system could be designed to support the handling of a specific type of interruption, that is nurse calls. Nurse calls differ from information requests in the form of phone calls in that the former is expected to be responded to more or less immediately, while that is not always the case for the latter.

Activity Awareness to Support Nurse Call Handling

A few years ago a new, wireless nurse call system was deployed at a Norwegian university hospital. The system allows patients to issue a nurse call by using a draw-string mounted inside each patient room. The signal is then delivered to nurses on both public displays and on wireless phones carried by the nurses. A call plan allows nurses to configure to which nurse a nurse call should be delivered first. If the primary nurse is not able to respond to the call, it can be forwarded to the next nurse. Nurses usually configure the call plan according to agreed patient responsibility. By doing so nurses' receive nurse calls on the wireless phone from patients they have the primary responsibility for first [12].

Through observations and workshops, we investigated nurses' strategies to handle nurse calls at the hospital where the above system was deployed [6]. The findings report a number of contextual factors that play a role in nurses' decision whether to respond to a nurse call in a busy situation. An important factor, however, is their awareness of colleagues' activities.

Nurses continuously monitor colleagues' activities as well as their own, in order to know who is available. Knowing that someone is available when, for example, situated in a patient room talking to an anxious patient, allows the nurse to remain focused on the task at hand, trusting that a colleague will take care of the call. Similarly, nurses prioritize their own activities based on their awareness of colleagues' activities. For example, if a nurse is aware of that his or her colleagues are busy and unable to respond to nurse calls, the nurse may not undertake an activity that will make him or her unavailable as well. Rather, the nurse chooses to remain available in order to act as a backup in responding to nurse calls for the other nurses [6].

However, it is not always the case that nurses are able to monitor colleagues or display their own activities. Nurses report that sometimes a patient visit can take an unexpected turn. In these cases, when nurses normally have not told anyone about the prolonged stay, it might be that no one is able to respond to nurse calls [6].

Methods

Research Design

To meet the first objective, to co-design a system with domain experts, participatory design workshops were held. To trigger discussion, and to demonstrate to the participants technological possibilities, a prototype was developed [21]. The prototype system allowed nurses to communicate their availability status through the wireless phone, as well as, become aware of colleagues availability when a nurse call was issued.

Mogensen and Trigg discuss how artefacts can be used to foster analysis of both current and future practice in participatory design workshops [13]. Scenarios were designed for the workshop where the prototype was used to address the second objective, to analyse possible effects of the designed technology.

Two workshops were held with nine female student nurses from five different hospital departments. All participants had at least one month of experience working at the hospital and using the wireless nurse call system. The workshops were held in a usability lab furnished as a hospital ward and videotaped to facilitate detailed data analysis afterwards. Each workshop lasted for about three hours. After an initial focus group interview, the workshops also included a role-play session, before allowing participants to reflect on their experience with the prototype in another focus group interview.

The scenarios for the role-play session were based on our previous observational studies of the system at the hospital. The scenarios aimed to replicate tricky situations where the acting nurse had to decide whether or not to abort the current activity in order to respond to a nurse call. Participants were instructed to use the prototype in the scenarios. The methodology applied was also influenced by scenario-based design, often employed in the design of collaborative systems [22], and the use of role-play in the design of mobile systems [23].

Prototype

The prototype was developed using a conceptual user interface design tool. The prototype was deployed on an iPhone and allowed users to interact with the application's different screens and menus. However, as the prototype only implemented the user interface, it was not possible to send messages between the phones. Additionally, the application did not receive nurse calls. Therefore, we configured the phones to display a nurse call before the scenario (Figure 1). Then, during the scenario, one of the researchers would play a sound that indicated that the acting nurse received a nurse call.

Figure 1 - Colleagues' statuses are displayed on the phone when a nurse receives a nurse call

In addition to displaying the room number from where the call was initiated, the prototype also displays the availability status for each colleague in the ward. The nurse can then use this information in deciding whether to reject ("avvis") or accept the nurse call ("ok"). Through the user interface, nurses can set their availability status to: available (green), busy (yellow), or unavailable (red), as illustrated in Figure 2. The idea was that a nurse could use the green indication when not occupied with anything important and is able to respond to nurse calls. Yellow indicates that the nurse is busy, but that the task is not of the highest importance. The red indicator communicates that the nurse is undertaking an important task that the nurse would not like to forsake.

Figure 2 - Nurses can be choose from three different availability statuses

Results

Availability Monitoring

When presented with the prototype, nurses' initial reactions were very positive. A nurse reflected: *"That's clever, then you see whether someone can respond to it or not, or if you have to assess responding to it yourself*". The nurses explained that in a situation where they are occupied with another task, it relives the decision making process if they know that there are other colleagues who can respond to the call, but also that this enhanced awareness of their colleagues' availability could alter their decision to engage in an activity in order to remain an available resource. A nurse explained: *"if I see that many have set themselves to busy I would have waited, it would have been great to have an overview really"*.

This resonates with nurses' current practice of monitoring their colleagues' activities and availability [6]. The nurses reported trying to keep each other informed about activities they undertake. However, as a nurse stated, it is impossible to know where everyone is all the time. For example, nurses said if they are just bringing something from a different floor they do not tell anyone about it. They also admit that it is more difficult to keep track of colleagues' activities while inside a patient room.

Availability Displaying

Being able to display ones' availability through the system to colleagues in times where it would have otherwise been tricky to do so, was seen as a benefit. According to the nurses, this would allow them a higher degree of focus on the task they are performing. A nurse said: *"It would have been useful to be able to give a notice (.), or to lock ones phone (.), so that when you're in a situation that is difficult to leave (.), that some of your responsibility of responding to nurse calls is taken away if there are others who are able to respond during that time"*.

In the focus group discussions, nurses expressed uncertainty in how to set ones' availability status in different situations. The prototype allowed nurses to set their availability to green, yellow, or red. But, it was far from clear in what situation a nurse's availability would be set, for example, to yellow or red. When discussing how the system should behave when different statuses were set, no nurse wished to make themselves completely unavailable (or unreachable) in any situation. They rather wished to indicate that they are occupied at the moment but not completely block incoming requests. While discussing a scenario where the acting nurse was visiting an anxious patient, a nurse said: *"I would never had set myself as unavailable – that is completely unavailable, no, because if the others are busy with various things that they can't leave, then I'm able to leave a patient who is a bit anxious if I explain myself and ask if I can leave for just two minutes"*. Hence, nurses wished to remain in the "loop" even when occupied to remain aware of what was going on outside. As a nurse told: *"You can't remain an overview [of what is happening] if you're completely unavailable or blocked"*. Especially at night shifts, were there are fewer nurses working, it important that nurses are notified about a nurse call even while "unavailable". A nurse explained: *"during the night for example (.), it isn't possible (.), then you are usually alone at the bed area (.), perhaps together with an assistance nurse"*.

One concern the nurses voiced was the extra work maintaining their status would require. Although they saw the benefit, they were afraid it would not be used or that they would forget to change their statuses. Therefore, they suggested the status of a nurse should be changed automatically whenever he or she enters and leaves a patient room. Further, it was proposed that there should be a timer, which would remind the nurses to change their availability back to green after some time.

Adaptive Notification Profile

In the deployed system at the hospital, when a nurse call is issued, nurses are notified through wall panels and the wireless phone. The wall panel where a nurse has marked his or her presence displays the room number and makes an alarming sound. The wireless phone also plays a ringtone when a nurse call is received. The wireless phone at the hospital is configured so that nurses are not able to turn the volume of the ring signal below a certain level.

In the focus group discussions it was evident that the nurses did not appreciate the rigid notification scheme. Nurses felt the ringing was too excessive, especially inside a patient room. A nurse said: *"Inside the room it is quite quiet so you don't need to have such a severe sound"*. Similarly, a nurse expressed that *"there is no point in having alarms both on the phone and on the wall"* inside a patient room. Nurses said the many alarms made it more difficult to focus on the patient they were caring for.

Instead nurses propose that the notification should be modified according to their availability status. A vibration, they explain, would be enough to make them aware of a nurse call in situations where they, for example, are busy with another patient. However, if a nurse call is not responded to by anyone after some time, nurses suggested the notification could become more persuasive. Another nurse proposed that the time the calling patient had waited for a response could be displayed together with the notification.

System Interaction and Feedback

After having forwarded a nurse call, nurses explained that the calling patients do their thoughts, making them wonder whether the patient received help or not. As this further takes some of their attention away from their current task, they said that they would wish to receive feedback, after having dismissed a nurse call, as to whether someone else responded. A nurse proposed that the room number displayed on the wall panel could change colour when a nurse confirmed that he or she will respond to the call. Another nurse confirmed: *"Yes, a type of confirmation that tells you that the nurse call you forwarded has been responded to"*.

Further, the nurses proposed that feedback should be provided to the patient that someone is on their way. The current system does not provide any information to the patient about whether a nurse has noticed their request.

During the focus group interview the nurses explained that the phones are badly suited for sterile environments and the phones should not be exposed in these situations. A badly designed user interface, which required too much attention, was also mentioned as a reason why the phones were not used. The nurses felt that interacting with the phones took too

much focus away from, for example, a visited patient. When asked how they would like to be notified about a nurse call, a nurse explained: *"To have a look at the wall-panel is not as disruptive as to pick up and look at the phone"*. Instead nurses preferred to use the wall-mounted displays to learn about a nurse call and to respond to them. It was suggested that colleagues' availability status should be displayed on public displays, to make the information accessible "at-a-glance". A nurse said: *"I think that the proposal made was very good, that the sound is turned off, and that you instead see it on the wall-panel"*.

Expected Effects

One expected effect of the new functionality the nurses discussed was that it would allow them to more fully focus on the patient they are nursing if they knew there were others available to care for a calling patient. The nurses explained that if they are aware a colleague is able to respond to a nurse call, they then do not rush away from the patient as quickly as they would otherwise.

Further, they expected the availability awareness to reduce the wait-time for patients. Although the nurses said the current system works as it is, the proposed functionality would make it more effective. A nurse explained: *"With the new functionality it would probably be more efficient and faster, five minutes for us seems like nothing, but for the patients it probably feels like forever"*. If the nurses know their colleagues are unavailable, there is no need to let the nurse call keep calling to find out whether someone is able to respond.

Similarly, nurses revealed that, even if they are not busy with something, they sometime hesitate to respond to a nurse call from a patient that is not their assigned responsibility. A nurse explains: *"It is best for the patient to be [in] contact with the same nurse as much as possible, so if she isn't busy there is no reason for me to go in there, otherwise you could just enter any room at any time"*. However, if the primary nurse for the patient is not responding and cannot be seen, nurses said they do respond to the call. Providing quick access to information about the primary nurse's availability status could therefore also reduce response times to nurse calls.

Summary of Proposed Functionalies

The following list summarizes the additional functionalities to the proposed awarenss system that were suggested by the nurses during the workshops.

- Nurse calls should not be blocked even if status is set to yellow or red so nurses can remain aware of what is going on in the department
- The notification for nurse calls should be modified according to set availability status and for how long the calling patient has waited
- Status should be set automatically when entering or leaving a patient room
- A timer should remind the nurses to update their status if it has been set to yellow or red
- Allow nurses to interact with wall mounted displays instead of the phone (monitoring and displaying availability)

Discussion

A concern raised during the workshop was the extra work required in maintaining ones' status, which also was mentioned as an issue in [20]. While the proposed solution to update the status automatically based on location is appealing, there is reason to be cautious when building context-aware applications [24]. Brown and Randell argue for a defensive use of context that allows users to easily correct the system when it makes an erroneous inference [25]. The system could well infer a nurse's availability based on the location, but make this inference flexible. For example, the system could automatically set the nurses status to busy (yellow) when entering a patient room. At the same time, this selection could be displayed on the wall panel inside the room and allow the nurse to change the status by pressing either a green or red button on the wall panel.

As both monitoring and displaying of co-located colleagues requires barely any effort [18, 19], the difficulty is to achieve the same awareness when designing a system to support spatially distributed team members [14]. Some degree of automatic inference of availability helps at the displayer's side, but it is important to not overload monitor with too much information, as Gross discusses [14]. In their paper, Avrahami et al., demonstrate how people often over- and under-estimate the significance of various cues when estimating the interruptibility of a person. In their study, contextual variables such as whether a person was on the phone, drinking, reading, or socially engaged were included. Similarly, another study found that people use contextual cues to merely find out whether a person is present, rather than assessing whether the person can be interrupted or not [26]. While the cues included in these two studies were more related to typical office work, it does raise the question whether such cues are beneficial when estimating whether a person can be interrupted or not? The main rationale to merely display a colour code is to lessen the effort required by the one monitoring. However, whether such an indication is correctly estimated is not addressed in this study.

With regard to system interaction, the results hint that the nurses do not prefer to pick up the phone when a nurse call is issued. Therefore, one alternative could be to present the number of available nurses along with the nurse call on a wall panel. Further, the availability information could be made easily accessible on a big screen in the hallway. Allowing nurses to change their status on the publicly available screen might also provide advantages over doing so through the wireless phone in form of reduced effort.

Scholars have argued for the need of user-centred design approaches in the development of technological systems within the healthcare domain [27, 28]. Participatory design has previously been used in the design of nursing tools [29], and a similar method was adopted in this study. The approach, which combined artefacts in the form of scenarios and a prototype, was found to stimulate participants to come up with ideas on how to design the system; system features that maybe participants would not have been able to envisage otherwise. The prototype, although an early version, allowed the participating nurses to widen their technological frame of reference [30].

The artefacts also trigged analytical discussions on the expected effects of the proposed awareness system. A short summary of these would include; faster response times to nurse calls, less noise, and allow the nurse to remain more focused on the patient. Both the reduced response time and the notification modification based on status, contributes to less noise in a department. Less noise means that nurses can better focus on their work. Also, knowing that someone else is able to respond to an issued nurse call allows nurses to more fully remain focused on the current task.

A study limitation is that all participants were nurse students with limited experience. However, the initial prototype was designed based on a thorough study of nurses work practices that included both observations and workshops with experienced nurses [6]. Another limitation is the relatively small sample size. Yet, in usability studies, for example, there is no consensus of an optimal number of participants [31]. Some advocate that five is enough, while others suggest around ten participants [32], or even more [31].

Conclusion

Through a particpatory design approach, this study has investigated how an awareness system could be designed to support nurses' handling of nurse calls in a hospital setting. Requirements for a system that is sensitive to and communicates availability information of nurses has been elicted. Further, through co-analysis with domain experts, expected effects of the co-desiged system hints at increased focus on current tasks, reduced noise, and faster response times to nurse calls.

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PAPER 5

Does revealing contextual knowledge of the patient's intention help nurses' handling of nurse calls?

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Does revealing contextual knowledge of the patient's intention help nurses' handling of nurse calls?

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ABSTRACT

Objectives: An inherent part of nurses' work is to handle nurse calls that often cause challenging interruptions to ongoing activities. In situations when nurses are interrupted by a nurse call, they need to decide whether to continue focusing on the task at hand or to abort and respond to the nurse call. The difficult decision is often influenced by a number of factors and can have implications for patient safety and quality of care. The study investigates how technology could be designed to support nurses' handling of nurse calls by allowing patients to communicate a more contextualised message revealing their intention to the nurse when issuing a nurse call.
Methods: Through a qualitative methodology employing a scenario-based design approach, three different nurse call system concepts are evaluated by nurses from different departments of a Norwegian university hospital.
Results: Nurses find the uncertainty of not knowing the reason behind a nurse call stressful in situations where they are required to prioritise either the calling patient or a patient they are currently nursing. Providing information about a patient's intention behind a nurse call influences the nurse's decision to various degrees depending on the situation in which they find themselves and the information that is communicated. The nurses' reflections suggested that the message communicated should be designed to contain neither too little nor too much information about the patient's needs.
Conclusions: A nurse call system that allows nurses to discern the reason behind a nurse call allows them to make a more accurate decision and relieves stress. In particular, the information communicated would reduce uncertainty and lessen nurses' dependence on other factors in their decision. The design of such a system should, however, carefully consider the needs of the department in which it is deployed.
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1. Introduction

Nurse call systems have been common practice in hospitals for some time. Perhaps one of the earliest accounts of a nurse call system can be ascribed to Florence Nightingale in the mid-nineteenth century. In her letter to Lady Charlotte Canning, she described how a nurse call system, or 'a system of call bells' in Nightingale's [1] words, should consist of bells that ring in the corridor when a patient has pulled a drawstring. Possibly influenced by the design of a servants bell, Nightingale explained how the bells should have valves attached to them that would open so that nurses knew which patient had called [1]. While copper wires or radio waves have since replaced the drawstring in these systems, the core functionality is practically the same in many of today's modern nurse call systems.

Having access to a nurse call system has implications for both the sender and receiver of the request. A study of older patients in an intensive care unit reported that the nurse call system is a central factor in making the patient feel safe [2], which in turn is an important ingredient for a successful recovery [3]. Patients found assurance in that they could ring the bell if they needed someone to come and see them quickly, providing a means of controlling their situation [2,4]. Another study revealed that patients found it essential that their request is taken seriously [5].

For the nurses at the receiving end of the nurse call, the system is an important tool for making them aware of patients in need of

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help and to coordinate work [6,7]. However, as a number of studies have identified, nurses' struggle with the interruptions that nurse calls cause to their work [4,6,8–11]. Little effort has been placed on supporting nurses in an effective way to manage the inevitable interruptions caused by nurse calls [6]. Instead, previous work has examined how to reduce the number of interruptions, for example, through the introduction of additional nursing rounds [4,11]. Contradictorily, although there could be other factors involved, Tzeng and Yin [12] found that departments with the most frequent use of nurse calls had the fewest fall rates and the highest patient satisfaction score, encouraging the use of nurse calls among patients.

Several studies have investigated the reasons for nurse calls and found that many of these do not always require immediate attention [4,11,13]. Studies have found that nurses perceive nurse calls 'as an interruption to their work rather than a means of patient communication' [10]. Nurse calls are not perceived to be of a critical nature that requires nurses' immediate attention [13], although patients take an opposite perspective [5]. Therefore scholars have argued that more focus needs to be directed towards fostering attitudes that prioritise responding to nurse calls in order to promote patient-centred care and reduce patient incidences [5,13,14].

Some studies of nurse calls have suggested that enabling nurses to better anticipate what a nurse call is about could save time and improve patient care [11,15,16]. For example, in a study of nurse calls in an orthopaedic unit, Tzeng [5,17] proposed that new technology should support nurses' prioritisation of patient care duties. Such a nurse call system should allow the patient to indicate whether the call is (1) an urgent call, (2) a normal call, or (3) an orderly assistance. However, few such nurse call systems are implemented in hospitals today [17] and only a few have been reported on in scientific litterature [18,19]. Within healthcare, and other contexts, call screening has been advocated as a way to allow people to manage interruptions mediated through mobile phones [20–22]. Such an approach allows the interrupted to make a more informed decision whether the positive effects of an interruption outweigh the negative [20].

In our previous studies of nurses' handling of nurse calls at a Norwegian university hospital [6,7], we found that nurses' decisions regarding whether to respond to a nurse call depend on several contextual factors. The first factor identified is the *patient's condition*, as seriously ill patients are prioritised over others. Patients expect that nurses are updated on their condition and expect them to be able to prioritise accordingly. However, we also found that nurses are not always updated on the status of the patients that are not their primary responsibility, which makes the assessment more difficult. Second, the *situation of a nurse*, or the ongoing activity, influences the nurse's availability towards a nurse call. Third, the *nurse's relationship with the calling patient* plays a role; that is, whether the nurse has the primary responsibility for the calling patient or not. Nurses are more inclined to respond to a patient for whom they are responsible. The fourth factor is the nurse's awareness of *colleagues' availability*, which also influences the decision-making. Knowing that someone else is able to respond to the call in their place during an activity that is difficult to leave relieves the nurse's stress. Previously, we have looked into how providing information about colleagues' availability through an awareness system could enhance nurses' nurse call handling [6,23].

This study seeks to investigate how technology could support nurses to make a more informed decision about whether to respond to a nurse call or continue with an ongoing activity. In particular, we are interested in how technology could be designed to support a fifth factor, namely the *patient's intention*, as previously suggested [17–19]. In many of today's nurse call systems, reminiscent of Nightingale's call bells, the only information revealed when a nurse call is issued is the identification of the calling patient.[1] Therefore, we explore the following research question: *How could the intention communicated by a patient influence nurses' handling of nurse calls and fulfil their need for further contextual information*? In other words, we aim to investigate whether a nurse call system that allows patients to communicate a more contextualised message could aid nurses in their decision-making, and if such information would decrease nurses' reliance on the other influencing contextual factors. To answer the research question, three different nurse call system concepts were developed that allow the patient to communicate different types of information to the nurse. Through a qualitative methodology, utilising a scenario-based design, nurses from different departments of a Norwegian university hospital evaluated whether the three design alternatives could support their handling of nurse calls.

2. Background

2.1. Affordances of technology

In his article *Technologies, Texts and Affordances*, Hutchby [24] argued for a 'third way', positioned somewhere between constructivism and determinism, to explain the interaction between technology and the social world. Technological determinism, which describes how a certain technology is used, is determined solely by its characteristics and has been largely dismissed in favour of social constructionism within science and technology studies (STS). Hutchby [24] criticised the logical conclusion that followed the constructivist position put forward by Grint and Woolgar [25], in which technological artefacts are merely a *tabula rasa* that lends itself to more or less any form of use, and that the artefacts meaning and form is ultimately socially shaped. To avoid withdrawing to determinism, Hutchby [24] suggested that technologies can be seen in the light of having different *affordances*, a term coined originally by Gibson [26] within the field of visual perception. The affordances are intrinsic properties of an object that limit or enable certain forms of use. Namely, that a technology is not open to just any interpretation but is open to be socially shaped within the boundaries of its affordances, and that those affordances can differ between species and contexts. According to Hutchby [24], a rock may provide the affordance of shelter from the sun for a reptile and afford a hideaway for a hunted insect.

On a number of points, Hutchby [24] extended the affordance concept brought about by Gibson [26] to highlight its relevance to STS. In particular, he explained that we need to learn how the affordances of a technology are restricted by social rules, for example, restricting a mobile phone's voice communication affordance within the context of a movie theatre. He also emphasised that affordances can be designed into the technology. Norman [27], who brought the affordance concept to the field of human–computer interaction (HCI), discussed the importance of making affordances visible in the design of technological artefacts. For affordances to be effective, Norman [27] wrote that they need to be discoverable; a property referred to as perceived affordance.

The theoretical framework of affordances has also previously been used within the health care domain to analyse and understand how technological artefacts support or restrict care processes [28,29] and their adaptation [30]. Rooksby et al. [29] analysed whether different reporting schemes afford a 'good' story in order to maintain and enhance safety. Alsos et al. [28] assessed the effects of three different mobile devices on doctor–patient communica-

[1] Often the room number of the calling patient is displayed. At the hospital that we investigated, patients had their own room, so the patient could be identified by the room number.

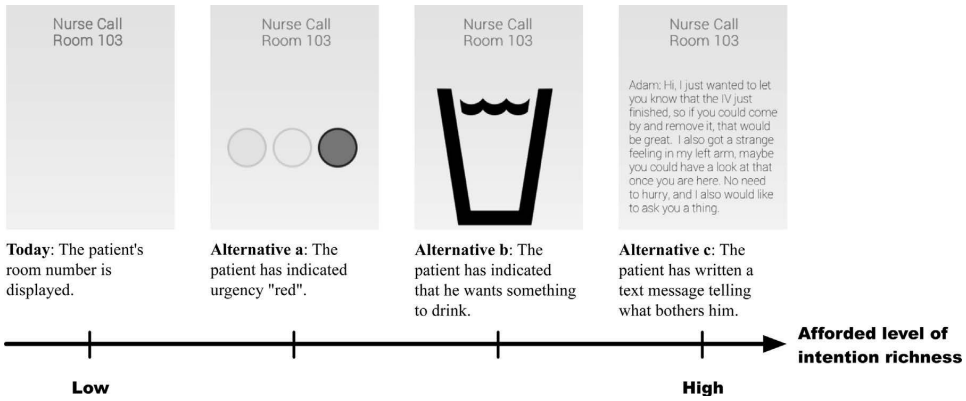

Fig. 1. The different alternatives allow the patient to convey their intention to various degrees.

tion in point-of-care situations and based the analysis partly on the concept of affordances. For example, the paper chart was found to afford good information overview and the handheld device afforded easy eye-contact re-establishment; however, the laptop failed to afford easy transfer between patient beds.

2.2. Prototype design

Three different conceptual system designs were developed that we envision patients could use to communicate further information about their requests. By applying the theoretical framework of affordance, each alternative has been designed to possess different affordances that allow different types of information to be communicated. Fig. 1 illustrates the different design alternatives alongside the current hospital nurse call system. The different systems afford various degrees of intention richness to be communicated and have been ordered accordingly in the figure.

2.2.1. Alternative a.

This design allows the patient to indicate the urgency level of their request, which is rather similar to the proposed system by Tzeng [17]. These three levels are represented by different colour codes: green (non-urgent call), yellow (normal call) and red (urgent). This alternative allows the patient to assess the urgency of the call, but it does not allow the nurse to make an independent judgement about whether the call is urgent or not based on the communicated information. Namely, the intention behind the call is not very visible to the nurse; however, the design allows the nurse to view and recognise the information at a glance, requiring little cognitive effort.

2.2.2. Alternative b.

The second alternative allows the patient to initiate communication with a nurse by pressing a button that corresponds to their need. Examples of these could be a toilet-bowl symbol for bathroom assistance, a symbol of a glass of water expressing thirst, or a symbol that indicates that the patient is in pain. This design allows the patient to communicate a concrete need, thus affording communication of a higher level of intention richness, which in turn allows nurses to make a more informed assessment about whether the need is urgent. Similar to the previous alternative, the information communicated is quickly accessible for the nurse.

2.2.3. Alternative c.

The third alternative allows the patient to send a text message to the nurse. The design provides a rich description of the patient's intention. Patients can freely express why they would like to receive attention. The design allows an informed decision to be made about whether a request is urgent or not. However, such a design does not afford quick discernment of the urgency, as the content of the message needs to be read, interpreted and understood.

3. Methodology

Scenario-based methodologies are commonly used at various stages in the development of computer-based systems, including strategic planning, HCI, requirements engineering, and object-oriented analysis and design. Within HCI, a scenario-based design is used to describe and envision future systems and to design usable solutions [31]. In this context, a scenario-based design is a way to engage the user in the design and evaluation of new technology and to provoke reflection about a design through the use of scenarios [32,33]. The scenarios are 'stories about people and their activities' [33] that incorporate the use of technology, with a purpose of (1) presenting and situating solutions, (2) illustrating alternative solutions and (3) identifying potential problems [32]. An important aspect is that the scenarios should be based on a good understanding of the context for which the system is developed [32,34,35].

Adopting a scenario-based approach, scenarios were designed based on previous qualitative studies of a wireless nurse call system deployed at a Norwegian university hospital. The system delivered nurse calls, which were issued by patients by pulling a drawstring, to fixed displays mounted in the department and to wireless phones carried by nurses. These studies sought to understand the context in which the system operates and its use through observations, interviews and workshops [6–8]. The studies found that the situations nurses find themselves in when receiving a nurse call can be divided into three general categories. The first category (1) contains situations where a nurse is not doing anything of importance and can leave the situation without it having any significant impact on their work. The second category (2) is where nurses are in an ongoing activity that they are reluctant to leave, but in which factors such as the patient's condition would have an influence on their decision whether to leave or not. The third category (3) consists of situations that nurses cannot leave unless there is an apparent emergency.

Five different scenarios (Table 1) were developed representing the three categories mentioned above. In addition, two scenarios (2 and 4) can be classified between two intersecting categories. Scenarios in the second category are most relevant to the study, as in these nurses have to make a complicated decision while con-

Table 1
Scenarios.

Scenario	Description	Category
1	The nurse is providing information (e.g. wound-dressing change instructions, check-up times) to a patient that is being dismissed from the hospital.	1
2	The nurse is engaged in a talk with a doctor about one of his or her patients.	1,2
3	The nurse is finishing the paperwork for a patient that is to be transferred to another department/hospital. The ambulance personnel are waiting for the nurse to finish.	2
4	The nurse is talking with an anxious patient who asks for clarification on something that the doctor told him.	2,3
5	The nurse is changing a more complex wound dressing (alternatively a central venous catheter placement or similar sterile procedure).	3

sidering different factors. Scenarios from the other two categories were included to compare with the second category based on the assumption that nurses' decisions would not be influenced by any factors in these situations. Hence, we expected that nurses would almost always choose to respond to a nurse call in scenario 1 and not at all in scenario 5.

In all five scenarios, a nurse is situated in a commonly occurring work situation with another actor–either a colleague or a patient–as the social dimension might also influence the interruption handling [36]. During the scenario, the nurse receives a nurse call from one of the patients in the department. The scenarios are largely open-ended [32], meaning that the nurse must decide how to handle the situation. Knowing that nurses' handling of nurse calls is highly context dependant [6], the scenarios are not described in great detail, allowing the nurses the freedom to fill in the missing details based on their own experiences.

Separate focus-group interviews were held with nurses from each of the seven different hospital departments included in the study.[2] Eighteen nurses participated in the study and each focus group consisted of 2–3 nurses. A semi-structured interview guide was designed for the interview in which each scenario was examined. For each scenario, the nurses were asked how they would handle the situation when receiving the nurse call through the system implemented at the hospital and when using the proposed design alternatives. For each alternative, the potential issues and benefits were discussed.

All interviews were audio recorded and transcribed. The data was analysed using the stepwise deductive-inductive (SDI) approach [37], which combines both inductive and deductive strategies, where both empirical data and theory guide the analysis. Initially, the transcribed data material was read through and coded to identify emerging themes. The theory of affordances, described in Section 2, was used to help explain the data in the later part of the analysis.

4. Results

4.1. A challenging decision

The nurses found it challenging to be interrupted by a nurse call in most of the presented scenarios. They perceived that the nurse call received not only affected them, but also the patients. A nurse from the department of haematology said the following when asked whether the nurse call could have an impact on their work: 'In a conversation, it is always disruptive if a nurse call keeps ringing. It is ok if it just rings for a short while but if it continues for a longer period it is disruptive. You are perhaps not so concentrated on your conversation with the doctor if you hear a nurse call that keeps ringing and ringing'.

If the alarms keep on ringing, the nurses explained that their focus towards the current activity is distracted. Nurses perceived the nurse call, especially in situations where they are engaged in taking care of a patient, as stressful and disruptive. When asked in what way the nurse call was frustrating in these situations, two dimensions were revealed. First, the sound that is created to notify the nurses was regarded as disruptive. The nurses explained that it is sometimes difficult to hear what the patient is saying or to get their message across when a ringing sound was played on both the wireless phone and the wall panel inside the patient's room. The nurses said that they would sometimes leave an anxious patient (scenario 4) to respond to a nurse call if it kept ringing for a long period, as they were unable to talk to the patient until the alarm was silenced. Second, the nurses worried about the calling patient, whom sometimes occupied their thoughts more than the current task. When asked whether it was the sound or the knowledge that another patient needs help that is most stressful, a nurse from the infection department responded: 'Well, you know that there is another patient that needs help, [but] how much pain is he in? You are counting the seconds it takes for someone else to respond to it, you think more about that than the one you are talking to'. Another nurse continued: 'You have an inbuilt limit to how much ringing you can bear before you have to respond'. As the nurse said, they respond to nurse calls eventually if no one else is responding, regardless of the situation they find themselves in. If they do not know the patient calling very well or they know that it is a patient who is in a bad condition, it is more stressful. A nurse from the department of haematology said: 'We do not know what awaits us behind the patient's door'.

Nurses felt that they needed to eventually abort the current activity to check up on a calling patient to ensure that it is not something urgent. However, it is not optimal to abort an ongoing activity to become engaged in another one. A nurse from the department of respiratory medicine explained: 'It is not good to leave, as you get all stacked up, but if you have to then you just have to. You tell the patient that you'll be right back; we often do that. If you are having a conversation, it does not have to be a conversation like this one, it could be a different conversation that is neither good to break off, but sometimes you have to'. In the same way, a nurse from the infection department reflected: 'You do not get to take time to be with the patient, you have to just try to finish as quickly as possible and then go on to the next one; you just get overloaded with a lot of things'. The nurses explained that the nurse call would sometimes make them try to finish the task faster in order to be able to go and check up on the calling patient.

4.2. Design alternative a

When presented with the design alternative where the patient is able to indicate the urgency of the call, the nurses reported that the indicator (green, yellow, or red) would, to some extent, affect how they reacted to the nurse call. If the patient has indicated that their need is not urgent (green), the nurses said they would finish what they were doing first before responding to the nurse call. On

[2] Department of haematology, infection department, department of respiratory medicine, orthopaedic department, department of otolaryngology, department of breast and endocrine surgery and maternity department.

the other hand, if the patient has signalled that their call is urgent (red), they would consider leaving the current activity, although other factors still would have a strong influence on their decision. Some nurses said that if they were talking to a doctor when a nurse call was issued (scenario 2), they would take the doctor with them to see the patient if the call was indicated to be urgent.

To some extent, when talking to an anxious patient (scenario 4), and almost exhaustively while in a sterile procedure (scenario 5), the indicated urgency would have little effect on the decision. Nurses were reluctant to leave these situations, even if the patient had indicated the matter as urgent. A nurse from the department of respiratory medicine explained: 'If it is a sterile procedure, a CVC [central venous catheter] or a wound dressing for that matter, then you have to finish the procedure, you cannot just leave it'.

The main issue with the proposed alternative was that nurses would find it difficult to trust whether the patients' assessment would correspond to how the nurses would have assessed the urgency. When asked if there were any potential problems with the proposed design, a nurse from department of respiratory medicine replied: 'Trust that they are able to [accurately assess the urgency]; it is not my assessment, it is their assessment, and those two assessments can be different with regard to urgency. Some might press the green button, but for me it would be a red one, right? It can be both ways; the patients are so different'. This issue was brought up in every focus group interview, and the nurses explained that their interpretation of the urgency level indicated would largely depend on their knowledge of the calling patient. A nurse from the infection department explained: 'I think that regardless of what colour code the patient had pressed I would have responded quickly if I knew the patient has chest pains, then it would not matter if it was green or red'. Nurses were concerned that in certain situations a colour code could make the situation more stressful for the nurse, as they would also have to consider whether the patient has correctly assessed the indicated level of urgency.

The nurses were unsure whether older patients or patients with dementia would be able to use such a system. They were also worried about if, for example, a patient experienced sudden pain and, in their rush to press a button, they failed to check for the correct one, they would risk the possibility of communicating a non-urgent matter when the opposite is true. However, the nurses said that for patients who are able to assess the urgency correctly, it would provide some benefit when deciding whether to engage immediately or not.

4.3. Design alternative b

The design alternative allowing patients to communicate a specific need using symbols received the most enthusiasm from the focus group participants. Nurses mentioned that receiving a clue about the matter of the call could help them relax in a situation where they need to be focused on the task at hand. A nurse from the department of respiratory medicine said: 'I like this one. If I received a message about a glass of water, I would relax more and it would not be as disruptive because then, okay, a glass of water, then I know a bit'. The nurses appreciated the symbols, as they communicate a concrete need, allowing them, rather than the patient, to assess the urgency. However, some said that if a nurse call kept ringing without anyone answering it, it would eventually become disruptive, even if the patient just wants something to drink.

According to the nurses, design alternative b would make it easier to delegate the duty of responding to a nurse call to either an assistant nurse or a student nurse, who can provide assistance for matters that require less medical expertise, such as providing a glass of water. Similarly, a nurse from the infection department explained that it could lower the barrier of responding to a nurse call from a different bed area[3] if they know the reason for the call beforehand. The nurse said: 'If it is a nurse call from another bed area at the department and you see that it is a room that you are not responsible for, but that the patient needs a glass of water or something to drink, then it might be easier for others [that are not formally responsible] to go and check it because you know that it something simple that they need assistance with; a concrete need'. At the same time, the nurses explained that they would be able to prepare before entering the room if they know what the need is, which could save time.

Similar to the first design alternative, the nurses said that the symbol indicated by the patient would affect their decision to respond or not in scenarios 1–4. However, there would be less uncertainty about whether the matter is really urgent or not when the nurse is able to make that judgement rather than the patient. Therefore, the decision could be leveraged to a larger extent on the intention communicated by the patient than on other factors. When asked whether the symbol would impact their decision making, a nurse from the department of respiratory medicine said: 'Yes it definitely would. If it is a glass of water, I will finish my discussion with the doctor first, so it provides us with a pointer to what it could be, how urgent it is, absolutely'. Likewise, if the patient had indicated pain or a need to go to the toilet, the nurses would be more likely to respond quickly. In sterile situations (scenario 5), nurses said that it did not really matter what need the patient communicated, as long as it was not an emergency, as they would likely not abort the procedure.

Again, some nurses were concerned that older patients or patients with limited cognitive capacity would not be able to discern which symbol corresponds to their actual needs. A nurse from the department of otolaryngology said that the need to be able to communicate toileting assistance often goes hand in hand with being unable to handle a more sophisticated system than the drawstring to issue a nurse call in their department. In these cases, the nurses said that they would need to rely on their knowledge of the patient rather than on the communicated symbol to assess the urgency.

Another problem discussed was that the number of symbols could become unmanageable if a different symbol is required for every need. The nurses pointed out that it is important to carefully select symbols that are general, but also tailored to the needs of different patient groups in different departments. For example, in the department of respiratory medicine, a separate button indicating breathing difficulties was suggested.

4.4. Design alternative c

Similar to the other two alternatives, some nurses said that the information contained in the text message would influence how they handled a nurse call, with exception to the fifth scenario where the nurse was undertaking a sterile procedure. A nurse from the orthopaedic department said: 'The message would be decisive in whether to respond immediately or not'. However, others were of the opinion that if the patient is capable of writing a text message it could not be very urgent. A nurse from the infection department expressed: 'There is no real urgency if they are able to send a text message'. The benefit of receiving a text message, the nurses explained, was that they knew the reason for the call beforehand and could therefore prepare for it in advance.

However, the option allowing patients to send a text message was generally not appreciated among the nurses because they felt

[3] Departments at the hospital are divided into smaller logical units referred to as bed areas. Typically, a bed area consists of seven to nine patient rooms and nurses primarily nurse the patients within the bed area to which they have been assigned.

that reading a text message in any of the situations where they were caring for a patient would seriously distract their attention. While discussing the issue with nurses from the department of respiratory medicine, a nurse said: 'It would be very disruptive, I think, both for me and the patient'. A nurse from the infection department said that she would feel uncomfortable reading a message in such a situation: 'I would feel a bit rude if I was to pick up my phone and read a text message'. Another nurse continued: 'It would seem as if you don't care or that you are not present [mentally] with the anxious patient'. In situations where the nurse was busy with a colleague (scenario 2 and 3), nurses said that reading a text message was more acceptable. A nurse explained: 'It would be distracting in this situation as well, but not as distracting as when you are talking to a patient. The doctor has to tolerate that you are reading a nurse call message, I suppose. [However,] it takes a bit more time to read a message than to look at a symbol, and it is more distracting'.

The nurses pointed out that reading a text message would also take more of their time, something that they do not have in abundance, especially if the message contains too much information that at times would be difficult to interpret. A nurse from the orthopaedic department reflected: 'It would take time and be very disruptive. It is almost better to respond than to stand there and fiddle with the phone trying to understand what the patient is saying in the text message'. Therefore, an effective system was asked for, and the nurses suggested that the functionality should be constrained with a one-word limit.

The participants also expressed their concern that if they start corresponding with patients using texting devices, the patient contact could be harmed. Nurses feared that it would create a larger distance between them and the patient if they were to communicate mainly through text messages rather than face-to-face. A nurse from the department of haematology commented: 'I think it is better to go and talk to the patient. The system could perhaps support minor notifications such as that they need help or want to talk to someone'. Another nurse from the same department continued: 'You can read a lot of things from a conversation, how things are expressed and how the patient behaves'. Similar to the other two alternatives, nurses believed that this type of functionality is best suited for patients that are used to similar communication technologies, e.g. mobile phones, and that are cognitively functional.

4.5. Challenges to a new type of nurse call signal

A concern with regard to the additional information that a new type of nurse call provides was that less urgent needs, such as a request for a glass of water, might take longer to meet. A nurse from the department of haematology said: 'If someone calls for a glass of water and I am currently involved in more important tasks, the nurse call would not be prioritised, which could feel discouraging for the patient: No one is responding to my water glass request, I have to wait'.

Further, the nurses reflected that such functionality should be carefully considered in terms of which patient groups it should be offered to, especially as there were variations among the departments regarding the degree to which they perceived the prototypes as useful in their work; according to the nurses this depended heavily on the patient group that would be using the system. For example, nurses representing the department of breast and endocrine surgery were not convinced that any of the proposed system alternatives would provide any obvious benefits. As one of the nurses said: 'The average age of our patients is around 80 years, so if we are to provide them with all these alternatives I believe that their condition will get worse than it was when they arrived (laughter)'. Another nurse from the same department continued: 'We would use 10 times as much time explaining to them how the system works as we would use to visit them 10 times. It is simple for younger patients, but others can barely understand how to use the drawstring. The simpler the better really, so I am afraid that it is too complicated'. Contrastingly, the maternity department nurses did not believe that their patients would experience any difficulties using any of the system alternatives presented. Rather, they thought that any of the proposed alternatives would improve their work. However, in agreement with the nurses from other departments, they also stressed that the drawstring, which patients currently use to issue a nurse call, should always be available, as some patients such as those that recently returned from surgery, would not be able to use a more sophisticated nurse call system.

5. Discussion

5.1. Decision influences

The results indicate that a nurse's decision to respond to a nurse call or not is influenced by how the patient's intention is communicated and other factors, such as the situation the nurse is in when the call presents itself. In the first scenario, in which the nurse is providing information to a patient that is being dismissed from the hospital, the information communicated by the patient issuing a nurse call through either alternative b or c had a direct influence on whether the nurse chose to respond immediately. Although in contention with our initial assumption that nurses would respond regardless in the first scenario, this behaviour could possibly be explained by the social dimension tied to interruption handling [36], as the nurse in this scenario is situated with another patient. If the patient communicated an urgency level through alternative a in this situation, the nurses questioned whether they could trust the patient's assessment; therefore, other factors such as the patient's condition were considered as well. Contrastingly, and in line with our assumption, when occupied with a sterile procedure (scenario 5), the information communicated would have little influence on the decision regardless of the communication alternative. Owing to the infection risk, nurses did not want to leave the procedure unfinished, and they stated that a nurse call indicating that the call is of an urgent nature could appear stressful, which again could have a negative impact on their work. In this scenario, whether the patient's intention was communicated through alternative a–c, had no significant impact on the decision.

In scenarios 2–4, in which the nurse was busy but able to leave if really necessary, the nurses were even more reluctant to leverage their decision on a colour code communicated through alternative a. Although the message content communicated through alternative c would have some influence, the nurses doubted the urgency of the patients' need if they were able to write a text message, indicating that alternative c did not provide an appropriate medium to communicate a matter of high urgency. Nurses found it improper to read a text message in front of a patient, although it was not perceived as a problem in situations where the nurse was with a colleague. This observation resonates with Hutchby's [24] discussion on how social rules also limit the affordances of technology. To overcome the issue, the nurses suggested that the text message could be limited to one word, which in a sense is a similar to alternative b. Hence, the nurses appreciated the ability to discern a patient's intention 'at-a-glance', requiring little cognitive effort, which was afforded by alternatives a and b.

Generally, the nurses agreed that if the patient's intention was expressed as a symbol (alternative b), they could assess the urgency more accurately. Nurses assessed the urgency of the nurse call largely based on the communicated intention rather than other contextual factors, although these were not completely ruled out. Knowing that the patient wanted a glass of water would allow them

Table 2
Influence of the design alternatives on nurses' decision-making in various situations.

Scenario	Description	Decision influence
1	The nurse is providing information (e.g. wound-dressing change instructions, check-up times) to a patient that is being dismissed from the hospital.	*Alternative a:* Although the colour code communicated would have an influence on the decision, a few nurses expressed concern that they would not always trust the urgency level communicated by the patient. *Alternatives b and c:* The information communicated through either alternative had a direct influence on the nurses' decision about whether to respond to the nurse call or not.
2	The nurse is engaged in a talk with a doctor about one of his or her patients.	*Alternative a:* The colour code would have some influence on the nurse's decision; however, other factors such as colleague's activity and the patients' condition are more persuasive. *Alternatives b and c:* Both alternatives allowed the nurses to base their decision largely on the information communicated by the patient in these situations. An exception was scenario 4, in which nurses did not appreciate having to read a text message (alternative c) in front of the patient.
3	The nurse is finishing the paperwork for a patient that is to be transferred to another department/hospital. The ambulance personnel are waiting for the nurse to finish.	
4	The nurse is talking with an anxious patient who asks for clarification on something that the doctor told him.	
5	The nurse is changing a more complex wound dressing (alternatively a central venous catheter placement or similar sterile procedure).	*Alternatives a, b and c:* The intention communicated by the patient through either alternative did not significantly affect the nurses' decisions.

to focus on the task at hand, while a patient in pain is a concern that they would want to address immediately.

However, the urgency of a nurse call is ambiguous in that it is subjectively evaluated. Since nurses wish to ultimately assess the urgency of a nurse call, alternative a, which allows patients to influence the urgency interpretation, was not perceived as a viable option. Alternatives b and c offer a more objective assessment to be made from the nurses' viewpoint and were therefore more appreciated by nurses. However, the nurses' reflections on scenarios 2–4 revealed that the patient's ability to influence the urgency assessment is also to some extent present, even if their intention is communicated through alternatives b or c. Hence, that a communicated symbol might not always reveal the patient's true intentions. Table 2 presents a summary of how the different design alternatives influences nurses' decision-making for different scenarios.

5.2. Unanticipated affordances

In line with Hutchby's [24] observation that affordances can vary between 'members of our own species', the nurses perceived that the proposed prototypes provide new ways of collaborating with colleagues that were not initially anticipated. In a situation where the nurse is talking to a doctor and a patient communicates an urgent need, nurses would take the opportunity to ask the doctor to visit the calling patient. Likewise, if nurses knew more about the reason for a nurse call, they could, where appropriate, delegate it to someone in a better position to respond to the nurse call at the time, even if they had less experience or knowledge about the calling patient. This would allow the experienced nurse to continue focusing on an activity that requires his or her attention, while making sure that the patient received timely care. Conversely, if the information communicated could indicate what the patient would like to discuss, nurses could make sure that the primary nurse, who knows the patient best, could respond to the patient in line with the primary nursing care model [38]. This affordance is closely linked to the benefits of alternatives b and c, which, on receipt of the information communicated by the patient, nurses could prepare before visiting the calling patient, saving both time and effort. Such an effect was also observed in a study [15], where a system allowing phone calls to be made to a secretary was investigated.

5.3. Technology interpretation

Just as people innovatively interpret technology within its frame of affordances [24], nurses' interpretation of alternative c was often not restricted to a one-way communication device, such as the deployed nurse call system. Rather, similar to their own phone's text messaging function, they envision the alternative to allow a two-way asynchronous communication between the nurse and the patient. A rather common and immediate comment on this interpretation of the design was that nurses preferred to talk to their patients face to face and not through a messaging system. Another study also reported that nurses did not find a similar functionality that allowed them to make phone calls to patients useful. The nurses stressed that patients are unable to explain their issue properly in speech only and that they expect the nurses to visit them [39].

During the interviews it became evident that nurses viewed the proposed prototypes in light of their previous experiences with similar technology [40]. Although nurses thought the information communicated through the prototypes would allow them to make a more informed decision about whether or not to respond, some associated the proposed prototype with the nurse call system deployed at the hospital. The system, according to the nurses, generated an alarming sound whenever a nurse call was issued that was difficult to disregard [8]. A nurse from the department of breast and endocrine surgery explained: 'If it keeps calling you are interrupted by it regardless of whether the colour code is green or red. The sound is so loud that you just have to leave eventually, you would not be able to talk anyhow'. Hence, regardless of the urgency of the call, the nurse would not have been able to continue the current activity due to the sound, which also illustrates the importance of considering these issues in any real implementation.

5.4. Open issues and study limitations

While the proposed technology offers a variety of affordances with regard to its technical capabilities, other factors could play an essential role in the adaptation of a new nurse call system. Although nurses thought that the information communicated through the proposed prototypes would relieve their decision-making, a concern that some nurses expressed was whether the patients would be able to use such a system. The patients' high age was often used as an argument for why they would not be able to use the system correctly. Whether this could be attributed to nurses' attitudes towards new technology or an honest concern for their patients, or perhaps more plausibly, both, is difficult to discern based on the data. Yet, the importance of taking on a patient perspective in the design of a nurse call system should not be neglected.

Hence, this study is limited in that it only focuses on the nurses' perspectives and how their handling of nurse calls could be improved through the means of new technology. However, as the nurses also pointed out, a nurse call system involves both a sender

Summary points
What was already known on the topic:

- Handling interruptions in the form of nurse calls is a challenging part of nurses' work.
- Nurses evaluate their availability towards a nurse call based on a number of factors.
- Little work has been done to support nurses' decision-making when faced with the dilemma of whether or not to respond to a nurse call during an activity.

What this study added to our knowledge:

- A nurse call system that allows the patient's intention to be revealed facilitates nurses' ability to make a more informed decision and reduces uncertainty.
- The level of intention richness communicated by a patient should allow nurses to make an objective urgency assessment with minimal cognitive effort.
- Having access to the patient's intention reduces nurses' reliance on other contextual factors when deciding to respond to a nurse call.

and receiver; thus, future work should investigate the design of technology from the patient's perspective by including real patients in the process. Another limitation is the relatively low fidelity prototypes used in the study should be developed to evaluate further issues such as usability. How nurses should be notified about a request and possible privacy issues should also be explored.

6. Conclusion

The study has investigated, through three different nurse call system concepts, how a patient's intention could be communicated to improve nurses' urgency evaluation of a nurse call. The results indicate that technology allowing nurses to objectively assess the intention behind a patient's nurse call could support nurses' ability to make a more informed decision about whether or not to respond to a nurse call in situations where they are interrupted in their work. The intention communicated through an enhanced nurse call system seemed also to reduce nurses' reliance on other contextual factors in their decision-making. An important aspect in the design of a new type of nurse call system is that the information communicated to nurses should be easily accessible and require little cognitive effort to discern in order to avoid disrupting ongoing work. The most promising candidate for such a nurse call system would allow patients to communicate symbols corresponding to their needs. However, as hospital departments treat different patient groups, each with its own particular needs, a solution should be tailored accordingly.

Author contributions

Joakim Klemets contributed to the design, data collection, data analysis and writing. Pieter Toussaint contributed to the design, data analysis and writing.

Conflict of interest

The authors declare they have no conflict of interest in the research or the development of the manuscript.

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PAPER 6

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