DEVELOPING AN INFORMATION SYSTEM FOR NURSING IN ACUTE CARE CONTEXTS

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Abstract

The objective of this study, which is part of a wider longitudinal research project, was to assess the fidelity and feasibility of a NIS for acute care contexts. In order to do this, principles of design science research and user-centred design were drawn upon. The stages of the study discussed in this paper involved nurses as the intended users and evaluated the system at two early stages of development; user acceptance of the concept and testing of the prototype using simulation. Analyses of data collected in the early stages of the research highlight the importance of nurses' involvement during system development to ensure fidelity for nursing work. Findings from this research provide suggestions about the potential for the NIS to improve nurses work processes and factors likely to impact the usability and acceptability of the system for nursing work. In addition, the need for co-evaluation of both the problem space as well as solution space in design science is confirmed. Face validity of the solution has been established. In addition, lessons have been incorporated into the refinement of the tool and will be evaluated in a large scale clinical trial which will involve multiple hospitals.

Keywords: Nursing Informatics Solution (NIS), Nursing Information Systems, Acute Care Setting, Design Science Research, User-centred design.

1   INTRODUCTION

The primary purpose of technology in healthcare is to facilitate clinical processes to improve the efficiency, quality and safety of care through innovative technology-enabled solutions. While evidence for positive results is emerging through the literature (Buntin et al. 2011, Häyrinen et al. 2008, Lau et al. 2010), user dissatisfaction and barriers to technology adoption remain as significant issues; this appears to be particularly problematic in nursing contexts. Nurses represent a critical link in healthcare delivery as they are the largest group of health professionals in the healthcare system and the only healthcare professionals that provide constant patient surveillance at the bedside for 24 hours a day; but limited access to health information systems have been recognized as problems for nurses (Ballard 2006, Hegney et al. 2007). Problems that may explain the slow uptake of technology solutions by nurses, include low usability, poor fit with nursing practice and failure to address nurses' specific needs, and due to the high presure on nurses during their work hour, which may reduce their chances to use technology (for example see Ballard 2006, Haddad et al. 2014, Stevenson et al. 2010). This paper serves to examine these issues in the context of a nursing informatics solution that has been designed and developed to expressly support nursing-specific care delivery needs.

2   NURSING INFORMATION SYSTEMS IN ACUTE CARE SETTINGS

Health information systems are increasingly being introduced into acute care contexts with an expectation of providing high quality, safe and efficient care. While there is the potential for these technologies to offer benefits, there are several key concerns. These include low usability of the systems fir the day-to-day complex interactive work of nurses, workflow disruptions, and computer errors (for example, Lau et al. 2010, Meijden et al. 2003, Stevenson et al. 2010).

In acute care contexts, slow adoption of - and limited access to- information systems useful to nurses' and their mixed perceptions about the impacts of technology on nursing work have been reported in the literature (Hegney et al. 2007, Saneipour and Asgari 2013, Stevenson et al. 2010). Stevenson's et al. (2010) review of empirical studies found only five papers published from 2000 to 2009 that addressed their criteria of original empirical research related to nurses' experiences with electronic clinical documentation. This low number of papers was surprising and indicates limited research in this area. Stevenson et al. (2010) also found nurses were dissatisfied with technology due to low usability, poor fidelity with nursing workflow patterns and poor integration with nursing professional culture. Similar findings are reported in Australia by Darbyshire (2004). While it has been argued that technology has the potential to transform and innovate nursing processes (Courtney et al. 2005), there is a clear gap between nurses' actual experiences and its expected potential.

2.1   Initial vision of a Nursing Informatics Solution for acute care contexts

The Nursing Informatics Solution (NIS) will be located at the patient's bedside in acute hospital wards to replace the current paper based nursing documentation system. The tool is expected to enable nursing staff to document patient care, review patient care information, plan changes in care, communicate

changes in delivery of care and make real time nursing specific information easily accessible to all multidisciplinary health care practitioners. We envisage that the tool will create value through two ways: 1) increasing patient care quality (prompts and reminders and safety) and 2) increasing efficiency to release nursing time for other activities. The challenge as identified previously is how to develop a NIS that is usable for nurses, reflects and responds to the complexity of their work including frequent disruptions in nursing workflow patterns. Further, we integrated User Centred Design (UCD) (Avison and Fitzgerald 2008, Gulliksen et al. 2003, Norman and Draper 1986) within Design Science Research (DSR) to enable the solution to be more suited to the specific nursing contexts and also involve users in the design of the solution with the expectation that this will lead to higher feasibility, fidelity and usability.

3   INTEGRATING USER CENTRED DESIGN WITHIN DESIGN SCIENCE RESEARCH

Drawing on the original principle of design science as a problem solving activity, DSR is a well-recognised approach in Information Systems Research (Hart and Gregor 2010, Hevner and Chatterjee 2010) as a useful approach to developing and evaluating technology innovations to serve human purposes in organisational contexts, and at the same time generating useful knowledge for research. Two important characteristics of DSR include 1) a strong focus on creating innovative and appropriate solutions and 2) it draws on relevant ideas from an existing knowledge base while also making contributions to it. In our project, the integration of DSR with the usability principles of UCD are reflected in the strategy to engage and involve nurse users to inform and shape the NIS through frequent development and evaluation cycles. We believe this represents a unique approach. Using principles of UCD, groups of nurses expected to be users were purposively recruited and involved at multiple stages of the research and NIS development process; from project conception (relevance cycle), and through repeated prototype evaluations and feedback [design cycles] over the duration of the DSR project. The specific initial goal for this project was to develop a NIS with high usability and fidelity to nursing work and flexible to support and respond to the variable and frequently interrupted patterns of nursing work within complex acute care environments in hospitals. Table 1, outlines the application of DSR guidelines (Hevner et al. 2004) to this project:

DSR guidelines	Our application
Guideline 1: Design as an Artefact	A viable application was produced by the SME in the form of a prototype NIS (Version 1).
Guideline 2: Problem Relevance	Nurse expert and users were exposed to the concept as a short simulation of the prototype NIS.
Guideline 3: Design Evaluation	The usability, acceptability and efficacy of the NIS were evaluated over ten high fidelity scenario-based simulations.
Guideline 4: Research Contributions	Nurses participated in design cycles informed by UCD principles. Nurses' perspectives of the usability, fidelity and acceptability of the NIS for nursing work are explored in the data.
Guideline 5: Research Rigor	Theoretical foundations and conceptual models drawn from IS, DSR, UCD, nursing, healthcare quality and safety were used to inform the development cycles to evaluate the NIS in the acute care context. Mixed methods research and triangulation of data from multiple sources are used.

DSR guidelines	Our application
Guideline 6: Design as a Search Process	A conceptual gap was identified between the developers (IT) and users (nurses) regarding the usability and fidelity of the NIS.
Guideline 7: Communication of Research	Internal communication: The research is presented to technology and clinically-oriented users through focus groups, simulations exercises, brainstorming meetings, as well as technical and managerial meetings. External communication: Progress and findings are reported in a book chapter and peer review papers submitted to international conferences and professional peer-reviewed journals in each discipline.

Table 1.   Application of DSR guidelines to the development of NIS – an information system to support nursing work in acute care contexts

4   METHODS

During the initial DSR phase (relevance cycle), both conceptual development by the research team and field testing using qualitative focus groups were undertaken. This approach was also consistent with the UCD principle of users' active participation. The prototype concept was then tested with a wide range of nurses expected to use the system. Qualitative methods were used to explore nurses' opinions, needs and initial reactions to the NIS in relation to possible use in acute health care settings. Data were collected using four focus groups that involved 60 nurses purposefully selected to include both "native technology users" as well as "migrant technology users" (Bayne 2007, Toledo 2007) and cover a wide range of experiences as well as views and orientation toward technology adoption in nursing. The sample was drawn from medical and surgical wards at two large hospitals that represented the major hospital types: one was private and one a public hospital in Melbourne, Victoria.

At the start of each focus group nurses were exposed to a video simulation of a prototype of the NIS. Their immediate impressions were captured during a subsequent group discussion. The focus groups were audio recorded, transcribed and then analyzed in two stages: 1. Content analysis was conducted using the twelve domains of the Theoretical Domains Framework (Michie et al. 2005) as a theoretical lens to examine and understand nurses' perceptions, interests and opinions about the NIS; and 2. thematic analysis was used to identify nurses' perceptions of possible barriers and enablers to the implementation of the NIS (Michie et al. 2005).

During the subsequent design phase, a prototype of the NIS was evaluated in a high-fidelity simulation setting using a group of nurses from the same two hospitals and volunteer actor patients. Ideas and concepts from the Information Systems knowledge base in usability and acceptability, especially Unified Theory of Acceptance and Use of Technology - UTAUT (Venkatesh et al. 2003). The preclinical trial was conducted in a four-bed ward of a Simulated Nursing Learning Environment (SNLE) in Melbourne, Victoria over 10 days during July 2012. The NIS prototype was installed and placed on a bedside table next to the four patient beds in the SNLE. On each day during a three-hour session, four nurses from the various hospitals and four volunteers from the public who agreed to act as patients [referred to as pseudo-patients hereafter] were provided with instructions relevant to their roles and performed a scenario.

During the first week, the scenarios were simple; nurses cared for one patient at a time and undertook patient admission, clinical handover and prepared discharge information. During the second week, patients' data entered during one sessions in the first week was reused and the scenario was made complex by asking one nurse to care for two pseudo-patients and the addition of a Nurse Unit Manager role. Pseudo-patients were also encouraged to place extra demands on the nurse and the nurse was required to respond to clinical deterioration of one pseudo-patient (a mannequin). All the 10 one-hour simulated ward sessions were observed by the research team, who used iPads to take field notes and did not interfer with the nurses' duties,. All nurses ascertained that this research activitiy did not have any impact of their behaviour. They were also videotaped from a central observation room located in the same building but on another level to avoid interfering with the participants' behaviors. Immediately after completion of each one hour scenario, nurses' impressions were captured in a subsequent 30-45 minute focus group and a structured UTAUT-based survey (Venkatesh et al. 2003).

A large volume of data was collected for analyses and included ten-hours of audiovisual of the simulation sessions, eight hours of focus group audio recording, the researchers' field notes and 36 survey responses. Descriptive statistics were used to analyze the survey data, the coded nurse behaviors and comments of nurses from the simulation sessions and focus group. Content and thematic analysis methods were used to analyze the focus group as well as the simulation video data. Learning's drawn from the analyses of the survey and focus group data are presented in the next section. The video data analysis is subject to finalization. Findings from this stage were used to help guide the next step of the design on the system.

5   RESULTS

Several key findings from this study make an important contribution to UCD. First, the initial reaction of the participating nurses to the video simulation of the NIS prototype was favorable. They quickly linked the potential of the NIS to common problems they experienced in their daily work. From a UCD perspective, this finding supports understanding of problem relevance from the user perspective.

The second finding important to UCD relates to understanding nurses' perceptions of the potential barriers and enablers to the application of the NIS to their work and work setting. The participating nurses expressed awareness that the NIS can be a useful resource to support their work. In particular, nurses who indicated they had been exposed to other "smart technology" ideas in their hospitals were optimistic about using the NIS and its potential benefits.

The Theoretical Domains Framework (Michie et al. 2005) provided opportunity to explore nurses' perceptions using a socio-technical perspective. 'Environment context and resources' was most often perceived as a barrier by nurses. A small number of private hospital nurses identified barriers related to the 'nature of behaviours' while most of nurses were from public hospitals and they most frequently commented on the system's impact on their 'Beliefs about capabilities' as a barrier.

The third finding highlighted areas that potentially influence nurses' acceptance of the NIS. Through the group discussions, nurses expressed a vision of an intelligent tool that would be both interactive and adaptable to their complex and chaotic work patterns. Further, they expressed their need for a system

that would inform their care processes and enhance their ability to provide high quality and safe care for their patients. They did not want a system that would remove their professional autonomy (e.g. automating their decisions or tasks) or diminish nurses' clinical decision making which is critical for patient safety.

This exploration of nurses' perspectives informed the design cycle by highlighting nurses' positive attitudes towards the NIS as potential enablers and their desire for a system that is sophisticated, flexible and adaptable to the complex and frequently unpredictable nursing workflow patterns. This exploratory study also revealed various social-technical concerns about potential impacts of the system on nurses' clinical skills, critical thinking and professional autonomy. In addition, this study reaffirms the importance of UCD principles and nurses' participation in subsequent design cycles to evaluate not only the system usability, but also its acceptability.

5.1 Learnings from the user acceptance survey

A survey based on UTAUT (Venkatesh et al. 2003) was used to examine nurses' perceptions and expectations about the NIS in relation to Performance, Effort, potential Social Influence (on acceptance), Voluntariness or compulsoriness [at workplace], Facilitation Conditions, and Behavioral Intention to use the system. A clear majority of the nurses supported the system's concept and agreed that it had potential to assist them in their nursing work. Weak agreements were found in user acceptance of functions for patient admission and planning and adherence to care plan, as presented at Figure 1.

A moderately positive result was found in relation to effort expectation of the NIS. There were different levels of disagreement [EE1 and EE3] on how easy it was for them to interact with and operate the 'as it is' system while they held a moderately a strongly positive view on how easy it is to learn and be skillful at using it [EE2 and EE4], as presented at Figure 2. Overall, the survey responses showed nurses' had high interest in the system, a high level of acceptability, and a common agreement about potential user acceptance. It also indicated possible usability and fidelity issues to be examined in detail in focus group and video analyses. There were few undecided responses that may be attributed to the short time available for nurses to familiarize themselves with the NIS before the high-fidelity simulation session and/or the limited tasks, duration and artificial nature of the simulation-based evaluation.
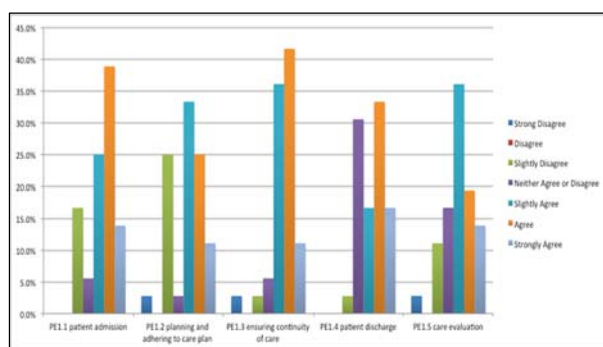

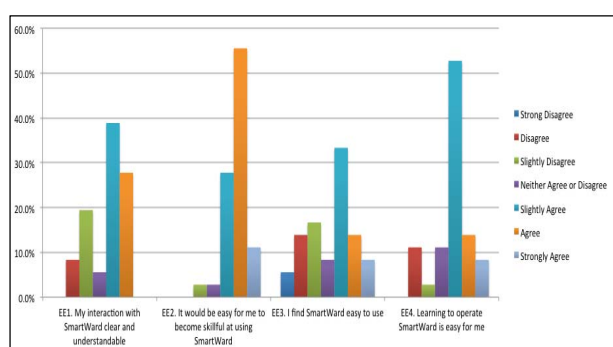*Figure 1.   Nurses' performance expectation*   *Figure 2.   Nurses' effort expectation*

5.2   Learning from the focus groups

Results of the focus groups are summarised as follows:

Overall positive attitudes and high acceptance: Similar to the survey findings, the participating nurses expressed an overall high level of acceptance of the concept behind the system for clinical nursing practice. They agreed the NIS had potential to enhance nursing work.

Usability: In terms of effort expectancy, nurses found they were able to use the system with little training, and it became easier after a short period of use. Nurses also identified a number of issues related to the user interface design, search and navigation mechanisms that affected usability. Nurses also made many suggestions to improve information presentation and visualization.

*Fidelity:*Using a simulation environment to evaluate the fidelity of the NIS to support real-time nursing documentation within complex and dynamic nursing work was difficult. Nurses' comments implied a better navigation mechanism was needed to support mental mapping of their work and their nursing information needs. During the simulation exercises the nurses repeatedly searched screens for specific information and asked questions to inform their decision making when navigating through the system. The nurses expressed the need for a NIS that reflects current practice in relation to behavioral support and behavioral moderating. Behavioral support includes elements such as backward and forward processing. The NIS is expected to provide nurses who need quick access to multiple sources of information with an integrated view of information and a pertinent information presentation. In terms of behavioral moderating, the participating nurses also were conscious of the possibility of the tool taking over their independent clinical judgments. Their current behaviour is autonomous in the decision making process and the nurses were vehemently protective of this.

The nurses also discussed the importance of training and education; they also highlighted a limitation of the simulation was that it did not capture the true complexity and dynamics of real nursing work.

6   DISCUSSION AND CONCLUSIONS

Analyses of data collected in the early stages of the research demonstrate the application of UCD in DSR through nurses' involvement during early stages of system development to achieve the ultimate goal of high system fidelity for nursing work. The research process provided opportunities for nurses to interact with the system at key developmental stages and provided feedback to inform ongoing development:

- The application of UCD in this project is in line with a previous research-based recommendations for user engagement during development of systems for inpatient care contexts (Meijden et al. 2003). Engaging nurses has encouraged 'discipline ownership' of the solution and findings assist to increase its relevance to nursing practice. Building on previous research finding, this study has found that despite positive attitudes toward adopting technology (Huryk et al. 2010), nurses were still dissatisfied with the technology solutions implemented at their organizations (Darbyshire 2004).

- This project has supported learning through an iterative process of building and evaluation to close the gap between the conceptual model of the system and its intended context for use. Using principles of DSR (Avison and Fitzgerald 2008, Hevner and Chatterjee 2010) learnings drawn from user perspectives of usability and fidelity will inform the next design cycles to improve the system's quality, safety for patient care and its usability for nursing work in acute care contexts.
- Initial findings also provided suggestions about the potential for the NIS to improve nurses' work as well as the processes and factors likely to impact the usability and acceptability of the system for nursing work.

Through the above application of UCD and DSR principles, the paper draws on the following learnings to contribute to the current knowledge base:

- Fidelity is important and requires understanding and supporting the way expected users (in this case nurses) think and practice in context; there is a challenge in how innovate technology can support nursing practice to serve the goals of improved care quality, safety and efficiency.
- An integrated adaptable framework is needed to integrate UCD and DSR with theory underpinning the specific user context to conduct formative evaluations at different stages of development. The framework should support:
  - Learning related to both problem space and solution space. Both the problem space and solution space co-evolve as evaluations move from an artificial simulated environment to the naturalistic intended environment.
  - Nurses' involvement and the feedback loops.
  - Evaluation of usability, fidelity and acceptability in artificial and natural environments.
  - Subsequent large scale implementation and impact evaluation in acute care contexts.
- An integrative theory in nursing informatics is needed and it should recognize key theories from the associated disciplines such as nursing, health informatics, and information systems.

Findings from this stage of the longitudinal research highlight benefits of integrating UCD in DSR with context specific knowledge for healthcare informatics, and especially nursing informatics to examine the design, development and implementation of large scale technology solutions for healthcare contexts. We close by strongly recommending more use of design science principles and a user-centred design approach when designing and developing technology solutions for healthcare contexts especially those in complex , dynamic environments which contain heterogeneous user groups.

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