How do mobile devices support clinical work on hospital wards: an investigation of the selection and use of computing devices

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The mobile and information intensive nature of clinical work in hospital settings presents a critical challenge: how to provide clinicians with access to information at the time and place of need? This challenge is particularly pertinent to decision-makers responsible for the selection of computing devices. Mobile devices are often promoted as a means to meet this challenge, with existing literature tending to portray the mobility of devices as inherently beneficial. However, evidence to clearly demonstrate how mobile devices support clinical work is limited.

This research aimed to generate new knowledge to contribute to answering two significant questions: (i) how do decision-makers select computing devices? and (ii) how do mobile devices support clinical work practices? The research was conducted in two stages. In stage one, interviews were conducted with 28 individuals involved in decisions regarding the selection of computing devices for hospital wards. Decision-makers reported a range of factors that influenced device selection. Role of the user, types of tasks, and location of tasks, for example, were deemed important.

In stage two, a mixed methods design comprising structured observations, interviews, and field notes was employed. A sample of 38 clinicians, on two wards of a metropolitan hospital, was observed for 90 hours. In total 4,423 clinical tasks were recorded, capturing key information about tasks doctors and nurses undertake, where, and devices used. The findings provide evidence validating core assumptions about mobile devices: namely, that they support clinicians' work by facilitating access to information at patients' bedsides. Notably, mobile devices also supported work away from the bedside and whilst clinicians were in transit, allowing continuity in work processes. However, mobile devices did not provide the best fit for all tasks and additional factors, such as the temporal rhythms of the ward and structure of ward round teams, affected how mobile devices supported work.

Integration of findings from the two stages resulted in the development of a detailed list of factors that influence the use of mobile devices on hospital wards. This new evidence provides valuable knowledge to guide the selection of computing devices to support, and potentially optimise, clinical work.

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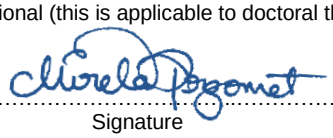

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ABSTRACT

The mobile and information intensive nature of clinical work in hospital settings presents a critical challenge: how to provide clinicians with access to information at the time and place of need? This challenge is particularly pertinent to decision-makers responsible for the selection of computing devices. Mobile devices are often promoted as a means to meet this challenge, with existing literature tending to portray the mobility of devices as inherently beneficial. However, evidence to clearly demonstrate how mobile devices support clinical work is limited.

This research aimed to generate new knowledge to contribute to answering two significant questions: (i) how do decision-makers select computing devices? and (ii) how do mobile devices support clinical work practices?

The research was conducted in two stages. In stage one, interviews were conducted with 28 individuals involved in decisions regarding the selection of computing devices for hospital wards. Decision-makers reported a range of factors that influenced device selection. Role of the user, types of tasks, and location of tasks, for example, were deemed important.

In stage two, a mixed methods design comprising structured observations, interviews, and field notes was employed. A sample of 38 clinicians, on two wards of a metropolitan hospital, was observed for 90 hours. In total 4,423 clinical tasks were recorded, capturing key information about tasks doctors and nurses undertake, where, and devices used. The findings provide evidence validating core assumptions about mobile devices: namely, that they support clinicians' work by facilitating access to information at patients' bedsides. Notably, mobile devices also supported work away

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Integration of findings from the two stages resulted in the development of a detailed list of factors that influence the use of mobile devices on hospital wards. This new evidence provides valuable knowledge to guide the selection of computing devices to support, and potentially optimise, clinical work.

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ABBREVIATIONS

CI	Confidence Interval
CIAP	Clinical Information Access Portal
CIM	Contextual Implementation Model
COREQ	Consolidated Criteria for Reporting Qualitative Research
CPOE	Computerised Provider Order Entry
DECT	Digital Enhanced Cordless Telecommunication
DOI	Diffusion of Innovation
DSS	Decision Support System
ECG	Electrocardiogram
ED	Emergency Department
EMR	Electronic Medical Record
FDA	Federal Drug Administration
FITT	Fit between Individuals, Task, and Technology
ICT	Information and Communication Technology
ICU	Intensive Care Unit

ID	Identification
IT	Information Technology
IV	Intravenous
MMS	Medication Management System
NHS	National Health Service (United Kingdom)
NICU	Neonatal Intensive Care Unit
NSAID	Non-Steroidal Anti-Inflammatory Drug
NSW	New South Wales (Australia)
OR	Odds Ratio
PACS	Picture Archiving and Communication System
PAS	Patient Administration System
PDA	Personal Digital Assistant
RCT	Randomised Controlled Trial
RIS	Radiology Information System
RR	Relative Risk
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour

TRA	Theory of Reasoned Action
TTF	Task-Technology Fit
WOMBAT	Work Observation Method By Activity Timing

Glossary of Key Terms

Clinical Information	Data that is used to help make patient care decisions, such as from evidence-based resources and decision support systems.
Clinical Information System	Software applications devised to facilitate clinical functions. Examples include: patient administration systems, electronic medical records, medication management systems, decision support systems, computerised provider order entry systems, picture archiving and communication systems, and radiology information systems.
Clinician	A doctor or a nurse.
Coding	Segmenting data into units and rearranging them into categories or themes that facilitate insight, comparison, and interpretation of the data.
Computer Network	The interconnection of a group of computers that can share data and exchange information.
Connectivity	The ability to link to a wired or wireless internet connection in order to receive or send information.
Constructivism	A paradigm in which understanding is created (or "constructed") during interaction between the researcher and the participants.

Decision Support Systems	Software applications that provide patient care recommendations, assessments, alerts, and reminders to support clinical decision-making.
Documentation Latency	The interval of time between obtaining information and electronically documenting the information.
Effectiveness	The degree to which a desired result is produced.
Efficiency	The extent to which time or effort is well used for the intended task.
Electronic Medical Record	An electronic record of health information about patients, which can include: patient demographics, medical history, medications and allergies, vital signs, and laboratory test results.
Fit	The match between two attributes, which can include task attributes, technology attributes, or user attributes.
Fixed Computing Devices	Stationary hardware computing devices. Examples include: desktop computers and wall-mount computers.
General Inductive Analysis	A qualitative data analysis technique that involves: close reading of the data; creation of upper-level themes derived from the study objectives; creation of lower-level themes emerging from the data; coding of data; continuous revision and refinement of the themes; and selection of quotations conveying the essence of each theme.

Hardware	The physical component of computers. Hardware computing devices come in many shapes and sizes but are generally classified into two main categories: fixed computing devices and mobile computing devices.
Hawthorne Effect	Participants modifying their behaviour in the presence of the researcher.
Homegrown	Clinical information systems that have been developed within the hospital setting in which they are used.
Hybrid System	Systems where paper-based processes and electronic systems were used in conjunction.
Independent Parallel Coding	Two (or more) researchers independently reviewing data to identify recurrent concepts and develop a set of themes, which are then compared and merged into a coding schema.
Information and Communication Technology	A wide array of software and hardware technologies designed to support information and communication needs.
Medication Management Systems	A software application that allows clinicians to electronically prescribe medications, alter or cease medications, and record the administration of medications.
Member Checking	Getting feedback from study participants to check the researcher's interpretations of the data.

Mixed Method Research	The integration of quantitative and qualitative research approaches.
Mobile Computing Devices	Hardware computing devices that are easily moveable from location to location. Examples include: computer carts, laptops/notebooks/netbooks, tablet computers, personal digital assistants, and smartphones. Mobile computing devices can be further subcategorised into portable devices and handheld devices. Handheld devices are generally smaller than portable devices and are designed to be operated whist being held by the user.
Open-Ended Questions	Interview questions that are to be answered in the respondents own words, rather than selecting from pre-formulated responses.
Operating System	An intermediary between computer programs/applications and the computer hardware allowing the computer to function. Examples include: Microsoft Windows, iOS, Android, and Linux.
Paradigm	A framework for thinking about research design, measurement analysis, and personal involvement.
Patient-Related Information	Any data relating to a patient, including laboratory and radiology results, medication lists, and progress notes.
Pragmatism	A paradigm which advocates situational responsiveness and orients itself towards solving practical problems in the real world.

Purposive Sampling	The purposeful selection of individuals who are likely to be key informants on a given issue.
Qualitative Research	Qualitative research approaches aid in addressing queries of what, how, and why, and are generally characterised by: the investigation of perspectives in an endeavour to understand a particular matter; the conduct of research in natural settings or contexts; and the use of data in the form of words.
Quantitative Research	The numerical measurement and analysis of data.
Reflexivity	The introspection and acknowledgement of the researcher's experiences and assumptions, and the manner in which these experiences might shape the research.
Snowball Sampling	Obtaining recommendations from participants regarding additional relevant informants that are knowledgeable about the issue being investigated.
Software	The non-tangible component of computers, including the operating system and computer programs/applications.
Theoretical Framework	A frame of reference that aids our understanding of phenomena by helping to explain why a set of patterns occurred or can be anticipated to occur.
Transparency	The explicit description of the conduct of research.
Triangulation	A cross-verification technique by using multiple: data sources; investigators; research methods; or theories.

List of Publications

The following is a list of publications and presentations that arose from the research. A copy of the refereed journal article and conference poster can be found in Appendix A.

Refereed Journal Article

Prgomet M, Georgiou A, Westbrook J (2009) The impact of mobile handheld technology on hospital physicians' work practices and patient care: a systematic review. Journal of the American Medical Informatics Association. 16(6): 792-801.[1]

Refereed Conference Poster

Prgomet M, Callen J, Westbrook J (2010) Selecting clinical computing hardware devices for hospital wards: the role of IT vendors. In: Safran C, Marin H, Reti S (editors). Medinfo 2010. Proceedings of the Thirteenth World Congress on Medical and Health Informatics. Cape Town, South Africa. IOS Press: Amsterdam. p.1551.

Other Publications

Prgomet M, Westbrook J, Callen J, Georgiou A (2009) Implementation and use of computing devices in hospitals. In: Rose C, Cox J, Caillaud C, Davis G (editors). Biennial Faculty of Health Sciences Research Higher Degree Student Conference. Lidcombe, Sydney. Faculty of Health Sciences, The University of Sydney: Sydney. p.61. [Abstract]

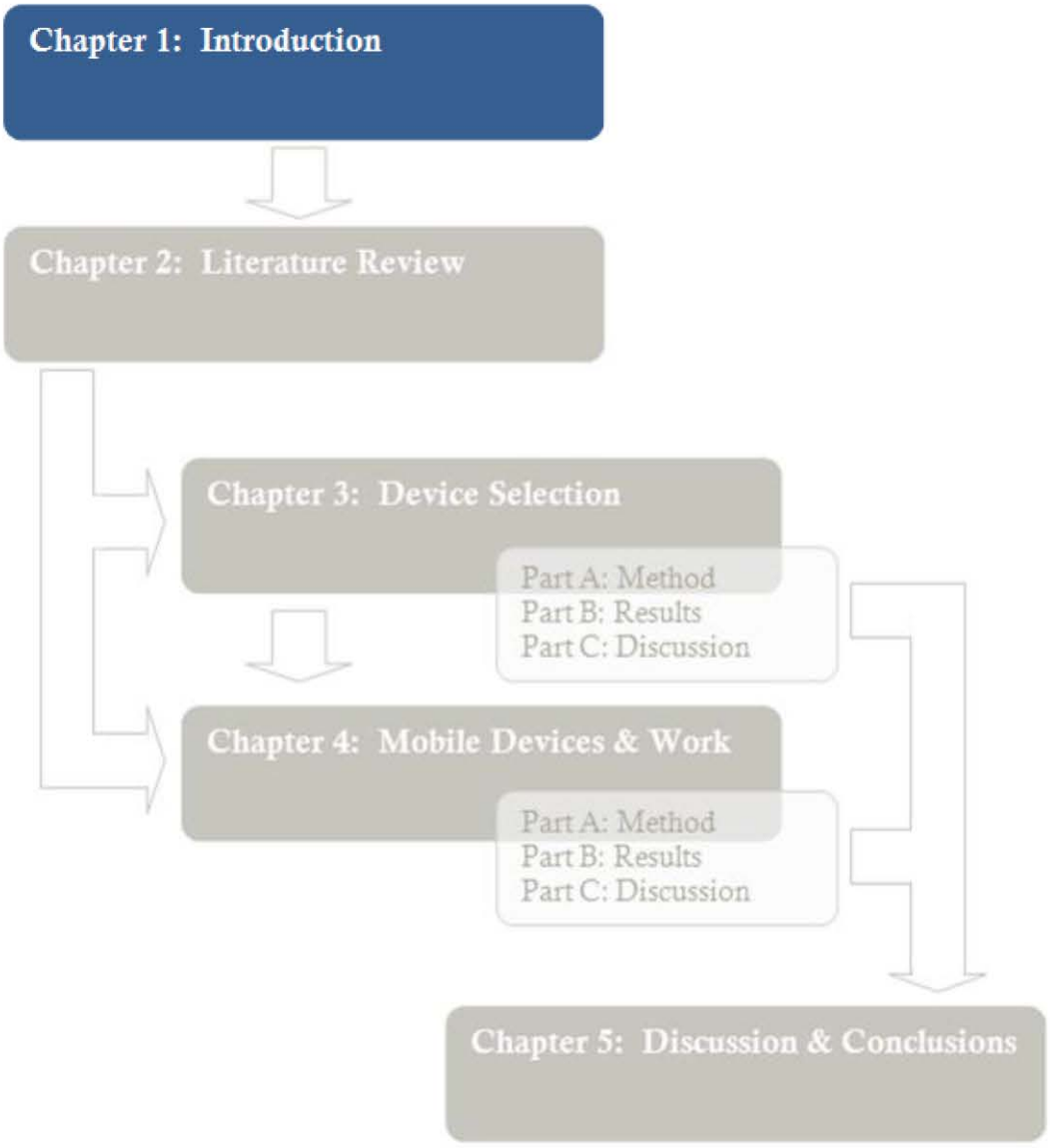
[1] This publication has been cited in 84 articles *(citation source: Google Scholar, 14 February 2014).*

Prgomet M (2011) Selecting clinical computing hardware devices for hospital wards. Annual Research Symposium. Advances in Public Health and Health Services Research. Kensington, Sydney. School of Public Health and Community Medicine, Faculty of Medicine, The University of New South Wales: Sydney. p.50. [Abstract]

Invited Presentation

Prgomet M (2011) The implementation and use of mobile information and communication technology on hospital wards. Health Informatics Society of Australia NSW Bi-monthly Meeting: Health Informatics Research at the Cutting Edge. 18 August 2011. Darlinghurst, Sydney.

CHAPTER 1


Chapter 1: Introduction
Chapter 2: Literature Review
Chapter 3: Device Selection
Part A: Method
Part B: Results
Part C: Discussion
Chapter 4: Mobile Devices & Work
Part A: Method
Part B: Results
Part C: Discussion
Chapter 5: Discussion & Conclusions

Chapter 1. Introduction

1.1. Introduction

The following chapter provides an introductory overview of the content of this thesis. The chapter begins by describing the broad problem area underlying the impetus for the research presented in the thesis. It touches on the complex nature of health care delivery and the potential for technology to make health care delivery more efficient and effective. It also draws attention to the need for a clearer understanding of how technology supports health care work practices, in order to inform decisions about the selection of technology, so that such benefits may be realised. The chapter concludes by presenting the aim of the research and the structure of the thesis.

1.2. Problem Description

Health care is complex and knowledge intensive. Some of the complexities of health care delivery include "the fragmented nature of health care, the large volume of transactions in the system, the need to integrate new scientific evidence into practice, and other complex information management activities" (Chaudhry et al. 2006, p.742). Dependence on pen, paper, and human memory has been identified as "fallible" and insufficient to support modern health care delivery (Australian Health Ministers' Advisory Council 2008). The use of information and communication technology (ICT) has, therefore, been proffered as a means to meet the many challenges of growing

demand and complexity in health care (Australian Health Ministers' Advisory Council 2008; Bates & Gawande 2003; NHS England 2013).

The potential for ICT to have positive effects in the health care arena has long been asserted within the research literature. Reports from the Agency for Healthcare Research and Quality (Shekelle et al. 2006), The Health Foundation (Shekelle & Goldzweig 2009), the National Health Service (NHS) Connecting for Health Evaluation Programme (Sheikh et al. 2011), and the Institute of Medicine (Institute of Medicine 2012) point to the tremendous potential for ICT to advance the efficiency, effectiveness, and safety of health care delivery. Such benefits have seen Governments, in Australia and around the world, make considerable investments to drive the implementation of ICT in health care (Anderson et al. 2006; Chantler et al. 2006; Department of Health 2013; Department of Health and Ageing 2012a; Department of Health and Ageing 2012b; Institute of Medicine 2012; Singer 2009). Estimates of worldwide ICT health care expenditure exceeded USD$169 billion in 2009 (OECD 2010).

While a wealth of literature speaks to the many promising facets of ICT innovations, there is also growing recognition of the problems associated with ICT implementations (Ash et al. 2007a; Bloomrosen et al. 2011; Campbell et al. 2006; Han et al. 2005; Harrison et al. 2007; Kaplan & Harris-Salamone 2009; Redwood et al. 2011). Several studies have demonstrated that the implementation of ICT can lead to both intended and unanticipated changes in the delivery of care (Ash et al. 2004; Audet et al. 2005; Buntin et al. 2011; Embi et al. 2004; Eslami et al. 2008; Garg et al. 2005; Poon et al. 2006; Sidorov 2006; Wachter 2006; Zhan et al. 2006). Campbell et al. (2009; 2006) found that the implications of ICT on clinical work practices can include: unfavourable workflow issues; problems related to paper persistence; changes in work practices, such as altering of the pace and sequencing of clinical activities; and the provision of only partial support for the work practices of clinicians.

Unintended consequences and ICT failures are commonly attributed to inadequacies of the technology, bad programming, or poor implementations (Kleinke 2005; Littlejohns et al. 2003; van Rosse et al. 2009). Wears and Berg (2005) argue, however, that difficulties in ICT implementations often arise due to insufficient understanding of the role of ICT in clinical work, particularly by decision-makers responsible for acquiring and implementing ICT. Likewise, Holden and Karsh (2010) suggest that "the fit between ICT and the clinical work system will lead intended end users to accept or reject the ICT, use it or misuse it, to incorporate it into their routine, or work around it" (p.159). Other researchers also echo this notion underscoring the need to understand how ICT fits into and supports health care work practices (Aarts et al. 2004; Ammenwerth et al. 2006; Cardno 2000; Goodhue 1998; Goodhue & Thompson 1995; Handel et al. 2011; Novak et al. 2012; Peute et al. 2010; Sittig et al. 2000). The importance of addressing this need is that the intended benefits of ICT implementations may not be achieved if the capabilities of the technology are not clearly understood and if there is a mismatch between the selected technology and clinical work practices (Baldwin et al. 2007; Harkke 2006; Murphy 2008; Reddy et al. 2005; Tang & Carpendale 2008).

1.2.1. Defining ICT in Health Care

Within the scope of health care, the term "information and communication technology" encompasses a wide array of software and hardware technologies designed to support clinical information and communication needs (Health Informatics Society of Australia 2008). Some of the key software applications (commonly referred to as clinical information systems) devised to facilitate clinical functions include: patient administration systems (PAS); electronic medical records (EMR); medication management systems (MMS); decision support systems (DSS); computerised provider order entry (CPOE) systems; picture archiving and communication systems (PACS);

and radiology information systems (RIS). These clinical software applications are accessible through hardware computing devices connected to a hospital's computer network.

Hardware computing devices come in many shapes and sizes but are generally classified into two main categories: fixed computing devices and mobile computing devices. Fixed computing devices are stationary and include desktop computers and wall-mount computers. By contrast, mobile computing devices are moveable from location to location and include devices such as computer carts, laptops/notebooks/netbooks, tablet computers, personal digital assistants (PDAs), and smartphones.

Mobile computing devices can be further subcategorised into portable devices and handheld devices (Davis 2008). Handheld devices are generally smaller than portable devices and are designed to be operated whist being held by the user. Figure 1.1 depicts examples of common types of fixed computing devices and Figure 1.2 depicts examples of common types of mobile computing devices.

Fixed Computing Devices

Desktop Computer Wall-mount Computers

Figure 1.1. Examples of Common Types of Fixed Computing Devices

Mobile Computing Devices	
Portable Devices	Handheld Devices
 Computer Cart	 Tablet Computer (Slate)  Tablet Computer (Convertible)
 Laptop / Notebook / Netbook	 Personal Digital Assistant  Smartphone

Figure 1.2. Examples of Common Types of Mobile Computing Devices

1.2.2. Imperative for a Focus on Hardware Computing Devices

Software and hardware technologies go hand in hand. Software applications provide the means to perform data processing but this cannot be achieved without an enabling instrument. Hardware computing devices act as this instrument; providing a mechanism by which to access software applications. Parallel with the infiltration of software systems in health care has been the increasing pervasiveness of hardware computing devices. Mobile computing devices, in particular, have experienced considerable growth in both their development and use in health care (Garritty & El Emam 2006; Health Information and Management Systems Society 2012; Kuziemsky et al. 2005; Payne et al. 2012; Visvanathan et al. 2011; West 2012).

However, literature that investigates the use of ICT in health care has by and large focused on software systems. Chaiken (2008) indicates that organisations invest

significant amounts of time and effort researching software systems, while the hardware computing devices needed to interface with the software systems are a secondary consideration. He further highlights that in order to achieve optimal beneficial outcomes from ICT implementations it is essential to not only consider software systems but to ensure selection of the right hardware computing devices. Morrison et al. (2011) and Murphy (2008) echo this notion, emphasising that the selection of hardware computing devices requires just as much attention as the selection of software systems.

Considering that hardware computing devices play an integral part in the success of software implementations, the selection of hardware computing devices for use in health care, and how devices fit into and support clinical work practices, warrants far greater attention.

1.3. Aim of Thesis

The aim of this thesis is to contribute new knowledge about the selection of hardware computing devices and how they support clinical work practices, with a particular focus on mobile computing devices within the context of hospital settings. This aim is addressed in two stages.

The first stage of the research investigates the perspectives of individuals involved in the selection of hardware computing devices, for use by clinicians (doctors and nurses) on hospital wards, in order to determine the factors considered when selecting computing devices.

The second stage of the research investigates clinicians' use of hardware computing devices on hospital wards in order to ascertain how mobile computing devices support clinical work practices.

1.4. Structure of Thesis

This thesis consists of five chapters, beginning with the present introductory chapter. The rest of the thesis is structured as follows:

Chapter 2, *Literature Review*, presents a synthesis of key literature and identifies the major gaps in the knowledge base. Included is literature relevant to both the first and second stages of the research.

Chapter 3, *Device Selection*, describes the first stage of the research, which involved investigation of the selection of hardware computing devices for use on hospital wards. It includes three major sections: Part A outlines the method used to undertake the first stage of the research; Part B reports the results of the first stage of the research; and Part C presents the discussion relevant to the first stage of the research.

Chapter 4, *Mobile Devices and Work*, describes the second stage of the research, which involved investigation of how mobile computing devices support clinical work practices on hospital wards. As with the preceding chapter, Chapter 4 includes three major sections: Part A outlines the method; Part B reports the results; and Part C presents the discussion relevant to the second stage of the research.

Chapter 5, *Discussion and Conclusions*, draws the first (Chapter 3) and second (Chapter 4) stages of the research together. The chapter discusses key findings from the two research stages and highlights the significance and implications of the research.

An illustration of the structure of the thesis is presented in Figure 1.3.

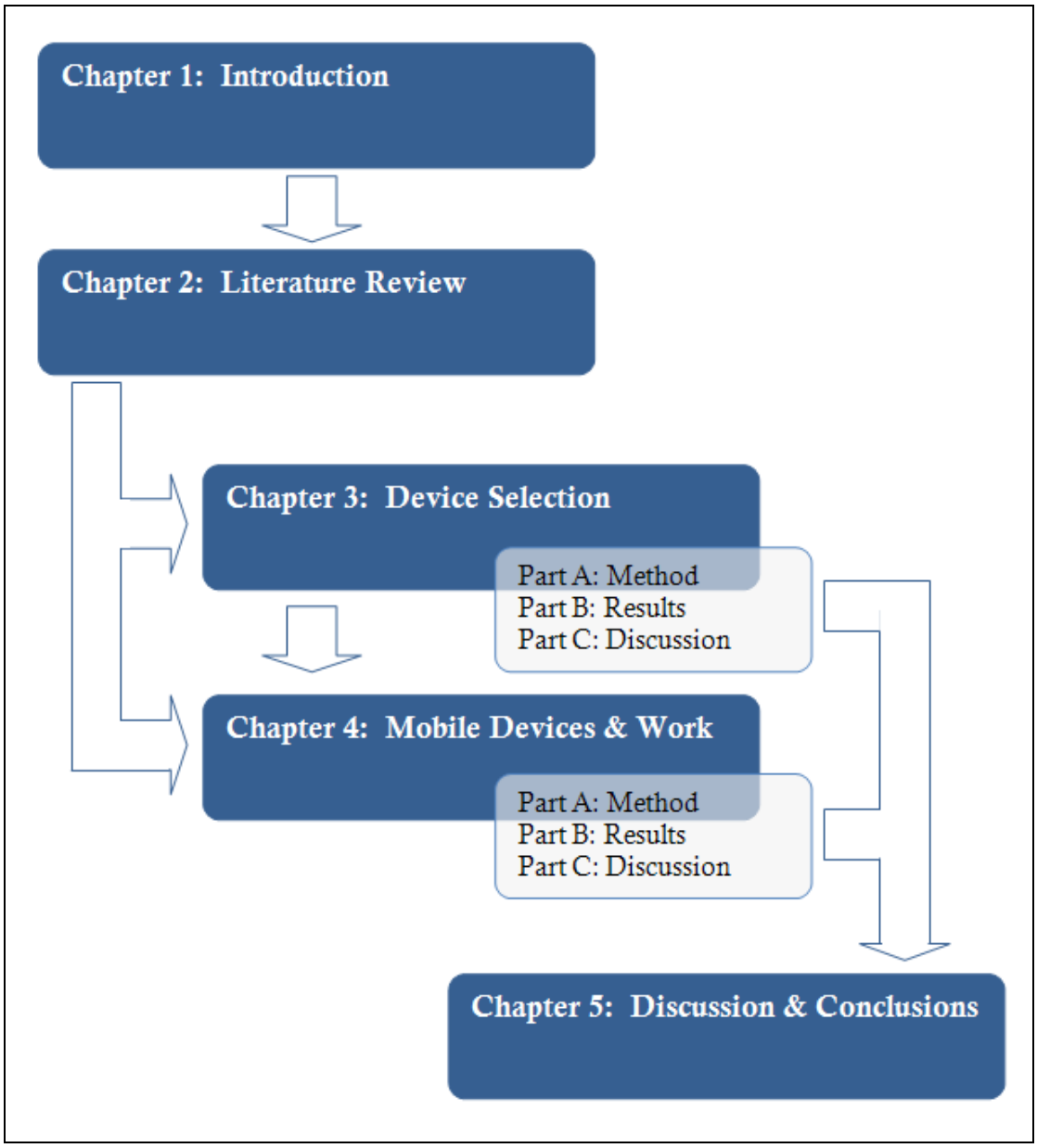
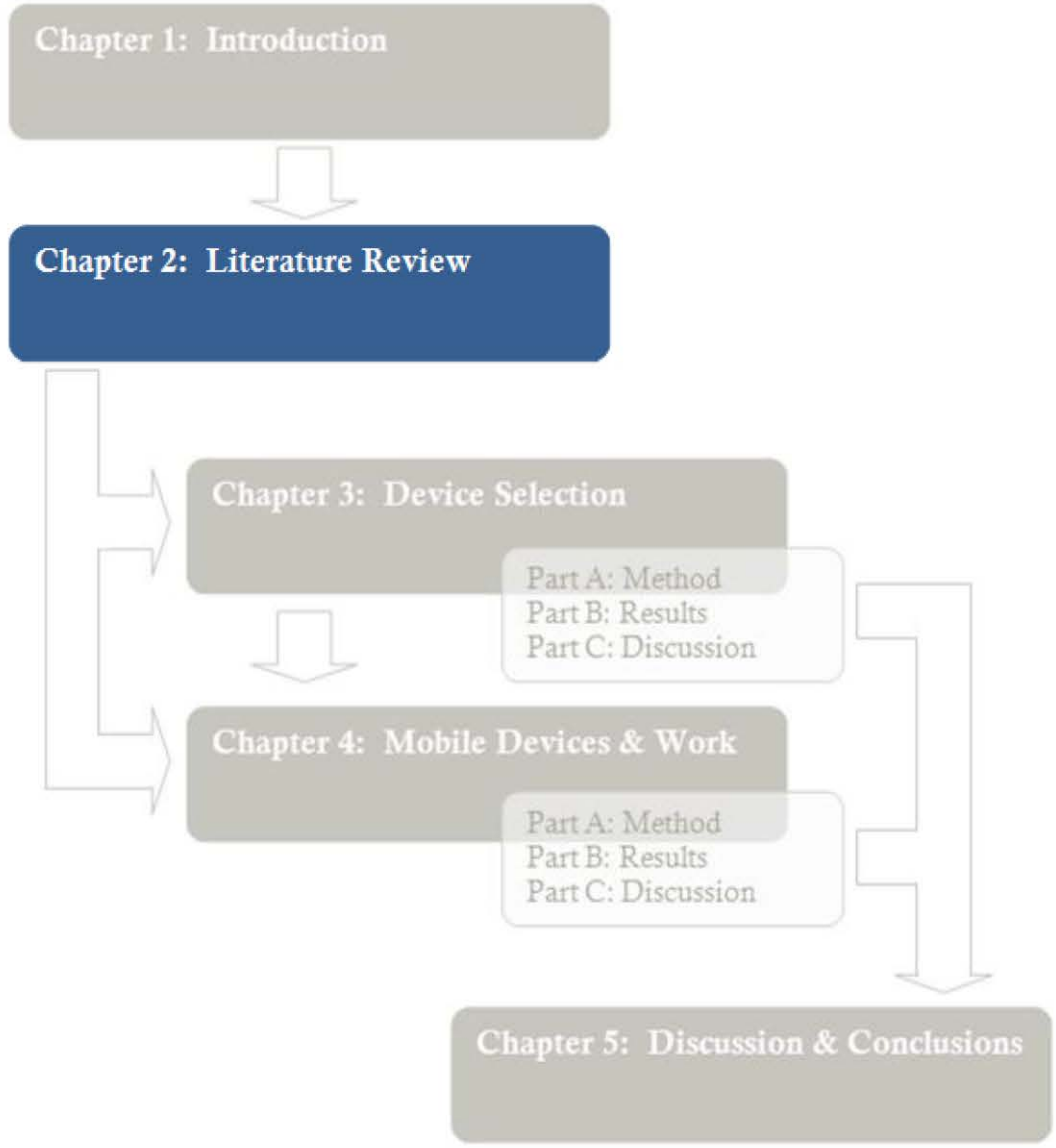


Figure 1.3. Illustrative Representation of the Structure of the Thesis

CHAPTER 2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Part A: Method
Part B: Results
Part C: Discussion
Chapter 5: Discussion & Conclusions

Chapter 2. Literature Review

2.1. Introduction

The preceding chapter provided an outline of the problem area underlying this thesis and drew attention to the need for a clearer understanding of hardware computing devices, how they are selected, and how they support clinical work practices. This chapter delves deeper into the literature to further explore these issues, with a particular focus on mobile computing devices within the context of hospital settings. In reviewing the existing evidence, this chapter aims to identify the gaps in current knowledge and presents an outline of the research required to address these gaps.

2.2. The Mobile and Information Intensive Nature of Clinical Work in Hospital Settings

Hospitals are dynamic places and clinical work in hospital environments is often characterised as being intensely mobile (Bardram & Bossen 2005; Coiera & Tombs 1998; Mejia et al. 2007; Sorby et al. 2010; Svanæs et al. 2010). Indeed, mobility is a central feature of health care delivery (Bardram 2005a; Moran et al. 2006b) with clinicians[2] continuously transitioning between patients, wards, clinics, operating theatres, and their offices in the course of undertaking their work (Ammenwerth et al. 2000; Bardram & Bossen 2003). The need to attend to patients, locate co-workers, access information, and obtain resources, all of which might be distributed throughout

[2] Within this thesis the term 'clinician' refers to doctors and nurses.

the hospital, necessitates this mobility (Bardram & Bossen 2003; Bardram & Bossen 2005; Bossen 2002; Camacho et al. 2006; Moran et al. 2006). Even while located within a single ward of the hospital clinicians can be highly mobile (Andersen et al. 2009; Cornell et al. 2010; Feufel et al. 2010; Hendrich et al. 2008; Wolf et al. 2006). Andersen et al. (2009) found that doctors on wards completed ward round tasks in several different locations including the patient bedside, the patient room, and the corridors of the ward. Likewise, nurses have been found to complete clinical tasks in varying locations throughout a ward including the patient bedside, the patient room, the medication room, the central workstation area, and the corridors of the ward (Andersen et al. 2009; Cornell et al. 2010).

As well as being highly mobile, clinical work in hospital settings is also information intensive (Favela et al. 2007; Lærum et al. 2001; Moran et al. 2006; Reddy et al. 2005; Sorby et al. 2010). Clinicians absorb, interpret, and document a wealth of information about their patients each and every day (Baumgart 2005; Carroll et al. 2002). Studies have reported that clinicians spend up to one third of their time on information tasks, such as documenting, accessing, or synthesising information (Ammenwerth & Spotl 2009; Fontaine et al. 2000; Hendrich et al. 2008; Lunin & Hersh 1995; Moran et al. 2006; Weigl et al. 2009; Westbrook et al. 2011; Westbrook et al. 2008; Wolf et al. 2006). The undertaking of such information tasks is an integral aspect to the diagnosis, treatment, and care of patients (Baumgart 2005; Smith 1996; Wager et al. 2010). As such, the need for clinicians to have timely access to information is crucial to supporting clinical work.

A systematic review by Gurses and Xiao (2006), which examined the information needs of clinicians during ward rounds, underscored the importance for clinicians to have access to both patient-related information (such as laboratory and radiology results, medication lists, and progress notes) and clinical information (such as evidence-based

resources and decision support tools) in order to facilitate effective clinical decision-making. The review also highlighted the necessity for this information to be up-to-date. Other researchers have further argued that as well as being up-to-date, information should ideally be readily accessible to clinicians at the time and place that the need for it arises (Baldwin et al. 2007; Lau et al. 2006; Leape 1997; Reddy et al. 2005). The validity of this argument is sustained by evidence indicating that two of the key factors inhibiting use of clinical information include lack of time and ease of access (Cook et al. 2013; Davies 2007; Gosling et al. 2003; Sackett & Straus 1998; Westbrook et al. 2005). Furthermore, a seminal systematic review of seventy randomised controlled trials (RCTs) identified that the provision of decision support at the time and location of clinical decision-making was a significant predictor of improved clinical practice (Kawamoto et al. 2005).

As clinical work is largely mobile in nature the locations in which clinical decisions are made and information needs may arise are in effect distributed throughout the hospital. Not only is work completed in different locations but clinicians are also said to undertake work whilst they are in transit from one location to the next and, hence, need "to move about and have access to resources…at the same time" (Bardram & Bossen 2005, p.134). The challenge that therefore emerges is how to provide clinicians with access to up-to-date information, at the time and place of need, in order to support efficient and effective clinical work practices. The following sections describe the characteristics of paper and hardware computing devices, and evaluate their ability to meet this challenge.

2.3. Paper and its Ability to Support Clinical Work

Paper, including paper-based medical records and paper resources such as textbooks, has long been used in health care. Paper remains resilient because it provides a number

of affordances, including: tangibility, spatial flexibility, tailorability, and manipulability (Sellen & Harper 2002). In other words, paper can be physically handled and quickly flicked through; it can be spread out on a table so that multiple aspects can be viewed at the same time; it can be easily annotated and scribbled on; and it can be arranged in various ways to suit the needs of the user (Dahl et al. 2006; Luff & Heath 1998; Sellen & Harper 2002). Additionally, paper-based medical records can be dismantled to allow them to be rearranged or shared with collocated colleagues (Dahl et al. 2006; Luff & Heath 1998). Luff and Heath (1998) and Fitzpatrick (2000) suggest a further attribute of paper's success lies in its mobility: paper can be carried from one location to another so that it may be utilised for accessing or documenting information when and where it is needed, including whilst the clinician is in transit. This mobility is well suited to the mobile nature of clinical work practices.

Some of the above benefits, however, also lend themselves to shortcomings. Paper may be mobile and tangible but clinicians are limited in the amount and type of paper they can feasibly carry (Berner et al. 2006; Rudkin et al. 2006). As Bardram and Bossen (2003) assert "it is impossible for clinicians to carry with them all the records and documents for the different patients they are treating" (p.367). Paper-based medical records are also limited by inefficient retrieval processes (Bardram & Bossen 2005), competing accessibility amongst clinicians (Bardram & Bossen 2003; Grasso & Genest 2001), and a lack of simultaneous access from remote locations or by spatially distributed users (Dahl et al. 2006). As such, the paper-based medical record, and thus the information it contains, may not be available or accessible to clinicians at the time and place in which it is needed. These drawbacks are largely due to the fact that "the paper medium and the information it contains are inseparable" (Dahl et al. 2006, p.e2). That is to say, the information amassed within the paper-based medical record is bound to the paper on which it is documented, which makes the sharing of this information difficult. As there is usually only one copy of each patient's paper-based medical record,

it also means that should a record be misplaced or destroyed the information held on that paper would be lost. Dahl et al. (2006) further highlight that the information documented on paper is inflexible and cannot easily be reformatted, revised, or transferred into other documents. In addition, the accelerating rate with which new clinical information is emerging means that paper-based resources are unlikely to be up-to-date and, thus, the information they contain may not be reliable (Hersh 2009; Smith 1996; Taylor 2006).

Given the shortcomings of paper, and the information intensive nature of health care, there has been increasing recognition that paper-based systems do not adequately meet the challenge of supporting efficient and effective clinical work practices (Australian Health Ministers' Advisory Council 2008; Blois & Shortliffe 1990; Chaudhry et al. 2006; Sheikh et al. 2011). As stated in the Bulletin of the World Health Organization "the volume and complexity of knowledge and information have outstripped the ability of health professionals to function optimally without the support of information management tools" (Kwankam 2004, p.800). This recognition has led to demands for new approaches to provide clinicians with up-to-date information in real-time. It has also served as a catalyst for the shift from paper-based practices to computer-based practices based on the notion that many of the limitations of paper could potentially be addressed by computing devices.

2.4. Computing Devices and Their Ability to Support Clinical Work

Hardware computing devices first made their way into the health care environment in the late 1950s (Hannah et al. 2006; Hannan 1991; Kaplan 1995). They were primarily used for administrative purposes, such as payroll and patient charges (Hannah et al. 2006). By today's standards these initial computing devices were bulky, stand-alone systems, with limited functionality. Nonetheless, farsighted medical computing experts

of the time expressed optimism about the future potential of computing devices. According to Kaplan (1995), it was perceived that computers would provide the means to improve clinical practice and aid in the retrieval of clinical information.

As computing devices have evolved they have significantly decreased in size while, at the same time, becoming more powerful; enabling fast processing and storage of vast amounts of information. In fact, many of the mobile computing devices of today are more powerful than the fixed computing devices of just a couple of decades ago (Shortliffe 2005). In addition, the development of networking technologies has allowed computing devices to be linked to one another so that information can be shared and accessed remotely (Hannah et al. 2006). The advent of the internet has also enabled the instantaneous exchange of information amongst users, be they on opposite ends of the hospital or opposite ends of the globe.

Present day hardware computing devices have several advantages over paper-based medical records and resources, including easy storage, searching, retrieval, accessing, and sharing of legible information (Dahl et al. 2006; Sellen & Harper 2002). Additionally, computing devices allow for the amendment and updating of information and, unlike paper, information can easily be reformatted and exported into other documents. Sellen and Harper (2002) characterise computing devices as being dynamic in that they allow the viewing of moving images and provide a means to easily link related information, such as through hyperlinks. Computing devices also allow the manipulation of images, for example, altering the contrast or brightness of a radiology image (Creswick et al. 2011). These attributes are common across both fixed and mobile computing devices; however, each category of computing device has its own strengths and weaknesses.

2.4.1. Fixed Computing Devices

Fixed computing devices, such as desktop computers, have several beneficial features. Their main attribute is that they have a large storage capacity and a fast processor (Davis 2008). Data input into fixed computing devices in generally performed via a keyboard and displayed on a relatively large screen (screen sizes range from approximately 15-inches to 24-inches). The large screen allows for several documents or windows to be opened and placed into view at the same time; although it is argued by some that spreading paper out on a desk is, nonetheless, easier (Sellen & Harper 2002).

The reported limitations of fixed computing devices include that they are static (Bardram & Bossen 2003; Luff & Heath 1998) and consume valuable space in the location that they are stationed (Ammenwerth et al. 2000; Davis 2008). This immobility requires clinicians to be present at the location of the fixed computing device in order to electronically document or access information (Baldwin et al. 2007; Bardram & Bossen 2005; Luff et al. 1992; Tang & Carpendale 2008). When this location is not at the point where information needs arise, clinicians are required to walk back and forth from the point of information need to the location of the fixed computing device in order to access information; a process that is not conducive to efficient clinical work practices (Cheng et al. 2003; Embi et al. 2004; Kushniruk et al. 2006; McCord et al. 2007). A number of studies have found the documentation of test orders on desktop computers, located away from the patient bedside, to be substantially more time consuming than the documentation of test orders on paper (Bates et al. 1994; Shu et al. 2001; Tierney et al. 1993). Hence, while clinicians have reported information to be more accessible when available electronically than when it is on paper, they have also reported a lack of computing devices in the locations that information is needed to be problematic (Bond 2007; Callen et al. 2013a; Kossman & Scheidenhelm 2008; Lærum et al. 2004). Such findings reveal that a lack of fit between clinical work practices and the capabilities of

the technology can hinder the attainment of the intended benefits of technology implementation (Baldwin et al. 2007; Harkke 2006; Reddy et al. 2005). In other words, while the introduction of hardware computing devices is intended to support clinical work practices, fixed computing devices have not completely delivered on this promise as they constrain the work practices of clinicians by mandating where information can be accessed or documented. The emergence of mobile computing devices has, therefore, brought with it expectation that the challenge of supporting efficient and effective clinical work practices will be better met due to their inherently mobile nature.

2.4.2. Mobile Computing Devices

Mobile computing devices, such as computer carts, tablet computers, smartphones, and personal digital assistants (PDAs), have been advocated as a means to overcome the immobile nature of fixed computing devices (Al-Ubaydli 2004; Gandsas et al. 2004). As reported by Alsos (2011):

> *"Since the advent of handheld computers, it has been assumed that such devices will become of great value to health care personnel. The prospect of bedside computing devices opens up the possibility of instant access to up-to-date knowledge sources as well as to patient records"* (p.190).

The key virtue of mobile computing devices is often cited to be their inherent mobility, which allows them to be utilised where and when they are needed (Carroll et al. 2001; Dahl et al. 2006; Lu et al. 2005). Advancements in mobile technology have also made it possible to wirelessly connect mobile computing devices to a hospital's network so that real-time patient data can be electronically accessed and documented at the point of need (Carter 2008).

However, the ease of documenting and accessing information on a mobile computing device can vary depending on the type of device (Fischer et al. 2003; Lu et al. 2003). The screen size of a mobile computing device can range from as small as 2.4-inches for a handheld device, such as that of a smartphone (Milian 2010), to around 17-inches for a portable device, such as that of a laptop (Strickland 2009); whilst data input mechanisms can include a keyboard, keypad, stylus, and/or touchscreen. Commonly cited limitations of mobile computing devices, particularly handheld devices, include usability issues related to small screen sizes (Arshad et al. 2003; Carroll et al. 2002; Chang et al. 2009; Lu et al. 2003; Moran et al. 2006; Thomas et al. 2001) and input mechanisms (Carroll et al. 2002; Fischer et al. 2003; Lu et al. 2003; Moran et al. 2006). Additionally, as mobile computing devices are not tied to one location, they largely rely on an inbuilt battery, and thus inadequate battery life can also be a limitation (Bullard et al. 2004; Lu et al. 2003; Oder et al. 2010).

Despite their limitations there has been great enthusiasm for mobile computing devices. They have been heralded as a device that can potentially provide a best of both worlds solution; combining the mobility of paper with the expeditious data processing of fixed computing devices. But is there evidence to substantiate assumptions that mobile computing devices will support clinical work practices by allowing information to be accessed and documented at the time and place of need? The following sections examine the available evidence regarding the use of mobile computing devices in hospital settings and their impact on clinical work practices.

2.5. Existing Reviews of Mobile Computing Devices in Health Care

The scope of existing literature pertaining to mobile computing is incredibly broad, encompassing discussion of the application of mobile computing devices within a wide

range of settings and for a diverse range of potential uses. With regard to health care, several reviews have been published that summarise much of the literature relating to:

- the technical features and functionality of mobile computing devices (Baumgart 2005; Fischer et al. 2003; Klasnja & Pratt 2012; Lu et al. 2005; Orwat et al. 2008);
- the adoption rates and primary users of mobile computing devices (Garritty & El Emam 2006; Kho et al. 2006; Kuziemsky et al. 2005; Lindquist et al. 2008; Lu et al. 2005; Orwat et al. 2008);
- the barriers to the adoption of mobile computing devices (Kuziemsky et al. 2005; Lu et al. 2005; Martins & Jones 2005a);
- the potential uses of mobile computing devices (Baumgart 2005; Dale et al. 2007; Fischer et al. 2003; Free et al. 2013; Garritty & El Emam 2006; Kho et al. 2006; Kuziemsky et al. 2005; Lindquist et al. 2008; Lu et al. 2005; Mosa et al. 2012; Ozdalga et al. 2012); and
- the potential benefit or impact of mobile computing devices (Free et al. 2013; Kuziemsky et al. 2005; Lindquist et al. 2008a; Lu et al. 2005; Martins & Jones 2004; Martins & Jones 2005a).

The above reviews reported the potential uses of mobile computing devices to include: administrative activities (e.g., billing, scheduling); clinical activities (e.g., patient tracking, prescribing); documentation and access to patient information; access to decision support (e.g., clinical and drug references); communication; and education and research. The benefits of mobile computing devices advocated by the reviews included: enhanced productivity and efficiency; improved communication; error reduction; and increased information accessibility. Although these reviews synthesised a vast amount of information about mobile computing devices, several highlighted that their synthesis

was largely based on anecdotal information and that empirical evidence about the use and impact of mobile computing devices was relatively limited (Dale et al. 2007; Fischer et al. 2003; Kho et al. 2006; Kuziemsky et al. 2005; Martins & Jones 2004). As stated by Dale et al. (2007):

> *"Some of the claims made in the literature are not necessarily supported by empirical data, but may be a result of a somewhat unbridled enthusiasm for the technology examined…some of the claims made are beyond what the concrete empirical evidence supports"* (p.13).

Further, in their review, Kuziemsky et al. (2005) specified that the impact of mobile computing devices on clinical work practices is an area of particular importance requiring greater evidence through rigorous empirical investigation. The authors indicate that such evidence is needed in order to substantiate why mobile computing devices should be adopted and used within health care.

2.6. Impact of Mobile Computing Devices on Clinical Work in Hospital Settings

In order to ascertain the level of existing evidence regarding the impact of mobile computing devices on clinical work practices both quantitative and qualitative literature were sought. In line with the focus of this thesis, the scope of the literature search was limited to studies conducted in hospital settings. The findings from these quantitative and qualitative studies were categorised into one of three key themes:

- *rapid response* (i.e., allowing clinicians to identify patient needs, provide prompt intervention, and improve modes of communication);

- *error prevention* (i.e., providing clinicians with readily accessible resources and decision support tools, and providing use at the point of care to eliminate illegibility and decrease transcription errors); and
- *data management and accessibility* (i.e., enabling clinicians to access up-to-date patient information at the point of care to assist with monitoring and documentation).

These key themes represent areas in which researchers have suggested that the use of mobile computing devices could have positive impacts on clinical work practices (Bates & Gawande 2003; Martins & Jones 2005b). The identified literature was also assessed using a "mobility aspects" framework (described below) in order to determine how mobile computing devices support clinical work practices.

Mobility Aspects Framework

In their review on the use of mobile computing devices, Martins and Jones (2005a) found that literature imparted "very poor descriptions of the mobility aspects of work practices, limiting the insight they offer on workflow mobility" (p.131). To clearly understand how mobile computing devices support clinical work it was necessary to attempt to discern these "mobility aspects." As such, research by Bardram (1997) was utilised in the present study as a foundation upon which to develop a framework to explore the "mobility aspects" of the impact of mobile computing devices.

Bardram (1997) employed core concepts from Activity Theory (conceptualised by Vygotskij (1978) and Leontjev (1978; 1981)) in order to better understand work and the use of computers. Part of these core concepts included: levels of activity, which explain *why* an activity is being carried out; levels of action, which describe *what* is being done; and levels of operation, which examine *how* an activity is achieved.

Within the present study the concepts of *what* is being done and *how* it is achieved were adopted and the notions of *who*, *when*, and *where* were added to form a "mobility aspects" framework. This framework was utilised to appraise whether the identified studies looked at the impact of mobile computing devices in terms of changes in:

- *who* is undertaking an activity;
- *what* resources support undertaking an activity;
- *when* the activity is performed;
- *where* the activity is performed; or
- *how* the activity is performed.

2.6.1. Quantitative Studies on the Impact of Mobile Computing Devices on Clinical Work Practices

Eighteen studies, published between 1998 and 2012, that quantified the impact of mobile computing devices on hospital clinicians work practices were identified. Three of these studies examined the use of mobile computing devices to facilitate rapid response; seven studies looked at error prevention; and eight studies examined data management and accessibility.

2.6.1.1. Mobile Computing Devices Facilitating Rapid Response

Three studies were identified that assessed the use of mobile computing devices as a means to help clinicians respond to clinical situations in a timely manner. Adams et al. (2006) and Clemmensen et al. (2005) examined the use of mobile computing devices to aid in providing prompt treatment, while Aziz et al. (2005) examined the use of mobile computing devices for enhancing inter-professional communication.

Prompt Treatment

Adams et al. (2006) and Clemmensen et al. (2005) investigated the feasibility of wireless transmission of electrocardiograms (ECGs) to a cardiologist's mobile computing device (a PDA) to enable earlier notification, assessment, and interpretation of ECGs and, thus, faster treatment. Adams et al. (2006) obtained 17-months of pre-intervention data during which time 48 patients with acute coronary occlusion were transported to the study site by emergency medical services. The pre-intervention data were compared with 24-months of intervention data, during which time 24 patients with successful transmission of pre-hospital ECGs were transported by emergency medical services. In 19 cases pre-hospital transmission of ECGs failed and, thus, this group were used as concurrent controls alongside 101 patients who self-transported to the Emergency Department (ED) during the intervention phase. In the intervention phase pre-hospital ECGs were transmitted to a desktop computer located at the study site. This allowed the ED nurses to forward the ECG images to a cardiologist's PDA. The findings demonstrated a significantly shorter median door-to-treatment time with successful ECG transmission (50 minutes) compared with: the pre-intervention time (101 minutes; $p<0.0001$); patients who self-transported (96 minutes; $p<0.0001$); and patients with failed ECG transmission (78 minutes; $p<0.0001$). The authors concluded that transmitting ECGs to a cardiologist enabled earlier notification and decreased time to treatment.

Similar findings were demonstrated by Clemmensen et al. (2005). The authors obtained 15-months of data during which time 408 pre-hospital ECGs were transmitted to a desktop computer at the study site and simultaneously to a cardiologist's PDA. The cardiologist subsequently notified ambulance personnel as to whether the patient needed to be redirected to a hospital with invasive facilities for coronary intervention (113 patients). Results showed that there was a substantial reduction of 54 minutes in door-

to-treatment times for coronary intervention patients compared with historical controls from a previous study by Andersen et al. (2003) (average time of 40 minutes compared with 94 minutes respectively; $p<0.01$).

Although both Adams et al. (2006) and Clemmensen et al. (2005) showed improved door-to-treatment times with the wireless transmission of ECGs, neither study explicitly discussed the benefit that the mobility of the computing devices had on the study outcomes. For example, whether cardiologists actually utilised mobile computing devices or fixed computing devices to review the ECGs, where, and which device provided faster response times were not examined. As such, the benefit of mobile computing devices over fixed devices was not clearly distinguished. Applying the mobility aspects framework, the impact of mobile computing devices on clinicians' work practices in these studies focused on *when* investigatory images were accessible by the clinician to allow treatment to be planned or initiated. The extent to which mobile computing devices supported easier and more frequent access to information from different work locations, or the effects of this, were not discussed within these studies.

Communication

Aziz et al. (2005) examined the use of mobile computing devices (PDAs) to facilitate inter-professional communication. A team of nine doctors were given, on alternate weeks during the six-week study period, either a PDA with mobile phone functionality or the use of a conventional pager. Comparisons in communication efficiency were assessed by measuring call response times for random calls initiated by the researchers. Doctors were given a five-minute response interval, after which it was considered that they had failed to respond. The results indicated that average response times were lower and failures to respond occurred less often with use of the PDA compared with the conventional pager (RR 0.44; 95% CI 0.20–0.93). The authors suggested that the

mobile phone functionality of the PDA overcame the limitation of conventional pagers where clinicians need to locate an available phone to return a call. However, as acknowledged by the authors, the actual location in which the PDAs were used compared with the location in which conventional pagers were used was not examined in the study. The impact of mobile computing devices on clinicians' work practices in the study focused on *when* a clinician was able to respond to a call.

2.6.1.2. Mobile Computing Devices Facilitating Error Prevention

Several studies were identified that investigated the use of mobile computing devices to facilitate informed patient care decisions and reduce errors. Three studies (Bullard et al. 2004; Rudkin et al. 2006; Sackett & Straus 1998) assessed the impact of accessibility to evidence via mobile computing devices on patient care decisions; two studies (Berner et al. 2006; Sintchenko et al. 2005) examined the impact of a decision support system (DSS) on prescribing practices; and two studies (Grasso et al. 2002; Shannon et al. 2006) assessed the use of mobile computing devices for electronically generating medication lists or prescriptions.

Evidence-Based Care

Based on the premise that clinicians require evidence to make effective patient care decisions, Sackett and Straus (1998), Rudkin et al. (2006), and Bullard et al. (2004) examined whether the use of mobile computing devices supported accessibility to clinical information during care delivery. Sackett and Straus (1998) investigated the use of an "evidence cart" amongst a team of 18 doctors during one-month of ward round observations. The evidence cart consisted of a mobile computing device (a computer cart) which provided accessibility to electronic evidence-based resources via compact discs and which was also used as a means to store paper-based resources. The authors indicated that, although the computer cart was meant to provide portability, the doctors

found it too bulky to take to the patient bedside. Nonetheless, the findings indicated that the evidence cart was used to conduct 98 searches for evidence. Seventy-nine (81%) of these searches were for evidence that could affect diagnostic and/or treatment decisions of which 71 (90%) were successful: 37 (52%) successful searches confirmed a tentative diagnostic or treatment decision; 18 (25%) led to a new diagnostic or treatment decision; and 16 (23%) led to a corrected diagnostic or treatment decision. Both paper-based and electronic resources were used to conduct evidence searches. When the evidence cart was removed from the ward, the authors observed 41 instances when evidence was required but it was actively sought in only 5 of these instances.

Rudkin et al. (2006) also investigated the use of electronic and paper-based resources and their impact on the rate of change in patient management decisions. Thirty doctors were observed on two occasions: once while using electronic resources on a mobile computing device (a PDA) and once while using paper-based resources. Doctors were observed accessing electronic resources (n=181) more often than paper-based resources (n=131) (OR 1.99; 95% CI 1.41–2.80). The average time it took doctors to access electronic resources and paper-based resources was similar (9.39±1.4 seconds and 9.4±1.4 seconds respectively). However, access times only reflected the time it took to find the necessary information within the relevant resource. The time it took for doctors to locate and obtain paper-based resources that were not available at the point of need was not recorded. The rate of change in patient management was significantly higher with the use of electronic resources (29.8% compared with 17.6%; OR 2.00; 95% CI 1.11–3.60), particularly for changes in drug type (21.5% compared with 13.0%; OR 1.84; 95% CI 0.95–3.59). The authors suggested that this result may be due to differences between the levels of information available via electronic resources and paper-based resources such as drug interaction information, which was not available via the paper-based resource.

Bullard et al. (2004) assessed the frequency with which doctors accessed clinical practice guidelines on a mobile computing device (a computer cart) compared with a desktop computer. Ten ED doctors each undertook five shifts using a computer cart and five shifts using a desktop computer. The doctors perceived that their use of guidelines was more frequent with the computer cart than the desktop computer (mean rating 4.1 versus 3.5; p=0.03). A database audit confirmed this perception, demonstrating significantly higher use of guidelines during shifts when the computer cart was used compared with shifts when the desktop computer was used (mean 3.6 versus 2.0; p=0.033). The authors concluded that use of the computer cart allowed doctors to access information at the bedside and use guidelines more frequently. However, whether computer carts were actually used at the bedside was not assessed in the study.

The above studies indicated that clinicians utilised mobile computing devices to access evidence more frequently than paper-based resources (Rudkin et al. 2006) and fixed computing devices (Bullard et al. 2004), and that accessibility to evidence influenced patient management decisions (Rudkin et al. 2006; Sackett & Straus 1998). However, the studies did not explicitly discuss *where* clinicians utilised mobile computing devices to access evidence. As such, the specific benefits of mobile computing devices were not clearly distinguished. The impact of mobile computing devices on clinicians' work practices predominantly focused on *how* clinicians were able to access information.

Decision Support

Berner et al. (2006) and Sintchenko et al. (2005) conducted studies where the use of a DSS, via mobile computing devices, was designed to improve care by reducing unsafe or unnecessary prescribing. Within the studies, mobile computing devices were introduced primarily for use as a source of information and decision support at the clinician's discretion, with documentation and prescribing carried out separately.

Berner et al. (2006) evaluated the effectiveness of a DSS on the prescribing safety of non-steroidal anti-inflammatory drugs (NSAIDs). Thirty-one doctors were assigned to an intervention group and 28 to a control group. All doctors were given mobile computing devices (PDAs) with which they could access the DSS; but the intervention group received an additional NSAID-related risk assessment decision rule with real-time treatment recommendations. Standardised patients, trained to portray clinical conditions that could result in adverse outcomes with inappropriate NSAID prescription, presented to each participating doctor at least once during the six-months of baseline data collection and once during the eight-month follow-up period. Safe and unsafe prescribing, and documentation of key risk factors, was determined through chart review. The findings showed that at baseline unsafe prescribing was similar for the intervention and control groups (mean proportion of unsafe prescribing cases per doctor was 0.27 and 0.29 respectively; $p>0.05$). Introduction of the intervention rule significantly affected error rates (0.23 cases per doctor in the intervention group compared with 0.45 in the control group; $p<0.05$). However, this was attributed to performance degradation in the control group rather than a substantial improvement in the intervention group, whose performance remained relatively constant. The authors also noted a significant association between obtaining key risk factors, which were documented more frequently in the intervention group, and safe prescribing. An interesting finding was that patients reported minimal use of PDAs in their presence. The authors suggested that doctors may have utilised the PDAs outside of the patient's room, however, they also acknowledged that the absence of reliable data regarding how doctors actually used the PDAs and DSS was a limitation of the study.

Sintchenko et al. (2005) also assessed the impact of a DSS, accessible via a mobile computing device (a PDA), on patient management. During the six-month study period 12 doctors were provided with PDAs that contained a locally developed DSS. The rate of DSS use during the intervention period was compared with six-months of historical

data during which no computerised DSS was available. The findings showed that the DSS was used 674 times (an average of four times per day) during the study period. A significant difference was observed in the number of antibiotics used with the pre-intervention consumption rate of 1,925 defined daily doses per 1,000 patient days decreasing to 1,606 defined daily doses per 1,000 patient days in the intervention period ($p=0.04$). The authors suggested that despite the infrequent use of the DSS (relative to the number of prescribing decisions that doctor's make on a daily basis) accessibility to additional information can lead to improvements in clinical decisions. However, the authors highlighted that they were unable to identify the specific contributions of using a mobile computing device over a fixed computing device to the study results.

Amongst the above studies by Berner et al. (2006) and Sintchenko et al. (2005) the impact of mobile computing devices on clinicians' work practices primarily related to *what* information is accessible by clinicians to help inform patient care decisions.

Medication Safety

Grasso et al. (2002) and Shannon et al. (2006) both conducted studies with the aim of examining the use of mobile computing devices for the documentation of medications. Grasso et al. (2002) compared error rates in discharge medication lists when nurses transcribed doctors' handwritten medication orders with those occurring when doctors directly entered medication orders onto a mobile computing device (a PDA). The 110 transcribed discharge medication lists and the 90 electronically generated discharge medication lists were retrospectively reviewed for errors by a pharmacist. The findings showed significantly fewer errors with the electronically generated discharge medication lists compared with the transcribed discharge medication lists (8% versus 22%; $p<0.05$). The seven errors identified in the electronically generated discharge medication lists all involved erroneous exclusion of medications, while transcription errors were eliminated.

Similar results, however, could also have been achieved with the direct entry of medication orders into fixed computing devices.

Medication error reduction, such as those due to illegibility, was also the impetus for a study by Shannon et al. (2006). The authors aimed to increase the rate of voluntary electronic prescribing amongst nine ED doctors by providing them with mobile computing devices (PDAs) with which they could access the hospital's clinical information system. During the three-month pre-intervention period both paper-based prescribing and electronic prescribing via desktop computers were available. In the one-week intervention period the additional method of prescribing via PDAs was made available. The researchers hypothesised that leaving a patient's bedside to access a desktop computer and enter a prescription was inconvenient and, thus, was hindering the uptake of electronic prescribing. A total of 78 pre-intervention prescriptions and 89 intervention prescriptions were reviewed. There was a significant increase in the average rate of electronic prescribing with the introduction of PDAs (64% electronic prescribing compared with 52% pre-intervention; $p=0.03$). Of the electronic prescriptions generated during the intervention period, half were completed using the PDAs and the other half using the desktop computers. A high degree of variability in the rate of electronic prescribing amongst individual doctors was found; ranging from no electronic prescriptions to all electronic prescriptions. The authors examined whether a prior preference for handwriting paper-based prescriptions was a predictor for PDA use. They found that, rather than a preference for handwriting being a predictor, a prior preference for electronic prescribing via a desktop computer was a positive indicator for subsequent electronic prescribing with the PDA. The authors further stated that amongst the doctors who elected to prescribe electronically, some continued to use the desktop computer in preference to the PDA. The reasons for this preference were not investigated but the authors suggested that factors, in addition to mobility, are important to the adoption of electronic prescribing.

Both the Grasso et al. (2002) and Shannon et al. (2006) studies showed positive findings, with the impact of mobile computing devices on clinicians' work practices focusing on *who* performs tasks and *how* medications were documented or prescribed.

2.6.1.3. Mobile Computing Devices Facilitating Data Management and Accessibility

Eight studies were identified that evaluated the use of mobile computing devices to facilitate the documentation of, or accessibility to, patient information during care delivery. Three studies (Carroll et al. 2003; Stengel et al. 2004; VanDenKerkhof et al. 2003) examined documentation quality; a further three studies (Chan et al. 2004; Hamid et al. 2010; Rodriguez et al. 2003) assessed documentation efficiency; and two studies (Horng et al. 2012; Park et al. 2007) examined information accessibility.

Documentation Quality

Stengel et al. (2004), Carroll et al. (2003), and VanDenKerkhof et al. (2003) conducted studies that assessed the comprehensiveness and accuracy of patient information documented on paper compared with electronic documentation via mobile computing devices. Stengel et al. (2004) examined whether the use of mobile computing devices (PDAs) could have a positive impact on the quantity and quality of documentation and coding of patient diagnoses. During the study a team of four doctors and two medical students performed either conventional paper-based documentation or electronic documentation via a PDA to record a patient's history, clinical findings, and treatments. The documented diagnoses were then translated into standardised codes. The coding process was completed manually for paper-based documentation but became automated with electronic documentation. A total of 39 patients were assigned to paper-based documentation, while 38 patients were assigned to electronic documentation. Documentation via the PDA resulted in the recording of significantly more diagnoses

per patient compared with paper-based documentation (9 median diagnoses versus 4 median diagnoses respectively; $p<0.0001$). However, the rate of false or redundant codes was also higher with electronic documentation (11.7%) than paper-based documentation (4.5%); although this did not impact on the findings which remained significant even after the false codes were removed ($p<0.0001$). The authors concluded that use of mobile computing devices increased the recording of diagnoses and improved the overall quality of patient records.

Carroll et al. (2003) conducted a study in a neonatal intensive care unit (NICU) to determine whether the use of a mobile computing device (a PDA) to record patient information could reduce the prevalence of documentation discrepancies in progress notes. The authors analysed 339 progress notes documented on paper and 432 progress notes documented on a PDA with respect to information about a patient's weight, medications, and vascular lines. A documentation discrepancy was considered as having occurred when the information documented on the progress note did not match the information noted in the nursing flow sheet, assessment sheet, or pharmacy medication administration record. Documentation via the PDA resulted in significantly fewer documentation discrepancies of patient weight (14.4% compared with 4.4%; OR 0.29; 95% CI 0.15–0.56). However, there were no significant changes in the number of progress notes with medication discrepancies (27.7% compared with 17.1%; OR 0.63; 95% CI 0.35–1.13) or vascular line discrepancies (33.6% compared with 36.1%; OR 1.11; 95% CI 0.66–1.87). Although the authors indicated that PDAs were introduced for point of care use, the study did not measure where doctors used the PDAs to document information at the point at which it was obtained or whether it was recalled and documented at a later stage.

VanDenKerkhof et al. (2003) examined the use of structured pain assessment forms on a mobile computing device (a PDA) and compared the encounter time and

comprehensiveness of documentation with the existing unstructured paper-based process. In the course of the three-week study period one doctor performed 100 assessments on 44 patients using paper-based forms, where documentation was completed outside the patient rooms. A further 94 assessments on 30 patients were performed using the PDA, where documentation was completed at the patient bedside. Completeness of documentation was assessed based on the frequency of recorded pain variables (characterisation, location, and duration of pain) and common side effects. The median encounter time for each patient (including chart review, patient assessment, and documentation) was significantly shorter with use of the PDA compared with the use of paper-based forms (227 seconds versus 301 seconds respectively; $p<0.001$). The frequency of documented side effects ranged from 5%–100% for paper-based forms and 98%–100% for recording via the PDA. Pain variables were also more likely to be documented via the PDA than with the paper-based process. The authors highlighted that documentation on the paper-based forms occurred after patient assessment, while documentation on the PDA occurred during patient assessment. They suggested that the difference in the comprehensiveness of the documentation may have been due to the location of the recording and the structured nature of the electronic forms.

Although the above studies demonstrated positive findings regarding the comprehensiveness and accuracy of documentation completed on mobile computing devices, only VanDenKerkhof et al. (2003) explicitly stated that the location of device use contributed to the study outcomes. Thus, the impact of mobile computing devices on clinicians' work practices in the VanDenKerkhof et al. (2003) study focused on *where* documentation of patient information was completed, while Stengel et al. (2004) and Carroll et al. (2003) focused on *how* documentation of patient information could be performed to improve data quality.

Documentation Efficiency

The efficiency of documenting patient information via mobile computing devices was investigated by Hamid et al. (2010), Wager et al. (2010), Chan et al. (2004), and Rodriguez et al. (2003). Hamid et al. (2010) examined documentation latency for vital signs charting and medication administration with the use of mobile computing devices; initially with computer carts and then with the use of tablet computers. Documentation latency was defined as the interval of time between obtaining information and electronically documenting the information. The study was conducted across two wards, a medical ward and multidisciplinary ward, and included 48 nurses. The findings indicated that mean documentation latency for vital signs charting decreased significantly following the change from computer carts to the use of tablet computers: from 8 minutes to 1 minute in the medical ward, and 28 minutes to 2 minutes in the multidisciplinary ward ($p<0.0001$). Likewise, mean documentation latency for medication administration also decreased significantly: from 33 minutes to 4 minutes in the medical ward, and 2 hours 43 minutes to 4 minutes in the multidisciplinary ward ($p<0.0001$). The authors indicated that only 22 of the 48 nurses (45.8%) used the tablet computer frequently during the study. However, there was no discussion regarding differences in the use of the computer carts and the tablet computers, nor an explanation as to the factors leading to such substantial differences in documentation latency between the two types of mobile computing devices examined.

Chan et al. (2004) provided one mobile computing device (a PDA) for use amongst a clinical team. The PDA was used to replace the paper-based process, where doctors used a paper-based form to record patient information during their rounds, which was subsequently manually entered into a database via a desktop computer. Data from the PDA, on the other hand, were transferred through synchronisation with the desktop computer. The authors designed the electronic forms and included prompts to ensure

all mandatory information was entered. A sample of 60 visits documented on paper-based forms and 68 visits documented electronically via the PDA during the three-month study period were analysed. The findings indicated no significant change in the average duration required to attend to a patient while using a PDA for documentation compared with paper-based documentation (7.0±2.0 minutes versus 8.8±3.2 minutes respectively; p=0.151). This duration did not include the time required to electronically transfer data from the PDA to the desktop computer, or the time required to manually enter data from the paper-based form to the desktop computer, which took an average duration of 12 minutes.

Documentation duration was also assessed by Rodriguez et al. (2003), who compared documentation via two mobile computing devices: a laptop and a PDA. Eighteen nurses performed eight different data management tasks on each mobile computing device, with documentation completed via a keyboard for the laptop and via a stylus for the PDA. The findings indicated that, overall, tasks were completed 16.6% faster on the laptop. Documenting specified text as a note, documenting vital signs, and reading results were all completed faster on the laptop (55.3%, 5.1%, and 18% faster respectively). Documenting medication administration, documenting intake/output data, documenting specific assessment information, and searching for vital signs data were all completed faster on the PDA (47.1%, 16.7%, 4.7%, and 47.5% faster respectively). These findings were largely attributed to differences in the software applications and, thus, differences between the interface on the laptop and PDA.

Amongst the above studies by Hamid et al. (2010), Chan et al. (2004), and Rodriguez et al. (2003) the impact of mobile computing devices on clinicians' work practices primarily related to *how* the documentation of patient information could be performed with greater efficiency.

Information Accessibility

Park et al. (2007) and Horng et al. (2012) assessed whether the use of mobile computing devices improved accessibility to patient information, thus increasing efficiency. Park et al. (2007) examined the use of mobile computing devices (PDAs) for information accessibility during pre-rounds. Seventeen doctors were provided with PDAs with wireless access to up-to-date patient information, including vital signs, laboratory data, radiological reports, medication lists, and fluid intake/output. The doctors were initially observed for a four-week period, during which patient information was accessed on a desktop computer. The pre-rounding time was found to significantly decrease, from an initial time of 50.5±15.4 minutes with the use of desktop computers to 40.7±15.7 minutes with the use of PDAs ($p=0.02$). The authors indicated that the PDAs freed doctors from being tied to the desktop computer and allowed them to access information from anywhere within the hospital, at anytime. However, the location in which doctors actually utilised the PDAs to access information was not examined as part of the study.

Horng et al. (2012) assessed whether accessibility to information via a mobile computing device (a tablet computer) decreased the time doctors spent on desktop computers. Thirteen doctors were provided with tablet computers, however, use was voluntary and doctors could elect to use either a tablet computer or a fixed computing device. The participating doctors all had at least some experience with the use of mobile computing devices and were highly experienced with the use of desktop computers. The findings showed that doctors use of tablet computers was associated with a 38 minute decrease in time spent per shift accessing information via a desktop computer ($p<0.001$). Responses to a survey, administered pre and post introduction of the tablet computers, indicated that doctors perceived tablet computers to be useful during ward rounds to access laboratory information and previous patient records. The authors suggested that

reducing the need to access information via a fixed computing device increased the potential amount of time doctors could spend at the patient bedside. However, only 31% of the doctors perceived that use of the tablet computers was associated with increased time at the patient bedside.

Amongst the above studies by Park et al. (2007) and Horng et al. (2012) the impact of mobile computing devices on clinicians' work practices primarily addressed *how* clinicians are able to access patient information.

2.6.1.4. Summary of the Quantitative Evidence on the Impact of Mobile Computing Devices on Clinical Work Practices

The preceding review of quantitative studies reveals that literature regarding the impact of mobile computing devices on clinicians' work practices, while not extensive, provides some evidence that the use of mobile computing devices may be beneficial in supporting health care delivery processes by facilitating rapid response, error prevention, and data management and accessibility. In the area of rapid response, Adams et al. (2006) and Clemmensen et al. (2005) found that enabling clinicians to receive earlier notification of investigatory patient information expedited treatment, while Aziz et al. (2005) demonstrated improved inter-professional communication with the use of mobile computing devices. The literature on error prevention showed that accessibility to clinical evidence influenced patient management decisions (Bullard et al. 2004; Rudkin et al. 2006; Sackett & Straus 1998), use of DSS promoted safer prescribing (Berner et al. 2006; Sintchenko et al. 2005), and enabling direct electronic input of medications eliminated transcription errors (Grasso et al. 2002). In the area of data management and accessibility, the studies demonstrated improvements in the comprehensiveness and accuracy of documented patient information (Carroll et al. 2003; Stengel et al. 2004; VanDenKerkhof et al. 2003) and in the efficiency of documenting and accessing patient

information (Chan et al. 2004; Hamid et al. 2010; Horng et al. 2012; Park et al. 2007; Rodriguez et al. 2003).

Application of the framework, to explore the mobility aspects of the impact of mobile computing devices on clinical work practices, illustrates that the majority of literature focused on changes in either *when* or *how* an activity is performed. Studies in the area of rapid response all addressed *when* an activity is performed; studies examining error prevention addressed either *how* an activity is performed, *what* resources support undertaking an activity, or *who* is undertaking an activity; while studies in the area of data management and accessibility predominantly addressed *how* an activity is performed, with one study addressing *where* an activity is performed.

Using this framework it is interesting to note that only one of the studies expressly observed *where* mobile computing device use occurred and addressed the subsequent impact the location of use had on the study outcomes. Although much of the literature alluded to the benefit of mobility for point of care (Berner et al. 2006; Carroll et al. 2003; Sintchenko et al. 2005) or bedside use (Horng et al. 2012; Rudkin et al. 2006; Shannon et al. 2006), none of these studies specifically measured whether mobile computing devices were used in this manner. Thus, in line with the findings of Martins and Jones (2005a), the extent to which mobile computing devices supported work practices because of their inherent mobility was often not clearly portrayed. Hamid et al. (2010), for example, compared documentation latency with the use of computer carts and tablet computers and found significant differences between the two mobile computing devices. However, as there was no discussion regarding *where* the mobile computing devices were used, there was no clear indication as to why one mobile computing device led to significantly better documentation efficiency than the other. Similarly, many of the studies failed to clearly delineate the benefits of providing clinicians with mobile computing devices over fixed computing devices. As such, many of the reported

benefits could also have occurred with the use of fixed computing devices. Sintchenko et al. (2005) adequately summarise the shortcomings of many studies on mobile computing devices when referring to their own inability "to identify the specific contributions of using a handheld platform over [a] fixed [device] to the results" (p.401).

The paucity of evidence in this area highlights the need to explicitly examine *where* clinicians utilise devices in order to determine how the inherent mobility of mobile computing devices supports clinical work practices. It also suggests the need for research that evaluates the use of both fixed and mobile computing devices in clinical settings in order to clearly distinguish the benefits of providing clinicians with mobile computing devices.

2.6.2. Qualitative Studies on the Impact of Mobile Computing Devices on Clinical Work Practices

Seven qualitative studies, published between 2004 and 2011, that investigated the impact of mobile computing devices on hospital clinicians work practices were identified. The qualitative studies primarily utilised interviews to elicit clinicians' perceptions regarding the benefits of using mobile computing devices, and/or undertook observations to provide descriptive explanations of the use of mobile computing devices. The qualitative literature largely focused on examining the areas of error prevention, and data management and accessibility. No qualitative studies were identified that examined the area of rapid response.

2.6.2.1. Mobile Computing Devices Facilitating Error Prevention

Three studies (Alsos et al. 2011; Harkke 2006; McAlearney et al. 2004) were identified that investigated perceptions regarding whether the use of mobile computing devices facilitated access to clinical resources and aided in preventing errors.

McAlearney et al. (2004) and Harkke (2006) sought to ascertain doctors' perspectives regarding the use and impact of mobile computing devices (PDAs). McAlearney et al. (2004) undertook eight focus group sessions with a cohort of 54 doctors, which included both users (83%) and non-users of PDAs (17%). The focus group sessions lasted 60–90 minutes and were conducted across a range of health care settings, including a children's hospital and a community hospital. The findings from the focus groups indicated that doctors, who were users of PDAs, perceived that mobile computing devices provided them with the means to access information regarding medications at the point of need. They believed that the ability to access information when it was needed increased their productivity, as it saved them from having to locate and potentially wait in queue to use a fixed computing device, and improved patient care. One doctor was quoted as saying: *"For example, if you were talking to a patient and came across a medication that you didn't know, if you didn't have a PDA you probably wouldn't go in the other room and look it up. But if you have the PDA you can pull it out and say, oh yeah, that is a hypertensive medication"* (p.1163).

Similar perceived benefits were reported by Harkke (2006) who undertook interviews with 30 doctors; six of whom were hospital-based doctors, while the remainder were general practitioners. The interviews were conducted between four and 10 months after the doctors were provided with mobile computing devices (PDAs) and, on average, lasted 30 minutes. The six hospital-based doctors indicated that they conducted a large proportion of their work outside of their offices. The doctors perceived that the PDAs supported their work practices by mobilising information, such as clinical resources, making information accessible at the point of need and decreasing the need to walk to a fixed computing device. They reported access to a pharmaceutical database to be the most useful, particularly for quickly checking information such as the proper dosage of a medication. The majority of doctors felt that PDAs had at least a slightly positive effect on speeding up work routines and reducing errors, but not on reducing working hours.

Alsos et al. (2011) conducted semi-structured interviews with 14 doctors and undertook observations of simulated ward rounds, during which a total of 56 patient visits were recorded. For each patient visit, the doctor prescribed a new medication or changed, paused, or ceased an existing medication which was documented using either a mobile computing device (PDA) or paper-based medical record. Doctors reported that they felt more confident and comfortable using paper-based medical records, nonetheless most doctors indicated that they preferred the PDA. They perceived that PDAs facilitated error prevention as PDAs provided the means to access medication information and, therefore, reduced the need to rely on memorised information. During the prescribing of medications, doctors were observed using PDAs to seek information regarding various medications prior to selecting which medication to prescribe. Doctors expected that they would receive drug interaction warnings when using the PDA and highlighted that paper-based medical records lacked such a mechanism to detect or prevent errors.

2.6.2.2. Mobile Computing Devices Facilitating Data Management and Accessibility

Four studies were identified that investigated whether the use of mobile computing devices facilitated accessibility to patient information during care delivery. Martins and Jones (2005b) examined doctors' perceptions, while Fisher et al. (2006), Tang and Carpendale (2008), and Murphy (2008) examined nurses perceptions.

Martins and Jones (2005b) utilised multiple qualitative methods, including questionnaires, interviews, and participant observations, to investigate the use of mobile computing devices (computer carts) by doctors on ward rounds. The study was conducted five years after introduction of the computer carts, with 33 doctors from five ward round teams participating in the research; a quarter of which had never utilised the computer carts. One doctor, from a team which did not use the computer carts,

perceived that laboratory reports were often not completed by the time that the team conducted their ward round so the computer carts were not seen to add value during the round. However, a doctor from a team that did use computer carts reported that laboratory reports were usually completed when the team did their ward round and accessibility to the reports via the computer carts made things easier during the round. Other doctors that used the computer carts similarly felt that the carts increased efficiency by providing the means to access information and input urgent test orders during the ward round.

Fisher et al. (2006) undertook interviews with seven nurses, two nurse unit managers, and the stroke liaison manager of a Neuroscience Ward. The participants were queried regarding their expectations, experiences, and use of the mobile environment, which included two laptops, a tablet computer, a PDA, and two computer carts. The nurse unit managers and stroke liaison manager, who were the initial drivers behind implementation of mobile computing devices on the Neuroscience Ward, were naturally enthusiastic supporters of technology. It was expected that mobile computing devices could provide access to patient information, such as laboratory and radiology results, at the time of need. As stated by one participant: *"Having information you can access right there and then and not having to go back to the computer all the time…actually have it there at the bedside…I think it will be quite beneficial time management and for the patients getting their results a lot quicker"* (p.5). However, some nurses indicated that they had a tendency to leave the computer cart in one location and walk to the device, rather than taking the computer cart around with them. Nurses explained that that the information available via the mobile computing devices was only occasionally needed and, thus, it was not worth bringing the mobile computing device with them. One nurse conveyed: *"There is no purpose in wheeling the trolley [computer cart] into the room if you are only doing random things on it"* (p.4).

Likewise, Tang and Carpendale (2008), who administered surveys to 29 nurses in the acute medical unit of an urban hospital a year after the implementation of mobile computing devices (computer carts), found that nurses reported rarely taking computer carts to the point of care. The nurses perceived the computer carts to be bulky and clumsy, and expressed a preference for using desktop computers for accessing and documenting patient information. The majority of nurses felt that completing activities electronically on the computer cart was too time-consuming; therefore, they would write information on a piece of paper and enter that information onto a desktop computer at the end of their shift. In addition to issues regarding the physical characteristics of the computer carts, nurses reported the battery life of the carts to be suboptimal. Nurses commented that it was tedious having to plug in computer carts to recharge the battery, which contributed to the computer carts being used in a stationary manner.

Similar findings were also conveyed by Murphy (2008) who reported on the results of a survey completed by more than 650 nurses across 13 hospitals. The majority of nurses perceived that mobile computing devices (computer carts) provided them with access to the information they needed. However, nurses also voiced that they found the computer carts to be cumbersome, which they felt affected the efficiency of their workflow. Many nurses described stationing the computer cart in the hallway in favour of taking the cart to the patient room. An additional survey was administered following a 90-day pilot study in one ward where barcode scanners were added to the computer carts, which mandated that nurses take the computer carts into patient rooms. Twenty-two nurses (representing half of the ward's nursing staff) completed the survey. The nurses admitted that, prior to the implementation of the barcode scanners, they had not utilised the computer carts in a mobile manner. While the nurses expressed satisfaction that the barcode scanners supported patient safety, they maintained that the computer carts were difficult to manoeuvre and that their productivity was negatively impacted.

2.6.2.3. Summary of the Qualitative Evidence on the Impact of Mobile Computing Devices on Clinical Work Practices

The review of qualitative studies further adds to the evidence that the use of mobile computing devices may be beneficial in facilitating error prevention and data management and accessibility. Several studies reported that clinicians perceived that mobile computing devices provided the means to access information; both patient-related information and clinical resources, at the point of need (Fisher et al. 2006; Harkke 2006; Martins & Jones 2005b; McAlearney et al. 2004). Two of the studies also highlighted that clinicians perceived that being able to access information via mobile computing devices would subsequently decrease the need to walk to fixed computing devices to access information (Harkke 2006; McAlearney et al. 2004).

However, Fisher et al. (2006), Tang and Carpendale (2008), and Murphy (2008) reported that mobile computing devices were often not used in a mobile manner or at the point of care. By providing some indication of *where* the use of mobile computing devices occurred, these studies drew attention to the fact that assumptions about the manner in which mobile computing devices will be used may not always hold true in practice. As emphasised by Tang and Carpendale (2008), the mobile computing devices "failed to live up to its intended use as a mobile and ubiquitous information artefact" (p.212). The authors concluded that mobile computing devices were not used as intended due to a mismatch between the technology and clinical work practices. Similarly, Harkke (2006) and Murphy (2008) suggested that for mobile computing devices to have a positive impact there needs to be a fit between the technology and work practices.

These findings reinforce the need to examine the ways in which mobile computing devices are used in practice. The findings also highlight that assessing the fit between

technology and work is of critical importance in determining the success of mobile computing devices as a tool for supporting efficient and effective clinical work practices.

2.7. Selection of Computing Devices for Use by Clinicians on Hospital Wards

The above examination of quantitative and qualitative literature, regarding the impact of mobile computing devices, reveals a paucity of evidence that clearly demonstrates how mobile computing devices support clinical work practices. This limited evidence base undoubtedly poses significant challenges to decision-makers responsible for acquiring computing devices, particularly in light of indications that difficulties in the implementation of technology can arise due to insufficient understanding of the role of technology in clinical work (Wears & Berg 2005). A critical question therefore emerges: how do decision-makers determine which devices to select in order to adequately support clinical work?

In order to address this question, literature regarding the selection of hardware computing devices for hospital settings was sought. While several studies examining decision-making processes surrounding the selection of clinical information systems were identified (for example, Ahmad et al. (2002); Allen (1991); Chaiken (2007); Cresswell et al. (2013); Damberg et al. (2009); Handel and Hackman (2010); Kushniruk et al. (2009); Kushniruk et al. (2010); Lorenzi et al. (2009); Mooney and Boyle (2011); Weathers and Esper (2013); Weiner et al. (2004)), studies discussing the selection of hardware computing devices proved to be far more scarce. This scarcity of literature was also highlighted by Oder et al. (2010) and Murphy (2008), whose studies were amongst the five identified articles that addressed device selection decisions, as described below.

Oder et al.'s Examination of Device Selection

Oder et al. (2010) reported on a case study undertaken at an academic hospital that was embarking on the implementation of an integrated EMR and that needed to select computing devices to provide clinicians with access to the new system. The process involved in the selection of devices was found to entail several steps. To begin with, an interdisciplinary committee, consisting of information technology (IT) specialists, and doctors and nurses that represented a cross-section of the hospital, was formed to make decisions regarding device acquisition. The role of the IT specialists was to assess the ruggedness of the potential devices and to test the ability of each device to run the selected EMR software, while the role of the clinicians was to evaluate the fit of potential computing devices with clinical workflows.

The committee began the selection process by identifying the different types of computing devices that were available. Their list of potential devices included: computer carts, laptops, tablet computers, desktop computers, wall-mount computers, and PDAs. The committee developed a list of requirements that the selected computing devices needed to meet, including minimal use of space/storage, ability to provide bedside documentation, ability to provide documentation outside of patient rooms, and that the devices could work within the electrical capacity of each ward. Desktop computers (which were already available at central nursing stations in wards throughout the hospital) and wall-mount computers were eliminated from the list as the numbers required to facilitate bedside documentation would exceed the electrical capacity of the wards. Tablet computers and PDAs were rejected because testing by the IT specialists revealed that the EMR software was not optimised to correctly display on a small screen size. Laptops were eliminated from the list because the patient rooms lacked space to set down the laptop and type while still being able to face the patient. Hence, by process of elimination, the committee elected to pursue computer carts. Computer carts also

met the committee's requirements in that they could be used for documentation both at the bedside as well as outside patient rooms.

Upon deciding on computer carts, the committee held a trade fair for clinicians to view and provide feedback on the different types of computer cart models that were available. Two models were subsequently chosen for clinicians to test on the wards and provide further feedback via online surveys. Once a specific computer cart had been selected, the next challenge was determining the number of carts that needed to be acquired. The committee took into consideration the floor plans of each ward, the acuity of the patients, the clinical workflows, and the peak staffing numbers in order to calculate the adequate number of devices for each ward.

While a seemingly straightforward process, additional factors emerged that influenced the type and number of computing devices ultimately selected. The type of ward was one such factor. Although initially rejected, wall-mount computers were acquired for each room of the bone marrow transplant unit in order to maintain the necessarily level of sterility. Similarly, specific computing devices had to be assigned to remain in isolation rooms. Clinicians' preferences were also influential. Inpatient psychiatry clinicians requested tablet computers as they perceived them to be less intrusive during patient encounters, while resident rounding teams wanted laptops. Some wards had to be provided with a combination of computing devices as they lacked the space to either store the number of computer carts they ideally required or to take the computer cart to locations throughout the ward. Furthermore, in order to support the influx of new computing devices, the electrical capacity had to be upgraded in the hospital's older buildings. Complaints from clinicians regarding unavailable or dropped wireless connections also resulted in the hospital having to upgrade their wireless infrastructure.

Senior's Examination of Device Selection

Similar findings to those discussed above were reported by Senior (2006) who described how computing devices were selected for deployment at a network of three children's hospitals that were implementing an EMR. A leadership team (consisting of the Chief Information Officer, Chief Financial Officer, Vice President of Clinical Operations, Vice President of Quality, Director of Information Services and Technology Implementations, Director of Clinical Informatics, and Medical Directors of Informatics) was formed to decide on the computing devices with which clinicians could access the EMR. The potential list of devices included wall-mount computers, computer carts, laptops, tablet computers, and PDAs.

In order to narrow down this list, the leadership team closely examined the existing paper-based workflows. They identified that paper-based medical records were constantly being moved from one location to the next, and thus decided that a key requirement was that the selected computing device needed to mimic the mobility of paper. Wall-mount computers were, therefore, eliminated from the list of potential devices as the team perceived that the stationary nature of wall-mounts would change clinicians' workflows by forcing them to seek out a computer any time they needed to access or input patient information. PDAs were also eliminated as the team discovered that the hospital's EMR was not compatible with PDAs. After examining the advantages and disadvantages of the remaining devices (tablet computers, laptops, and computer carts) the leadership team decided against laptops and tablet computers as they were not considered to be rugged enough for the hospital environment. Hence, as was found by Oder et al. (2010), this process of elimination left the team with the option of computer carts.

In order to select amongst the different types of computer cart models, the team held a trade fair attended by 120 clinicians chosen as champions by their respective wards.

The clinicians provided the leadership team with evaluation forms for each type of computer cart. The leadership team then chose three computer carts, which were placed on each ward for a period of 24-hours for clinicians to test and provide their feedback. The computer cart ultimately selected, the Flo 1750 from Flo Healthcare, was based on user feedback and the battery life of the cart. The leadership team decided to acquire one computer cart for every two beds in general wards, but opted for a 1:1 ratio for the intensive care unit (ICU).

Rescorl's Examination of Device Selection

A study conducted by Rescorl (2006) described the process of selecting computing devices for the ED of a large teaching hospital. As was identified in the above studies, one of the first steps was establishing a project team responsible for making the device selection decisions. The project team was made up of ED leaders and representatives from each of the ED staffing roles (physicians, resident physicians, physician's assistants, nurse practitioners, and nurses). The project team began the selection process by determining the status quo of the ED. This involved an inventory of existing computers, printers, and medication dispensing machines and mapping the location of each on a floor plan of the Department. The project team also mapped high-use areas and projected future needs. They found that space to accommodate computing devices was a key factor influencing their decisions, and therefore, for areas such as the central nursing station, the team selected desktop computers that had flat screen monitors and mounted the processing units below the desks.

The project team representatives also solicited input from their respective staffing groups regarding the computing devices that they wanted. Physicians, resident physicians, physician's assistants, and nurse practitioners all expressed an interest in notebook computers, as they wanted to be able to travel from room to room with the computing

device. Nurses, on the other hand, expressed an interest in computer carts. The project team liaised with various vendors and obtained the requested computing devices so that they could be trialled and evaluated by the staff. Nurses reported finding the computer carts heavy and difficult to steer, with many choosing to use the desktop computers at the central nursing station instead. Laptops were therefore selected for implementation in the medication rooms to enable nurses to access information when obtaining medications from the dispensing machines. Wall-mounts were also acquired and installed in the critical care rooms allowing nurses to record patient care activities.

Wagner and Moore's Examination of Device Selection

Wagner and Moore (2011) reported on the device selection process undertaken at a 100-bed hospital. A distinction of this study, to those discussed above, was that the hospital already had both desktop computers in outpatient clinics and computer carts on inpatient wards. However, the need for additional computing devices was identified because the existing computer carts required frequent repairs and were, therefore, often not available on the wards.

The process began with the convening of a multi-disciplinary team (which included the patient safety manager, a biomedical engineering representative, an IT representative, a quality improvement engineer, a pharmacist, physicians, and nurses) and an assessment of the hospital's existing computing devices. The desktop computers available in the outpatient clinics were found to create workflow problems and, as the desktop computers were located in the exam rooms, clinicians would occupy some of the rooms to utilise the computers meaning that the rooms were unavailable for patient consultations. The computer carts were reported to be difficult to manoeuvre and, consequently, many nurses left the carts in the hallway rather than taking them to the patient bedside. It was therefore decided that tablet computers would be acquired; with

the project team anticipating that tablet computers would increase efficiency in the outpatient clinics and allow clinicians on inpatient wards to document patient information at the bedside.

The device that the project team selected was the only tablet computer that had received Federal Drug Administration (FDA) approval, so the team opted to forgo further assessments of the tablet. Instead the team visited a local hospital and several other health care facilities that were utilising tablet computers in order to gather information on how tablets were utilised in practice. Based on their observations, the project team decided to purchase a smaller number of tablet computers (16 in total) to pilot within selected areas of the hospital, including one inpatient nursing ward, one outpatient clinic, and one surgical ward.

Following a few months of use, the project team discovered that the selected computers did not meet their initial assumptions, with factors that the team had not considered affecting use of the tablet computers. Nurses, for example, did not have a place to set down the tablet computers while providing care at the patient bedside. In addition, nurses found the stylus mode of data entry difficult to use but also reported that the onscreen keyboard was not a viable option for entering information into the patient's medical record. Doctors experienced issues with the encryption software on the tablet computers; which required each user to be registered on the device. The high turnover of residents on the selected pilot wards made sustaining registration updates difficult, so therefore residents did not use the tablet computers. Most of the acquired tablet computers were subsequently reassigned to other Departments within the hospital (such as Pharmacy and Interventional Radiology) and fixed computing devices were installed in each patient room.

Murphy's Examination of Device Selection

Difficulties in selecting a computing device were also highlighted by Murphy (2008), who reported on a study within a network of 13 hospitals. The hospitals already had computer carts, however, a satisfaction survey completed by 650 nurses revealed some issues, with nurses reporting that they found the computer carts to be cumbersome and that the carts negatively affected their productivity. Nurses also reported leaving computer carts in the hallways rather than using them in a mobile manner. The hospital, therefore, decided to re-evaluate its options. While the selection process undertaken at the hospital was not described in as much detail as the above studies, the study nonetheless reports valuable lessons regarding device selection.

Both fixed computing and mobile computing device options were assessed and nurses' feedback regarding the different types of computing devices was sought. Some nurses perceived that fixed computing devices at each patient bedside was the best option, while others highlighted that this would require frequent logging in and out. Some nurses wanted PDAs as they could easily be carried into patient rooms. However, PDAs were vetoed due to their small screen size and inability to run all of the hospital's software applications. Tablet computers were perceived to hold promise, but the lack of a keyboard again presented challenges with the use of the hospital's software applications. The hospital also held a trade fair where different types of computer carts were exhibited and further feedback was obtained from nurses who attended the fair.

Based on the nurses' overall feedback the hospital decided to pilot test a number of different options, including fixed computers, tablet computers, and computer carts with drawers to hold medications, in several nursing units. The author of the study summed up the selection of computing devices by describing it as a "dilemma" and "a tough nut to crack, but one we will have to figure out" (Murphy 2008, p.9).

2.7.1. Summary of the Evidence Regarding Device Selection

Each of the above studies (by Oder et al. (2010); Senior (2006); Rescorl (2006); Wagner and Moore (2011); and Murphy (2008)) reported a unique case study regarding the selection of computing devices for use by clinicians on hospital ward. While no two studies undertook the exact same process in selecting devices there were several commonalities across the processes that each of the studies described. Almost all of the studies reported: establishing a team to make the device selection decisions; identifying the types of computing devices that were available; assessing the different computing devices with certain requirements in mind; holding a trade fair or testing the computing devices; and obtaining input or feedback from clinical staff. There were also some distinct differences amongst the described processes. Wagner and Moore (2011) were the only ones to report visiting other hospitals and health care facilities to observe clinicians and obtain information about the use of computing devices in practice. Rescorl (2006) was the only one to report undertaking an inventory of existing computing devices and mapping their locations on a floor plan prior to deciding on additional computing device needs.

An area of substantial variance amongst the studies, however, was in the types of factors that were considered during device selection decisions. There were only two factors that were uniformly reported in all five studies: the physical characteristics of mobile computing devices (e.g., ruggedness, manoeuvrability) and compatibility with the hospital's EMR software. Yet, a number of additional factors were found to influence the selection and successful use of computing devices. Oder et al. (2010) reported that the type of ward, isolation requirements, space to store or manoeuvre devices, and quality of the wireless network connection all influenced the type of computing devices that could be selected. Furthermore, Wagner and Moore (2011) and Oder et al. (2010) were the only two studies to report considering the location of device use as part of their

selection process. Yet, the location of devices has been highlighted as a critical factor affecting the use of computing devices (Bond 2007; Lærum et al. 2004).

Overall, what is evident from the five studies reviewed above is that the selection of computing devices is a complex process that can be influenced by a number of different factors, making the selection of the right types and quantities of computing devices incredibly challenging. Undoubtedly adding to this challenge is the limited evidence base to inform device selection decisions. What is recognised in literature, however, is the importance of selecting the optimal type and number of computing devices in order to support clinical work (Andersen et al. 2009; Ash et al. 2005; Chaiken 2008; Martinez 2012; Nagle 2008; Wager et al. 2010).

These findings point to the critical need for further evidence about the various factors that can influence which computing devices best suit a given context in order to help guide device selection decisions.

2.8. Research Gaps and Questions

The literature reviewed and discussed in this chapter helped to identify key gaps in the existing knowledge base. Examination of studies that looked at the impact of mobile computing devices on clinical work revealed that existing literature has a tendency to view the mobility of devices as inherently beneficial. This view was largely found to be based on assumptions about *where* clinicians use mobile computing devices; often presumed to be the patient bedside. While such assumptions may seem valid, there is some evidence to suggest that notions about the manner in which mobile computing devices will be used may not always hold true in practice. What is therefore needed is research that examines clinicians' actual use of mobile computing devices in order to clearly demonstrate how these devices support clinical work practices and in what circumstances mobility provides value.

Literature discussing device selection decisions provides further evidence that assumptions about the use of mobile computing devices may not be reflected in practice. Some of the studies identified problems with the use of mobile computing devices, including issues related to the computing device itself (e.g., computer carts being difficult to manoeuvre) and constraints related to the environment (e.g., lack of a place to set down a tablet computer at the patient bedside). The fact that such issues only became apparent after the mobile computing devices were selected and implemented highlights the imperative for research that examines the factors that need to be considered when making decisions about the selection of computing devices for use by clinicians on hospital wards.

The research presented in this thesis aims to contribute new knowledge to help address these critical gaps in evidence. The research is conducted in two stages.

Stage one investigates the perspectives of individuals involved in the selection of computing devices in order to answer: (1) how do decision-makers select computing devices and what factors do they consider when making decisions about the selection of devices?

Stage two investigates clinicians' use of computing devices on hospital wards in order to answers: (2) how do mobile computing devices support clinical work practices and what factors affect their use?

2.9. Theoretical Framework

A common view raised in the literature is the need to achieve fit between technology and clinical work in order to ensure the successful implementation and use of computers in health care settings. To help investigate this notion within this present research a theoretical framework was adopted. Theoretical frameworks provide a lens through

which to better understand phenomena (Brennan 2008). While data, such as that collected through observation, aid in describing patterns of what is occurring, theory helps to explain why a set of patterns occurred or can be anticipated to occur (Sutton & Staw 1995). In line with the views of scholars, such as Kaplan (1964) and Merton (1967), Sutton and Staw (1995) assert that:

> *"Theory is about the connections among phenomena, a story about why acts, events, structure, and thoughts occur. Theory emphasizes the nature of causal relationships, identifying what comes first as well as the timing of such events. Strong theory, in our view, delves into the underlying processes so as to understand the systematic reasons for a particular occurrence or non-occurrence"* (p.378).

Several theories exist that potentially provide a mechanism by which to explore the use of technology and the notion of fit between computing devices and work practices. In a review of prominent theories utilised to explain technology usage, Kukafka et al. (2003) indicate that theories such as the Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB), Diffusion of Innovation (DOI), and Social Cognitive Theory have largely been used to study relationships between attitudes and behaviours. In contrast, the Technology Acceptance Model (TAM) and Task-Technology Fit (TTF) model are more applicable to studies aimed at understanding relationships between computer interactions and work (Dishaw & Strong 1999; Kukafka et al. 2003).

The TAM (Davis 1989; Davis 1993), although not developed specifically for use in the health domain, has been widely used in health care to predict and explain the use and acceptance of technology (Holden & Karsh 2010). The model employs the constructs of perceived usefulness and perceived ease of use as determinants of: attitudes towards using technology; intention to use technology; and the actual use of technology (Davis 1993). Findings from Holden and Karsh's (2010) seminal review of TAM, and its application in health care literature, underscored TAM's value as a theoretical

framework to assess the relationship between users and technology. However, the review also points to the need for additional constructs to allow for further relationships to be explored. Dishaw and Strong (1999), likewise, highlight that a weakness of TAM in aiding understanding of the use of technology may lie in the absence of an explicit construct examining tasks. They indicate that, unlike TAM, the TTF model provides explicit inclusion of a task–technology construct.

The TTF model (Goodhue 1998; Goodhue & Thompson 1995) looks at task characteristics and technology characteristics, which together determine task–technology fit and influence technology utilisation. The premise of the model is that technology will be used if it adequately supports the demands of a task (Goodhue & Thompson 1995). In applying the TTF model to assess the fit of a picture archiving and communications system (PACS), Lepanto et al. (2011) concluded that "TTF is a valid tool to assess perceived benefits, but it is important to take into account the characteristics of users" (p.951). Other researchers (Dishaw & Strong 1999; Junglas et al. 2009) have similarly indicated that a shortcoming of the TTF model is that it does not explicitly include a construct that examines user characteristics.

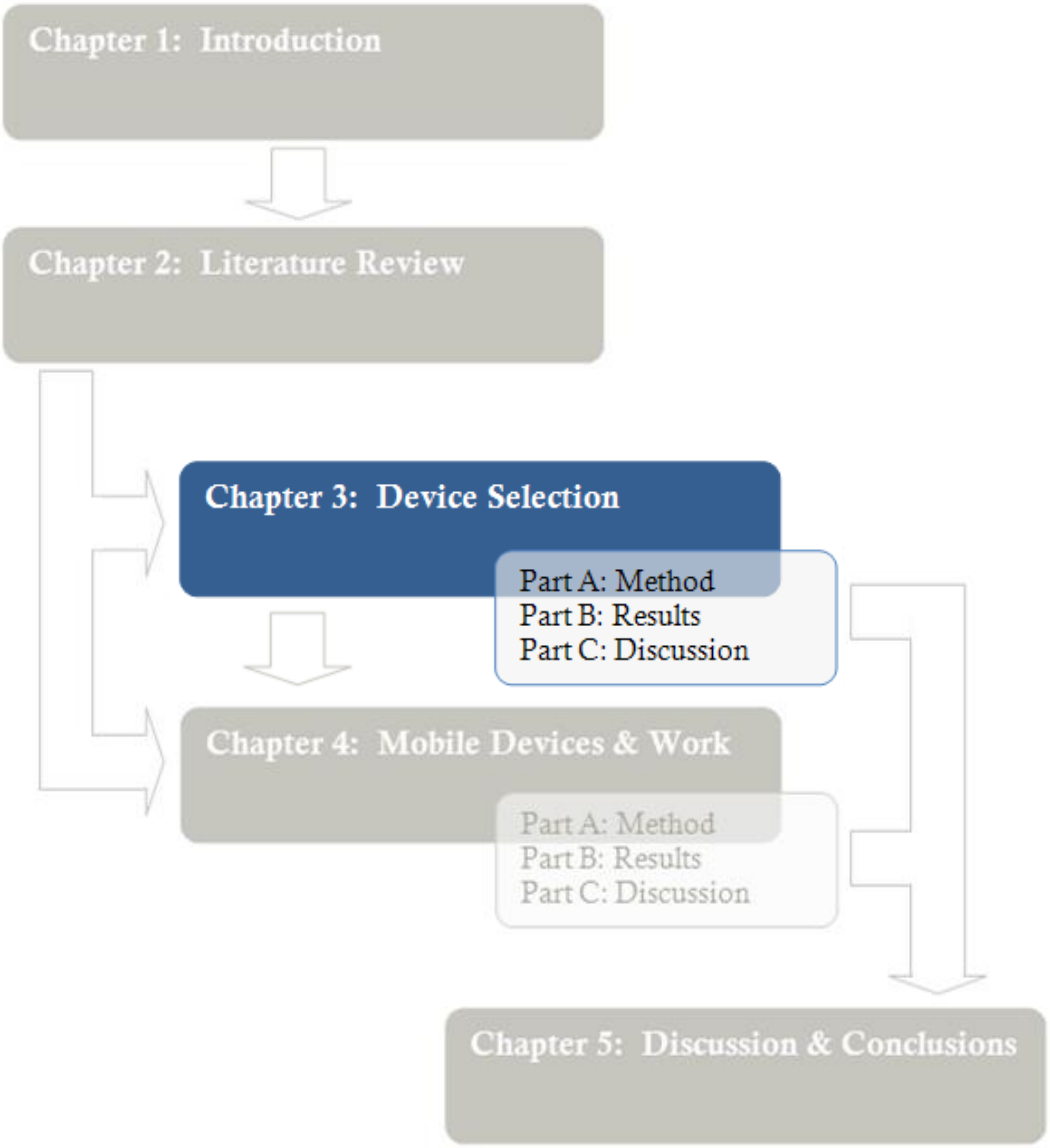
While TAM focuses on the interaction between users and technology and TTF focuses on the interaction between tasks and technology, a recently developed framework that encompasses both of these interactions, as well as adding the interaction between users and tasks, is Ammenwerth et al.'s (2006) fit between individuals, task, and technology (FITT) framework. The FITT framework was developed specifically for the health care domain and was based on an analysis of literature on technology adoption. FITT posits that the use of technology is dependent on the fit between the attributes of the users, attributes of the tasks, and attributes of the technology.

The framework defines "users" (used interchangeably with "individuals") as either an individual user or a user group. The given examples of user attributes include: knowledge of the technology; motivation to execute tasks; openness to new ways of working; cooperation within a team; and organisational context. "Tasks" comprise whole tasks or work processes (such as, nursing documentation or order entry), the attributes of which can include: organisation of tasks; activities and their interdependence; and task complexity. "Technology" is defined as any tool required to execute a task; encompassing both computer-based and paper-based tools. Examples of technology attributes include: usability of the tool; functionality of the tool to support a given task; integration of tools; and availability of tools. Where fit between attributes of the users, tasks, or technology is lacking problems with the adoption of technology may arise (Ammenwerth et al. 2006).

Considering the relative newness of the FITT framework, its application in the literature to date has not been extensive. In the same article that described the FITT framework, Ammenwerth et al. (2006) undertook a retrospective analysis of a case study, which assessed the adoption of a nursing documentation system in a Dermatology Ward, Paediatric Ward, and Psychiatric Ward to test and validate FITT. Application of the FITT framework was shown to facilitate understanding of the relationships between users, tasks, and technology, and the factors leading to either the failure of or the successful adoption of technology in each ward. For example, a factor affecting overall fit in the Paediatric Ward was identified in the fit between tasks and technology dimension, whereby the unavailability of mobile computing devices or fixed computing devices located at the patient bedside disrupted the workflow of nurses who were accustomed to undertaking documentation at the patient bedside. By pinpointing the issues affecting the use of technology, the FITT framework helped to determine areas related to users, tasks, or technology where changes could be instilled in order to optimise the fit between the three attributes.

Other researchers who have employed FITT have likewise found the framework to be an applicable tool for explicating factors affecting the use of technology in health care (Honekamp & Ostermann 2011; Schnall et al. 2012; Sheehan et al. 2012; Tsiknakis & Kouroubali 2009). The majority of these studies utilised the FITT framework to assess clinical information systems, however, Sheehan et al. (2012) used the framework to assess the use of mobile computing devices. Sheehan et al.'s (2012) study compared adolescent use of four different mobile computing devices (three of which were smartphones and one a tablet computer) for accessing health information and found that fit (or lack thereof) between task and technology influenced task efficiency. Of the four mobile devices tested, the touchscreen smartphone (iPhone) was identified to be the most usable device, had the fewest number of errors, and took the least amount of time to undertake the task of accessing health information. Thus, utilising the FITT framework allowed the researchers to determine which technology best suited the users for a given task. Given that the FITT framework can aid in making such relationships transparent, it was adopted as the theoretical framework for the research presented in this thesis.

CHAPTER 3


Chapter 1: Introduction
Chapter 2: Literature Review
Chapter 3: Device Selection
Part A: Method
Part B: Results
Part C: Discussion
Chapter 4: Mobile Devices & Work
Part A: Method
Part B: Results
Part C: Discussion
Chapter 5: Discussion & Conclusions

Chapter 3. Device Selection

3.1. Chapter Overview

The previous chapter provided a review of literature regarding device selection decisions and highlighted the limited knowledge base available to inform decision-making processes when selecting computing devices for use by clinicians on hospital wards. It drew attention to the need for evidence about the selection of computing devices, particularly regarding the various factors that can influence device use.

This chapter presents a detailed description of the first stage of the research, which aimed to address this need. The chapter begins by outlining the research objectives relevant to this stage of the research. The rest of the chapter is then presented as three distinct sections, which include:

- Part A: Method (3.3. – 3.11.);
- Part B: Results (3.12. – 3.19.); and
- Part C: Discussion (3.20. – 3.26.).

3.2. Research Objectives

This stage of the research sought to elicit the perspectives of key individuals, involved in the selection of hardware computing devices for use by clinicians on hospital wards, in order to determine:

1) the process by which decisions regarding the selection of computing devices occur;
2) the factors considered when selecting computing devices; and
3) the anticipated impact of mobile computing devices on clinical work practices.

PART A: METHOD

Chapter 3. Part A: Method

3.3. Introduction

The following section presents a description of the method that was used to conduct this stage of the research. The section begins with an overview of the research setting and the context in which the study was conducted. It describes the selected research design and paradigm that framed the conduct of the research, along with a reflexive account of the role of the researcher. The sampling, data collection, and data analysis procedures are discussed and a justification for each choice is provided. Strategies used to enhance the quality of the research approach are outlined and details of the ethical approval are provided.

3.4. Research Setting

This stage of the research was conducted within the New South Wales (NSW) public health system, known collectively as NSW Health. NSW Health has the largest population base and highest service demands in Australia, comprising more than 220 public hospitals and facilitating an extensive geographical area (NSW Department of Health 2010a). At the time that the study was conducted (August 2009 – August 2010) NSW Health consisted of eight Area Health Services, each responsible for a defined

geographical area.[3] Four of these Area Health Services encompassed the metropolitan areas of NSW and four encompassed the rural areas of NSW. A central body, known at the time as the NSW Department of Health, held the responsibility of providing advice, state-wide planning, and direction to the Area Health Services (NSW Department of Health 2005).

3.4.1. Information System Context

In the 2009–2010 financial year the NSW Department of Health (2010a) announced "a record AUD$15.1 billion budget to enable continued improvements and better access in delivering health services and health infrastructure for NSW" (p.2). An aspect of these improvements included the NSW Electronic Medical Record (EMR) program. The NSW Department of Health (2010a) considered the EMR program to be "one of the largest clinical information system implementations outside of the USA and UK" (p.e1) and described the program as:

> *"…a multi-stage project to progressively capture key clinical information electronically and provide this information at the point of care to health professionals treating their patients"* (p.244).

The components of the EMR program included: electronic test ordering; electronic results viewing; an electronic discharge referral system; an Emergency Department (ED) information system; and an operating theatre information system. Implementation of the EMR was intended to enable clinicians to: electronically access patient information and clinical resources; review patient progress and order tests or treatments; review test results and modify patient care as required; access and utilise decision support when

[3] NSW Health has since undergone reform, with the Area Health Services restructured as Local Health Districts and Specialty Networks. The NSW Health reforms are outlined in:
NSW Department of Health (2011a) Future Arrangements for Governance of NSW Health: Report of the Director-General. North Sydney, NSW: NSW Department of Health.

ordering tests or reviewing patient outcomes; and generate discharge summaries and referrals by using information in the EMR (NSW Department of Health 2011c).[4]

3.4.2. Implementation of the EMR Program

Seven, of the eight, Area Health Services were involved in the NSW EMR program. Within the Area Health Services, project teams were established to coordinate the implementation of the EMR. The Area Health Service project teams undertook EMR implementation in partnership with: (a) branches of the NSW Department of Health responsible for eHealth initiatives; and (b) the nominated clinical software information technology (IT) vendor.

Alongside implementation of the EMR clinical software, one of the major projects of the EMR program was an upgrade of the hardware computing devices within hospitals in the Area Health Services (Fuchter et al. 2008). The Area Health Service EMR project teams held primary responsibility for the selection of these computing devices. The selected computing devices were required to comply with the technology standards outlined in a NSW Health policy directive for the acquisition of IT (NSW Department of Health 2010b). The policy directive aimed to establish state-wide technology standardisation and, as such, specified the technology that was "preferred", "acceptable", or "not allowed" to be used within NSW Health. For example, with regard to operating systems, Microsoft XP Pro was classified as a "preferred" operating system, while Microsoft Windows 95 was classified as "not allowed." The policy directive did not specify the types of hardware computing devices that were preferable but did stipulate that computing devices were to be procured from IT vendors that held

[4] Additional details about the NSW EMR program can be found at:
NSW Department of Health (2011b) About the EMR. North Sydney, NSW: NSW Department of Health. Available from: http://www.emr.health.nsw.gov/about-the-emr

contractual agreements with the NSW Government.[5] Beyond the requirements of this policy directive the Area Health Services could select hardware computing devices, be they fixed computing devices or mobile computing devices, based on determination of their own needs. The process by which the selection of hardware computing devices occurred and the factors considered when selecting computing devices were central queries of this stage of the research.

3.5. Research Design

In order to fulfil the objectives of this stage of the research, a qualitative research design was employed. A qualitative approach was deemed to be appropriate for this study as such approaches are useful for illuminating processes and understanding phenomena, while quantitative research approaches are useful for determining causes or predicting outcomes (Bradley et al. 2007; Denzin & Lincoln 2005; Hoepfl 1997; Kaplan & Maxwell 2005; Kitto et al. 2008; Polgar & Thomas 2000; Stoop & Berg 2003).

Qualitative research approaches are generally characterised by: the investigation of perspectives or behaviours of individuals in an endeavour to understand a particular matter; the conduct of research in natural settings or contexts; and the use of data in the form of words (Fossey et al. 2002; Kaplan & Maxwell 2005; Pope & Mays 1995; Wallen & Fraenkel 2001). The use of qualitative methods, such as interviews, observation, or focus groups, can provide rich descriptions of the matter being investigated (Sofaer 1999; van Teijlingen & Forrest 2004) as they aid in addressing queries of what, how, and why (Ash & Guappone 2007; Kaplan & Maxwell 2005; Pope & Mays 1995; Stoop & Berg 2003). Researchers have indicated that qualitative methods can provide a means

[5] For the contractual period of May 2007 to April 2012, these hardware IT vendors included: Acer; ASI; Corporate Express; Dell; Fujitsu; Hewlett-Packard; Lenovo; Panasonic; Pioneer; Toshiba; and ToughCorp (NSW Procurement 2011).

to gain critical insights into complex fields such as health care (Ash & Guappone 2007; Bradley et al. 2007; Tong et al. 2007).

3.5.1. Qualitative Research Paradigm

Qualitative research methods are steeped in interpretive traditions (Denzin & Lincoln 2005; Pope et al. 2002). Denzin and Lincoln (2005) indicate that there are many interpretative paradigms that can structure qualitative research including feminism, Marxism, cultural studies, ethnic models, queer theory, and constructivism. They describe the qualitative researcher as a "bricoleur" whose role is to employ interpretive practices to piece together a set of representations in order to gain a "better understanding of the subject matter at hand" (p.4).

The interpretive paradigm[6] elected for this stage of the research was constructivism. In a constructivist paradigm understanding is created (or "constructed") during interaction between the researcher and the participants (Guba & Lincoln 1994). Lincoln and Guba (1985) and Appleton and Kind (1997) outline that application of the constructivist methodology involves: the use of purposive sampling (that is, the purposeful selection of informants); selection of a suitable qualitative method (for example, interviews); inductive data analysis; and the development of theory or a case report representative of what has been discovered about the phenomena studied.

[6] The notion of paradigms was popularised by Kuhn (1962; 1970) in his book *The Structure of Scientific Revolution.* However, as discussed by Morgan (2007) the term "paradigm" lacks consensus regarding its meaning. It is not the intention, nor within the scope, of this thesis to enter into this debate; but the meaning of "paradigm" within the context of this thesis requires establishment. Accordingly, the term paradigm, as used within this thesis, refers to a "framework for thinking about research design, measurement analysis, and personal involvement" (Morgan 2007, p.50).

3.5.2. Role of the Researcher

Alongside establishing the paradigm underlying the research, qualitative approaches call for the researcher to reflect on their personal experiences and how these experiences may influence the research (Creswell 2009; Kaplan & Maxwell 2005). As expressed by Denzin and Lincoln (2005), "the interpretive bricoleur understands that research is an interactive process shaped by his or her own personal history" (p.6). This personal history, and any pre-existing assumptions that the researcher may have about the phenomena being studied, require explicit articulation to enhance the credibility of the research (Mays & Pope 2000).

My experiences within health care research extend from 2003 to the present. From 2003 to 2005 I undertook an undergraduate degree in Applied Science majoring in Health Information Management; during which time I also commenced part-time employment as a data entry clerk at a research centre that evaluated care provision by General Practitioners in Australia. In 2006 I completed a research project, which examined information and communication processes in a Microbiology Department, to successfully obtain first class honours in my degree. In the same year I took up a position as a research assistant in the field of Health Informatics; a role which I still maintain. This role has allowed me to develop my research skills and has provided me with exposure to the workings of the Australian health care system.

In 2009 I commenced my PhD and began working on the present study. Undertaking the literature review that informed this study afforded me with background knowledge on the issue and shaped the research questions, which inherently influenced the type of research approach that was employed. Beyond this, I had little experience or pre-existing assumptions about the process by which the selection of computing devices occurred in NSW Health. Further, I was not known to nor had prior interaction with the vast majority of the study participants. I acknowledge that this may bear some

impact on the level of information that the participants may have been willing to impart; though it is my personal impression that the study participants were quite forthcoming.

3.6. Sampling Procedure

In line with the constructivist methodology, purposive sampling was utilised as the primary sampling technique for this study. Purposive sampling involves the purposeful selection of individuals who are likely to be key informants on a given issue (Fossey et al. 2002; Kuper et al. 2008; Patton 1990). Alongside purposive sampling, snowball sampling, which involves obtaining recommendations from participants regarding additional relevant informants (Fossey et al. 2002; Kuper et al. 2008; Patton 1990), was also employed to identify pertinent individuals and invite them to participate in the study. The advantage of purposive and snowball sampling is that participants are selected due to their knowledge about the issue being investigated and thus rich information can be obtained (Patton 1990).

As outlined in the section regarding the implementation of the EMR program (section 3.4.2.), three groups were responsible for coordinating the implementation of the EMR program:

- Area Health Service project teams;
- branches within the NSW Department of Health responsible for eHealth initiatives; and
- IT vendors.

As such, representatives from each of these three groups were sought in order to acquire a range of perspectives regarding the issue under investigation. The process of identifying key informants from each of these groups was multi-tiered. A flowchart of the sampling process is depicted in Figure 3.1.

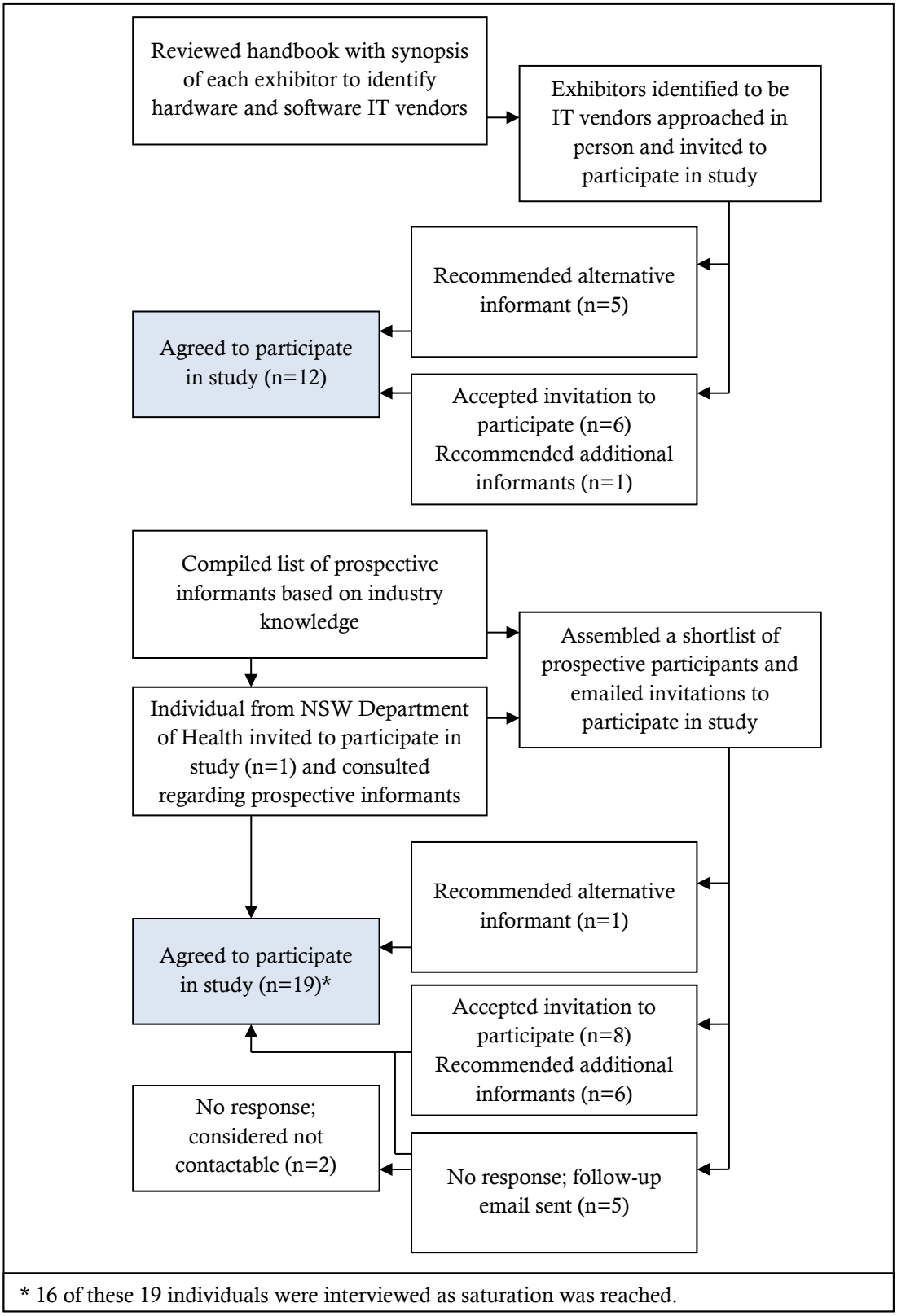


Figure 3.1. Flowchart of the Sampling Process

Recruitment of the IT vendors occurred first and was carried out at a national industry conference where technology providers had converged for an industry exhibition. I utilised a handbook that was distributed to all conference attendees and provided a short synopsis about each exhibitor, which I reviewed in order to identify relevant exhibitors. Exhibitors identified as IT vendors that supply hardware or software products for use by clinicians in hospitals were approached in person, provided with an information statement outlining details about the study (Appendix B.1), and invited to participate in the study. The information statement also advised that the research was being conducted as part of my PhD. All IT vendors that were approached agreed to take part in the study, or voluntarily nominated another individual from their team who they advised was more informed about the issue.

To recruit individuals from the Area Health Service project teams and relevant branches within the NSW Department of Health, a list of prospective participants was compiled based on the industry knowledge of my PhD supervisors. One of these prospective participants, an individual from the NSW Department of Health who was associated with the EMR program, was invited to take part in the study and was also consulted regarding further prospective participants. An email was sent to each of the shortlisted prospective participants inviting them to take part in the study. The email included a brief introduction to the researcher (myself) and a concise explanation about the study. An information statement outlining further details about the study and what participation entailed was attached to the email, along with a consent form for the individual to complete should they wish to participate in the study (Appendix B.1). A follow-up email was sent in cases where a response had not been received after a period of two months. If no response was received to the follow-up email, as occurred in two cases, the individual was considered to not be contactable. Of the individuals that were invited to participate in the study, the vast majority agreed to do so. Several of these individuals also recommended additional prospective participants, whom they carbon

copied into their responding email. One individual felt that she was not adequately informed about the issue and recommended an alternative informant. The recommended prospective participants were subsequently sent an email inviting them to take part in the study; all of whom accepted the invitation.

The sampling process was carried out between August 2009 and August 2010, with data collection and data analysis undertaken concurrently. As is common in qualitative research, a predetermined sample size was not established prior to the commencement of participant recruitment as sampling within qualitative research is usually ongoing until saturation is reached. Saturation refers to the point at which no new data is emerging, thus making further sampling redundant (Fossey et al. 2002; Lincoln & Guba 1985). Therefore, although a total of 31 individuals were recruited to take part in the study, data was only obtained from 28 of these individuals as saturation was reached.

3.7. Data Collection Procedure

Data collection was conducted between August 2009 and August 2010. For the purposes of this stage of the research, interviews were considered the most suitable qualitative method to collect data. Brender (2005) describes interviews as being "particularly suited for the elucidation of individuals' opinions, attitudes, and perceptions regarding phenomena" (p.142). Interviews can be structured, semi-structured, or in-depth. Structured interviews are highly standardised with specific questions generally administered in the same order and with the same wording (Friedman & Wyatt 1997). On the other end of the spectrum, in-depth interviews are highly unstructured with one or two key issues explored in great detail (Britten 1995; van Teijlingen & Forrest 2004). Semi-structured interviews offer a middle ground. Unlike in-depth interviews, semi-structured interviews are usually based around a set of open-ended questions outlined in an interview guide (Fossey et al. 2002; Pope et al.

2002). However, unlike the rigid nature of structured interviews, semi-structured interviews afford the flexibility to ask additional questions in order to gain clarification regarding a response or to pursue further information regarding unanticipated issues that may arise (Barriball & While 1994; Kaplan & Maxwell 2005; van Teijlingen & Forrest 2004). As such, semi-structured interviews were utilised for this study.

Two interview guides were developed, one tailored to Area Health Service and NSW Department of Health participants (Appendix C.1) and one tailored to IT vendors (Appendix C.2). Both versions of the interview guide included a core set of questions to allow comparison across the groups of participants. The guides were referred to during interviews to ensure the same core topics were covered. The core questions asked during the interviews sought to gain information about:

- the participant's role within their organisation and in decisions regarding the selection of computing devices for hospital wards;
- the process by which decisions regarding the selection of computing devices are made;
- the availability of guidelines to inform decisions regarding the selection of devices;
- factors that are considered, or that should be considered, when making decisions regarding the selection of computing devices; and
- perceptions of the impact of mobile computing devices.

Questions were loosely adapted from an interview guide developed by Gallego et al. (2008), which was applied in their study examining perceptions of health technology decision-making. In line with the nature of semi-structured interviews, questions were open-ended to allow participants to provide responses in their own words. Additional questions were asked of the participants in cases where clarification of their response

was required or to obtain further information where unanticipated issues of interest were raised.

Interviews with the participants were predominantly conducted face-to-face at the participants' workplace (generally in their office or a meeting room) or, in the case of the IT vendors, their exhibition stand. In three cases face-to-face interviews were not feasible due to the distant location of the participant, thus these individuals were interviewed via telephone. All interviews were conducted by one researcher (myself) and were digitally recorded to allow for the precise recollection of the information conveyed by the participant. Each recording was transcribed verbatim in preparation for data analysis.

3.8. Analysis of Data

Qualitative data analysis is defined by Bogdan and Biklen (1982) as:

> *"Working with data, organizing it, breaking it into manageable units, synthesizing it, searching for patterns, discovering what is important and what is to be learned, and deciding what you will tell others"* (p.145).

This process can be guided by several different qualitative data analysis approaches, such as grounded theory (Glaser & Strauss 1967; Strauss & Corbin 1990) or phenomenology (Moustakas 1994; van Manen 1990), each of which has a distinct analytical strategy. Grounded theory, for example, provides a systematic analytical framework which involves open coding, axial coding, and selective coding; the outcome of which is theory development with specific components including a central phenomenon, causal conditions, specific strategies, and consequences (Creswell 1998). A phenomenological analysis, on the other hand, involves horizonalization (i.e., division of data into statements), transformation of statements into clusters of meanings

or themes, and tying of transformations to create a general, textural, and structural description of the lived experiences of individuals (Moustakas 1994).

The commonality across approaches such as grounded theory and phenomenology is that the researcher must attempt to set aside, or "bracket" (Patton 1990), any experiences or pre-existing notions about the phenomena being studied (Creswell 1998). Greenhalgh (1997), however, argues that it is "inconceivable" for a researcher to hold no views or ideological perspectives. Likewise, constructivists recognise that the researcher's experiences inherently influence data interpretation (Creswell 2009). Given that this study was underpinned by a constructivist paradigm the general inductive approach to data analysis, as described by Thomas (2006), was utilised as it aligns with constructivist assumptions in recognising that interpretations are inevitably shaped by the researcher's experiences.

Rather than attempting to bracket experiences, the general inductive approach advocates the use of techniques that promote trustworthiness of the research. One such technique is independent parallel coding where two (or more) researchers independently review the data to identify recurrent concepts or statements and develop a set of themes, which are then compared and merged into a coding schema. This technique was employed during the general inductive analysis process, which involves: preparation of raw data files into a common format; close reading of the data; creation of upper-level categories or themes derived from the study objectives; creation of lower-level categories or themes emerging from the data; coding of data, which can include overlapping coding where a segment of data can apply to more than one theme; continuous revision and refinement of the themes; and selection of quotations conveying the essence of each theme (Thomas 2006).

As per the general inductive analysis process, the transcript of each interview was formatted in a uniform manner in preparation for data analysis. The formatted transcripts were imported into, and coded using, QSR NVivo (Version 8); a software program that aids in the management and analysis of qualitative data. An initial round of data analysis was conducted following the interviews with the IT vendors. Two researcher (one of my supervisors and I) undertook independent parallel coding where each researcher reviewed the transcripts in depth and coded the transcripts (i.e., highlighted and labelled relevant segments of data) to identify themes within the data. Subsequent to the independent coding, the two researchers came together to compare and discuss the themes that each had identified and, from this discussion, a coding schema was developed by the researchers. The coding schema was then used by one researcher (myself) to uniformly re-code all the IT vendor transcripts.

The same coding schema was also used to code the transcript of each successive interview conducted with participants from the Area Health Service project teams and the NSW Department of Health. Analysis occurred iteratively and when new themes were identified the coding schema was revised. When new themes were no longer emerging from the data, indicating that saturation had been reached, the collection of additional data was suspended.

Once all the data had been collected the coding scheme was once again reviewed and refined, by the two researchers, ensuring that the research objectives and core views conveyed by participants were represented by the themes. One researcher (myself) then re-read and re-coded all the transcripts, in accordance with the finalised coding schema, and selected representative quotations for each theme for reporting in the results. This process of constant review and refinement allows for meanings and interrelations to be explored, resulting in a greater understanding of the data (Fossey et al. 2002; Thomas 2006).

3.9. Quality of the Qualitative Research Approach

The quality of qualitative research is judged by examining issues of rigor and credibility (Kitto et al. 2008). The rigor and credibility (often also referred to as trustworthiness) of qualitative research approaches can be strengthened through the use of strategies such as triangulation and reflexivity (Ash & Guappone 2007; Creswell 2009; Mays & Pope 2000). Kitto et al. (2008) also advocate the transparency of reporting as a means of enhancing quality. Each of these techniques was incorporated within this study to strengthen its quality.

Transparency relates to the explicit description of the conduct of research (Kitto et al. 2008). Achieving transparency is of vital importance as inadequate reporting can undermine quality. In order to attain transparency the consolidated criteria for reporting qualitative research (COREQ) (Tong et al. 2007) was used to guide the exposition of the research. COREQ, a 32-item checklist, promotes completeness for the reporting of research in which interviews or focus groups have been utilised (Appendix D.1). The 32-items in the COREQ checklist are encompassed by three core domains: the research team; the study design; and data analysis. In addressing items relating to the research team domain the strategy of reflexivity was used. Reflexivity refers to the introspection and acknowledgement of the researcher's experiences and assumptions, and the manner in which these experiences might shape the research (Mays & Pope 2000). A reflexive account is provided in the section describing the role of the researcher (section 3.5.2.).

To add robustness to the study design and data analysis domains the strategy of triangulation was employed. Triangulation can involve the use of multiple: data sources; investigators; research methods; or theories (Ammenwerth et al. 2003a; Kitto et al. 2008; Patton 1990), and is promoted as a means to moderate potential bias (Kitto et al. 2008). Within this study data triangulation and investigator triangulation were

utilised. Data triangulation was achieved by obtaining perspectives from representatives from each group of individuals involved in the EMR program, including: Area Health Service project teams; branches within the NSW Department of Health responsible for eHealth initiatives; and IT vendors. Investigator triangulation was realised through the use of two researchers conducting independent parallel coding during data analysis. In addition to promoting trustworthiness, the use of investigator triangulation is seen as a way of "encouraging a more reflexive analysis of data" (Mays & Pope 2000, p.51).

As well as comprising items regarding the researcher, study design, and analysis, the COREQ checklist also includes items for results reporting and stipulates the inclusion of "quotations from different participants to add transparency and trustworthiness" to the data interpretation (Tong et al. 2007, p.356). Likewise, Greenhalgh (1997) suggests that presenting verbatim quotes increases credibility. As part of the data analysis quotes representative of each theme were selected and are presented in the ensuing results section (Chapter 3. Part B: Results).

3.10. Ethical Approval

Ethical and scientific approval for this stage of the research was granted by The University of Sydney Human Research Ethic Committee (Appendix E.1). As per the approval, conduct of the study adhered to the National Statement on Ethical Conduct in Research Involving Humans (NHMRC 2007). Additional approval to conduct part of the study at a national industry conference was sought from, and approved by, the conference organisers.

All potential participants were provided with a copy of an information statement that outlined details about the study and what involvement entailed (Appendix B.1). Signed consent, acknowledging the participants choice to partake in the study and providing

permission for the interview to be recorded, was obtained from each participant prior to proceeding with an interview.

3.11. Conclusion

The information presented above described the method used to conduct this stage of the research, with reporting guided by the COREQ checklist. A qualitative research approach was employed, underpinned by a constructivist paradigm. The approach entailed the following key elements: the use of purposive and snowball sampling for participant recruitment; data collection through the use of semi-structured interviews; and use of the general inductive approach for data analysis. Transparency, reflexivity, and triangulation were used to strengthen the rigor and credibility of the research. A narrative description of the findings emerging from the data analysis is presented in the following section (Chapter 3. Part B: Results).

PART B: RESULTS

Chapter 3. Part B: Results

3.12. Introduction

The previous section provided a detailed description of the research approach that was used to conduct this stage of the research. The following section presents a narrative account of the results emerging from analysis of the data obtained via the semi-structured interviews. The identified themes are presented and each theme is then discussed in detail. Verbatim quotes from the participants are presented throughout the results to enhance the transparency of data interpretation.

3.13. Participant Demographics

Semi-structured interviews were conducted with 28 individuals involved in decision-making processes regarding the selection of computing devices for use on hospital wards. The 28 individuals included:

- 12 IT vendors;
- 13 individuals from Area Health Service project teams; and
- three individuals from braches within the NSW Department of Health responsible for eHealth initiatives.

Responses from the Area Health Service and NSW Department of Health individuals were grouped together and are henceforth referred to collectively as "Health Service representatives".

The participating IT vendors, 11 male (91.7%) and one female (8.3%), represented 11 different IT companies that provide technologies to the Australian and (in most cases) international health sectors. Eight of the IT vendors were from companies that were predominantly hardware oriented, while four IT vendors were from predominantly software oriented companies. The types of products provided to hospitals by these companies include: mobile computing devices; fixed computing devices; software applications; and infrastructure hardware. The roles of the participating IT vendors included: product managers; development managers; solution architects; regional sales managers and sales executives; and a marketing manager.

The participating Health Service representatives, 10 female (62.5%) and six male (37.5%), represented all seven of the NSW Area Health Services involved in the NSW Electronic Medical Record (EMR) program, and two NSW Department of Health branches that were responsible for providing advice on eHealth initiatives within NSW Health. The roles of the Health Service representatives included: EMR project directors and managers; clinical informatics program directors and managers; information management and technology officers; decision support project officers; clinical projects coordinators; health infrastructure managers; health support services managers; and a clinician manager.

3.14. Interview Statistics

Interviews with the IT vendors were conducted over a three-day period in August 2009, while interviews with the Health Service representatives were conducted between February 2010 and August 2010. The interviews amounted to a total duration of 8

hours and 12 minutes. Transcription of the recorded interviews amounted to 192 typed A4 pages containing 80,191 words. Table 3.1 outlines the length of the interviews conducted with the IT vendors and Health Service representatives.

Table 3.1. Length of Interviews with IT Vendors and Health Service Representatives

Participants (n=28)			
IT Vendors (n=12)		**Health Service Representatives (n=16)**	
Length of Interviews		***Length of Interviews***	
Total Duration	1h58m	Total Duration	6h14m
Approximate Average	10m	Approximate Average	24m
Number of Typed A4 Pages	45	Number of Typed A4 Pages	147
Number of Words	20,429	Number of Words	59,762

3.15. Results Emerging from the Interviews

The interviews conducted with the IT vendors and Health Service representatives aimed to elicit perceptions in relation to: (a) the process by which decisions regarding the selection of computing devices for use on hospital wards occur across the NSW Area Health Services; (b) the factors considered when selecting computing devices for use by clinicians on hospital wards; and (c) the perceived impact of mobile computing devices on clinical work practices.

The concepts that emerged from these interviews were categorised into the following themes and subthemes:

Theme I: The Decision-Making Process for Device Selection

Subtheme i: Researching What Computing Devices are Available

Subtheme ii: Seeking Advice from External Sources

Subtheme iii: Trialling Devices and Consulting Clinical Staff

Theme II: Factors Considered in Device Selection Decisions

Subtheme i: Technology Attributes

Subtheme ii: User and Task Attributes

Subtheme iii: Environment Attributes

Theme III: Perceived Impact of Mobile Computing Devices

Subtheme i: Efficient Work Practices

Subtheme ii: Effective and Safe Patient Care

3.16. Theme I: The Decision-Making Process for Device Selection

The IT vendors and Health Service representatives were asked about the process by which decisions regarding the selection of hardware computing devices for use on hospital wards occur across the NSW Area Health Services. The Health Service representatives indicated that device selection decision-making was largely decentralised, with one Health Service representative stating that "*the Area Health Services are very much independent operating entities in the scheme of how NSW Health is set up" (Health Service Representative 6).* Other Health Service representatives echoed this sentiment conveying that *"everyone's got their own thing" (Health Service Representative 16)* and that computing device selection is *"decentralized"* and a *"local decision" (Health Service Representative 8).* The IT vendors likewise perceived device selection decision-making to be decentralised with some IT vendors describing the Area Health Services as *"silos"*.

This standalone approach to the selection of hardware computing devices was highlighted as an issue by many Health Service representatives who believed, as relayed by one Health Service representative, that *"there [are] significant difficulties with the Area by Area approach" (Health Service Representative 7).* A number of Health Service representatives indicated that they perceived a need for greater collaboration across the NSW Area Health Services. One Health Service representative suggested that a more centralised approach to computing device selection is warranted, stating *"we definitely need to do that a bit more often, not just pick your own devices, but as a whole in terms of the health entity" (Health Service Representative 16).*

Further, the IT vendors and Health Service representatives conveyed that, to their knowledge, there were no specific guidelines to help inform computing device selection decisions.

> *"There's no standard or guideline." (IT Vendor 8)*

> *"When it came to purchasing clinical computers there was nothing. And I don't think any Health Service had anything." (Health Service Representative 8)*

The IT vendors and Health Service representatives felt that the complexity of health care and differences across Area Health Services, hospitals, and wards made it difficult to develop specific guidelines. It was suggested that the paucity of guidelines may be because the selection of computing devices: *"Depends on the needs" (IT Vendor 2)*; *"It varies from ward to ward" (IT Vendor 7)*; "*It's different for everyone" (IT Vendor 3);* and *"You can't have a one size fits all" (Health Service Representative 13).* One IT vendor remarked that guidelines may not have been developed yet due to the relative newness of many mobile computing devices.

"A lot of people are only looking at these things now. So they haven't had a chance to develop their understanding as to how best to implement these types of devices in hospitals." (IT Vendor 1)

Although the underlying differences across health care settings was seen as an inhibitor to the development of guidelines, the IT vendors commented that many similarities also exist in and across health care settings. It was suggested that recognising these common traits could assist in guiding device selection decisions.

"Health care has a lot of similarities. Where there are similarities that can be taken advantage of." (IT Vendor 7)

These commonalities were reflected in the comparable steps that the Health Service representatives reported undertaking when making decisions regarding the selection of hardware computing devices for use on hospital wards. The steps were categorised into three subthemes: (i) researching what computing devices are available; (ii) seeking advice from external sources; and (iii) trialling computing devices and consulting clinical staff.

3.16.1. Researching What Computing Devices are Available

The Health Service representatives specified that one of the initial steps in the decision-making process was to research what types of hardware computing devices were available on the market. The most frequently cited source for undertaking such research was the internet, which Health Service representatives utilised to look into what computing devices were available both locally and internationally. The Health Service representatives highlighted that they felt accumulating knowledge on what computing devices were available was necessary so that they were aware of the latest technological developments.

"We wanted to definitely see what the United States are doing or what the UK is doing and so we're obviously trying to get as much sources as we can to help us know what's out there." (Health Service Representative 16)

"Technology is moving along all the time, so it's really important that we make sure that we understand what's out there…to make sure that we have the most current information about what devices are out there, both from mobile computing and fixed computing." (Health Service Representative 9)

3.16.2. Seeking Advice from External Sources

Another step the Health Service representatives reported undertaking when making decisions about the selection of hardware computing devices was seeking advice from various external sources. Several Health Service representatives stated that they carry out discussions with individuals from other Area Health Services and often visit facilities in other Area Health Services to observe the types of computing devices that had been selected for implementation on the hospital wards.

"[We] visited about, probably about half a dozen sites…to see how they had all approached it." (Health Service Representative 10)

The Health Service representatives also stated that they sought advice from IT vendors. They perceived that the IT vendors were able to provide recommendations regarding hardware computing devices and share lessons based on their previous experiences with computing device implementations.

"The first port of call is with the vendor of the solution; what do they recommend from previous implementations." (Health Service Representative 1)

"The vendor recommendation of course. I mean from multiple implementations they obviously have valuable guidelines to give." (Health Service Representative 10)

"We had [an IT vendor] come in quite a few times and we say 'Look this is a specific ward area and what would you suggest?' So they've been very helpful." (Health Service Representative 5)

Likewise, the IT vendors characterised their part in decisions regarding the selection of computing devices as a *"consulting"* or an *"advisory"* role. The IT vendors perceived that their function was to provide *"strategies"* and *"recommendations"* on what types of computing devices, and how many, might be required in a given situation.

"A lot of Area Health's say 'we need to implement carts'. But carts isn't always the best solution. So I go in and try and understand the workflow, the information that's needed to be accessed, who needs to access it, where, and how often they need to access it. And then we can put together a proposal or a solution." (IT Vendor 8)

In providing advice on the type and number of computing devices, the IT vendors felt that they contribute to the decision-making process by assisting Health Service representatives to allocate their limited funds wisely.

"The first thing I advise them is don't buy too many. If you find that…there's not enough resources, then buy another cart. It's easier to buy one cart and add, but there's no sense in having five carts when four would have done." (IT Vendor 11)

"We'll just go into these wards and you've got a cart and it stays up against the wall and it never actually becomes mobile. They basically end up using this mobile cart and turn it into a computer stand. So they've gone and invested several thousand dollars on a very nice cart that they're now using basically as a wall mount that they could have bought for probably a tenth of the cost. So that's again where we want to kind of come in and help

them spend their dollars wisely and not come up with a dissatisfaction or end up with a whole bunch of equipment…that they're actually not using in its intended purpose." (IT Vendor 9)

Several IT vendors stated that they often undertake *"assessments"*, *"scoping exercises", "walkthroughs",* or *"motion studies"* of the proposed implementation site to assist with identifying the most adequate computing devices for a given situation. The IT vendors also highlighted that being involved in various projects, both nationally and internationally, helped them to build on their expertise. They perceived value in their abilities to draw on these past experiences to assist with device selection decisions in current and future projects.

"What we've found by the various projects we've been involved with is actually we've acquired a lot of shared learning. Therefore we can use those learnings to help people in local projects take advantage of overseas learnings." (IT Vendor 7)

3.16.3. Trialling Devices and Consulting Clinical Staff

The Health Service representatives indicated that another step that they undertake in the decision-making process is acquiring computing devices from IT vendors which they can then evaluate or trial on the ward. Some Health Services representatives reported holding trade fairs to demonstrate the computing devices to clinicians, while others reported providing the computing devices to clinicians for utilisation and testing in clinical practice. They suggested that this process allowed clinicians the opportunity to impart their opinions and feedback about the computing devices. Some Health Service representatives stated that they obtained feedback from clinicians through informal discussion, while others administered evaluation questionnaires to the clinicians.

"We got samples of the devices and physically manhandled them around the Health Service showing people the various trolleys. They got to make comments about the different devices, and they could say whether or not they liked one or the other and which one they wanted. And we recorded that and as much as possible we gave them what they asked for." (Health Service Representative 8)

"We actually got one or two trolleys and we actually put it out there for a month for the staff to use and we gave a piece of paper where they could write down which one they prefer and what they like." (Health Service Representative 11)

The Health Service representatives explained that they felt seeking input from clinicians and giving them an opportunity to trial computing devices was important, not only to obtain feedback, but to determine the practicality of the devices in the clinical setting. They suggested that it provided an opportunity to test assumptions about the use of computing devices, particularly mobile computing devices.

"We want to give them some devices to trial to see if they're actually going to use it because we suspect that they won't use the tablets to the extent they think." (Health Service Representative 5)

Some Health Service representatives also said that they consulted with departmental directors and nursing unit managers to elicit their opinions regarding computing device requirements.

3.17. Theme II: Factors Considered in Device Selection Decisions

The IT vendors and Health Service representatives were asked to describe the factors that they considered, or think should be considered, when making decisions about the selection of hardware computing devices for use on hospital wards. The IT vendors and the Health Service representatives identified several factors that they deemed important

to consider when selecting the type and number of hardware computing devices for implementation on hospital wards. It was frequently conveyed that it was necessary to consider a range of factors to determine what type of computing devices were feasible and suitable for a specific site.

> *"You can't just put everything paper on electronic and say 'Here's a cart, off you go.' There's so many other factors in it that will affect the quality of your implementation." (Health Service Representative 4)*

> *"I think it's multi-factorial. It's number of patients, it's number of staff, it's what they're doing, how much of the EMR they're doing…and when they're doing it. And it's whether or not it's stuff that needs to be done at the bedside or not." (Health Service Representative 9)*

> *"[We] look at their infrastructure, the software they have, the existing hardware, the type of ward it's going to go into, and then determine what the best case would be." (IT Vendor 2)*

> *"We consider the hardware devices we provide as enablers. If they're not put into the right workflow situation, with the right software, the right place and environments, they'll be useless to them." (IT Vendor 3)*

The various factors conveyed by the IT vendors and Health Service representatives were categorised into three subthemes: (i) technology attributes; (ii) user and task attributes; and (iii) environment attributes. These subthemes, and the factors categorised within each subtheme, are presented in Table 3.2.

Table 3.2. Factors Considered in Computing Device Selection Decisions

Subthemes	Factors
Technology Attributes	Infrastructure Existing Hardware Device Characteristics Software Applications
User and Task Attributes	Role of User Task Type Location of Task
Environment Attributes	Ward Type Space Available Accessing Dynamics

3.17.1. Technology Attributes

The IT vendors and Health Service representatives outlined a number of factors to consider in the selection of hardware computing devices that were encompassed by the technology attributes theme. These factors included: infrastructure; existing hardware; device characteristics; and software applications.

Infrastructure

Infrastructure, in terms of the means to access the hospital's network, was perceived to be a key factor impacting on device selection decisions. Both the IT vendors and the Health Service representatives highlighted that infrastructure, whether wired or wireless, had a bearing on the type of computing devices that could be selected for implementation on hospital wards. The Health Service representatives indicated that hospitals or wards with a solely wired infrastructure were largely limited to fixed

computing devices, while those that also had wireless infrastructure had a broader choice of computing devices.

> *"There's no point in delivering a wireless laptop if you haven't got [wireless infrastructure]. What the staff member would have to do is walk around with a blue cable and plug it in to all these ports. Yeah you could do that but, my God, people would disengage from that very quickly." (Health Service Representative 15)*

> *"In terms of wall mounts, really we've put a lot of these into some of the wards…because they're not wireless, we didn't have a choice." (Health Service Representative 2)*

Likewise, an IT vendor gave an example of a situation where the wireless infrastructure capabilities of a hospital were not adequate for the mobile computing devices the hospital wished to implement. This, in turn, limited the choice of computing devices that could be selected for implementation as the hospital had to work within their existing infrastructure.

> *"Some of the hospitals I've worked in just haven't had the ability to upscale their network. So you…can't go mobile because they just don't have enough access points to go mobile and the poor infrastructure won't allow them to add anymore." (IT Vendor 7)*

The IT vendors and Health Service representatives specified that the capacity of the wireless infrastructure was a particularly important consideration for mobile computing devices. Wireless infrastructure that is slow or has problems with connectivity, for example susceptibility to frequent *"drop outs"* or numerous *"black spots"*, can affect the ability of mobile computing devices to maintain an uninterrupted connection to the hospital's network.

> *"When you do wireless…you need to understand how many wireless points you need. You have to have enough saturation that wireless devices will actually work; otherwise it's*

just not going to work. You're going to lose connectivity somewhere around the corner." (Health Service Representative 9)

"You have to take into consideration…their wireless connectivity. So that's pretty critically important to how the devices will actually work; whether there is going to be spots where they just won't work." (IT Vendor 9)

"You've got to have the infrastructure in place. If your network runs at, you know, a very slow [pace]…then again people just get frustrated. The infrastructure is a key factor to make sure that you can deliver the right solution at the end." (Health Service Representative 15)

Both the IT vendors and Health Service representatives highlighted that insufficient wireless infrastructure would significantly influence the successful implementation and use of mobile computing devices.

"I think the main failing that we see is the network and whether the robustness and speed of the network is sufficient. You know, so it can just take [clinicians] too long so they just don't use it." (Health Service Representative 1)

Existing Hardware

A number of IT vendors cited that existing hardware, including computing devices, communication devices (such as phones), and medical devices (such as infusion pumps), should be taken into account when selecting new computing devices. They emphasised the need to note the number of electrical outlets being utilised by these existing devices and the number of electrical outlets that remained available for new computing devices.

The IT vendors also suggested that it was necessary to consider the wireless frequency of existing devices. One IT vendor specified that, although interference problems were

unlikely with newer technology, the wireless frequency of some devices (such as mobile phones) had the potential to interrupt medical devices (such as respirators).

> *"There's a lot to be considered, especially when we're working with medical devices as well. We need to look at the wireless frequency so they don't interrupt the important life saving devices that they also use in the hospital environment." (IT Vendor 2)*

Another IT vendor recalled a situation where the addition of new computing devices on a hospital ward increased the stress on the ward's wireless infrastructure and caused problems for the existing devices.

> *"Bringing another device into the mix can also cause other major issues as well. For instance…one of the hospitals recently asked us to come and do a trial in their ED…with mobile computing running in a wireless network. However the stress on the infrastructure that we increased by putting mobile devices into the wireless environment there meant that they had problems with their DECT [Digital Enhanced Cordless Telecommunication] phones." (IT Vendor 3)*

Device Characteristics

The need to consider the physical characteristics of hardware computing devices when making selection decisions was frequently mentioned by both the IT vendors and the Health Service representatives. Characteristics that the Health Service representatives felt were important to consider, particularly for mobile computing devices, included: ruggedness and robustness; battery life; recharge times; weight (if carrying or manoeuvring the device); wireless capabilities; screen size; type of data input (keyboard, touchscreen, or stylus); and user friendliness.

> *"Weight, size of screen, and keyboard. They were certainly all the factors that we were grappling with and there's no easy answer. When it came to mobile computing the most*

popular device was the one that was light and easy to push around. We deliberately didn't go with handheld [devices] because the…'ruggedisation' of the device is pretty poor." (Health Service Representative 8)

"Tablets were wonderful in theory but very difficult in practice because they were very heavy at the time…as well there's the issue that they can be dropped." (Health Service Representative 11)

"Battery life is one of the key factors. One of the key things that people say is they are sick of things running out of power after three hours." (Health Service Representative 14)

Another key characteristic conveyed by the Health Service representatives was the ability to sanitise the computing device. The Health Service representatives perceived that being able to sanitise a device was necessary to avoid any potential risks of infection being spread throughout a ward or hospital. The IT vendors frequently used tablet computers to provide examples of key characteristics that they felt were important to consider when contemplating the selection of such devices. The IT vendors suggested that tablet computers needed to be rugged, easily sanitised, and light in weight.

"With the tablet computer one of the things we want to look at is, is it rugged? If I happen to drop it is it going to keep working? Can I clean it? -Especially with a tablet. The tablet is going to be set on the bedside and maybe a patient may touch it, or two or three people may move it around as they're providing care to the patients, so you've got to make sure that you're able to completely sanitise a device like that." (IT Vendor 10)

Software Applications

The IT vendors and Health Service representatives commented that the type of clinical software application required to run on a hardware computing device can impact on device selection decisions. The Health Service representatives specified that the clinical

software applications utilised within their hospitals predominantly required computing devices with the Microsoft Windows Operating System.

> *"When a new device such as iPad comes out the questions that we get asked is 'Well can we run [the clinical application] on iPad?' And that's when it comes down to…the software operating environment. Unfortunately it was a platform that, at this point in time, is not compatible with our environment. We need to look at how the device fits in within our software environment. In terms of the platform that it runs on…most of the time it's Windows." (Health Service Representative 16)*

The IT vendors and Health Service representatives also highlighted that the transferability of the software application onto different screen sizes needs to be considered when selecting computing devices. That is, if a software application has been designed for use on the large screen of a desktop computer, the layout may not transfer properly onto the small screen of a handheld device.

> *"One of the challenges with mobility…is that most clinical applications today, including ours, are not necessarily written for that particular form factor. We're displaying a lot of information on the screen at once. And in order to display a lot of information on the screen you've got to have real estate. So when you take that and…you go from a 17-inch monitor to a 7-inch screen and you're trying to display the same type of information – it's very difficult." (IT Vendor 10)*

> *"Some software resized itself so we're lucky because [the medications management system] partially resizes itself. Whereas our electronic medical record unfortunately doesn't do it as much. So we have some buttons that even on the 15-inch laptops people have to now scroll down to actually find their save button, which is unfortunate." (Health Service Representative 11)*

3.17.2. User and Task Attributes

The IT vendors and Health Service representatives emphasised that, when selecting hardware computing devices for hospital wards, there was a need to evaluate how the different types of computing devices would integrate with clinical tasks. They perceived that evaluating clinical workflow, that is how and where different users undertake tasks, was important not only to identify the means to support current clinical workflows but to potentially improve them. The IT vendors and Health Service representatives described several user and task related factors that they perceived would influence which type of computing device would be most suitable in a given situation. These factors included the: role of the user; task type; location of the task; and quantity of information needs.

Role of User

The role of the intended user was considered to be influential in device selection decisions. The IT vendors and Health Service representatives perceived that different clinical roles perform tasks differently and, as such, may require different computing devices.

> *"There's a difference in the way that nurses document and medical staff document. Nurses would probably utilise the mobile carts whereas a doctor will often go away and write up notes in a doctors' room. So profession by profession, I think there's a variation in their needs." (Health Service Representative 10)*

> *"Doctors tend not to use the computers at the bedside. They tend to go and see the patient and then go back to the central station and do their work there, where they can sit down and think quietly." (Health Service Representative 8)*

The Health Service representatives frequently referred to doctors undertaking their work in *"teams"*, particularly during ward rounds. It was perceived that doctors undertaking ward rounds often shared one or two computing devices amongst the team.

> *"One project that we've just done is with the Neurosurgery team. They actually do a ward round every morning at 8:30 of two units and they push the cart around…they push that around the ward to do their ward round. At the same time the interns and registrars are carrying a tablet computer. The whole idea really was that that suited their workflow." (Health Service Representative 16)*

The IT vendors explained the need to identify the intended users of computing devices, and the tasks that those users will perform on computing devices, in order to determine which device to select.

> *"Understanding what the key role of clinicians or the people on the ward is and actually making sure that whatever you're implementing is relevant to them. If you map the clinical processes and then try and equate that back to the IT needs, that's when you understand really what their IT requirements are." (IT Vendor 7)*

> *"In essence you don't want an admissions person that registers patients to move around the facility. So their [device] won't necessarily be tailored for something like that." (IT Vendor 5)*

Task Type

The type of tasks to be undertaken on devices was also raised as an important factor to consider. In particular, it was suggested that the quantity of information that needs to be accessed or captured for different types of tasks would greatly influence computing device selection. The quantity of information related to both the amount of information and the variety of information that the task required. One IT vendor suggested that

tasks requiring access to, or documentation of, *"lightweight"* quantities of information may be suited to handheld devices. Another IT vendor echoed this opinion stating that handheld devices "*are great for retrieving data and for smaller parts of data entry…tick box type data entry" (IT Vendor 7).*

Likewise, the Health Service representatives perceived that handheld devices were suited to tasks requiring access to or documentation of smaller amounts of information. Where tasks necessitated access to or documentation of larger amounts of information, such as graphs of trends over time or progress notes, the Health Service representatives advocated the selection of computing devices with bigger screens and keyboard input for easier data entry.

> *"PDAs...might be good at looking at maybe results, like a full blood count or something, but it would be very difficult to do much data entry. Again maybe ordering a test might be easy, but doing anything else apart from that I think would be difficult." (Health Service Representative 9)*

> *"People undervalue the benefit of having a keyboard and people think that a tablet, click, click, click, just you know, poke a little stylus at the screen and everything is taken care of, but unfortunately you need the keyboard for a lot of the work that you do." (Health Service Representative 11)*

The Health Service representatives also highlighted the need to consider the various items necessary to complete different tasks. It was frequently specified that nurses often need items such as medications, glucose testing kits, or sphygmomanometers when undertaking tasks. The Health Service representatives suggested that carrying such items in addition to a mobile computing device, such as a tablet computer, may pose some difficulty for nurses when undertaking tasks independently. They proposed that

devices such as computer carts, which provide a means to stow items, may be more suitable to tasks requiring additional items.

> *"Much of the time you're taking something with you to the bedside for the patient. You might be going to do someone's observations so you've got to carry a sphygmomanometer…so, you know, you've got to think about 'Gosh, I've also got to take a computer with me'. So, I mean, that's probably one of the down sides of having that kind of device [tablet computer]. I mean, the carts are ideal." (Health Service Representative 2)*

> *"We're still in the hybrid stage…the documentation of the clinical notes is done manually. So we've still got to be able to provide them with something to move those notes around. So until we can get a…paperless environment they're going to be wanting to load up the trolleys with things." (Health Service Representative 5)*

Location of Task

The location in which users need to access or capture information in order to complete tasks was frequently cited by both the IT vendors and Health Service representatives as a significant factor influencing computing device selection decisions. The Health Service representatives considered *"improved accessibility of information to clinicians" (Health Service Representative 1)* to be one of the main objectives in determining which computing devices to select.

> *"We regard access to the system as probably the most important factor to success. If [clinicians] can get to a machine when and where they need it, then that will make a successful implementation." (Health Service Representative 10)*

The IT vendors considered information to be *"mission critical"* in health care. As such, they considered providing the means to access or capture information in the location of

a task to be a *"prime objective"* in the selection of devices. The IT vendors explained that accessibility to computing devices in the immediate location of a task was important to avoid users having to traverse back and forth between the location where information was needed to complete a task and the location of the computing device.

> *"You want the clinicians and the nursing staff to do the data entry at the place of care, whether that's with the patients in the triage area, or if it's out in the waiting room, or at the bed…you don't want to be going back and forward to make notes." (IT Vendor 11)*

The IT vendors also felt it was necessary to ensure that a sufficient number of computing devices were available to users in the locations where tasks are performed. One IT vendor suggested that if there are not enough computing devices available clinicians will *"try to avoid it because they have to queue and wait to get their information" (IT Vendor 1).*

The Health Service representatives perceived that the predominant locations of tasks requiring accessibility to a computing device on hospital wards included the patients' bedside and a central workstation or office away from the patients' bedside. They suggested that it was necessary to select computing devices that would allow users to undertake tasks both at and away from the patient bedside. A number of Health Service representatives specified that this could be achieved by either selecting fixed computing devices for implementation both at the bedside and at a central workstation, or by selecting mobile computing devices that could be moved to various locations.

> *"Any facility that goes with…[fixed] computer units at the bedside need to also make sure that they have something away from the patient because the doctor doesn't want to be standing there for twenty minutes writing up their notes with the patient looking straight at them." (Health Service Representative 12)*

"The benefit of having laptops on trolleys is you can go to the bedside when you need to be at the bedside, but you can leave the bedside when you don't need to be there. So there are certain things that you need to do at the bedside. Nursing staff need to check medications at the bedside. When doctors do their ward rounds they need to be able to see pathology results often at the bedside and there's other things that you can do right then and there. But doing some of your documentation you don't need to be there." (Health Service Representative 11)

3.17.3. Environment Attributes

The IT vendors and Health Service representatives conveyed several factors related to the environmental context of a site that they considered would influence computing device selection decisions. These factors included the: ward type; space available; and accessing dynamics.

Ward Type

The type of hospital ward computing devices were being selected for was perceived to be a necessary factor to consider in device selection decisions. The IT vendors suggested that different types of wards had different processes and levels of activity and, as such, may require different types and numbers of computing devices.

"ICU is a lot different to a ward, is a lot different to theatres, a lot different to NICU [Neonatal Intensive Care Unit], and all that. So everything is judged on its own merit." (IT Vendor 8)

"The more acute wards, where there's a lot of activity happening you may well get very close to one device per person. In other places…[like] a rehab ward, you'd probably get away with one device per three or four, even more, clinicians because….there's more of a structured flow about what they do every day." (IT Vendor 7)

The Health Service representatives further specified that the processes and levels of activity on a ward are largely affected by patient acuity. They conveyed that patient acuity may have a bearing on the number of clinicians present on a ward and the length of ward rounds, which may impact on the number of computing devices required.

> *"The geriatric rounds last for a long time. It's not like a surgical round where you're in and out seeing a patient within a minute. The nature of the patients are different. There's also more teams in the surgical ward." (Health Service Representative 5)*

Both the IT vendors and the Health Service representatives gave the example of infection control rooms and isolation wards as areas where the selected computing devices may need to be either sanitisable or dedicated solely to those wards. The IT vendors also presented the example of Orthopaedic Wards where the removal of plaster casts can generate dust which would make mobile computing devices a more suitable selection.

> *"You need to look at things like infection control. If you've got isolated rooms you can't take things in and out of there. So do you put a desktop in there all the time? And then you've got to think about…are they able to be cleaned." (Health Service Representative 5)*

> *"If it's an infectious disease area…they can't take devices from ward to ward due to contamination shifts." (IT Vendor 3)*

> *"If it's plaster casting there's a lot of dust…[carts] are good because they can be wheeled in, the patient checked, and wheeled back out. Whereas, if you left a computer there it'd get pretty chalky and dirty in a very short space of time." (IT Vendor 11)*

Space Available

Another factor cited by both the IT vendors and Health Service representatives as impacting on device selection decisions was the space available on a ward. The IT

vendors suggested that an important consideration in selecting devices was determining whether there was space available to permanently install fixed computing devices. They perceived that in areas where space wasn't available for fixed computing devices mobile computing devices may be more feasible.

> *"Sometimes the wards and the rooms and the bed space is just so cramped that you don't have the room on the wall to actually mount a wall-mount and in that case obviously carts are a better idea. You've also got to take into [consideration] if it's on the wall, and especially in a corridor or a hallway, then it can't sort of protrude too far from the wall otherwise you're not going to be able to wheel beds past." (IT Vendor 8)*

Likewise, the Health Service representatives perceived that the space available on a ward was potentially restrictive on the types of computing devices that could be selected. They highlighted the need to consider the space available to install fixed computing devices and the space available to store or move mobile computing devices.

> *"Up here there are a lot of other devices around the beds. And that's a restricting factor. You can't have something between beds because you've got a lifter and you've got a chair, and you've got…commodes, weighing machines, all of that kind of thing is in the way as well." (Health Service Representative 4)*

> *"One of the great difficulties with all of these hospitals…most of them are old and they were never built to take computers. You go in to any ward and you'll see piles of things like drips, drip stands, and wheelchairs, and commode chairs, and walking frames. So the space was a real issue for a lot of hospitals. Carts are ideal but you then have to have the floor space to move them all around." (Health Service Representative 2)*

> *"We're very lucky because we…[have] relatively wide corridors so we can actually keep [carts] in areas that other hospitals may have more difficulty with because of the width of the corridors." (Health Service Representative 11)*

One Health Service representative emphasised the patient safety concerns related to the space available around the patient bedside. The Health Service representative suggested that mobile computing devices could easily be moved away from the patient bedside in the event of the patient requiring, for example, resuscitation, whilst fixed computing devices were deemed to be potentially obstructive in such circumstances.

> *"The reason we went with the trolleys for ICU is that if they need to get to that bedside because the patient's crashing or is having some sort of incident they can just unplug it and roll it away. And everyone can get to the bedside and easily get there. Whereas, if it's a fixed computer that's something else that they have to work around." (Health Service Representative 11)*

Accessing Dynamics

The accessing dynamics of a ward, that is, the number of clinicians that will be utilising the computing devices at concurrent times, was frequently cited as a factor impacting on device selection decisions. The IT vendors specified that it was important to identify, what they referred to as, the *"levels of concurrency"* of the intended implementation site.

> *"We look at concurrent users. That means how many people are on the system at any one time as opposed to how many people might actually be on the ward." (IT Vendor 10)*

The IT vendors and Health Service representatives explained that decisions about the number of computing devices required ascertainment of the number of clinicians accessing computing devices at *"peak"* times. They emphasised the need to provide a sufficient number of computing devices to cover peak accessing times to ensure computing devices were available to users when needed.

> *"In terms of the numbers we very much look at how many staff we have on the ward at some of the peak shifts. They have a number of consultants who tend to do slightly longer*

ward rounds with their patients and nursing staff are giving medications at the same time. So we need to make sure that we do have enough for everyone to access it when they need it." (Health Service Representative 11)

"I know that we had to probably get more devices than I thought we would need because when they did one of the medication rounds is when they also did the doctors round. So we needed more devices…because there were two separate groups of people doing things." (Health Service Representative 9)

"Unless you have enough devices, and people can get access to the device when they need it, that's going to be another barrier to people using the system." (Health Service Representative 9)

"The peaks and troughs are huge. But if you can't handle the peaks, you know, sometimes that'll mean that this guy is sitting there doing nothing." (IT Vendor 7)

In determining the type of computing devices to select the Health Service representatives also cited the need to consider the time of day the computing device will be accessed. They suggested that handheld mobile devices may be more suitable for use at the patient bedside at night as they would be less disruptive to patients when being moved around the ward compared with manoeuvring a computer cart.

"Someone on night duty might take [a tablet computer] out to the ward, rather than carting a noisy trolley around. Because the trolleys…don't sneak along quietly." (Health Service Representative 4)

The Health Service representatives further specified that the accessing dynamics of a ward are influenced by the number of electronic processes that have replaced paper processes. They indicated that sites which were largely electronic, and undertook clinical documentation, test ordering, results viewing, and medication management

electronically, would require a greater number of computing devices compared with predominantly paper-based sites.

> *"At the moment we're not doing clinical documents. Because we didn't roll out clinical documents, we could afford to have less computers." (Health Service Representative 8)*

> *"When we first started basically all we did was just…looking at results and placing orders electronically. So I think we had maybe two to three computers in a ward. Because that was not a lot you didn't have to go to the computer to do much. Everything else was in the [paper] record. But now we've got other things we're going to have to have a lot more [devices]." (Health Service Representative 9)*

3.18. Theme III: Perceived Impact of Mobile Computing Devices

The IT vendors and Health Service representatives were asked to reflect on what impact they perceived providing mobile computing devices on hospital wards would have on clinical work practices or patient care. The responses conveyed by the IT vendors and the Health Service representatives were categorised into two subthemes: (i) efficient work practices; and (ii) effective and safe patient care.

3.18.1. Efficient Work Practices

The IT vendors and Health Service representatives perceived that mobile computing devices would facilitate efficient work practices by providing clinicians with increased accessibility to clinical information at the place and time that it is needed. They explained that the current practice on wards that did not have mobile devices, or fixed devices at the bedside, was for clinicians to walk to and from a fixed device, generally located at a central workstation, to access information in between seeing each patient. The IT vendors and Health Service representatives anticipated that mobile computing

devices would negate the need for clinicians to traverse back and forth between a fixed device and the patient bedside and thus increase productivity by eliminating, what was considered to be, an *"intermediate step".*

> *"It can lead to dramatic productivity benefits. So just taking, for example, a normal ward round. What currently happens is…[the] doctor goes in, they collect information from their desktop workstation, or they print out a bunch of information on paper. Then they go to the first, potentially two beds, but…then they have to get some test results back and they then have to go back to the workstation. Then they might go back to bed three. So there's a lot of to-ing and fro-ing. With [a mobile] device, because they can carry it around all the time, because they're always connected to the system, there's no need to leave that patient to get information. They can do it at the bedside." (IT Vendor 1)*

Further, the IT vendors and Health Service representatives expected that mobile computing devices would provide clinicians with a means to access information while they were in transit. The Health Service representatives suggested that the *"immediacy"* of information access, that mobile computing devices may be able to provide clinicians with while they are on-the-go, would make activities such as ward rounds and medication rounds *"easier to conduct" (Health Service Representative 2).*

> *"They can log on to that patient record, they can order the tests, they can view the tests results, all while they're still walking around." (IT Vendor 1)*

The IT vendors and Health Service representatives also believed that mobile computing devices would facilitate efficient work practices by providing clinicians with the means to document clinical information at the place and time that it is obtained. The Health Service representatives cited the example of documenting patient observation data, such as blood pressure, obtained at the patient bedside. They suggested that lack of access to computing devices at the patient bedside would make clinicians more likely to either

memorise the information or document the information on paper and then transcribe the information to a desktop computing device.

> *"What they do is they'll write it down on paper at the bedside then they'll go back to a fixed device and they'll transcribe it. So one, its inefficient and two, it's not safe because every time you transcribe something there's a problem. I mean I know that you can actually write things down incorrectly the first time but transcribing is not a good thing." (Health Service Representative 9)*

> *"Doctors will still sit down beside the patient with a written piece of paper and then go back to a desk and type up what they've written. Or some that can remember will do it out of memory." (Health Service Representative 3)*

The IT vendors and Health Service representatives anticipated that mobile computing devices would aid in removing the step between obtaining clinical information and electronically recording the information. Additionally, they perceived that documenting clinical information in a timely manner and at the place that it is obtained would lead to an increase in the accuracy of recorded information alongside a decrease in transcription and omission errors.

> *"You can stand there and instead of writing it on pieces of paper or scribbling on your hand, you technically could type it in. So ideally you're looking at efficiencies." (Health Service Representative 12)*

> *"I think the most important thing about it is work efficiency and I suppose accuracy of data because you're doing it right there, at the bedside of the patient." (IT Vendor 5)*

> *"It will lead to less errors being recorded. It will lead to having more correct data and not forgotten data put in." (IT Vendor 11)*

The Health Service representatives further underscored that the timely documentation of clinical information allowed it to become electronically accessible to other clinicians on the ward or from remote locations.

> *"The benefits for the clinicians…is the fact that that information is available immediately by multiple people from anywhere." (Health Service Representative 9)*

3.18.2. Effective and Safe Patient Care

The IT vendors and Health Service representatives perceived that mobile computing devices, through the provision of increased accessibility to clinical information, would positively impact on the effectiveness and safety of patient care. They suggested that mobile computing devices could be utilised to access a wide scope of information, such as the patient's medical record, electronic decision support, and clinical resources, at the place and time that it is required by clinicians. Both the IT vendors and the Health Service representatives anticipated that accessibility to such information would lead to more informed patient care decisions.

> *"It gives you point of care access and the information you need to make a decision at that specific time. So with the mobile device you do have your, potentially your x-ray, as well as your pathology result, as well as your medications available to you when you're there with the patient at the bedside so that you can make an informed up-to-date decision rather than using paper systems and having a pathology report from three days previously." (Health Service Representative 12)*

> *"The patient care component is significantly improved because they've got access to information to make decisions. So they're not making decisions without that information." (IT Vendor 7)*

Further, the IT vendors and Health Service representatives emphasised that accessibility to patient information and clinical resources at the patient bedside was particularly important when administering medication to patients. They perceived that mobile computing devices would increase safety by providing the means to confirm that medications were being administered to the right patient, that it was the correct dose, and that the patient did not have any documented allergies to the medication. The Health Service representatives highlighted that, although paper resources could also be utilised to access medication information, they believed that electronically available information was more likely to be up-to-date than paper resources.

> *"Potentially it will save lives…so that the nurse that's dispensing the medicine actually is confirming that this medicine is the right patient, right dosage." (IT Vendor 11)*

> *"When we rely on paper we rely on information that's out-of-date as soon as it's produced. I found this on the ward the other day; it's a…medication reference from 2006. If a nurse picks this up and injects the medication this way, based on the book, they could actually be harming the patient because something has changed about that medication. So you're giving them…access when they need it to the right references, up-to-date material. And electronic means that it's more likely to be current than something which has been printed at some stage." (Health Service Representative 11)*

3.19. Conclusion

The 12 IT vendors and 16 Health Service representatives conveyed a great deal of information about the selection of hardware computing devices for use on hospital wards and the factors that they perceived were necessary to consider in device selection decisions. Implications arising from these findings are discussed in the next section (Chapter 3. Part C: Discussion).

Chapter 3. Part C: Discussion

3.20. Introduction

The preceding sections of this chapter: outlined the research objectives that this stage of the research aimed to address; provided a comprehensive account of the methods employed in undertaking the research; and presented the study findings. The following section discusses the findings in relation to the study's central research questions, namely: how do decision-makers select computing devices and what factors do they consider when making decision about the selection of devices?

3.21. The Process of Selecting Computing Devices

Selecting computing devices to support clinicians' work practices is a multi-step process. Decision-makers within this present study reported that the process can involve: gathering knowledge about the different types of computing devices that are available; seeking advice from external sources, including both other hospitals and IT vendors, about their experiences with device selection; holding trade fairs and providing clinicians with devices to trial in practice; and obtaining feedback from clinical staff about the use of computing devices. Such findings largely align with the processes described in existing literature regarding the selection of computing devices. Studies by Oder et al. (2010), Senior (2006), Rescorl (2006), Wagner and Moore (2011), and Murphy (2008) all reported undertaking the steps of: identifying the types of computing

devices that are available; holding trade fairs or testing computing devices; and obtaining input or feedback from clinical staff. Wagner and Moore (2011) also reported seeking advice from other health care facilities regarding their experiences with computing devices.

Similar process steps are also reflected in literature regarding the selection of clinical information systems. Recent studies outline that the key steps in selecting clinical information systems include: determining what systems are available, and assessing and comparing the different systems (Cresswell et al. 2013; Kushniruk et al. 2010; Lorenzi et al. 2009); liaising with vendors for advice and system demonstrations (Kushniruk et al. 2010; Lorenzi et al. 2009; Weathers & Esper 2013); visiting other facilities to see the use of the system in practice (Cresswell et al. 2013; Lorenzi et al. 2009; Weathers & Esper 2013); and trialling systems and obtaining input and feedback from clinicians (Cresswell et al. 2013; Kushniruk et al. 2010; Lorenzi et al. 2009; Weathers & Esper 2013). The similarities in the decision-making processes described across literature investigating the selection of clinical information systems, literature regarding the selection of computing devices, and the findings emerging from this present study suggest that, in and of themselves, processes for the selection of technology tend to follow relatively consistent steps.

While each of the identified decision-making steps is undoubtedly important in facilitating an informed selection process, a step that is often highlighted as critical is end user involvement (Kushniruk et al. 2010; Lorenzi et al. 2009). Alongside other researchers (such as Oder et al. 2010 and Weiner et al. 2004), Berg (2001) considers involving end users in decisions to be paramount to implementing technology that will adequately support clinicians' work practices. At the same time, however, Berg (2001) suggests that "users are generally very bad…in imagining what specific configurations of the technology they 'need' or what would work 'best' in actual work situations" (p.148).

Hence, in addition to obtaining input from end users, Berg (2001) recommends examining clinical work in practice to better illuminate clinicians' working patterns in order to identify the technology that may be best suited. This notion was found to correspond with the opinions of decision-makers in this present study. They perceived that seeking input from clinicians was important but also felt that trialling devices in practice was necessary to test clinicians' assumptions about the use of computing devices. The importance of examining clinical work and the use of computing devices in practice is further evidenced by the lessons emerging in Wagner and Moore's (2011) study, which investigated the process of selecting devices. Decision-makers in the study, consisting of a multi-disciplinary committee including nurses, anticipated that tablet computers would better support clinical work than the existing computer carts or desktop computers. It was not until the tablet computers were deployed and used in practice that factors affecting their successful use became apparent. For example, nurses found that they did not have a place to set down the tablet computers while providing care at the patient bedside and that the stylus mode of data entry was difficult to use. The findings from Wagner and Moore's (2011) study highlight that a crucial step of decision-making processes needs to be consideration of all the factors that may impact on the use of computing devices.

3.22. Factors to Consider When Selecting Computing Devices

This study identified a broad range of factors that are important to consider when making device selection decisions. These factors were grouped under three key categories: technology attributes; user and task attributes; and environment attributes (Figure 3.2). Technology attributes encompass consideration of: the available infrastructure (wireless network versus wired network); the existing hardware devices; the characteristics of devices; and compatibility with the existing, or planned, software applications. User and task attributes include: the roles of the intended users; the types

of tasks conducted by the users; and the locations in which users conduct their work. Environment attributes encompass consideration of: the type of ward for which the devices are being selected; the space available on the ward; and the accessing dynamics of the ward (i.e., demand for computing devices at peak times).

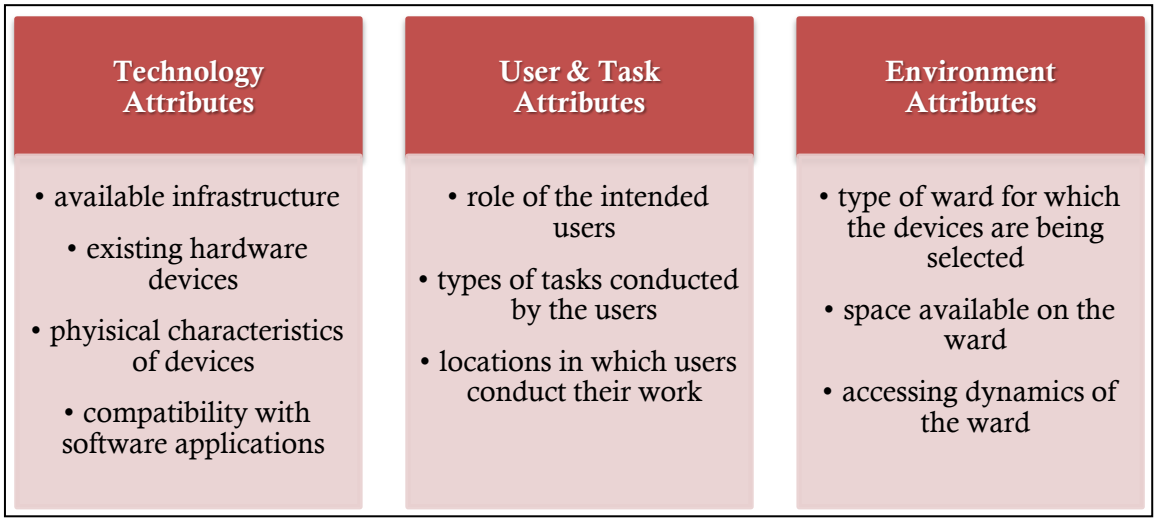


Figure 3.2. Key Factors to Consider in Computing Device Selection Decisions

A number of the identified factors have been previously found to influence the use of computing devices. A study by Oder et al. (2010), which described the process of selecting devices at a hospital implementing an integrated EMR, reported several factors that were influential in the selection and use of computing devices, including: fit with clinical workflow; compatibility with the EMR software; ability of devices to support work in different ward locations; how much space the devices required; ward type; and electrical capacity of the ward. Andersen et al. (2009), who undertook a multi-method investigation of clinicians' use of fixed and mobile computing devices on hospital wards, reported that decision-makers need to take into consideration: who will be using the devices; the nature and location of tasks; the space limitations of a ward; and the

characteristics of devices, such as whether they allow easy manoeuvrability, in order to determine the right selection of devices. Tang & Carpendale's (2008) examiniation of nurses' use of mobile computing devices highlighted the importance of assessing device characteristics, such as bulkiness and battery life, and wireless connectivity. The authors reported that such factors contributed to mobile computing devices failing to be utilised in the anticipated mobile manner; with the devices left stationary in coridoors instead. Decision-makers within this present study, similarly, highlighted that insufficient wireless infrastructure could significantly influence the successful implementation and use of mobile computing devices.

Looking at the above findings in light of Ammenwerth et al.'s (2006) fit between individuals, task, and technology (FITT) framework, it is interesting to note that the factors reported by the decision-makers are implicitly reflective of the FITT framework's dimensions. The FITT framework posits that use of technology is dependent on the fit between attributes of the users, attributes of the tasks, and attributes of the technology. Comparatively, decision-makers reported that selection of computing devices is influenced by factors related to user and tasks, and factors related to technology. While it has been noted that application of the FITT framework in the literature has largely been retrospective (Honekamp & Ostermann 2011), the above finding suggest that the framework could be utilised prospectively during device selection decisions to anticipate potential issues between user, task, and technology factors.

Decision-makers, however, also identified the need to consider factors related to the environment in which the technology is being implemented, such as ward type and the space available. Decision-makers perceived environment factors to be highly influential stating that the space available on a ward was potentially restrictive on the types of computing devices that could be selected. This suggests that environment factors exert an overarching influence on the selection of devices. In other words, even if fixed

computing devices were identified to best suit a given user role, lack of space on a ward may negate the ability to provide fixed computing devices in that situation. Based on the findings from this study, it is suggested that the FITT framework may benefit from the addition of an environment attribute. However, this is an area requiring further research.

3.23. Expectations of Selecting Mobile Computing Devices

Decision-makers anticipated that providing clinicians on hospital wards with mobile computing devices would facilitate efficient work practices by providing the means to expediently access and document information at the place and time that it is needed, including while the clinician is in transit. They also expected that the increased accessibility to patient-related information and clinical resources would lead to more informed patient care decisions, facilitating effective and safe patient care. Such perceptions are in line with the benefits reported in literature. Systematic reviews summarising literature on mobile computing devices cite the potential benefits as including: enhanced productivity and efficiency; improved communication; error reduction; and increased information accessibility (Free et al. 2013; Kuziemsky et al. 2005; Lindquist et al. 2008a; Lu et al. 2005; Martins & Jones 2004; Martins & Jones 2005a). Yet, as acknowledged by some of the systematic reviews (Kuziemsky et al. 2005; Martins & Jones 2004), there is a distinct lack of empirical evidence demonstrating the actuality of these benefits. This calls for much needed research that examines clinicians' use of mobile computing devices in practice in order to clearly demonstrate if and how these devices support clinical work practices; a central query that is addressed in the second stage of this research. Examining clinicians' use of computing devices in practice is also likely to aid in identifying factors affecting device use, thus, helping to validate some of the findings presented here.

3.24. Implications of the Findings

The findings from this study highlight the challenges inherent in decisions regarding the selection of computing devices for implementation on hospital wards. There is a complex range of factors that need to be considered when trying to determine which computing devices to provide clinicians with. The difficulty in determining what type and how many devices are required is compounded by the lack of guidelines to inform such decisions. Decision-makers must therefore make acquisition decision about the devices required to support clinicians' work based on untested assumptions grounded in limited evidence. This is the first study focusing on identifying the broad range of factors that decision-makers consider to be important in selecting computing devices for use by clinicians on hospital wards.

The multitude of factors that can affect device use stresses the need for decision-makers to undertake a structured decision-making process to ensure that all the influencing factors are considered. As stated by Kushniruk (2010), "ultimately, the success of our investments in HIT [Health Information Technology] depend on how rigorous and accountable our system procurement procedures are" (p.87). The importance of considering the identified factors is that computing devices undoubtedly affect clinical work practices; but whether this effect is positive or negative in facilitating efficient and effective work practices hinges on the selection of the right computing devices.

3.25. Limitations

Although strategies aimed at strengthening the quality of the research were utilised within this study potential limitations nonetheless remained. The strategy of member checking, for example, was not utilised within this study. Member checking can involve either returning transcripts to participants for checking or for obtaining feedback from participants regarding data interpretations (Ash & Guappone 2007; Mays & Pope 2000).

While some researchers, such as Kaplan and Maxwell (2005), view member checking as a vital means of preventing data misinterpretation other researcher, such as Kitto et al. (2008) and Mays and Pope (2000), argue that member checking can have limitations with participants potentially affecting interpretations. For this reason, and due to time restraints, member checking was not conducted.

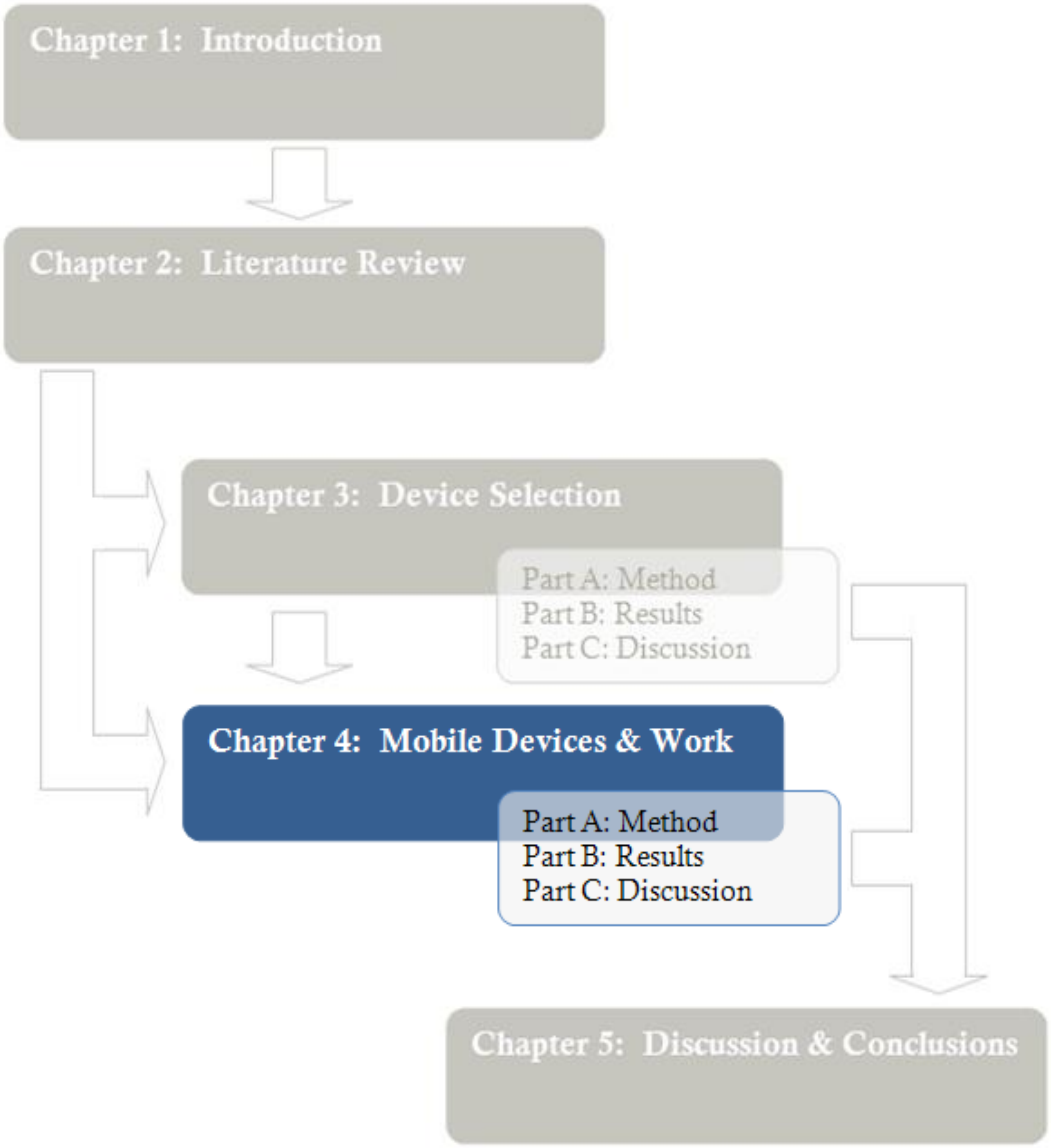
Another possible limitation of this study is that the interview guide was not pilot tested prior to the commencement of data collection. Pilot testing was not conducted as a number of questions were drawn from an interview guide developed and utilised by Gallego et al. (2008) in their study and, as such, these questions had already been tested. It has also been argued that, while essential in quantitative research, pilot testing is not a necessity in qualitative research (Holloway 1997). Nonetheless, pilot testing may have potentially facilitated the identification of additional questions to pose to participants. This limitation may, however, have been diminished by the use of semi-structured interviews, which afford the flexibility for additional questions to be posed to participants.

An important limitation that also requires acknowledgement is the commonly reported weakness associated with qualitative research approaches: subjectivity. As qualitative research relies on the views of a select group of individuals study findings may not be generalisable beyond the setting in which the research is conducted (Anderson 2010). In addition, interpretation of the views expressed by participants can be influenced by the researcher (Kaplan & Maxwell 2005). To assist in combating any potential bias the techniques of data triangulation (obtaining data from different groups of individuals) and investigator triangulation (multiple researchers independently analysing the data) were used within this study. Nevertheless, the emerging findings should be considered in light of the participant demographics and the setting in which the research was conducted.

3.26. Conclusion

This chapter discussed the first stage of the research, which involved an investigation of the selection of computing devices for use by clinicians on hospital wards. Interviews conducted with decision-makers revealed a range of factors that influenced device selection. These factors were grouped under three key categories: technology attributes; user and task attributes; and environment attributes. The factors were identified as important to consider in device selection decision so as to facilitate selection of devices that will adequately support clinical work practices.

CHAPTER 4


Chapter 1: Introduction
Chapter 2: Literature Review
Chapter 3: Device Selection
Part A: Method
Part B: Results
Part C: Discussion
Chapter 4: Mobile Devices & Work
Part A: Method
Part B: Results
Part C: Discussion
Chapter 5: Discussion & Conclusions

Chapter 4. Mobile Devices and Work

4.1. Chapter Overview

The preceding chapter discussed the first stage of the research, which involved investigating the selection of computing devices for use by clinicians on hospital wards. Interviews conducted with decision-makers revealed a range of factors that influenced device selection. Role of the user, types of tasks, and location of tasks, for example, were deemed important. These key findings were drawn upon to help inform elements of the second stage of the research.

A detailed description of the second stage of the research is presented in the ensuing chapter. This second stage of research involved the investigation of clinicians' use of computing devices in order to determine how mobile computing devices support clinical work practices on hospital wards. The chapter begins by providing a brief summary of the pertinent background literature underpinning this stage of the research and outlining the research objectives of this stage of the research. The rest of the chapter is then presented as three distinct sections, which include:

- Part A: Method (4.5. – 4.11.);
- Part B: Results (4.12. – 4.20.); and
- Part C: Discussion (4.21. – 4.29.).

4.2. Background Summary

Mobility is a central feature of health care delivery (Bardram 2005a; Bardram & Bossen 2003; Moran et al. 2006). In undertaking their work, clinicians attend to patients, locate co-workers, access information, and obtain resources, all of which necessitate a constant transitioning between patients, wards, clinics, operating theatres, and offices (Ammenwerth et al. 2000; Bardram & Bossen 2003; Camacho et al. 2006). Clinicians thus require systems of work that allow them to access information, resources, and people when and where they undertake clinical work (Bardram & Bossen 2005).

Technology has been advocated as a potential means of improving information accessibility (Baldwin et al. 2007) and facilitating the efficiency and effectiveness of health care delivery (Institute of Medicine 2012; Sheikh et al. 2011; Shekelle et al. 2006; Shekelle & Goldzweig 2009). However, mismatches between the capabilities of the technology and the needs and work practices of clinicians may hinder the realisation of such benefits (Baldwin et al. 2007; Harkke 2006; Reddy et al. 2005; Tang & Carpendale 2008). Fixed computing devices, such as desktop or wall-mounted computers, allow easy storage, searching, retrieval, accessing, and sharing of legible information (Dahl et al. 2006; Sellen & Harper 2002), but their static nature does not support many aspects of mobile work (Bardram & Bossen 2003; Luff & Heath 1998a). This immobility requires clinicians to seek out the location of a computing device in order to electronically document or access information (Baldwin et al. 2007; Bardram & Bossen 2005; Cheng et al. 2003; Embi et al. 2004; Kushniruk et al. 2006; Luff et al. 1992; McCord et al. 2007; Tang & Carpendale 2008).

Mobile computing devices, such as computer carts, tablet computers, and smartphones, have been heralded as providing a way to overcome the immobile nature of fixed computing devices (Al-Ubaydli 2004; Alsos et al. 2011; Gandsas et al. 2004). The key virtue of mobile computing devices is their inherent mobility; which is promoted as

allowing the devices to be utilised, and information to be accessed, where and when it is needed (Carroll et al. 2001; Dahl et al. 2006; Lu et al. 2005). As such, there has been great enthusiasm for mobile computing devices. But is there evidence to substantiate assumptions that the mobile nature of mobile computing devices supports clinical work practices on hospital wards? Based on the review of literature, conducted in the Literature Review (Chapter 2), the answer to this question is by and large no; with existing literature found to have a tendency of viewing mobile computing devices as inherently beneficial without clear indication of how this mobility supports clinical work practices.

Although much of the quantitative literature alluded to the mobility of devices for point of care (Berner et al. 2006; Carroll et al. 2003; Sintchenko et al. 2005) or bedside use (Horng et al. 2012; Rudkin et al. 2006; Shannon et al. 2006), none of these studies specifically measured whether mobile devices were used in this manner. A framework, developed and applied in the Literature Review to explore how mobile computing devices support clinical work practices (i.e., *who* is undertaking an activity; *what* resources support undertaking an activity; *when* the activity is performed; *where* the activity is performed; or *how* the activity is performed), illustrated that only one of the quantitative studies (by VanDenKerkhof et al. (2003)) expressly observed *where* mobile computing device use occurred and addressed the subsequent impact that the location of device use had on the study outcomes (i.e., use of mobile computing devices at the patient bedside facilitated more comprehensive documentation of pain assessments).

Several of the qualitative studies reviewed, on the other hand, provided indications of *where* the use of mobile computing devices occurred. Studies by Fisher et al. (2006), Tang and Carpendale (2008), and Murphy (2008) found that some nurses preferred not to take computer carts to the point of care, drawing attention to the fact that assumptions about the manner in which mobile computing devices will be used may not

always hold true in practice. As emphasised by Tang and Carpendale (2008), the mobile computing device "failed to live up to its intended use as a mobile and ubiquitous information artefact" (p.212). The authors concluded that the mobile computing device was not used as intended due to a mismatch between the technology and clinical work practices.

The paucity of evidence in this area highlights the need to explicitly examine the ways in which mobile computing devices are used in practice in order to understand if, why, and how they are useful in supporting clinical work.

4.3. Research Objectives

This stage of the research aimed to determine how mobile computing devices support clinical work practices on hospital wards. To achieve this aim, clinicians' use of computing devices on hospital wards was investigated in order to determine:

1) the types of tasks clinicians undertake when using mobile computing devices;
2) the locations in which clinicians use mobile computing devices when undertaking clinical tasks;
3) the fit between clinicians, tasks, and technology; and
4) the factors that affect the bedside use of mobile computing devices.

PART A: METHOD

Chapter 4. Part A: Method

4.5. Introduction

As outlined in the previous section, the aim of this stage of the research was to determine how mobile computing devices support clinical work practices on hospital wards. The research approach used to conduct this stage of the research, in order address the aim, is described in the following Method section.

The section begins with an overview of the setting in which the research was conducted, detailing the context of the study wards, the information system, and the workflow. The research design, strategy, and data collection procedures are discussed, followed by the data analysis techniques that were employed. The section concludes with details of the ethical approval for the research.

4.6. Research Setting

This stage of the research was conducted at a 320-bed metropolitan teaching hospital in NSW, Australia. Rationale for selection of the hospital as the study site was based on three factors. Firstly, the hospital had an established clinical information system and had selected both fixed and mobile computing devices as a means to provide clinicians with access to the information system. As such, the site afforded the opportunity to observe, and compare, clinicians utilising both fixed and mobile computing devices while undertaking their clinical tasks.

Secondly, although the clinical information system had been in place at the hospital for some time, the transition from a paper-based system to a completely electronic system can be a prolonged and complex undertaking (Ammenwerth et al. 2003b; Kuhn & Giuse 2001). As such, a number of clinical processes at the hospital remained paper-based resulting in, what is commonly referred to as, a hybrid system (Dykstra et al. 2009; Lærum et al. 2004; Sittig et al. 2002). This availability of paper-based and electronic systems at the one site provided the opportunity to compare clinicians' use of paper and computing devices within the same context.

Finally, in the first stage of this research program, interviews were conducted with Health Service representatives and IT vendors regarding the selection of computing devices for use on hospital wards. An emerging theme from these interviews was that advice was sought from external sources, such as other hospitals, during device selection decision-making processes. Several of the interviewed Health Service representatives identified the selected hospital as being *"ahead of the curve"* with regards to technology and indicated that it was a site from which they had sought advice when making their decisions regarding device selection. This suggested that the hospital would serve as an ideal setting in which to investigate the use of mobile computing devices.

4.6.1. Study Wards and Computing Devices

From the selected hospital, two wards were chosen in which to undertake the research: a 32-bed Cardiothoracic Transplant Ward (Ward A) and a 34-bed Geriatrics Ward (Ward B). The two wards were selected as they were the first and last wards within the hospital to receive mobile computing devices; Ward B in April 2005 and Ward A in October 2009.

At the time of the study, there were eight computer carts that were permanently located on each of the study wards. The carts, depicted in Figure 4.1, were available in two

styles: an ergonomic computer cart (an integrated computer and cart device) and a generic computer cart (a laptop mounted atop a trolley), both of which had 15.2-inch screens. Ward A had five ergonomic and three generic carts, while Ward B had one ergonomic cart and seven generic carts. Both the ergonomic and the generic carts had wireless capabilities and could be used to access the clinical information system via the hospital's wireless network.

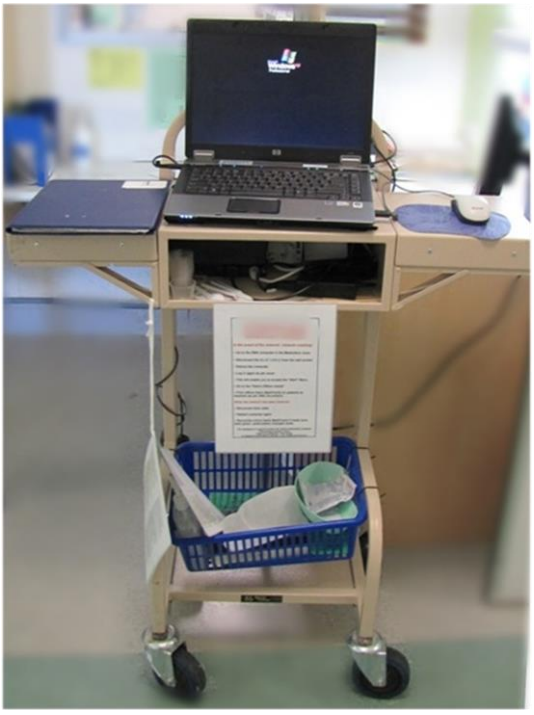
Computer Carts	
Ergonomic Cart	Generic Cart
	
Ward A (n=5); Ward B (n=1)	Ward A (n=3); Ward B (n=7)

Figure 4.1. Examples of an Ergonomic and a Generic Computer Cart

In addition, rather than one central nursing station, the wards had several designated areas, known as workbays, where desktop computers were stationed and paper-based medical records (for the patients on the ward) were kept (depicted in Figure 4.2). Each

workbay had one desktop computer and a set of shelves that housed the most frequently used paper forms and the paper-based medical records of the patients occupying the five to six beds in closest proximity to the workbay.

Figure 4.2. A Typical Workbay with a Desktop Computer and Paper-Based Records

There were six workbays in Ward A and seven in Ward B. Each ward also had two desktop computers in a shared office area and an additional desktop computer in the medication room.[7] Most of the desktop computers located on the two study wards had 19-inch screens and all could be used to access the clinical information system via a wired network. The layout of the wards, and general location of the computing devices on each ward, is depicted in Figure 4.3.

[7] There were additional computing devices located in offices on each ward (for example, desktop computers in the nursing unit manager's office and in the physiotherapists' office) but these were not used by doctors or nurses for clinical tasks and therefore were not included in the study.

Figure 4.3. Diagram of the Layout of Ward A and Ward B

4.6.2. Information System Context

As outlined above, the selected hospital had a hybrid system where paper-based and electronic systems were utilised in conjunction. Although the hospital's clinical information system had extensive functionalities not all of the available functions were in use at the time of the study; with the hospital undertaking a gradual transitioning from paper-based processes to mandatory electronic processes. For instance, while the clinical information system had provisions for the electronic documentation of progress notes, the documentation of progress notes remained a paper-based process. The main electronic functions that were in use on the wards at the time of the study are outlined below.

4.6.2.1. The Clinical Information System

The hospital's clinical information system was web-enabled and could be accessed by authorised personnel from any of the hospital's hardware computing devices. The system comprised several software applications; some of which were homegrown applications, while others were commercially available. A hyperlink to each application was available on the clinical information system homepage. The three key applications utilised on the study wards, included: an electronic medical record (EMR); an electronic medications management system (MMS); and an electronic whiteboard.

The Electronic Medical Record (EMR)

The EMR provided clinicians with access to a range of patient information, including details related to a patient's current admission and any electronic information related to a patient's previous admissions to the hospital (or its affiliated health care facilities). Computerised provider order entry (CPOE) and a picture archiving and communications system (PACS) were incorporated into the EMR. The CPOE allowed clinicians to electronically order tests and view test results, including radiology images

via PACS. The wards had also recently commenced using the EMR to electronically generate patient discharge summaries.

The Medications Management System (MMS)

The MMS allowed clinicians to electronically prescribe medications, alter or cease medications, and record the administration of medications. The system had an inbuilt clinical decision support system (DSS) in the form of order sets, prescribing alerts (for example, notifications regarding patient allergies or therapeutic interactions), reference information about therapeutic guidelines, and instructions regarding the administration of medications. Further decision support was accessible through hyperlinks to the Clinical Information Access Portal (CIAP): an online portal, established by a NSW Health initiative aimed at promoting evidence-based care, which provided clinicians with access to several resources containing extensive information about diseases, treatment guidelines, and medication information (NSW Health Support Services 2012).

The Electronic Whiteboard

The electronic whiteboard provided clinicians with information regarding patients and their location within the hospital. It contained the contact details of all the hospital staff, including both administrative and clinical personnel. The electronic whiteboard also had a function which allowed short text messages to be sent from a computing device to an individual's pager.

The above software applications (the EMR, MMS, and electronic whiteboard) were interoperable in the sense that data could be exchanged between the applications; however, each application was accessed as a separate entity. For example, if a doctor wanted to review a patient's test results they would need to log in to the EMR application. If, based on reviewing of the test results, adjustments needed to be made to

a patient's medications the doctor would need to access the MMS to make the necessary changes. This allowed different clinicians to concurrently utilise different parts of a patient's record. For example, a nurse conducting a medication administration round could utilise the medications management part of a patient's record to document the administration of a medication, while a doctor conducting a ward round at the same time could access the same patient's record to place an order for a blood test. A clinician could also have multiple applications running simultaneously in separate windows allowing them to easily switch between different parts of the electronic patient record. Users were logged off the clinical information system following a short period of inactivity.

4.6.2.2. The Paper-Based System

In a similar fashion to the way in which the electronic patient record was divided across different applications, the paper-based patient record was maintained in different folders. There were three types of paper-based medical records used on the study wards, including: the hospital medical record; the progress notes record; and the observations record.

The Hospital Medical Record

The papers forming a patient's hospital medical record were compiled in a heavy duty foolscap manila folder, bound with a tubeclip. The paper-based hospital medical records were generally kept in the hospital's Medical Record Department and were transferred to the necessary ward upon a patient's admission. The hospital medical record contained all the paperwork from any previous admissions that a patient may have had to the hospital. Upon a patient's discharge all the paper forms contained within the progress notes record and the observations record were relocated to the paper-based hospital medical record and returned to the Medical Record Department.

The Progress Notes Record

The progress notes record was an A4 25mm 2D-ring polypropylene binder which contained: an admissions form related to a patient's current admission; any notes from the Emergency Department (if the patient had been transferred from the Emergency Department to the ward); and a patient's progress notes. In addition, while the vast majority of test results were computerised, electrocardiogram recordings were printed from an electrocardiography machine and filed in the progress notes record.

The Observations Record

The observations record was a thinner A4 polypropylene binder, with a steel ring lock fastener, and also contained forms related to a patient's current admission. These forms included a multidisciplinary care plan, vital signs observation chart, and other relevant monitoring charts, such as a blood glucose monitoring chart, bowel chart, fluid balance summary, or wound assessment and management chart. In cases where a patient was transferred from the Emergency Department, the observations record would also contain a paper-based medication chart (which hospital policy required to be entered onto the electronic medications management system within 48-hours of a patient's transfer). The observation record also contained a paper-based medication chart in cases where a patient was prescribed certain types of intravenous (IV) therapies, including Heparin IV, Warfarin IV, or patient-controlled analgesia. In addition to appearing in the paper-based medication chart, IV therapies were documented in the electronic medication management system so as to provide nurses with an electronic prompt signalling the necessary administration times for the IV medications.

4.6.3. Workflow Context

As a result of the hospital's hybrid system, clinicians required the use of both paper-based medical records and computing devices to undertake their clinical tasks. To facilitate accessibility to the clinical information system, the hospital had provided the wards with fixed (desktop computers) and mobile (computer carts) computing devices. The computer carts were intended to allow clinicians to access the clinical information system at the patient bedside, particularly during ward rounds and medication administration rounds. Accordingly, in order to examine clinicians' use of mobile computing devices and determine how they support clinical work practices, ward rounds and medication administration rounds were selected as focal activities to investigate for this study.

Ward Rounds

Ward rounds generally involved a team of doctors visiting consecutive patients to: examine each patient; review their condition; discuss their progress; and determine their care plan. On each of the study wards there were different teams of doctors who conducted ward rounds, at least once a day, to review their allocated group of patients. The core of each team comprised a senior doctor (a consultant or senior registrar) who was responsible for leading the ward round, and two junior doctors[8] (a registrar or resident, and an intern). The core team was frequently accompanied by at least one or two other health care providers, such as other doctors, a nurse, medical student, or allied health professional (e.g., a physiotherapist). During ward rounds, teams needed access to the clinical information system to review test results and the medications relevant to each patient, and to place orders for tests, modify medications, or prescribe new medications as necessary. Teams also required paper-based medical records to

[8] Classification of doctors as "junior" was based on the Australian Medical Association's (1998; 2009) definition of junior doctors as those undertaking clinical training, including registrars, residents, and interns.

review vital sign observations and monitoring charts, and to document progress notes and treatment decisions.

Medication Administration Rounds

Medication administration rounds involved a nurse attending to his or her allocated group of patients to provide each patient their required medications. Medication administration rounds occurred several times per day on each of the study wards, however, nursing numbers and patient allocations differed across the wards. Within Ward A (a 32-bed ward) there were eight nurses on the ward, during the day shift, with each nurse allocated to administer medications to four patients. Within Ward B (a 34-bed ward) there were six nurses on the ward, during the day shift, with four nurses allocated to administer medications to six patients and two nurses allocated to administer medications to five patients. Ward B also had four assistant nurses on the ward; however, the assistant nurses were not qualified to administer medications.[9] During medication administration rounds, nurses needed to use the clinical information system in order to review each patient's medication record, determine the medications that they needed to prepare for each patient, and document the administration of medications. Nurses also required the paper-based medical records to review and document vital sign observations, and to check for paper-based medication charts.

While ward rounds and medication administration rounds were the focal activities, use of computing devices outside of rounds was also examined to try to obtain a more holistic picture of clinicians' work practices on hospital wards.

[9] The assistant nurses on Ward B were primarily responsible for attending to patients' needs (such as helping a patient with their bathroom needs) and changing patients' bed sheets. The assistant nurses also frequently provided support to the nurses that were responsible for medication administration by obtaining and documenting vital sign observations.

4.7. Research Design and Strategy

The central objective of this stage of the research was to investigate the use of computing devices on hospital wards in order to determine how mobile computing devices support clinical work practices. To fulfil this aim a mixed method research approach was employed. Mixed method research involves the integration of quantitative and qualitative research approaches (Hewson 2006; Johnson et al. 2007; Sittig et al. 2002; Teddlie & Tashakkori 2003). The premise of mixing quantitative and qualitative research approaches (to answer applicable research questions) is that their use in combination can provide greater breadth and depth of understanding than using a quantitative or qualitative approach in isolation (Creswell & Plano-Clark 2007; Greene & Caracelli 1997; Hewson 2006; Johnson & Onwuegbuzie 2004; Johnson et al. 2007).

Creswell and Plano-Clark (2007) outline six major types of mixed method research designs: the convergent parallel design; the explanatory sequential design; the exploratory sequential design; the embedded design; the transformative design; and the multi-phase design. The primary distinction amongst the designs lies in: the level of interaction (independent or interactive); timing (concurrent, sequential, or multi-phase combination); prioritisation (quantitative priority, qualitative priority, or equal priority); and mixing (during data collection, during data analysis, or during data interpretation) of the quantitative and qualitative "strands" (or components) of the research. The convergent parallel design, for example, involves conducting the quantitative and qualitative strands of research independently but concurrently, with equal prioritisation given to both strands, and mixing of the strands occurring at the point of result interpretation. The explanatory sequential design, on the other hand, prioritises the quantitative strand of the research, which is conducted and analysed first, followed by a supplementary qualitative strand, with mixing of the strands occurring at the point of data collection (Creswell & Plano-Clark 2007).

The mixed method design adopted for this study was the embedded design. The embedded design prioritises one strand of research and embeds the supplementary strand so that the strands are interactive (Creswell 2009; Creswell & Plano-Clark 2007). Data for both strands of research are collected concurrently and can be mixed during either data analysis or interpretation. Accordingly, for the present study, the quantitative strand was prioritised and the qualitative strand was embedded, with mixing of the strands occurring at the stage of data interpretation. This mixed method research approach was chosen for several reasons. Based on Bryman's (2006) detailed list of reasons for conducting mixed method research, developed from a review of 232 articles, these reasons included:

- completeness – that is, attaining a comprehensive account of the area of inquiry;
- context – coupling an understanding of both context and relationships amongst variables;
- illustration – utilising qualitative data to help illustrate quantitative findings; and
- explanation – utilising qualitative data to help explain quantitative findings.

4.7.1. Mixed Method Research Paradigm

All approaches to research are underpinned by paradigms[10] that influence the practise of research; be they implicit or explicitly acknowledged. Qualitative research approaches, for example, are traditionally guided by the interpretivist or constructivist paradigm, while quantitative research approaches are traditionally grounded in the positivist or

[10] As established in the preceding chapter, paradigms can be defined as "frameworks for thinking about research design, measurement, analysis, and personal involvement" (Morgan 2007, p.50). Working within this definition allows the researcher to shift between different paradigms as they perceive necessary. Indeed, Patton (1982) underscores the value in making "mind shifts back and forth between paradigms" (p.190) and believes it demonstrates flexibility and responsiveness of the researcher. Accordingly, although a constructivist paradigm was adopted in the preceding chapter it was not apt for the purposes of this chapter and a pragmatic paradigm was adopted instead.

postpositivist paradigm (Creswell & Plano-Clark 2007; Greene & Caracelli 1997; Guba & Lincoln 1994; Teddlie & Tashakkori 2009). Initially there was much contention amongst researchers regarding the integration of qualitative and quantitative research approaches as their respective paradigms were viewed as incompatible: characterised by Gage (1989) as the "paradigm wars". Teddlie and Tashakkori (2009) attest, however, that the paradigm debate has largely been resolved, with pragmatism emerging as the primary paradigm of choice for mixed methods research approaches.

Pragmatism advocates situational responsiveness (Greene & Caracelli 1997) and "orients itself towards solving practical problems in the real world" (Feilzer 2010, p.8). It promotes methodological pluralism and assumes that "what will work best is often a combination of different methods" (Greene & Caracelli 1997, p.8). A pragmatic paradigm doesn't stipulate a specific methodology, or steps that are to be followed, but rather places emphasis on the research question and the selection of methods offering the best potential to obtain answers to that question (Creswell 2009; Feilzer 2010; Johnson & Onwuegbuzie 2004). For the present study, the limitations identified in the quantitative and qualitative studies reviewed in the Literature Review (Chapter 2), in that they did not clearly demonstrate how mobile devices support clinical work, suggested the need for an integrative approach when assessing the use of mobile computing devices. As such, the quantitative approach of structured observation was employed to examine the ways in which clinicians utilise mobile computing devices in practice, in combination with the qualitative approaches of field notes and interviews.

4.7.2. Structured Observation, Field Notes, and Informal Interviews

Observing how technology is used for conducting work has long been recognised as an effective method for assessing the usability of technology (Neilsen 1993). Observation allows researchers to be first-hand witnesses and uncover what is actually occurring, as

opposed to solely relying on accounts of what people say occurs (Ampt et al. 2007; Arabadzhiyska et al. 2013; Ash & Guappone 2007; Bogdewie 1992; Garwood 2006; Patton 1990; Sorby et al. 2010). As such, observation can be particularly valuable for determining whether technology is utilised in expected or unexpected ways, and for identifying underlying issues that may impact on how technology is used in practice (Baysari et al. 2011a). As stated by Berg (1999):

> *"It is difficult to acquire a feeling for the intricate interrelations between health care professionals and (paper or electronic) documentation techniques without having seen the work patterns itself"* (p.93).

Observation can yield vast amounts of information on individuals, their working practices, and their use of technology as it happens. The use of structured observation, where the variables of interest are established and clearly defined prior to conducting observations (Bowling 2009; Brown & Lloyd 2001; Mulhall 2003), provides a systematic approach to collecting such data (Garwood 2006). Garwood (2006) highlights, however, that a limitation of structured observation is the potential for excluding behaviours that may be of importance. Documenting field notes alongside observation is said to help minimise this limitation (Bogdewie 1992). Field notes, which can include brief notations or jottings (Thrope 2008), allow researchers to capture observed behaviours that were not pre-empted in the scope of the structured observation but that are valuable in contributing to understanding the phenomena of interest (Bogdewie 1992).

Undertaking interviews with observed participants can also further understanding of the issues being investigated. Researchers have frequently utilised observation in combination with interviews when assessing the use and impact of technology in hospital settings (Ash et al. 2009; Ash et al. 2007b; Baysari et al. 2011a; Callen et al. 2013b; Campbell et al. 2009; Koppel et al. 2005; Koppel et al. 2008; Russ et al. 2009).

Interviews are said to "complement observation by helping answer questions about what was seen in the field" (Ash & Guappone 2007, p.S36). Informal interviews, that is, discussions between the researcher and participant that occur spontaneously during observation, are suggested to be a particularly valuable source of data (Friedman & Wyatt 1997). They can provide explanations and help uncover motives or causes for a participant's actions, which may not be observable (such as the influence of attitudes towards the use of technology), directly after the actions have occurred.

4.8. Data Collection Procedure

The initial step of the data collection procedure involved the development of a data collection tool to record the observations, field notes, and interviews. As the key research technique employed was structured observation, this required the development of a structured observation schedule that clearly delineated the variables to be observed (Bowling 2009; Brown & Lloyd 2001; Mulhall 2003) and established precise definitions for each variable (Bowling 2009; Garwood 2006). In addition, as an embedded mixed method approach calls for both the quantitative and the qualitative strands of data to be collected during one data collection phase, the data collection tool also needed to have an unstructured component to allow recording of the qualitative data. As a starting point, an existing, validated, structured observation tool was examined for suitability. Westbrook et al.'s (2007; 2008; 2009) work observation method by activity timing (WOMBAT) tool provides an electronic means to capture multiple dimensions of clinicians' work tasks, including the task being conducted and the means used to complete the task. As the data collection tool for this present study required the flexibility to capture both quantitative and qualitative data, the WOMBAT tool could not be utilised and a paper-based data collection form was developed instead.

The variables of interest to be captured by the data collection form were informed by: (i) the findings from the review of literature conducted in Chapter 2; (ii) the findings from the first stage of research outlined in Chapter 3; and (iii) the underpinning theoretical framework (Ammenwerth et al.'s FITT framework). The variables, which aimed to capture clinical work activities and use of devices, included the: activity being conducted (i.e., ward round, medication round, or outside of round); task being performed (e.g., administer medication, order medication, order test, document progress notes); device used to perform the task (e.g., desktop computer, computer cart, paper-based medical record); interaction with another individual while using a device; location in which the device is used to perform a task (e.g., patient bedside, corridor, medication room); and factors impeding the use of mobile computing devices at the patient bedside (e.g., lack of space, infection control/isolation room). For ward rounds additional variables, aimed at capturing information exchange, included the: information being exchanged (e.g., information regarding medications, test results, diagnosis, general health); person involved in the exchange of information; and the period of time the exchanged information related to (i.e., information from the last 24 hour period, information from a patients' current hospital attendance; or information from a patients' past hospital attendance. The data collection form also contained a section to allow free text from the field notes and interviews to be documented. The data collection form is illustrated in Figure 4.4. Detailed definitions for each of the above variables were established and outlined in a comprehensive data collection protocol (Appendix C.3). Definitions for the observed tasks were based on the WOMBAT work tasks and their associated definitions (as presented in Westbrook et al. (2008)).

Data Collection Form

Date ___/___/2011 Ward ____________

Session ID ____________ Participant ID ____________ Start Time ____________ End Time ____________

TASK CODES

RS – Review Summary Information
RR – Review Patient Record

PM – Prepare Medication
AM – Administer Medication
WM – Witness Medication

OM – Order Medication
CM – Modify Medication
IM – Lookup Medication Information

OT – Order Test
RT – Review Test Results

DV – Document Vitals/Observations
DP – Document Progress Notes
DI – Lookup Disease Information

DS – Document Discharge Summary

O – Other Task

If Ward Round – Primary Device/ Resource Used by Doctor Leading the Team ____________

WORK ACTIVITIES & USE OF DEVICES																											INFORMATION EXCHANGE												
Activity			Device/Resource						Location								Impede				Interact					Task	Exchange					Person					Period		
W – Ward Round; M – Med Admin Round; O – Outside of Rounds			F – Fixed Desktop PC; CC – Computer Cart; OC – Other Computing Device; PR – Paper Record; OP – Other Paper; O – Other (e.g. hand, memorise)						B – Patient Bedside; R – Patient Room; C – Corridor; W – Workbay; M – Medication Room; T – In Transit; S – Shared Office Area; O – Other								If mobile device not at bedside, why? S – Lack of Space; IC – Infection Control Room; P – Power Issue; O – Other				Using a device / resource with another: D – Doctor; N – Nurse; M – Pharmacist; P – Patient; O – Other					(Refer to task codes listed in first panel)	Request & response regarding: M – Meds; T – Test Results; D – Diagnosis; H – General Health; O – Other					Individual involved in info exchange: D – Doctor; N – Nurse; M – Pharmacist; P – Patient; O – Other					Info from: L – Latest (last 24 hrs); C – Current Attendance; P – Past Attendance		
W	M	O	F	CC	OC	PR	OP	O	B	R	C	W	M	T	S	O	S	IC	P	O	D	N	M	P	O	Code	M	T	D	H	O	D	N	M	P	O	L	C	P
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Figure 4.4. Data Collection Form

An initial pilot study was carried out in one of the study wards to test the data collection form and protocol. Researchers, such as Teijlingen van and Hundley (2001), consider pilot studies to be "a crucial element of a good study design" (page e1). Pilot studies are advocated as a means to improve a study by identifying its strengths and weaknesses (Kermode & Roberts 2006; van Teijlingen & Hundley 2001). Any problems that are identified during the pilot study can subsequently be rectified prior to undertaking the main study. The pilot study was conducted across two days (28th and 29th of July 2011). Five clinicians were recruited to participate in the pilot study; four nurses and one doctor. In total, the participating clinicians were observed for 9 hours and 35 minutes. The pilot study resulted in minor changes to the data collection form and clarifications being made to the study protocol. Data collected during the pilot was, therefore, not included as part of the main study to avoid any potential data collection inconsistencies (Kermode & Roberts 2006; van Teijlingen & Hundley 2001).

Data collection for the study was conducted between 1st August 2011 and 30th September 2011 between the hours of 7am and 5pm, Monday to Friday. Information sessions were conducted prior to the commencement of data collection on each of the two study wards in order to provide clinicians with details regarding the study and an information statement (Appendix B.2) inviting them to participate in the study. Clinicians who were not present at the information sessions were approached in person and provided with an information statement. It was stressed to all potential participants that involvement in the study was voluntary and that there would be no negative implications to those electing not to take part. Of the clinicians that were provided with an information statement, only one declined to partake in the study. All other clinicians provided signed consent.

Clinicians were observed in the course of their daily work. Observations focused on one clinician per session. Where the clinician was part of a ward round team, only data

relevant to one clinician's actions was recorded for that session (as it was not feasible to collect data for more than one clinician at a time). Each observation session lasted a maximum of two hours and no one clinician was observed for more than 10 hours in total. There were no set criteria for the selection of observed clinicians; they were chosen at random from those that were on the study ward on any given day that observations were conducted. Informal interviews were carried out opportunistically during observations when clarification was needed and the situation allowed.

4.9. Analysis of Data

The collected data were first transcribed from the paper-based data collection forms into Microsoft Excel. The structured observational data was re-coded from letters (i.e., W = ward round; M = medication administration round; O = outside of rounds) to numbers (i.e., 1 = ward round; 2 = medication administration round; 3 = outside of rounds). This facilitated exporting of the data into SPSS (Version 20) for quantitative analysis. Within SPSS, descriptive statistics were used to calculate frequencies of the collected variables, including: tasks conducted by doctors and nurses; devices used to conduct tasks; and locations in which tasks were conducted. The data were examined overall (i.e., data from the two study wards was merged to obtain overall frequencies), as well as individually for each of the study wards. This was done to determine if there were any important differences between the two wards and also as a means to validate the data (i.e., if there were distinct differences between the wards, could a valid reason for the difference be identified). To examine differences between the two study wards the Newcombe-Wilson method for calculating confidence intervals between two independent proportions was used (Newcombe 1998). An online confidence interval calculator was utilised to perform this analysis (http://www.pedro.org.au/wp-content/uploads/CIcalculator.xls). Confidence intervals were calculated at the 95% confidence level.

The qualitative data obtained from the field notes and interviews were analysed for common themes, particularly regarding the factors affecting device use. The emerging qualitative findings are presented alongside the quantitative findings (in the ensuing results section of this chapter) to provide explanations, illustrative examples, or contextual information where possible.

4.10. Ethical Approval

Ethical and scientific approval for this stage of the research was granted by a NSW Health lead Human Research Ethics Committee (Appendix E.2). The approved protocol was also ratified by The University of New South Wales Human Research Ethics Committee. Authorisation to commence the research within the study site was granted by the Executive Director of the hospital. As per the approvals, conduct of the research adhered to the National Statement on Ethical Conduct in Research Involving Humans (NHMRC 2007). All potential participants were provided with a copy of an information statement that outlined details about the study, what involvement in the study entailed, and the researcher's contact details should potential participant wish to seek additional information. Signed consent, acknowledging the participants choice to partake in the study, was obtained from each participant prior to their inclusion in the study.

4.11. Conclusion

The information presented above described the method used to conduct this stage of the research. An embedded mixed method research approach was employed, comprising structured observation, field notes, and interviews. Results from the analysis of the collected data are presented in the following section (Chapter 4. Part B: Results).

PART B: RESULTS

Chapter 4. Part B: Results

4.12. Introduction

The previous section (Part A: Method) described the methodological approach that was used to undertake this stage of the research, including: the research design (embedded mixed method); the research paradigm (pragmatism); and the data collection procedures (structured observation, field notes, and informal interviews). Part A also provided detailed contextual information regarding the setting in which the research was conducted: a Cardiothoracic Transplant Ward (Ward A) and a Geriatric Ward (Ward B) within a metropolitan teaching hospital.

The ensuing results section presents the findings resulting from analysis of the data collected via the observations, field notes, and interviews carried out on the two study wards. The findings describe clinicians' use of paper, fixed computing devices, and mobile computing devices when undertaking: medication administration round tasks; ward round tasks; and tasks outside of rounds. The findings also identify the locations where clinicians undertook tasks, while using paper or computing devices, in order to distinguish the specific manner in which mobile computing devices were used to support clinical work practices.

4.13. Participant Demographics

Across the two study wards a total of 38 clinicians participated in the observational aspect of the study. The characteristics of the participating clinicians, including their age group, level of qualification, years of clinical experience, and years working on the study ward, are outlined in Table 4.1. Each of the 38 clinicians was observed at least once during the study period. Twenty-seven clinicians also participated in interviews, which sought to obtain explanations regarding observed events.

Table 4.1. Characteristics of the Study Participants

Participating Clinicians (n=38)					
Nurses (n=26)			**Doctors (n=12)**		
	n	**%**		**n**	**%**
Gender			***Gender***		
Female	19	73.1	Female	6	50.0
Male	7	26.9	Male	6	50.0
Age Group			***Age Group***		
18-24	8	30.8	18-24	-	-
25-34	11	42.3	25-34	7	58.3
35-44	4	15.4	35-44	4	33.3
45-54	2	7.7	45-54	1	8.3
55-64	1	3.8	55-64	-	-
Qualification Level			***Qualification Level***		
Endorsed Enrolled Nurse	3	11.5	Intern	4	33.3
Registered Nurse	23	88.5	Resident	2	16.7
			Registrar	4	33.3
			Consultant	2	16.7
	Median	**Range**		**Median**	**Range**
Years of Clinical Experience	2	0.1 – 25	***Years of Clinical Experience***	2.8	0.5 – 18
Years on Study Ward	1	0.1 – 12	***Years on Study Ward***	0.5	0.1 – 6

Participant recruitment was evenly distributed across the two study wards with 19 clinicians representing each ward. Fourteen nurses and five doctors were observed on the first study ward (Ward A), while 12 nurses and seven doctors were observed on the second study ward (Ward B).

4.14. Observation Session Statistics

A total of 89 observation sessions were conducted across the two study wards; with field notes documented during two thirds of observation sessions and interviews conducted either during or directly following half of the observation sessions. The observation sessions were categorised into one of three activities: medication administration round; ward round; or outside of rounds. During 20 observation sessions the clinicians being observed undertook activities which fell under two activity categories (for example, during an observation session a doctor was observed participating in a ward round after which he commenced administrative activities outside of the round). Hence, a total of 109 activity sessions were observed across the two study wards. Of the 109 sessions, 49 (45.0%) were medication administration rounds, 32 (29.4%) were ward rounds, and 28 (25.7%) were outside of rounds activities.

During medication administration rounds only nurses were observed, while during ward rounds only doctors were observed. Outside of rounds both nurses and doctors were observed. In total, nurses were observed in the course of 73 (67%) activity sessions, while doctors were observed during 36 (33%) activity sessions. The observations were conducted for a total of 90 hours and 45 minutes. The average duration of an observation session was approximately 1 hour. Medication administration rounds accounted for 45 hours and 10 minutes (49.8%), ward rounds for 28 hours and 50 minutes (31.8%), and outside of rounds accounted for 16 hours and 45 minutes (18.5%)

of the total observation period. Nurses were observed for a duration of 57 hours and 5 minutes (62.9%), while doctors were observed for 33 hours and 40 minutes (37.1%).

A total of 4,423 tasks were recorded during the observations across the two study wards. Of the 4,423 tasks, 2,321 (52.5%) tasks were recorded during medication administration rounds, 1,444 (32.6%) tasks during ward rounds, and 658 (14.9%) tasks outside of rounds. Nurses conducted 2,753 (62.2%) of the observed tasks and doctors conducted 1,670 (37.8%) observed tasks.

Distribution of the number of observed activity sessions, their total duration, and the number of tasks recorded in each of the two study wards is presented in Table 4.2.

Table 4.2. Distribution of Observed Activity Sessions, Their Total Duration, and the Number of Tasks Recorded within the Two Study Wards

Study Ward A			**Study Ward B**		
Activity Sessions (n=54)	**n**	**%**	***Activity Sessions (n=55)***	**n**	**%**
Medication Round	24	44.4	Medication Round	25	45.5
Ward Round	16	29.6	Ward Round	16	29.1
Outside of Rounds	14	26.0	Outside of Rounds	14	25.5
Total Duration (min=2,725)	**min**	**%**	***Total Duration (min=2,720)***	**min**	**%**
Medication Round	1,495	54.9	Medication Round	1,215	44.7
Ward Round	740	27.2	Ward Round	990	36.4
Outside of Rounds	490	18.0	Outside of Rounds	515	18.9
Tasks Recorded (n=2,304)	**n**	**%**	***Tasks Recorded (n=2,119)***	**n**	**%**
Medication Round	1,323	57.4	Medication Round	998	47.1
Ward Round	669	29.0	Ward Round	775	36.6
Outside of Rounds	312	13.5	Outside of Rounds	346	16.3

min = minutes

4.15. Results from Observations, Field Notes, and Interviews

The observations, field notes, and interviews were carried out on the study wards in August (Ward A) and September 2011 (Ward B). Findings emerging from the collected data are presented under the three activity categories:

- medication administration rounds;
- ward rounds; and
- outside of rounds.

4.16. Medication Administration Rounds

Across the two study wards, nurses were observed in the course of 49 medication administration rounds over a period of 45 hours and 10 minutes, during which 2,321 tasks were recorded. Of these 2,321 tasks, 1,323 tasks were observed in Ward A and 998 tasks were observed in Ward B. Data pertaining to nurses on medication administration rounds were analysed in order to determine:

- the tasks conducted by nurses;
- the means (i.e., paper or computing devices) by which nurses conducted tasks;
- the locations where nurses used paper or computing devices while performing tasks;
- the issues affecting bedside use of mobile computing devices; and
- the use of paper or computing devices during interactions with another individual.

4.16.1. Tasks Conducted by Nurses on Medication Administration Rounds That Involved Paper or Computing Devices

The collected data were assessed to identify the types of clinical tasks nurses conducted during medication administration rounds for which they required the use of paper or computing devices. Overall, across the two study wards, nurses were most frequently observed: accessing information to prepare medications (n=816; 35.2%); documenting the administration of medications (n=809; 34.9%); and reviewing a patient's record (n=357; 15.4%). The types of tasks nurses undertook on medication administration rounds, and the frequency with which each of these tasks was performed, was found to be largely consistent within each of the two study wards (Table 4.3).

Table 4.3. Type and Frequency of Tasks Conducted by Nurses on Medication Administration Rounds in the Two Study Wards

Tasks	Ward A (n=1,323)			Ward B (n=998)			Total	
	n	%	(95% CI)	n	%	(95% CI)	n	%
Prepare Medication	484	36.6	(34.0–39.2)	332	33.3	(30.4–36.2)	816	35.2
Administer Medication	458	34.6	(32.1–37.2)	351	35.2	(32.3–38.2)	809	34.9
Review Patient's Record	191	14.4	(12.6–16.4)	166	16.6	(14.5–19.1)	357	15.4
Document Observations	58	4.4	(3.4–5.6)	15	1.5	(0.9–2.5)	73	3.1
Modify Medication	27	2.0	(1.4–3.0)	37	3.7	(2.7–5.1)	64	2.8
Witness Medication	33	2.5	(1.8–3.5)	24	2.4	(1.6–3.6)	57	2.5
Review Summary Info	17	1.3	(0.8–2.0)	34	3.4	(2.4–4.7)	51	2.2
Document Other Note	26	2.0	(1.3–2.9)	15	1.5	(0.9–2.5)	41	1.8
Lookup Medication Info	13	1.0	(0.6–1.7)	19	1.9	(1.2–3.0)	32	1.4
Review Test Results	9	0.7	(0.4–1.3)	3	0.3	(0.1–0.9)	12	0.5
Other Tasks	7	0.5	(0.3–1.1)	2	0.2	(0.1–0.7)	9	0.4

CI = Confidence Interval; Info = Information

As well as conducting medication related tasks (such as preparing and administering medications) nurses were observed documenting vital sign observations and, less frequently, reviewing results. When asked why such tasks were conducted during medication administration rounds a nurse explained that a patient's blood pressure or blood sugar levels could affect whether some medications were subsequently administered or withheld and, therefore, needed to be checked *(Nurse 12)*. The frequency with which the documentation of vital sign observations occurred varied across the two study wards; with the documentation of observations accounting for 4.4% (95% CI 3.4–5.6) of observed tasks in Ward A but only 1.5% (95% CI 0.9–2.5) in Ward B. This may have been attributable to the presence of assistant nurses on Ward B (not included in the study) who regularly provided assistance to the nurses that were responsible for medication administration by obtaining and documenting vital sign observations. In line with this difference, nurses on Ward B were observed reviewing patient information (such as documented vital sign observations) slightly more often than nurses on Ward A (16.6%; 95% CI 14.5–19.1 and 14.4%; 95% CI 12.6–16.4 respectively).

4.16.2. Means by Which Nurses Conducted Tasks on Medication Administration Rounds

The collected data were examined to determine the means (i.e., paper or computing devices) by which nurses conducted tasks on medication administration rounds. Nurses were observed to employ: mobile computing devices (computer carts); fixed computing devices (desktop computers); paper-based medical records; and temporary resources (such as a printed handover sheet or scrap piece of paper). As the tasks that nurses conducted during medication administration rounds were predominantly computerised, nurses naturally utilised computing devices to complete the majority of observed tasks (n=1,885; 81.2%). Of the available computing devices (computer carts and desktop

computers) nurses across the two wards by and large utilised computer carts (n=1,804; 77.7%); with desktop computers found to be the least prevalent means by which nurses performed tasks on medication administration rounds (n=81; 3.5%). Nurses that were asked about their use of computing devices on medication administration rounds expressed a preference for computer carts. Two nurses explained that the reason they preferred using computer carts on medication administration rounds was the ease of information accessibility, at the point at which it was needed, that the computer carts provided *(Nurse 12 and Nurse 15).*

As illustrated in Table 4.4, there were differences in the frequency with which computing devices were used within each of the two study wards. Nurses on Ward B were observed to use computer carts during medication administration rounds more often than nurses on Ward A (82.9%; 95% CI 80.1–85.1 and 73.8%; 95% CI 71.4–76.1 respectively). Conversely, nurses on Ward A used desktop computers, as well as paper-based medical records and temporary resources, more often than nurses on Ward B.

Table 4.4. Type and Frequency of Means by Which Nurses Performed Tasks on Medication Administration Rounds in the Two Study Wards

	Ward A (n=1,323)			**Ward B (n=998)**			**Total**	
	n	**%**	**(95% CI)**	**n**	**%**	**(95% CI)**	**n**	**%**
Computer Cart	977	73.8	(71.4–76.1)	827	82.9	(80.4–85.1)	1,885	81.2
Paper-Based Record	194	14.7	(12.9–16.7)	100	10.0	(8.3–12.0)	294	12.7
Temporary Resource	97	7.3	(6.0–8.9)	45	4.5	(3.4–6.0)	142	6.1
Desktop Computer	55	4.2	(3.2–5.4)	26	2.6	(1.9–3.8)	81	3.5

CI = Confidence Interval

The variation in the frequency with which nurses on the two study wards employed different means to perform tasks was due, in part, to differences in nursing numbers. On

Ward A eight nurses concurrently undertook medication administration rounds, while on Ward B six nurses concurrently undertook medication administration rounds; with eight computer carts available on each ward. Nurses on Ward A explained that there was competition for the use of computer carts as doctors conducted their ward round at the same time as the morning medication administration rounds. One nurse referred to this competition as a "battle"; which she indicated that doctors often won *(Nurse 8)*. Another nurse reported that when there were no computer carts available she would use a desktop computer and transcribe details about the medications her patients required onto her printed handover sheet so that she could take the information with her. She would then prepare the medications, administer them to her patients, and locate an available computing device to document that the medications had been administered *(Nurse 2)*.

Competing access was also noted to be an issue with paper-based medical records. In one instance, a nurse had taken several paper-based medical records for the patients that she was visiting during the medication administration round and placed them in the basket of a computer cart (a practice which was common amongst both nurses and doctors, and which is depicted in Figure 4.5). While the nurse was attending to a patient, a doctor was seen taking two of the paper-based medical records from the computer cart basket. When the nurse obtained vital sign data from the two patients, she had to document the observations data on a temporary resource (a printed handover sheet), which she then later transcribed into the paper-based medical record. Similarly, another nurse was unable to access a paper-based medical record to document the vital sign observations for one of his patients as a ward round team were in possession of the record. When the nurse noticed that the ward round team were reviewing that patient, the nurse advised one of the doctors on the team that the vital sign data in the patient's paper-based medical record were not the most current and verbally relayed the latest

observations; which the nurse had documented on a temporary resource (in this case, on a scrap piece of paper).

Figure 4.5. Computer Cart with Paper-Based Medical Records in the Basket

Another finding of interest was that, despite their availability on both wards, nurses were not observed to use paper-based textbooks when conducting tasks such as looking up medication information during medication administration rounds. Nurses were only observed looking up medication information electronically: via a computer cart (n=28; 1.2% of observed tasks) or a desktop computer (n=3; 0.1%). Nurses commented that they used computing devices to lookup medication information because of the ease of

locating the information they needed and because it saved them from having to search the ward for a paper-based textbook *(Nurse 2, Nurse 12, Nurse 13, and Nurse 19)*. One nurse stated that she liked having the ability to lookup medication information, particularly via the computer cart, because it allowed her to easily double check things she was uncertain about while she prepared medications *(Nurse 15)*.

4.16.3. Locations Where Nurses Used Paper or Computing Devices While Performing Tasks on Medication Administration Rounds

Nurses were found to conduct tasks, for which they used paper or computing devices, in a range of locations throughout the ward including: patients' bedsides (n=1,336; 57.6%); the medication room (n=369; 15.9%); the corridors of the ward (n=336; 14.5%); patients' rooms (n=123; 5.3%); in transit (n=75; 3.2%); the workbays (n=63; 2.7%); and the shared office area (n=19; 0.8%). The frequency with which nurses were observed in each of these locations was largely consistent across the two study wards (Table 4.5).

Table 4.5. Frequency of Tasks Performed in Different Locations for Which Nurses on Medication Administration Rounds Used Paper or Computing Devices in the Two Study Wards

	Ward A (n=1,323)			Ward B (n=998)			Total	
	n	%	(95% CI)	n	%	(95% CI)	n	%
Patients' Bedsides	761	57.5	(54.8–60.2)	575	57.6	(54.5–60.6)	1,336	57.6
Medication Room	215	16.2	(14.4–18.3)	154	15.4	(13.3–17.8)	369	15.9
Corridors	198	15.0	(13.1–17.0)	138	13.8	(11.8–16.1)	336	14.5
Patients' Rooms	63	4.8	(3.7–6.0)	60	6.0	(4.7–7.7)	123	5.3
In Transit	37	2.8	(2.0–3.8)	38	3.8	(2.8–5.2)	75	3.2
Workbays	32	2.5	(1.7–3.4)	31	3.1	(2.2–4.4)	63	2.7
Shared Office Area	17	1.2	(0.8–2.0)	2	0.2	(0.1–0.7)	19	0.8

CI = Confidence Interval

Nurses were observed to employ the use of computer carts and paper-based medical records on at least one occasion in each of the identified locations. The use of desktop computers was restricted to the medication room, workbays, and shared office area as they were only accessible in these locations. The locations found to reflect the most salient results regarding the use of paper or computing devices included: patients' bedsides; the medication room; in transit; and at workbays.

Patients' Bedsides

Computer carts were observed to be the primary means by which nurses on medication administration rounds conducted tasks at patients' bedsides (n=636; 83.6% of tasks observed at patients' bedsides on Ward A and n=539; 93.7% on Ward B). Computer carts were predominantly used to access electronic medication charts in order to prepare medications and to document the administration of medications. They were also the only means by which nurses looked up medication information while at patients' bedsides. Paper-based medical records were used at patients' bedsides (n=97; 12.7% of tasks observed at patients' bedsides on Ward A and n=21; 3.7% on Ward B) when nurses needed to access paper-based medication charts in order to prepare medications and to document the administration of medications. Paper-based medical records were also used for documenting vital sign observations.

While at patients' bedsides, nurses were also observed utilising temporary resources in the form of printed handover sheets and scrap pieces of paper (n=28; 3.8% of tasks observed at patients' bedsides on Ward A and n=15; 2.6% on Ward B). The handover sheet was primarily used to review a printed summary of patients' information and to document notes (such as self-reminders). Nurses were observed using the handover sheet, as well as scrap pieces of paper, to temporarily document vital sign observations; which they were noted to later transcribe into the paper-based medical record at the

workbay. On two occasions a nurse on Ward A was observed using the back of her hand as a temporary resource to document vital sign observations while at a patient's bedside.

Medication Room

Computer carts were observed to be the primary means by which nurses on medication administration rounds conducted tasks in the medication room (n=93; 43.3% of tasks observed in the medication room on Ward A and n=98; 63.6% on Ward B). Despite the availability of a desktop computer in the medication room of each ward, nurses were regularly observed wheeling computer carts into the medication room and utilising them to access electronic medication charts in order to prepare medications. The desktop computer in the medication room was also utilised to access electronic medication charts but with far less frequency (n=49; 22.8% of tasks observed in the medication room on Ward A and n=12; 7.8% on Ward B).

Nurses were also observed looking up medication information whilst in the medication room and utilised either the desktop computer or computer carts to do so. Several paper-based textbooks were located in the medication room on each ward, however, their use was not observed. When asked about the use of paper-based textbooks, one nurse commented that they were rarely used. She described an instance when she had been using a paper-based medical record while preparing medications in the medication room and realised that she required specific instructions on how to administer one of her patient's medications. A paper-based textbook had been close at hand so she utilised it to try to find the relevant information. The nurse stated that she had been unable to locate the information she needed in the paper-based textbook and, instead, utilised the desktop computer in the medication room to successfully obtain the relevant information *(Nurse 15)*.

Temporary resources were observed to be another means which nurses relied on while undertaking tasks in the medication room (n=49; 22.8% of tasks observed in the medication room on Ward A and n=15; 10.4% on Ward B). On a number of occasions (n=65; 2.8% of all tasks observed during medication administration rounds) nurses were observed using a computer cart or paper-based medical record elsewhere on the ward to access information from medication charts, which they then either transcribed onto their printed handover sheet (n=11) or temporarily memorised[11] the relevant details about the medications they needed to prepare (n=54). Nurses were subsequently observed going to the medication room and utilising the information they had transcribed or memorised in order to obtain the necessary medication. Upon obtaining the medication from the medication room, nurses that had temporarily memorised medication details were often observed returning to the location of the computer cart or paper-based medical record to re-check the medication details prior to administering the medication to the patient.

On one occasion, a nurse was observed obtaining medication, from the medication room, based on information that she had temporarily memorised after having accessed the relevant information via the computer cart at a patient's bedside. Whilst in the middle of obtaining the medication (nicotine patches), the nurse stated that she had forgotten the strength of the medication that the patient required. The nurse was asked why she did not utilise the desktop computer in the medication room to access the required information. She explained that, as she was already logged on to the patient's electronic medication chart on the computer cart that she had left at the patient's bedside, she was unable to log on to check the chart from another computing device. The nurse stated that she should have brought the computer cart to the medication room but that she hadn't done so as she felt it would be quicker not to *(Nurse 18)*.

[11] Nurses memorising information was only recorded when it was explicitly evident; for example, in situations where nurses were observed repeating aloud to themselves the information that they had obtained from the paper-based or electronic medication chart.

Other nurses were also queried regarding situations where they elected to memorise information in preference of taking a computer cart into the medication room. Nurses explained that they consistently took the computer cart into the medication room when they were required to prepare several medications. However, when they only needed to obtain one or two medications (particularly for medications such as paracetamol or vitamins) several nurses reported finding it quicker and easier to not take the computer cart into the medication room *(Nurse 12, Nurse 20, and Nurse 21)*. Some nurses stated that they didn't like taking the computer cart into the medication room because they felt it caused too much congestion in the room *(Nurse 5, Nurse 14, and Nurse 15)*.

A similar practice was also noted with the use of paper-based medical records. A nurse was observed accessing information from a paper-based medication chart at a workbay and temporarily memorising details regarding the medication that she needed to prepare in the medication room. The nurse conveyed that she didn't feel the need to take the paper-based medical record to the medication room as she had already obtained the necessary information and knew what medication her patient required *(Nurse 6)*.

In Transit

In the course of undertaking medication administration rounds, nurses were noted to be quite mobile: moving from one patient bedside to the next as well as leaving the patient bedside to obtain items located throughout the ward (such as medications from the medication room or a blood glucose testing kit from the supplies room). While in transit from one location to the next, nurses were occasionally observed utilising paper or computer carts to complete tasks (n=37; 2.8% of medication administration round tasks observed on Ward A and n=38; 3.8% on Ward B). Computer carts were used in transit for a variety of tasks including: reviewing the patient record; documenting the administration of medications; and reviewing a summary of patients' information.

Temporary resources, in one instance a printed handover sheet, were used to review a printed summary of patients' information and, in another instance the back of the nurses hand, to document vital sign observations. While computer carts and temporary resources were used for both accessing and documenting information, the paper-based medical record was observed solely being reviewed, with no documentation in transit.

Workbays

Nurses were infrequently observed undertaking tasks at the workbays during medication administration rounds (n=32; 2.5% of medication administration round tasks observed on Ward A and n=31; 3.1% on Ward B). When nurses were observed at the workbays, they largely undertook tasks for which they used paper-based medical records; primarily for documenting observations and reviewing the patient record. The use of desktop computers at the workbays was rarely observed (n=17; 0.7% of medication administration rounds tasks). A nurse conveyed that it was difficult using desktop computers at the workbay for medication administration tasks, particularly for the transplant patients of Ward A. The nurse explained that transplant patients required several medications and that the patients needed education about each of the medications as they were being administered. The nurse stated that she therefore preferred to undertake the tasks of preparing medications and documenting the administration of medications on a computer cart at the patient bedside, as opposed to having to walk back and forth from the patient bedside to a desktop computer at a workbay *(Nurse 9)*. On two occasions nurses were also observed pulling a computer cart into a workbay and utilising the cart, in preference of the desktop computer, to review information in the electronic patient record.

Table 4.6 provides an overview of the locations and the corresponding tasks for which computing devices, paper-based medical records, and temporary resources were used by

nurses during medication administration rounds. The table demonstrates that, unlike desktop computers whose use was limited to specific locations, computer carts could be, and were, utilised across a range of locations throughout the ward.

Table 4.6. Overview of Locations and the Corresponding Tasks for Which Paper or Computing Devices were Used by Nurses on Medication Administration Rounds

Tasks (n=2,321)	Location of Computing Device or Paper Use						
	Patients' Bedsides	Medication Room	Corridors	Patients' Rooms	In Transit	Workbays	Shared Office Area
Prepare Medication	Cart Paper	Cart Desktop Paper Temp	Cart Paper	Cart	Cart	Paper	Cart Paper
Administer Medication	Cart Paper	Cart Desktop Paper	Cart Paper	Cart	Cart	-	Cart Paper
Review Patient's Record	Cart Paper	Cart Desktop Paper	Cart Paper	Cart Paper	Cart Paper	Cart Desktop Paper	Desktop Paper
Document Observations	Paper Temp	-	Paper	Paper	Temp	Paper	Paper
Modify Medication	Cart	Cart	Cart	Cart	-	Desktop	-
Witness Medication	Paper	Cart Desktop Paper	Cart Paper	Cart	-	Desktop	-
Review Summary Info	Cart Temp	Temp	Cart Temp	Cart Temp	Cart Temp	Desktop Temp	-
Lookup Medication Info	Cart	Cart Desktop	-	Cart	-	-	-
Review Test Results	Cart	Cart	Cart	Cart	-	-	Desktop

Cart = Computer Cart; Desktop = Desktop Computer; Paper = Paper-Based Medical Record;
Temp = Temporary Resources; Info = Information

4.16.4. Issues Affecting the Bedside Use of Computer Carts on Medication Administration Rounds

The collected data sources were examined to determine issues affecting the use of computer carts at patients' bedsides during medication administration rounds. Three key issues were identified to impede the use of the computer carts at patients' bedsides. These three issues included: a lack of space to accommodate the computer cart directly at the bedside; the patient being quarantined in an infection control room; and low battery requiring the computer cart to be plugged into a power outlet.

Whilst undertaking medication administration rounds, nurses were generally observed positioning the computer cart beside the patient bedside so that they were in reach of the patient's bedside drawers (where most medications corresponding to the patient's needs were kept). When lack of space directly beside the patient bedside was an issue (observed during 1.5% of tasks; n=35) nurses were often still able to find adequate space to use the computer cart within the patient room. In instances where the patient was quarantined in an infection control room nurses used the computer cart in the corridor just outside the door to the infection control room (observed to be the case during the conduct of 3.7% of tasks observed on medication administration rounds; n=86). On occasions when low battery was an issue (observed during 0.8% of tasks; n=19) nurses plugged the computer cart into an available power outlet either in the patient room or in the corridor.

Issues impeding the use of computer carts at patients' bedsides during medication administration rounds varied within the study wards. While instances of using computer carts in the corridor due to infection control were similar across the two wards (4.3%; 95% CI 3.3–5.5 of observed tasks in Ward A and 2.9%; 95% CI 2.0–4.1 in Ward B), lack of space was observed almost exclusively, and battery issues exclusively, on Ward A. In most instances, lack of space on Ward A was observed to be due to nurses

requiring the use of a vital signs monitor, which was on a mobile stand (similar to that depicted in Figure 4.6), at patients' bedsides.

Figure 4.6. Vital Signs Monitor on a Mobile Stand

Another issue affecting the use of computer carts at patients' bedsides was that of wireless signal dropout. Signal dropout was not observed to impede the use of computer carts at the bedside; rather, it was observed to interrupt computer cart use. In instances where wireless connectivity was lost, nurses were observed manoeuvring the computer cart near the bedside until the wireless signal was picked-up again. If manoeuvring of the computer cart proved unsuccessful nurses were observed restarting the electronic medications management application and then resuming use of the computer cart at the patient bedside.

4.16.5. Use of Paper or Computing Devices During Interactions on Medication Administration Rounds

Nurses were observed utilising paper or computing devices whilst interacting with another individual during the conduct of 12.2% (n=284) of tasks on medication administration rounds. The vast majority of such interactions were with another nurse (n=258; 90.8% of observed interactions) while using the computer cart in the medication room or in the corridor. The tasks that nurses were observed undertaking together on computer carts primarily included: documenting the administration of medications; accessing information for the preparation of medications; and documenting that the preparation and administration of medications had been witnessed.

Nurses were also observed interacting with doctors (n=10), patients (n=9), pharmacists (n=6), and a physiotherapist (n=1). Interactions with doctors or with pharmacists involved reviewing the paper-based patient record and most commonly occurred in the corridor. Interactions with patients involved reviewing the patient record or reviewing test results and occurred at the patient bedside (n=7) or in the patient room (n=2).

Instances where nurses utilised paper or a computing device with a patient were often prompted by a query from the patient. When a patient's query required reviewing of the paper-based patient record (n=3), the nurse and the patient looked at the information in the paper-based medical record together while the nurse explained the information. In one instance, the patient enquired about his blood pressure. The nurse was observed retrieving the paper-based medical record from the workbay and then returning to the patient bedside where the nurse opened the record to the relevant page and showed the patient his blood pressure monitoring chart and explained what the numbers indicated.

When a patient's query related to a test result (n=5), nurses were observed manoeuvring the computer cart close to the bedside so that the patient could see the computer screen

while the nurse explained the result. Patients' test result queries related to medical imaging or pathology results. On one occasion, a patient that had enquired about her pathology results got out of bed and stood at the computer cart with the nurse. The nurse was observed accessing the patient's pathology results to show and explain to the patient her latest test results.

The use of paper or computing devices during such interactions with patients was observed to be slightly more prevalent on Ward A than Ward B (0.6%; 95% CI 0.3–1.2 and 0.1%; 95% CI 0.02–0.6 respectively). This finding may be attributable to differences in the patient demographics of the two wards: with the cardiothoracic transplant patients of Ward A appearing to be more inquisitive about their treatment and progress than the geriatric patients of Ward B.

4.17. Ward Rounds

Across the two study wards, doctors were observed during 32 ward rounds over a period of 28 hours and 50 minutes, during which 1,444 tasks were recorded. Of these 1,444 tasks, 669 tasks were observed in Ward A and 775 tasks were observed in Ward B. Data pertaining to doctors on ward rounds were analysed in order to determine:

- the tasks conducted by doctors;
- the means (i.e., paper or computing devices) by which doctors conducted tasks;
- the locations where doctors used paper or computing devices while performing tasks;
- the issues affecting bedside use of mobile computing devices; and
- the use of paper or computing devices during the exchange of information and interactions on ward rounds.

4.17.1. Tasks Conducted by Doctors on Ward Rounds That Involved Paper or Computing Devices

The collected data were assessed to identify the types of clinical tasks doctors conducted during ward rounds for which they required the use of paper or computing devices. Overall, across the study wards, doctors were most frequently observed reviewing the patient record (n=638; 44.2%) and reviewing test results (n=390; 27.0%). While the types of tasks that doctors undertook on ward rounds were found to be largely consistent between the two study wards, there was some variation in the frequency with which a number of the tasks were performed (Table 4.7).

Table 4.7. Type and Frequency of Tasks Conducted by Doctors on Ward Rounds in the Two Study Wards

Tasks	Ward A (n=669)			Ward B (n=775)			Total	
	n	%	(95% CI)	n	%	(95% CI)	n	%
Review Patient's Record	302	45.1	(41.4–48.9)	336	43.4	(40.0–46.9)	638	44.2
Review Test Results	177	26.5	(23.3–30.0)	213	27.5	(24.5–30.7)	390	27.0
Document Progress Notes	97	14.5	(12.0–17.4)	60	7.7	(6.1–9.8)	157	10.9
Review Summary Info	50	7.5	(5.7–9.7)	25	3.2	(2.2–4.7)	75	5.2
Order Medication	4	0.6	(0.2–1.5)	63	9.1	(6.4–10.3)	67	4.6
Document Other Note	22	3.3	(2.2–4.9)	40	5.2	(3.8–7.0)	62	4.3
Modify Medication	9	1.3	(0.7–2.5)	19	2.5	(1.6–3.8)	28	1.9
Order Test	4	0.6	(0.2–1.5)	11	1.4	(0.8–2.5)	15	1.0
Phone Contact Clinician	3	0.4	(0.2–1.3)	3	0.4	(0.0–0.6)	6	0.4
Document Observations	1	0.1	(0.0–0.8)	3	0.4	(0.0–0.6)	4	0.3
Lookup Disease Info	-	-	-	1	0.1	(0.0–0.7)	1	0.1
Lookup Contact Details	-	-	-	1	0.1	(0.0–0.7)	1	0.1

CI = Confidence Interval; Info = Information

A task that was found to substantially vary between the two wards was the ordering of medications, with doctors on Ward B observed placing orders for medications during ward rounds more frequently than doctors on Ward A (9.1%; 95% CI 6.4–10.3 and 0.6%; 95% CI 0.2–1.5 respectively). Doctors on Ward B also documented modifications to medications and placed test orders slightly more often than doctors on Ward A. Doctors on Ward A were observed discussing medication orders, medication modifications, and test orders during the ward round, however, decisions resulting from these discussions were usually documented in the progress notes for post ward round follow-up by the junior doctors. In line with this difference, doctors on Ward A were observed documenting in the progress notes with greater frequency than doctors on Ward B (14.5%; 95% CI 12.0–17.4 and 7.7%; 95% CI 6.1–9.8 respectively).

When asked why orders or modifications weren't entered during the ward round a doctor on Ward A explained that often, given the speed with which the ward rounds were conducted, there was insufficient time to enter orders electronically. Therefore the required changes were documented on paper and then entered electronically after the ward round *(Doctor 4)*. Indeed, ward rounds on Ward A were observed to be shorter than ward rounds on Ward B. On Ward A, the average duration of a ward round was 46 minutes during which time a greater number of patients were usually reviewed than on Ward B, where the average duration of a ward round was 62 minutes.

4.17.2. Means by Which Doctors Conducted Tasks on Ward Rounds

The collected data were examined to determine the means by which doctors conducted tasks on ward rounds. Doctors were observed to employ: mobile computing devices[12]

[12] At the time of the study, computer carts were the only type of mobile device provided by the hospital, that were available on both wards, and that were accessible to all clinicians. The tablet computers and smartphones were the doctors own mobile devices, and only one tablet computer (owned by a senior doctor) was noted to have access privileges to the hospital's clinical information system; however, the access was read only.

(computer carts, tablet computers, or smartphones); fixed computing devices (desktop computers); paper-based medical records; and temporary resources (a printed patient summary worksheet, which one of the junior doctors would print and distribute to each clinician on the team prior to the commencement of a ward round). As the tasks that doctors conducted during ward rounds were mainly computerised, doctors utilised computing devices to complete the majority of observed tasks (n=762; 52.7%). Of the available computing devices, doctors across the two wards predominantly utilised computer carts (n=702; 48.6%); with desktop computers rarely used by doctors to perform tasks on ward rounds (n=3; 0.2%).

Table 4.8 provides details of the type and frequency of means by which doctors performed tasks on the two study wards. While the use of tablet computers[13] and desktop computers was observed on Ward B, their use was not observed on Ward A during the study period.

Table 4.8. Type and Frequency of Means by Which Doctors Performed Tasks on Ward Rounds in the Two Study Wards

	Ward A (n=669)			Ward B (n=775)			Total	
	n	**%**	**(95% CI)**	**n**	**%**	**(95% CI)**	**n**	**%**
Computer Cart	304	45.4	(41.7–49.2)	398	51.4	(47.8–54.9)	702	48.6
Paper-Based Record	290	43.3	(39.6–47.1)	268	34.6	(31.3–38.0)	558	38.6
Temporary Resource	72	10.8	(8.6–13.3)	52	6.7	(5.2–8.7)	124	8.6
Tablet Computer	-	-	-	51	6.6	(5.0–8.5)	51	3.5
Smartphone	3	0.4	(0.2–1.3)	3	0.4	(0.1–1.1)	6	0.4
Desktop Computer	-	-	-	3	0.4	(0.1–1.1)	3	0.2

CI = Confidence Interval

[13] At least one doctor on Ward A was seen to have a tablet computer but she was not observed using it during the study.

The above table (Table 4.8) also illustrates that the use of paper-based medical records was more prevalent on Ward A than on Ward B (43.3%; 95% CI 39.6–47.1 and 34.6%; 95% CI 31.3–38.0 respectively). A reason for this may be differences in the way that the ward round teams were observed to allocate the use of paper and computing devices amongst the team. In the team observed on Ward A, the senior doctor led the ward round and predominantly utilised the computer cart while the junior doctors used the paper-based medical records: one junior doctor used the observations record while the other junior doctor used the progress notes record. In one of the teams observed on Ward B, the senior doctor leading the ward round predominantly used the observations record while one of the junior doctors used the computer cart and the other junior doctor used the progress notes record. In the second team observed on Ward B, the senior doctor leading the ward round mainly used a tablet computer, one of the junior doctors used the computer cart, and the other junior doctor used both the observations record and the progress notes record.

Table 4.9 examines the frequency of tasks performed by doctors on ward round teams when the doctor leading the ward round used the computer cart compared to those when the leading doctor did not use the computer cart. Ward rounds where the doctor leading the team primarily utilised the computer cart were found to have less medication orders placed during the ward round, compared with those where a junior doctor mainly utilised the computer cart (8.9%; 95% CI 7.0–11.2 and 0.5%; 95% CI 0.2–1.4 respectively). Likewise, modifications to medications and ordering of tests occurred more often on ward rounds were a junior doctor utilised the computer cart, although these differences were only modest. Conversely, the documentation of progress notes occurred more frequently on ward rounds when the leading doctor had primary use of the computer cart (14.3%; 95% CI 11.9–17.0 compared with 7.3%; 95% CI 5.6–9.5). This was noted to be a result of the junior doctors documenting details regarding the

necessary test orders, medication orders, or medication modifications that they needed to enter electronically after the ward round.

Table 4.9. Frequency of Tasks Performed by Doctors When the Lead Doctor Used the Computer Cart and Didn't Use the Computer Cart on Ward Rounds

Tasks	Lead Doctor Used Computer Cart (n=735)			Lead Doctor Didn't Use Computer Cart (n=709)		
	n	**%**	**(95% CI)**	**n**	**%**	**(95% CI)**
Review Patient's Record	323	43.9	(40.4–47.6)	315	44.4	(40.8–48.1)
Review Test Results	202	27.5	(24.4–30.8)	188	26.5	(23.4–29.9)
Document Progress Notes	105	14.3	(11.9–17.0)	52	7.3	(5.6–9.5)
Review Summary Information	52	7.1	(5.4–9.2)	23	3.2	(2.2–4.8)
Document Other Note	32	4.4	(3.1–6.1)	30	4.2	(2.9–6.0)
Modify Medication	8	1.1	(0.6–2.1)	20	2.8	(1.8–4.3)
Order Medication	4	0.5	(0.2–1.4)	63	8.9	(7.0–11.2)
Order Test	5	0.7	(0.3–1.6)	10	1.4	(0.8–2.6)
Phone Contact Clinician	4	0.5	(0.2–2.1)	2	0.3	(0.1–1.0)
Document Observations	-	-	-	4	0.6	(0.2–1.4)
Lookup Disease Information	-	-	-	1	0.1	(0.0–0.8)
Lookup Contact Details	-	-	-	1	0.1	(0.0–0.8)

CI = Confidence Interval

Doctors who were asked about the use of computing devices on ward rounds indicated that they would like a greater number of devices *(Doctor 2, Doctor 5, and Doctor 7)*. One doctor conveyed that when ward rounds occurred at the same time as morning medication administration rounds it was sometimes a struggle to get a computer cart. That doctor further suggested that the additional devices should be mobile computing devices rather than desktop computers, as desktop computers obviously cannot be taken

around the ward during ward rounds *(Doctor 7)*. Another doctor stated that he found computer carts to be bulky and that their battery often ran out, and felt that they should be replaced by tablet computers *(Doctor 3)*. One doctor indicated that although he perceived the cart aspect of computer carts to be useful and necessary, he believed that the current laptop computers that were on the carts should be replaced by touch screen devices to make accessing information more simple *(Doctor 2)*.

One of the doctors that owned a tablet computer (which, in this case, did not have access to the hospital's clinical information system) was observed utilising the device to document notes, such as self-reminders. Other doctors that were observed documenting such notes largely did so using the printed patient summary worksheet. When asked about her use of the tablet computer, the doctor explained that she preferred documenting notes electronically as she constantly misplaced the printed patient summary worksheets. The doctor further conveyed that the tablet computer allowed her to maintain a continuity of documented notes about her patients or things that she needed to follow-up, which she could refer to at any time *(Doctor 6)*.

4.17.3. Locations Where Doctors Used Paper or Computing Devices While Performing Tasks on Ward Rounds

Doctors were observed to conduct tasks, for which they utilised paper or computing devices, in a range of locations throughout the ward including: patients' bedsides (n=833; 57.7%); the corridors of the ward (n=351; 24.3%); patients' rooms (n=181; 12.5%); in transit (n=65; 4.5%); and in the workbays (n=14; 1.0%). The frequency with which doctors were observed in each of these locations was found to be similar across the two study wards, as illustrated in Table 4.10. One significant difference was that doctors on Ward A were observed directly at the patients' bedsides more often than doctors on Ward B. However, when considered in conjunction with tasks conducted in

patients' rooms, doctors within both wards were observed to undertake tasks in relatively close proximity to patients with the same frequency (72.3%; 95% CI 68.8–75.6 in Ward A and 68.4%; 95% CI 65.0–71.6 on Ward B).

Table 4.10. Frequency of Tasks Performed in Different Locations for Which Doctors on Ward Rounds Used Paper or Computing Devices in the Two Study Wards

	Ward A (n=669)			Ward B (n=775)			Total	
	n	**%**	**(95% CI)**	**n**	**%**	**(95% CI)**	**n**	**%**
Patients' Bedsides	427	63.8	(60.1–67.4)	406	52.4	(48.9–55.9)	833	57.7
Corridors	147	22.0	(19.0–25.3)	204	26.3	(22.3–29.5)	351	24.3
Patients' Rooms	57	8.5	(6.6–10.9)	124	26.3	(13.6–18.7)	181	12.5
In Transit	34	5.1	(3.7–7.0)	31	4.0	(2.8–5.6)	65	4.5
Workbays	4	0.6	(0.2–1.5)	10	1.3	(0.7–2.4)	14	1.0

CI = Confidence Interval

Doctors were observed to employ the use of mobile computing devices and paper-based medical records on at least one occasion in each of the identified locations. While desktop computers were available at the workbays and the shared office area, their use during ward rounds was only observed at the workbays. The locations found to reflect the most salient results regarding the use of paper or computing devices included: patients' bedsides; the corridors of the ward; in transit; and at workbays.

Patients' Bedsides

Mobile computing devices were the primary means by which doctors on ward rounds conducted tasks at patients' bedsides (n=215; 50.4% of tasks observed at patients' bedsides on Ward A and n=250; 61.2% on Ward B). Computer carts were predominantly utilised to review the patient record, review test results, order

medications, modify medications, and order tests; while tablet computers were used to review the patient record and review test results. Computer carts were also the only means by which doctors looked up disease/treatment information while at patients' bedsides. Doctors' use of paper-based medical records at patients' bedsides (n=183; 42.9% of tasks observed at patients' bedsides on Ward A and n=138; 34.0% on Ward B) was largely observed for the tasks of reviewing the patient record and documenting progress notes.

On one occasion, the doctor being observed was noted to have tried to access a patient's medication chart via the computer cart but found that an electronic medication chart was not available for that patient. At the time, the ward round team were not in possession of the patient's paper-based medical record, which contained the medication chart, so one of the junior doctors was sent in search of the record. After returning with the paper-based medical record several minutes later, the junior doctor commented that he was eager for paper-based medical records to become completely electronic. He indicated that paper-based medical records often get misplaced so clinicians have to run around the ward looking for them *(Doctor 5)*. Another junior doctor, likewise, expressed that she wished that more tasks were electronic so she could avoid having to walk around the ward searching for misplaced paper-based medical records *(Doctor 1)*.

Corridors

Doctors were often observed gathering in the corridors, in between visiting patients, to either continue their discussions regarding the patient they had just visited or to discuss the next patient prior to visiting them. A doctor explained that, at times this was because the ward round team needed to discuss things that they may not want to discuss in front of the patient, while at other times it was just a convenient location to briefly pause as the team moved from one patient room to the next *(Doctor 7)*.

While in the corridors, doctors predominantly used mobile computing devices to conduct tasks (n=75; 51.0% of tasks observed in the corridors on Ward A and n=119; 58.3% on Ward B), such as reviewing the patient record and reviewing test results. Doctors also occasionally utilised computer carts while in the corridor to place medication orders, modify medications, and order tests. Paper-based medical records were utilised in the corridor to review patient records and to document progress notes. The documentation of progress notes was observed to occur in the corridor as the doctor did not always get to finish documenting everything at the patient bedside.

In Transit

In the course of undertaking ward rounds, doctors were occasionally observed performing tasks while in transit from one location to the next (n=34; 5.1% of ward round tasks observed on Ward A and n=31; 4.0% on Ward B) for which they primarily utilised mobile computing devices. Computer carts were used in transit for a variety of tasks including: reviewing the patient record; reviewing test results; ordering medications; modifying medications; and reviewing a summary of patients' information. Tablet computers were used in transit to review the patient record and review test results; while smartphones were used to phone contact another clinician.

Doctors also utilised paper in transit. The printed patient summary worksheet was used to review a summary of patients' information and to document notes, such as self-reminders. The paper-based medical record was commonly observed being used in transit to review information in the patient record, but was rarely observed being used for documentation (n=2; 3.1% of tasks observed in transit).

Workbays

Doctors' use of devices at the workbays was infrequently observed during ward rounds (n=4; 0.6% of ward round tasks observed on Ward A and n=10; 1.3% on Ward B). When doctors were observed at the workbays, they most frequently used the paper-based medical record. In one instance a doctor was observed pulling a computer cart into a workbay and utilising the cart, in preference of the desktop computer, to review information in the electronic patient record.

The use of desktop computers on ward rounds was only observed on three occasions and only for the task of reviewing test results. On one of the occasions that a doctor used a desktop computer at the workbay, the doctor had walked over to the workbay from the patient bedside in order to use a landline phone to contact another doctor regarding a second opinion. Whilst on the phone, the observed doctor used the desktop computer to review a patient's test results and then asked the doctor on the other end of the phone to log on to the system to look at the test results. The observed doctor also had the patient's paper-based medical record at the workbay and was relaying information from the progress notes of the paper-based medical record to the doctor on the other end of the phone.

Table 4.11 provides an overview of the locations and the corresponding tasks for which computing devices, paper-based medical records, and temporary resources were used by doctors during ward rounds. The table demonstrates that, unlike desktop computers whose use was limited to one location, mobile computing devices could be, and were, utilised across a range of locations throughout the ward.

Table 4.11. Overview of Locations and the Corresponding Tasks for Which Paper or Computing Devices were Used by Doctors on Ward Rounds

Task (n=1,444)	Location of Computing Device or Paper Use				
	Patients' Bedsides	Corridors	Patients' Rooms	In Transit	Workbays
Review Summary Info	Temp	Cart Temp	Temp	Cart Tablet Temp	Temp
Review Test Results	Cart Tablet Paper	Cart Tablet Paper	Cart Paper	Cart Tablet	Desktop
Document Progress Notes	Paper	Paper	Paper	Paper	Paper
Review Patient's Record	Cart Tablet Paper	Cart Tablet Paper	Cart Paper	Cart Tablet Paper	Paper
Document Other Note	Temp	Tablet Temp	Tablet Temp	Temp	Temp
Modify Medication	Cart	Cart	-	Cart	-
Order Medication	Cart	Cart	Cart	Cart	-
Order Test	Cart	Cart	-	-	-
Phone Contact Clinician	Smartphone	Smartphone	Smartphone	Smartphone	-
Document Observations	Paper	Paper	Paper	-	-
Lookup Disease Info	Cart	-	-	-	-
Lookup Contact Details	Cart	-	-	-	-

Cart = Computer Cart; Tablet = Tablet Computer; Desktop = Desktop Computer;
Paper = Paper-Based Medical Record; Temp = Temporary Resource; Info = Information

4.17.4. Issues Affecting the Bedside Use of Computer Carts on Ward Rounds

As was the case with nurses, when doctors were observed using computer carts during ward rounds three key issues were identified to impede the use of the computer carts at patients' bedsides: the patient being quarantined in an infection control room; low battery requiring the computer cart to be plugged into a power outlet; and a lack of space to accommodate the computer cart directly at the bedside.

Instances where a patient was quarantined in an infection control room were observed to be the most frequent issue impeding doctors' use of computer carts at patients' bedsides (observed to be the case during the conduct of 3.3% of tasks observed on ward rounds; n=47). In such instances, doctors used the computer cart in the corridor just outside the door to the infection control room. When low battery was an issue (observed during 0.5% of tasks; n=7), doctors were observed plugging the computer cart into a power outlet in the corridor while they engaged in discussions in between visiting patients. When moving on from the corridor to visit their next patient, doctors were observed unplugging the computer cart from the power outlet in order to take the device with them despite the low battery. While at patients' bedsides, doctors would usually use the computer cart directly at the foot of the patients' bed. A lack of space directly at the bedside was observed to be an issue in a small number of instances (observed during 0.4% of tasks; n=6) but doctors were still able to find adequate space to use the computer cart within the patient room.

Issues impeding computer cart use at patients' bedsides during ward rounds were observed to be more common on Ward A (7.6%; 95% CI 5.8–9.9 of tasks observed in Ward A and 1.2%; 95% CI 0.6–2.2 in Ward B), particularly in relation to a lack of space and infection control. The use of computer carts with low battery issues, however, was only observed on Ward B. On one occasion, doctors on Ward A were about to

commence a ward round when they noticed that the computer cart had a low battery status. Instead of continuing to use that computer cart, the senior doctor instructed a junior doctor to find another computer cart that had a charged battery; which was then used on the ward round in place of the computer cart with the low battery.

4.17.5. Use of Paper or Computing Devices During the Exchange of Information and Interactions on Ward Rounds

The collected data were analysed to examine instances of information exchange (i.e., where an individual asked a question for which the doctor being observed had to access information via paper or a computing device in order to provide a response). During the course of ward rounds, the teams were observed to constantly engage in discussions regarding patients, as well as engaging with the patient that they were reviewing; though much of this interaction did not fall into the scope of the preceding definition.

Nonetheless, several instances of information exchange were observed (n=53; 7.9% of tasks observed in Ward A and n=42; 5.4% in Ward B) with questions posed by another doctor (n=88), patient (n=3), patient's relatives (n=3), and a nurse (n=1). The questions most frequently related to information about the patient's general health (such as their vital sign observations) (n=51), test results (n=21), medications (n=17), and other patient related information (such as the admission history) (n=6). The questions asked by patients related to test results and medications. For questions regarding the patient's general health, the observed doctor primarily utilised the paper-based medical record to access information in order to provide a response to the question. For questions regarding test results and medications, the observed doctor primarily used the computer cart to access information in order to provide a response to the question.

The vast majority of questions, and the subsequent responses, related to information from a patient's present hospital admission. On one occasion, however, a doctor

requested information regarding a patient's admission history. In order to provide a response to the requested information, the observed doctor utilised the computer cart to access the necessary information. In another instance, a patient's test result query was in regard to her most recent chest x-ray. The doctor was observed accessing the relevant medical image via a computer cart and, while answering the patient, was observed manoeuvring the computer cart so that the patient could also view the screen. The doctor then showed the patient the image of her chest x-ray prior to her transplant and flicked between the old x-ray image and the most recent x-ray image while explaining the differences in the images to the patient.

Such exchanges of information were largely observed at patients' bedsides, both when the paper-based medical record and computer cart were used to access information, but also occurred in the corridor and in the patient room. Table 4.12 shows the locations in which paper or computing devices were used to access information.

Table 4.12. Locations in Which Paper or Computing Devices Were Used During Exchanges of Information on Ward Rounds

Information Exchange (n=95)	Location of Computing Device or Paper Use		
	Patients' Bedsides	**Corridors**	**Patients' Rooms**
General Health Information	Cart Paper	Paper	Paper
Test Result Information	Cart	Cart Paper	Cart
Medication Information	Cart Tablet	-	Cart
Other Information	Paper	Paper	Cart Paper

Cart = Computer Cart; Tablet = Tablet Computer; Paper = Paper-Based Medical Record

The collected data were also assessed to determine how often doctors utilised paper or computing devices with another individual. Interactions were observed to occur during the conduct of 27.4% (n=396) of ward round tasks. The overwhelming majority of such interactions were with other doctors (n=384; 97.0% of observed interactions) and while using computing devices (n=227).

Computer carts were the most frequently used computing device (n=221), with interactions predominantly occurring between the observed doctor and one other doctor at the patient bedside. Several interactions (n=53; 24.0% of interactions on computer carts) also occurred between the observed doctor and two to four other doctors. Interactions between groups of doctors took place in the corridor, patient bedside, or patient room for the tasks of reviewing test results and reviewing the patient's record. Instances of doctors utilising paper-based medical records whilst interacting (n=169) was also observed to occur at the patient bedside, patient room, and in the corridor for the task of reviewing the patient's record. Most paper-based medical record interactions occurred between the observed doctor and one other doctor (n=144), with a small number of interactions occurring between a group of doctors (n=18).

Doctors were infrequently observed interacting with nurses (n=10) or other health care providers (e.g. physiotherapists) (n=2) whilst using paper or computing devices. Interactions with nurses all involved reviewing the paper-based patient record and most commonly occurred in the corridor.

4.18. Outside of Rounds

Across the two study wards, doctors and nurses were observed in the course of 28 outside of rounds activity sessions over a period of 16 hours and 45 minutes, during which 658 tasks were recorded. Of these 658 tasks, 432 tasks were conducted by nurses

and 226 tasks were conducted by doctors. Data pertaining to nurses performing outside of rounds activities were analysed in order to determine:

- the tasks conducted by nurses;
- the means (i.e., paper or computing devices) by which nurses conducted tasks;
- the locations where nurses used paper or computing devices while performing tasks; and
- nurses use of paper or computing devices during interactions.

Data pertaining to doctors performing outside of rounds activities were analysed in order to determine:

- the tasks conducted by doctors;
- the means by which doctors conducted tasks; and
- the locations where doctors used paper or computing devices while performing tasks; and
- doctors use of paper or computing devices during interactions.

4.18.1. Tasks Conducted by Nurses Outside of Rounds That Involved Paper or Computing Devices

The collected data were assessed to identify the types of clinical tasks that nurses conducted outside of rounds for which they required the use of paper or computing devices. Overall, across the two study wards, nurses were most frequently observed: reviewing a patient's record (n=180; 41.7%); documenting notes (n=65; 15.0%); and documenting observations (n=61; 14.1%). Nurses also commonly documented progress notes (n=41; 9.5%), reviewed a summary of patients' information (n=32; 7.4%), and

reviewed test results (n=30; 6.9%). The types of tasks nurses undertook outside of rounds, and the frequency with which each of these tasks was performed, was found to be similar within each of the two study wards (Table 4.13).

Table 4.13. Type and Frequency of Tasks Conducted by Nurses Outside of Rounds in the Two Study Wards

Tasks	Ward A (n=192)			Ward B (n=240)			Total	
	n	%	(95% CI)	n	%	(95% CI)	n	%
Review Patient's Record	71	37.0	(30.5–44.0)	109	45.4	(39.2–51.7)	180	41.7
Document Other Note	24	12.5	(8.5–17.9)	41	17.1	(12.8–22.4)	65	15.1
Document Observations	34	17.7	(13.0–23.7)	27	11.3	(7.8–15.9)	61	14.1
Document Progress Notes	20	10.4	(6.8–15.5)	21	8.8	(5.8–13.0)	41	9.5
Review Summary Info	11	5.7	(3.2–10.0)	21	8.8	(5.8–13.0)	32	7.4
Review Test Results	20	10.4	(6.8–15.5)	10	4.2	(2.3–7.5)	30	6.9
Send Page	2	1.0	(0.3–3.7)	5	2.1	(0.9–4.8)	7	1.6
Witness Medication	3	1.6	(0.5–4.5)	1	0.4	(0.1–2.3)	4	0.9
Complete Form	-	-	-	4	1.7	(0.7–4.2)	4	0.9
Modify Medication	2	1.0	(0.3–3.7)	1	0.4	(0.1–2.3)	3	0.7
Order Test	3	1.6	(0.5–4.5)	-	-	-	3	0.7
Lookup Medication Info	2	1.0	(0.3–3.7)	-	-	-	2	0.5

CI = Confidence Interval; Info = Information

4.18.2. Means by Which Nurses Conducted Tasks Outside of Rounds

The collected data were examined to determine the means by which nurses conducted tasks outside of rounds. Nurses were observed to employ: paper-based medical records; temporary resources (a printed handover sheet or scrap piece of paper); mobile computing devices (computer carts); and fixed computing devices (desktop computers).

Although nurses were observed to conduct a broad range of tasks outside of rounds, the tasks were predominantly paper-based (e.g., documenting observations and documenting progress or other notes). Correspondingly, nurses utilised paper-based medical records to complete the majority of observed tasks (n=248; 57.4%).

When undertaking computerised tasks, overall nurses utilised computer carts more frequently than desktop computers (n=58; 13.4% and n=34; 7.9% respectively). Computer cart use was greater than desktop use on Ward A (20.3%; 95% CI 15.2–26.6 and 4.2%; 95% CI 2.1–8.0 respectively), but not on Ward B (Table 4.14). When asked about the use of computing devices outside of rounds, a nurse on Ward B stated that she preferred the desktop computer for accessing and documenting information, when she wasn't undertaking a medication administration round, as she could sit at a desk while using the device *(Nurse 12)*.

Table 4.14. Type and Frequency of Means by Which Nurses Performed Tasks Outside of Rounds in the Two Study Wards

	Ward A (n=192)			Ward B (n=240)			Total	
	n	**%**	**(95% CI)**	**n**	**%**	**(95% CI)**	**n**	**%**
Paper-Based Record	112	58.3	(51.3–65.1)	136	56.7	(50.3–62.8)	248	57.4
Temporary Resource	33	17.1	(12.5–23.2)	59	24.6	(19.6–30.4)	92	21.3
Computer Cart	39	20.3	(15.2–26.6)	19	7.9	(5.1–12.0)	58	13.4
Desktop Computer	8	4.2	(2.1–8.0)	26	10.8	(7.5–15.4)	34	7.9

CI = Confidence Interval

4.18.3. Locations Where Nurses Used Paper or Computing Devices While Performing Tasks Outside of Rounds

Nurses were found to conduct tasks, for which they utilised paper or computing devices, in a range of locations throughout the ward including: the workbays (n=207; 47.9%); the corridors of the ward (n=175; 40.5%); patients' bedsides (n=34; 7.9%); in transit (n=10; 7.0%); patients' rooms (n=3; 0.7%); the medication room (n=2; 0.5%); and the shared office area (n=1; 0.2%).

The locations where tasks were performed varied slightly within the two study wards as illustrated in Table 4.15. Nurses on Ward A were largely observed in the corridors, while nurses on Ward B were predominantly observed in the workbays. This corresponded with the means by which nurses completed tasks: with nurses on Ward A frequently using computer carts and nurses on Ward B using desktop computers.

Table 4.15. Frequency of Tasks Performed in Different Locations Outside of Rounds for Which Nurses Used Paper or Computing Devices in the Two Study Wards

	Ward A (n=192)			Ward B (n=240)			Total	
	n	**%**	**(95% CI)**	**n**	**%**	**(95% CI)**	**n**	**%**
Workbays	61	31.8	(25.6–38.7)	146	60.8	(54.5–66.8)	207	47.9
Corridors	105	54.7	(47.6–61.6)	70	29.2	(23.8–35.2)	175	40.5
Patients' Bedsides	19	9.9	(6.4–14.9)	15	6.3	(3.8–10.1)	34	7.9
In Transit	4	2.1	(0.8–5.2)	6	2.5	(1.2–5.3)	10	2.3
Patients' Rooms	1	0.5	(0.1–2.9)	2	0.8	(0.2–3.0)	3	0.7
Medication Room	2	1.0	(0.3–3.7)	-	-	-	2	0.5
Shared Office Area	-	-	-	1	0.4	(0.1–2.3)	1	0.2

CI = Confidence Interval

Paper-based medical records were used both in the corridors (22.9%; 95% CI 17.5–29.4 on Ward A and 15.4%; 95% CI 11.4–20.5 on Ward B) and the workbays (23.4%; 95% CI 18.0–29.9 on Ward A and 32.9%; 95% CI 27.0–39.1 on Ward B) with similar frequency in both study wards. When paper-based medical records were used in the corridors, for tasks such as documenting vital sign observations or progress notes, nurses were often observed using the computer carts as makeshift benches on which to place the paper-based medical record to facilitate ease of documenting. On several occasions it was noted that nurses would take the paper-based medical record to a patient's bedside, where they would review the patient, and then return to a workbay to document their observations in the paper-based medical record.

Table 4.16 provides an overview of the locations and the corresponding tasks for which computing devices, paper-based medical records, and temporary resources were used by nurses outside of rounds.

4.18.4. Nurses Use of Paper or Computing Devices During Interactions Outside of Rounds

Nurses were observed utilising paper or computing devices whilst interacting with another individual during the conduct of 10.4% (n=45) of tasks conducted outside of rounds. Most interactions were with another nurse (n=29; 64.4% of observed interactions) while using the paper-based medical record and predominantly occurred at the workbay or in the corridor. Nurses were also observed interacting with doctors (n=13), a pharmacist (n=1), and a physiotherapist (n=1). Interactions largely involved the task of reviewing the patient's record.

Table 4.16. Overview of Locations and the Corresponding Tasks for Which Paper or Computing Devices were Used by Nurses Outside of Rounds

Tasks (n=432)	Location of Computing Device or Paper Use						
	Patients' Bedsides	Medication Room	Corridors	Patients' Room	In Transit	Workbays	Shared Office Area
Review Patient's Record	Cart Paper	-	Cart Paper	Cart	Paper	Desktop Paper	Paper
Document Other Note	-	-	Temp	-	-	Temp	-
Document Observations	Paper	-	Paper	-	Paper	Paper	-
Document Progress Notes	Paper	-	Paper	-	-	Paper	-
Review Summary Info	Cart	-	Cart Temp	Cart	Temp	Desktop Temp	-
Review Test Results	Cart	-	Cart	-	-	Desktop	-
Send Page	-	-	Cart	-	-	Desktop	-
Witness Medication	-	Paper	Cart Paper	-	-	-	-
Complete Form	-	-	-	-	-	Desktop	-
Modify Medication	-	-	Cart Paper	-	-	Desktop	-
Order Test	-	-	Cart	-	-	-	-
Lookup Medication Info	-	-	Cart	-	-	-	-

Cart = Computer Cart; Desktop = Desktop Computer; Paper = Paper-Based Medical Record;
Temp = Temporary Resources; Info = Information

4.18.5. Tasks Conducted by Doctors Outside of Rounds That Involved Paper or Computing Devices

The collected data were assessed to identify the types of clinical tasks that doctors conducted outside of rounds. Overall, across the two study wards, doctors were most frequently observed: reviewing a patient's record (n=82; 36.3%) and documenting discharge summaries (n=45; 19.9%). Doctors were also observed ordering medications (n=22; 9.7%), ordering tests (n=16; 7.1%), and reviewing test results (n=15; 6.6%). The types of tasks doctors undertook outside of rounds, and the frequency with which each tasks was performed, was relatively similar within each of the two study wards (Table 4.17).

Table 4.17. Type and Frequency of Tasks Conducted by Doctors Outside of Rounds in the Two Study Wards

Tasks	Ward A (n=120)			Ward B (n=106)			Total	
	n	%	(95% CI)	n	%	(95% CI)	n	%
Review Patient's Record	36	30.0	(22.5–38.7)	46	43.4	(34.4–52.9)	82	36.3
Discharge Summary	21	17.5	(11.7–25.3)	24	22.6	(15.7–31.5)	45	19.9
Review Summary Info	29	24.2	(17.4–32.6)	3	2.8	(1.0–8.0)	32	14.2
Order Medication	12	10.0	(5.8–16.7)	10	9.4	(5.2–16.5)	22	9.7
Order Test	7	5.8	(2.9–11.6)	9	8.5	(4.5–15.4)	16	7.1
Review Test Results	7	5.8	(2.9–11.6)	8	7.5	(3.9–14.2)	15	6.6
Document Progress Notes	5	4.2	(1.8–9.4)	1	0.9	(0.2–5.2)	6	2.7
Complete Form	-	-	-	3	2.8	(1.0–8.0)	3	1.3
Send Page	1	0.8	(0.1–4.6)	1	0.9	(0.2–5.2)	2	0.9
Modify Medication	1	0.8	(0.1–4.6)	-	-	-	1	0.4
Lookup Contact Details	1	0.8	(0.1–4.6)	-	-	-	1	0.4
Document Other Note	-	-	-	1	0.9	(0.2–5.2)	1	0.4

CI = Confidence Interval; Info = Information

4.18.6. Means by Which Doctors Conducted Tasks Outside of Rounds

The collected data were examined to determine the means by which doctors conducted tasks outside of rounds. Doctors were observed to employ: fixed computing devices (desktop computers); paper-based medical records; temporary resources (a printed patient summary worksheet); and mobile computing devices (computer carts and smartphones). The tasks that doctors conducted outside of rounds were predominantly computerised. Of the available fixed and mobile computing devices doctors across the two wards by and large utilised desktop computers (n=116; 51.3%); with computer carts found to be one of the least prevalent means by which doctors performed tasks outside of rounds (n=2; 0.9%). Table 4.18 details the type and frequency of means by which doctors performed tasks on the two study wards.

Table 4.18. Type and Frequency of Means by Which Doctors Performed Tasks Outside of Rounds in the Two Study Wards

	Ward A (n=120)			Ward B (n=106)			Total	
	n	**%**	**(95% CI)**	**n**	**%**	**(95% CI)**	**n**	**%**
Desktop Computer	59	49.2	(40.4–58.0)	57	53.8	(44.3–63.0)	116	51.3
Paper-Based Record	29	24.2	(17.4–32.6)	45	42.5	(33.5–52.0)	74	32.7
Temporary Resource	19	15.8	(10.4–23.4)	3	2.8	(1.0–8.0)	22	9.7
Computer Cart	2	1.7	(0.5–5.8)	-	-	-	2	0.9
Smartphone	1	0.8	(0.1–4.6)	1	0.9	(0.2–5.2)	2	0.9

CI = Confidence Interval

Although most tasks were computerised, doctors were often also observed to require information from paper-based medical records in order to complete tasks (n=74; 32.7%). Documenting discharge summaries, for example, was performed electronically but also required doctors to review the paper-based medical record in order to obtain relevant

information necessary for inclusion in the discharge summary. On one occasion a doctor was observed documenting a discharge summary on a desktop computer when he realised that he did not have the patient's paper-based medical record. The doctor was seen searching the ward for the paper-based medical record but was unable to locate it. He commented that the information he required was not available electronically and that he would have to search for the paper-based medical record again later in order to complete the discharge summary *(Doctor 4)*.

4.18.7. Locations Where Doctors Used Paper or Computing Devices While Performing Tasks Outside of Rounds

Doctors were observed to conduct the majority of tasks, for which they utilised paper or computing devices, in two key locations: in the workbays (n=113; 50.0%) and in the shared office area (n=99; 43.8%). Doctors on Ward A were also occasionally observed in the corridors of the ward (n=11; 4.9%), in transit (n=2; 0.9%), and at patients' bedsides (n=1; 0.4%). The frequency with which doctors in the two study wards were observed in each of these locations is outlined in Table 4.19.

Table 4.19. Frequency of Tasks Performed in Different Locations Outside of Rounds for Which Doctors Used Paper or Computing Devices in the Two Study Wards

	Ward A (n=120)			Ward B (n=106)			Total	
	n	**%**	**(95% CI)**	**n**	**%**	**(95% CI)**	**n**	**%**
Workbays	28	23.3	(16.7–31.7)	85	80.2	(71.6–86.7)	113	50.0
Shared Office Area	78	65.0	(56.1–72.9)	21	19.8	(13.3–28.4)	99	43.8
Corridors	11	9.2	(5.2–15.7)	-	-	-	11	4.9
In Transit	2	1.7	(0.5–5.9)	-	-	-	2	0.9
Patients' Bedsides	1	0.8	(0.1–4.6)	-	-	-	1	0.4

CI = Confidence Interval

While at the workbays (n=28; 23.3% in Ward A and n=85; 80.2% in Ward B), doctors were most frequently observed utilising desktop computers, primarily for the tasks of documenting discharge summaries, ordering tests, and ordering medications. On one occasion a doctor, that had been using a computer cart in the corridor, was observed pulling the computer cart into the workbay so that she could sit down on a chair while she used the computer cart to review test results.

Table 4.20 provides an overview of the locations and the corresponding tasks for which computing devices, paper-based medical records, and temporary resources were used by doctors outside of rounds.

4.18.8. Doctors Use of Paper or Computing Devices During Interactions Outside of Rounds

Doctors were infrequently observed utilising paper or computing devices whilst interacting with another individual during tasks outside of rounds (n=12; 5.3%). Of the observed interactions, 58.3% (n=7 observed interactions) were with a nurse and 41.7% (n=5 observed interactions) were with another doctors. Interactions predominantly occurred in the shared office area while using fixed computing devices to review a patient's record.

Table 4.20. Overview of Locations and the Corresponding Tasks for Which Paper or Computing Devices were Used by Doctors Outside of Rounds

Task (n=226)	Location of Computing Device or Paper Use				
	Patients' Bedsides	Corridors	In Transit	Workbays	Shared Office Area
Review Patient's Record	-	Paper	Paper	Desktop Paper	Desktop Paper
Discharge Summary	-	-	-	Desktop	Desktop
Review Summary Info	Temp	Temp	Temp	Temp	Temp
Order Medication	-	-	-	Desktop	Desktop
Order Test	-	-	-	Desktop	Desktop
Review Test Results	-	Cart	-	Cart Desktop	Desktop
Document Progress Notes	-	Paper	-	-	Paper
Complete Form	-	-	-	-	Paper
Send Page	-	-	-	-	Desktop
Modify Medication	-	-	-	Desktop	-
Lookup Contact Details	-	-	-	-	Smartphone
Document Other Note	-	-	-	Smartphone	-

Cart = Computer Cart; Tablet = Tablet Computer; Desktop = Desktop Computer;
Paper = Paper-Based Medical Record; Temp = Temporary Resource; Info = Information

4.19. Assessment of FITT Between Clinicians, Tasks, and Technology

The collected data sources were further assessed using the structure of Ammenwerth et al.'s (2006) fit between individuals, tasks, and technology (FITT) framework. FITT was examined for each of the observed groups of individuals: doctors and nurses.

4.19.1. FITT: Doctors, Tasks, and Technology

Doctors and Tasks

The work practices of doctors differed on ward rounds and outside of rounds. Ward rounds were conducted in teams, with doctors moving from one patient's bedside to the next in order to review each patient. Ward round tasks were subsequently observed to occur across several ward locations, including the patient bedside, in the corridors, and while doctors were in transit between locations. Outside of rounds tasks were usually conducted independently and doctors were observed to predominantly be located in a single location, conducting 93.8% (n=212) of tasks in either a workbay or the shared office area.

Tasks and Technology

The hospital's hybrid information system meant that some information was maintained electronically (such as test results), while other information was paper-based (such as vital sign observations and progress notes). Doctors therefore needed access to both computing devices and paper-based medical records when undertaking tasks. For ward rounds, mobile computing devices fit the mobile manner in which tasks were conducted. Of the computerised tasks on ward rounds (n=762), almost all were completed with the use of mobile computing devices (n=759; 99.6%). The computer cart design of the

mobile device also provided a convenient means to store items, allowing doctors to transport several paper-based medical records at a time.

Outside of rounds fixed computing devices appeared to provide a better fit. Of the computerised tasks conducted outside of rounds (n=120), the substantial majority were completed on desktop computers (n=116; 96.7%). The desks on which the computers were stationed provided doctors with space on which to place paper-based medical records so that they could view paper-based and electronic information at the same time.

Doctors and Technology

Several doctors expressed a preference for electronically available information *(Doctor 1, Doctor 4, Doctor 5, and Doctor 7)*. The doctors indicated that paper-based medical records were often misplaced and time had to be spent searching for them. One doctor, while searching for a printed pathology form that he ultimately failed to locate, stated that a benefit of information being computerised was that he could just reprint the pathology form *(Doctor 4)*. Doctors also reported a preference for accessing electronic information via mobile computing devices, with two doctors explaining that they need mobile devices for ward rounds as their work practices are mobile *(Doctor 1 and Doctor 7)*. While doctors liked the computer carts, many conveyed a want for tablet computers *(Doctor 1, Doctor 2, Doctor 3, Doctor 5, and Doctor 6)*. One doctor stated that he believed it would be easier to conduct his work with a tablet computer than with the computer carts, which he felt were bulky and had battery issues *(Doctor 3)*.

4.19.2. FITT: Nurses, Tasks, and Technology

Nurses and Tasks

Nurses were observed to largely undertake their work independently during both medication administration rounds and outside of rounds. Nurses undertaking medication administration rounds were constantly on-the-move throughout the ward: often going from a patient's bedside, to the medication room to obtain medications, and back to the bedside. When undertaking tasks outside of rounds nurses tended to have a base location (in a workbay or at a parked computer cart in the corridor) where they completed most tasks (n=382; 88.4%).

Tasks and Technology

As with doctors, the hybrid information system meant that nurses required the use of both computing devices (to access the electronic medications management system) and paper-based medical records (to access or document observations and progress notes). For medication administration rounds, mobile computing devices fit the mobile manner in which tasks were conducted. Of the computerised tasks on medication administration rounds (n=1,966), the substantial majority were completed using mobile computing devices (n=1,885; 95.9%). Fixed computing devices were not considered to be conducive to medication administration round tasks *(Nurse 2 and Nurse 9)* and were rarely used.

Outside of rounds both mobile and fixed computing devices appeared suited to undertaking tasks. Of the computerised tasks conducted outside of rounds (n=92), most were completed using mobile computing devices (n=58; 63%), despite the availability of a number of fixed computing devices in workbays throughout the ward. As tasks conducted outside of rounds were predominantly non-mobile, the mobile computing

devices were largely observed being used in a stationary manner in the corridor. Nurses also often used the computer cart as a bench on which to place the paper-based medical record while documenting information in the corridor.

Nurses and Technology

A number of nurses perceived that it was quicker and easier to complete tasks using paper-based medical records *(Nurse 4, Nurse 5, Nurse 8, and Nurse 11)*, but the general consensus was that the computer-based system, particularly mobile computing devices, provided several benefits over paper-based medical records. A key benefit identified by the nurses was the ease of access to patient information and clinical information when the need for it arose *(Nurse 12, Nurse 13, Nurse 15, Nurse 16, and Nurse 19)*. Not having to carry around several paper-based records at a time, being able to stow other necessary items in the basket of the computer cart, and not needing to search for paper-based textbooks were also seen to be benefits of having mobile computing devices *(Nurse 2, Nurse 12, Nurse 13, and Nurse 15)*. One nurse explained that if there are special instructions on how to administer a medication then that information appears on the system next to the medication order so it saves her from having to go looking for it in a textbook *(Nurse 2)*. The nurse further conveyed that while she liked having a mobile device to conduct medication administration round tasks, she preferred to sit down and use the desktop computer for tasks outside of rounds.

4.20. Conclusion

The above section described findings regarding clinicians' use of paper, fixed computing devices, and mobile computing devices when undertaking: medication administration round tasks; ward round tasks; and tasks outside of rounds. The findings identified the locations where clinicians undertook tasks, while using paper or computing devices, in

order to distinguish the specific manner in which mobile computing devices were used to support clinical work practices. Implications arising from these findings are discussed in the next section (Chapter 4. Part C: Discussion).

Chapter 4. Part C: Discussion

4.21. Introduction

The preceding sections of this chapter presented: a summary of the key background literature underpinning this stage of the research; a comprehensive account of the methods employed in undertaking the research; and results regarding clinicians' use of computing devices on hospital wards. The following section discusses the results in relation to the study's central research questions, namely: how do mobile computing devices support clinical work practices on hospital wards and what factors affect their use?

4.22. Mobile Devices Supporting Work at Patients' Bedsides

A key location in which clinicians undertake work and need access to information is at the patient bedside (Andersen et al. 2009; Banitsas et al. 2004; Campbell & Ash 2006; Creamer et al. 2010; Dahl et al. 2006; Gurses & Xiao 2006; Leape 1997; Luff & Heath 1998a; Moran et al. 2006; Rodriguez et al. 2003; Rothschild et al. 2002). Results from this study showed that doctors on ward rounds and nurses on medication administration rounds, indeed, carried out a substantial proportion of clinical tasks involving access to, or documentation of, information at patients' bedsides. Nurses required information at the bedside in order to prepare and administer medications to patients, while doctors needed to review each patient's record in order to make decisions regarding their

ongoing plans of care. Observational data demonstrated that mobile computing devices were largely used to support clinicians' information needs at patients' bedsides.

Contrary to findings by Tang and Carpendale (2008), where nurses reported rarely taking mobile devices to the bedside, both doctors and nurses within this present study frequently took mobile computing devices to use at patients' bedsides. Both also expressed a preference for mobile devices over fixed computing devices for accessing information during ward rounds and medication administration rounds; a preference that was reflected by the minimal use of fixed computers during the conduct of ward round and medication administration round tasks. Mobile computing devices were valued as they facilitated ease of access to information when the need for it arose. Nurses particularly liked being able to access decision support at the bedside, such as special instructions regarding the administration of certain medications. Doctors liked that mobile devices provided ready access to electronic patient information at the bedside; whereas, at times, they had to search the ward to find the paper-based medical records they required. Doctors were consistently observed accessing patients' current information, including test results and medication charts, as well as occasionally accessing information from patients' prior hospital admissions; both of which were supported by the use of mobile computing devices at patients' bedsides. Such findings affirm suggestions by Martins and Jones (2005b) that bedside access to timely patient information (such as the latest test results) and access to patients' medical histories (which clinicians may not always expect to need) are distinctive benefits of mobile computing devices, particularly compared to paper-based medical records.

The finding that mobile devices supported clinicians' bedside information needs, meaning that clinicians didn't need to leave the bedside to use a fixed computing device or to locate paper-based resources, may have positive implications on the efficiency of clinical work. Studies have consistently pointed to the workflow interruptions,

inefficiencies, and the redundancy of duplicate documentation caused by fixed computing devices located away from the patient bedside (Bates et al. 1994; Callen et al. 2013a; Chan et al. 2004; Embi et al. 2004; Fuchs et al. 2006; Kossman & Scheidenhelm 2008; Kushniruk et al. 2006; McCord et al. 2007; Moran et al. 2006; Niazkhani et al. 2009; Shu et al. 2001; Tierney et al. 1993). Mobile computing devices can diminish such interruptions, as exemplified in a workflow study by Cummings et al. (2008) that examined pharmacists' use of fixed and mobile computing devices during ward rounds. The study found that using fixed computers resulted in the pharmacist having to leave the ward round team for a total of 37 minutes (of 213 minutes of observations) in order to access information. Use of a mobile computing device, however, allowed the pharmacist to stay at the bedside with the ward round team, improving access to information and significantly decreasing interruption to workflow.

As well as facilitating efficient work practices, mobile devices providing access to information at patients' bedsides can have important implications on the effectiveness of care delivery. A seminal systematic review highlighted that access to decision support at the time and location of clinical decision-making is a significant predictor of improved clinical practice (Kawamoto et al. 2005). Subsequent studies have similarly shown that clinicians' use of decision support, via mobile computing devices, can lead to improved treatment decisions (Berner et al. 2006; Rudkin et al. 2006) and patient outcomes (Newton et al. 2010; Sintchenko et al. 2005). While observation of the use of decision support information was relatively infrequent in the present study, as it was in the Sintchenko et al. (2005) study, on the occasions that clinicians did seek out information at patients' bedsides they were observed using mobile computing device to fulfil their information needs. This suggests that the benefit of mobile devices in supporting clinical work is that they provide a convenient mechanism by which to access clinical information at patients' bedsides if, and when, the need for it arises. Such findings are noteworthy in light of the importance of convenient access to information; as

underscored in prominent research by Sackett and Straus (1998) who found that clinicians rarely seek out clinical information when it is not readily accessible, even when the need for it arises.

In addition to supporting clinicians' information needs, the use of mobile computing devices at patients' bedsides was observed to support interactions with patients. This is somewhat contrary to findings from several qualitative studies that have reported potentially negative effects of computing devices on bedside interactions between clinicians and patients; with clinicians perceiving that the use of computing devices distracted attention away from the patient (Alsos et al. 2011; Duffy et al. 2010; Ilie et al. 2007; Kossman 2006; Linder et al. 2006). Consequently, some clinicians preferred not to use computing devices during interactions with patients (Ilie et al. 2007; Kossman 2006). Patients that were interviewed in one of the studies conveyed that they felt hesitant to ask questions when doctors used mobile computing devices as they did not want to disturb the doctor (Alsos et al. 2011). While a limitation of the present study is that neither clinicians' nor patients' perceptions about the effect of mobile computing devices on interactions were elicited, the frequency with which clinicians were observed using mobile devices at patients' bedsides suggests that they likely did not perceive the devices to detract from interactions with patients. Furthermore, on a number of occasions patients were observed to enquire about their medications or test results. Rather than just providing a verbal response, clinicians' occasionally utilised mobile computing devices to show patients their information while responding to the enquiry. A salient example was that of a doctor not merely telling a patient that her post-operative x-ray was clear, but showing the patient the image of the x-ray result. Moreover, the doctor was able to access the pre-operative x-ray to both explain and visually demonstrate to the patient the changes in her pre- and post-operative results. Such interactions were made possible by the availability and use of mobile computing devices at patients' bedsides.

While evidence from hospital settings to support such findings is limited, a systematic review of 14 studies, predominantly from primary care settings, similarly found that computing devices could positively influence interactions between doctors and patients (Shachak & Reis 2009). The review indicated that the use of computing devices during consultations facilitated enhanced information exchange between doctors and patients, particularly regarding medications. Doctors using computing devices were found to clarify information and provide education, which in turn encouraged patients to ask questions, to a greater extent than doctors using paper-based medical records. The review highlighted several important factors that contributed to positive interactions between doctors and patients. Some of these factors included: use of a manoeuvrable monitor that could be turned toward the patient; encouraging patients to engage regarding their own information; and pointing to the screen to highlight the information being discussed. As suggested by the authors, such findings have important implications in demonstrating that the use of computing devices can be elevated beyond the primary purpose of supporting clinicians' information needs, to the greater potential of integrating computing devices as a critical component in supporting interactions between clinicians and patients.

4.23. Mobile Devices Supporting Work in Other Ward Locations and In Transit

While most ward round and medication administration round tasks were conducted at patients' bedsides, the bedside by no means represented the only location in which clinicians undertook their work. In line with the findings of Andersen et al. (2009) and Cornell et al. (2010), clinicians were observed to perform tasks in various locations throughout the ward, such as the corridors, the workbays, the medication room, and the shared office area. Of these, the corridors represented the location in which doctors carried out a large proportion of ward round tasks, while both the corridors and the

medication room were key locations in which nurses undertook medication administration rounds tasks.

The corridors of the ward were found to be more than just a space through which clinicians moved from one patients' room to the next. They served as a location in which ward round teams would gather to have clinical discussions. Similar findings were identified in studies by Baysari et al. (2011b) and Moran et al. (2006); with Moran et al. (2006) describing corridors as a meaningful space in which doctors exchange information and have many discussions about their patients. For nurses, who generally conduct medication administration rounds independently, the corridors were a location in which much of their interactions with other clinicians occurred. As has been consistently found in the literature, most interactions were observed to occur within professional roles; with nurses largely interacting with other nurses and doctors predominantly interacting with other doctors (Creswick et al. 2010; Creswick et al. 2009; Creswick & Westbrook 2010; Degeling et al. 2001; Moran et al. 2006; Westbrook et al. 2008; Westbrook et al. 2013).

During discussions and interactions in the corridors, clinicians' access to electronic information was supported by the use of mobile computing devices. Despite fixed computers being stationed in workbays directly beside the corridors they were rarely utilised for ward round or medication administration round tasks. Similarly, nurses undertaking tasks in the medication room regularly elected to bring mobile computing devices into the medication room to utilise in preference to the readily available fixed computing device in the room. This is likely a reflection of the inherent benefit of mobile computing devices: their mobility. Being able to take a mobile computing device from one location to the next meant that clinicians didn't need to log off one computing device and then log on to another computing device when moving to a different location; a process which is recognised to be inconvenient and interruptive to workflow

(Bardram 2005b; Callen et al. 2013a; Cheng et al. 2003; Tang & Carpendale 2008; Wagner & Moore 2011). Rather, mobile devices allowed clinicians to maintain a continuous connection to the clinical information system and, hence, maintain continuity of work processes.

As well as supporting work within different ward locations, mobile computing devices supported work while clinicians travelled in-between locations further facilitating continuity of work processes. The mobile manner in which doctors on ward rounds and nurses on medication administration rounds conducted their work meant that they were frequently in transit from one location to the next. Observational time and motion studies have found that nurses spend 4.6% to 7.4% of time in transit (Westbrook et al. 2011), while doctors spend 5% to 7% of time in transit (Westbrook et al. 2008). Mobile computing devices allowed clinicians to make potentially valuable use of time in transit by allowing them to complete tasks while they walked from one location to the next. Observational data demonstrated that both doctors and nurses utilised mobile computing devices to not only access information but to document information in transit; with nurses documenting the administration of medications and doctors documenting modifications to medications or entering new medication orders. The ability for mobile computing devices to support the conduct of clinical work in transit represents a distinctive benefit of mobile devices over fixed computing devices.

4.24. Devices Supporting Non-Mobile Work

Although clinicians were highly mobile during the conduct of ward rounds and medication administration rounds, outside of these activities clinicians were observed to be far less mobile. Tasks conducted outside of rounds, involving access to or documentation of information, largely occurred at the workbays. While the tasks nurses undertook outside of rounds were primarily paper-based, doctors' tasks were

predominantly computer-based. Observational data revealed that doctors almost exclusively used desktop computers to support their electronic information needs outside of rounds. Such findings correspond with those reported in studies by Andersen et al. (2009) and Martins et al. (2005). Both of these studies found that outside of ward rounds, even with the availability of mobile computing devices, doctors elected to use desktop computers. As raised by Martins et al. (2005), the question that arises from such observations is – why didn't doctors use mobile computing devices outside of rounds?

The findings from this present study suggest that doctors' decisions to use a desktop computer, as opposed to a mobile computing device, were influenced by several factors. Firstly, unlike the work practices observed on ward rounds, outside of rounds doctors were not constantly shifting locations and they had substantially less interaction with patients. Thus the shift to desktop computers was likely a reflection of these changes in work practices, where tasks outside of rounds could be conducted in one location and away from the patient bedside. Secondly, one of the key tasks that doctors performed outside of rounds was documenting patient discharge summaries. This task required reviewing of patients' records in order to obtain all the information necessary to ensure comprehensive documentation of discharge summaries, including diagnoses, medications, test results, progress while in hospital, and on-going treatment plans (Kripalani et al. 2007). Due to the hospital's hybrid system doctors needed access to both a computing device and paper-based medical records to obtain and document such information. A contributing factor in doctors electing to use desktop computers may, thus, have been because the computers were stationed on desks; providing space on which to place paper-based medical records so that both paper-based and electronic information could easily be viewed at the same time. Finally, while ward rounds were team based, outside of rounds doctors largely conducted tasks independently. Doctors could, therefore, sit at a desk and work on their own, and at their own pace.

4.25. Factors Affecting the Use of Computing Devices

A large portion of the observed results could be attributed to a relationship between attributes of the tasks and attributes of the technology: with the mobile nature of ward round and medication administration round tasks found to be suited to the mobile nature of computer carts; and the substantially less mobile nature of tasks conducted outside of rounds suited to the stationary nature of desktop computers. However, this relationship alone does not account for all of the device use behaviours that were observed in this study.

Ammenwerth et al.'s (2006) fit between individuals, task, and technology (FITT) framework, posits that the optimal use of technology is dependent on the interaction between three key dimensions: attributes of users, tasks, and technology. A distinction of the FITT framework, compared to other theoretical frameworks aimed at understanding technology use, is the emphasis on the interaction between users and tasks and the subsequent impact that this interaction has on the use of technology. Application of the FITT framework in this present study aided in the identification of distinct differences between the attributes of the observed user groups and how they conduct tasks. Nurses were found to largely conduct their work independently and, hence, could select the computing device that they perceived provided the best fit for their tasks. Doctors, on the other hand, worked in teams during ward rounds. As was found by Martins and Jones (2005b) in a study examining doctors' use of computer carts during ward rounds, the use of computing devices within a ward round team is largely influenced by the team leader.

While all ward round teams within this study were observed to use mobile computing devices, there was variation amongst the teams in terms of who each team leader assigned as the primary user of the computing device. This assignment was found to have important implications on how mobile computing devices supported clinical work

on ward rounds. When junior doctors were the primary users the documentation of test orders, medication orders, and modifications to medications were largely entered directly onto the computer cart during the ward round. When senior doctors were the primary users it meant that junior doctors had to document orders and modifications on paper to be entered electronically outside of rounds. Such findings reflect the hierarchical structure of ward round teams: where senior doctors make clinical decisions, while junior doctors tend to be responsible for documenting decisions (Baysari et al. 2011a; Lewis & Tully 2009; Ross et al. 2012).

This hierarchical structure has been recognised to pose challenges to the effective use of technology on ward rounds. Research conducted by Baysari et al. (2011a), which examined the effectiveness of a decision support system (DSS) on medication prescribing during ward rounds, found that when junior doctors entered medication orders onto computer carts they largely ignored DSS alerts. This is likely because junior doctors are hesitant to question senior doctors' prescribing decisions (Lewis & Tully 2009; Ross et al. 2012). The information provided by the DSS was therefore not incorporated into clinical decision-making as it failed to reach the senior doctors who make the prescribing decisions (Baysari et al. 2011a). In essence, the DSS was rendered ineffective, despite the fact that it was available at the time of order entry.

The above findings highlight that, irrespective of a congruent relationship between mobile computing devices and the mobile nature of ward rounds, the user of the mobile device within the ward round team affected optimal fit: validating Ammenwerth et al.'s (2006) argument about the importance of the user dimension when examining the use of technology. However, even when adequate fit between the attributes of users, tasks, and technology was attained (for example, computer carts supporting nurses' work practices during medication administration rounds) additional factors, related to the environment in which the technology was used, were found to affect the use of mobile computing

devices. These factors included the temporal rhythms of the ward, infection control rooms, and lack of space.

4.25.1. Environment Factors Affecting the Use of Mobile Computing Devices

One of the key factors found to affect the use of mobile computing devices was the temporal rhythms of the ward. When the timing of ward rounds and medication administration rounds coincided it resulted in more clinicians requiring the concurrent use of mobile computing devices than what was available. Nurses that were not able to access a mobile device reported using a desktop computer instead. As desktop computers were not available at the patient bedside, where information is largely needed during medication administration rounds, nurses would transcribe information from the desktop computer onto paper. Although transcribing allows information to be taken to the bedside it also introduces the potential for errors (Armutlu et al. 2008; Benkirane et al. 2009; Callen et al. 2010; Knudsen et al. 2007; Pham et al. 2011; Wilton & Pennisi 1994), as well as negatively impacting on efficiency as a result of the additional documentation (Fuchs et al. 2006; Kossman 2006).

The presence of infection control rooms on a ward was also found to affect the use of mobile computing devices. In cases where a patient was isolated in an infection control room, clinicians could not take the computer carts into the infection control room. Instead they had to leave the computer cart outside of the room and walk between the patient bedside and the computer cart when needing to access or document information. Similarly, lack of space at the patient bedside, often due to the presence of other essential medical equipment or furniture, impacted on clinicians' ability to use computer carts at the bedside. Andersen et al. (2009), who observed clinicians' use of computing devices on hospital wards, found that lack of space was a critical factor preventing the

use of computer carts at the patient bedside. Nurses surveyed by Moody et al. (2004), reported that a lack of space resulted in the need to undertake double documentation: using paper to document information at the bedside and then copying the data into onto the computer cart.

The commonality amongst the above factors is that they restricted the ability of clinicians to use mobile computing devices at the patient bedside and, hence, impacted on the use and optimal fit of computing devices. This meant that, not only were the benefits associated with having a mobile device at the bedside, such as ease of access to information, subsequently lost, but the potential for errors was introduced due to clinicians having to work around the restraints imposed by these factors.

Such findings highlight the importance of examining environmental factors as an entity in and of themselves. While the FITT framework considers factors related to the environment (or context) as an intrinsic part of user attributes, the above findings suggest that such factors represent an overarching influence that can affect the use of devices even when there is fit between individuals, tasks, and technology.

4.26. Persistence of Paper

An incidental finding emerging from this study was the persistence of temporary paper resources, such as nurses' handover sheets, doctors' patient summary worksheets, and scrap pieces of paper. In some instances the use of temporary paper resources was observed to be an interim means by which clinicians' overcame factors affecting the use of computing devices. For example, nurses transcribing information from desktop computers onto their handover sheet when mobile devices were unavailable or junior doctors' documentation of treatment decisions on their patient summary worksheets when senior doctors were using the computer carts. Chen (2010) describes temporary paper resources used in such instances as "transitional artifacts" which are used to

bridge a gap between clinical workflow needs and formal electronic documentation. The persistence of temporary paper resources in such cases could potentially be decreased, or even eliminated, by addressing the factors hindering direct electronic information access or input.

A more notable use of temporary paper resources, however, was for the documentation of personal notes, such as self-reminders regarding tasks to be completed or requiring follow-up. In such instances clinicians utilised temporary paper resources even when computing devices were readily accessible. This was similarly shown to be the case in a study by Tang and Carpendale (2008). The authors found that nurses carried paper-based worksheets throughout their shift and utilised them alongside computing devices. The worksheets were identified to be a critical resource supporting nurses' work. Nurses' relied on the notes they documented on the worksheets to "inform them of the tasks to be performed, the order in which the tasks should be carried out and an overview of their shift work" (p.213). As suggested by Fitzpatrick (2000), the use of temporary paper resources in these instances is borne out of a need to fill the void of information that doesn't fit in the formal electronic record.

Such findings highlight a critical gap where technology currently fails to support clinical work and highlights an area of opportunity to develop systems that facilitate clinicians need for information of a temporary nature. Having a system where doctors and nurses can quickly enter notes that do not form part of the permanent record and which are privy only to themselves may help to reduce the persistence of paper. Such a system could help streamline clinicians' work by removing the need to rely on multiple resources. In addition, the system could provide additional technological benefits that paper cannot; such as being able to set alerts to notes as a reminder to complete a task.

4.27. Implications of the Findings

The findings from this study highlight the importance of undertaking evaluations of clinicians' work in practice. In particular, assessing *where* clinicians undertake work and whether their work practices are adequately supported by the technology available to them is necessary in order to identify the types of technology that may help optimise work practices.

As established earlier in the thesis, existing literature examining clinicians' use of mobile computing devices tends to portray mobile devices as inherently beneficial without clear indication of how they support clinical work practices. By observing clinicians' use of computing devices in practice, in particular *where* device use occurs, this study has provided empirical evidence demonstrating that mobile computing devices support clinicians' work by facilitating access to information at patients' bedsides. While such evidence is important, of potentially greater significance was the fact that mobile devices also supported clinicians' work away from the bedside, facilitating continuity of work processes as clinicians moved throughout the ward. Such findings have important implications for the selection of computing devices. They suggest that, in wards sharing similar characteristics to those examined in this study, mobile computing devices may be a preferential choice to fixed computing devices at the bedside as fixed devices may compromise the ability for clinicians to maintain continuity in their work. As stated by Martins and Jones (2005b) providing clinicians with mobile devices brings the information to the clinician, rather than the clinician having to seek out information as is the case with fixed computing devices.

However, despite the enthusiasm surrounding mobile computing devices on their own they cannot meet the challenge of adequately supporting clinical work practices. Desktop computers still have their place on the ward. Doctors were observed using desktop computers outside of rounds, for tasks such as discharge summaries, even when

mobile devices were available and accessible. Likewise some nurses expressed a preference for desktop computers when conducting tasks outside of rounds as they could sit down during such tasks. The reliance on different types of computing devices for different tasks suggests that while mobile devices support mobile tasks they need to exist alongside fixed devices. A number of researchers have likewise suggested that the use of mobile devices should be used to complement fixed computing devices (Ammenwerth et al. 2000; Harkke 2006; Lindquist et al. 2008b) and that the combination and integration of various technologies can achieve the greatest result for both clinicians and their patients (Ammenwerth et al. 2000; Dahl et al. 2006; Luff & Heath 199b; Moran et al. 2006). This requires understanding and acknowledging both the advantages and disadvantages of various technologies, how they are used in real-work clinical situations, and the factors which determine their utility.

4.28. Limitations

This study had several limitations. As with any observational research there is a possibility of introducing the Hawthorne effect: where participants modify their behaviour in the presence of the researcher. While it cannot be known whether participants changed their behaviour, given that the focus of the study was examining how computing devices supported clinicians' work and that no assessment of quality was being made, any magnitude of behavioural change is likely to have had minimal influence on the study findings.

The scope of this study was to evaluate the use of the computing devices, not the clinical information systems accessible via those devices. However, software undoubtedly affects the use of hardware and, as such, may have had an impact on the study findings. Differences in the way that nurses in this study, for example, were observed to use mobile computing devices compared to findings in other studies of a similar nature

(such as the study by Tang & Carpendale (2008)) may be due to differences in the available information systems. The findings from this study, therefore, need to be considered in light of the information system context of the study site. Further, the study findings are based on data obtained from two study wards of one hospital and thus may not be generalisable to other hospitals or wards with very different practices.

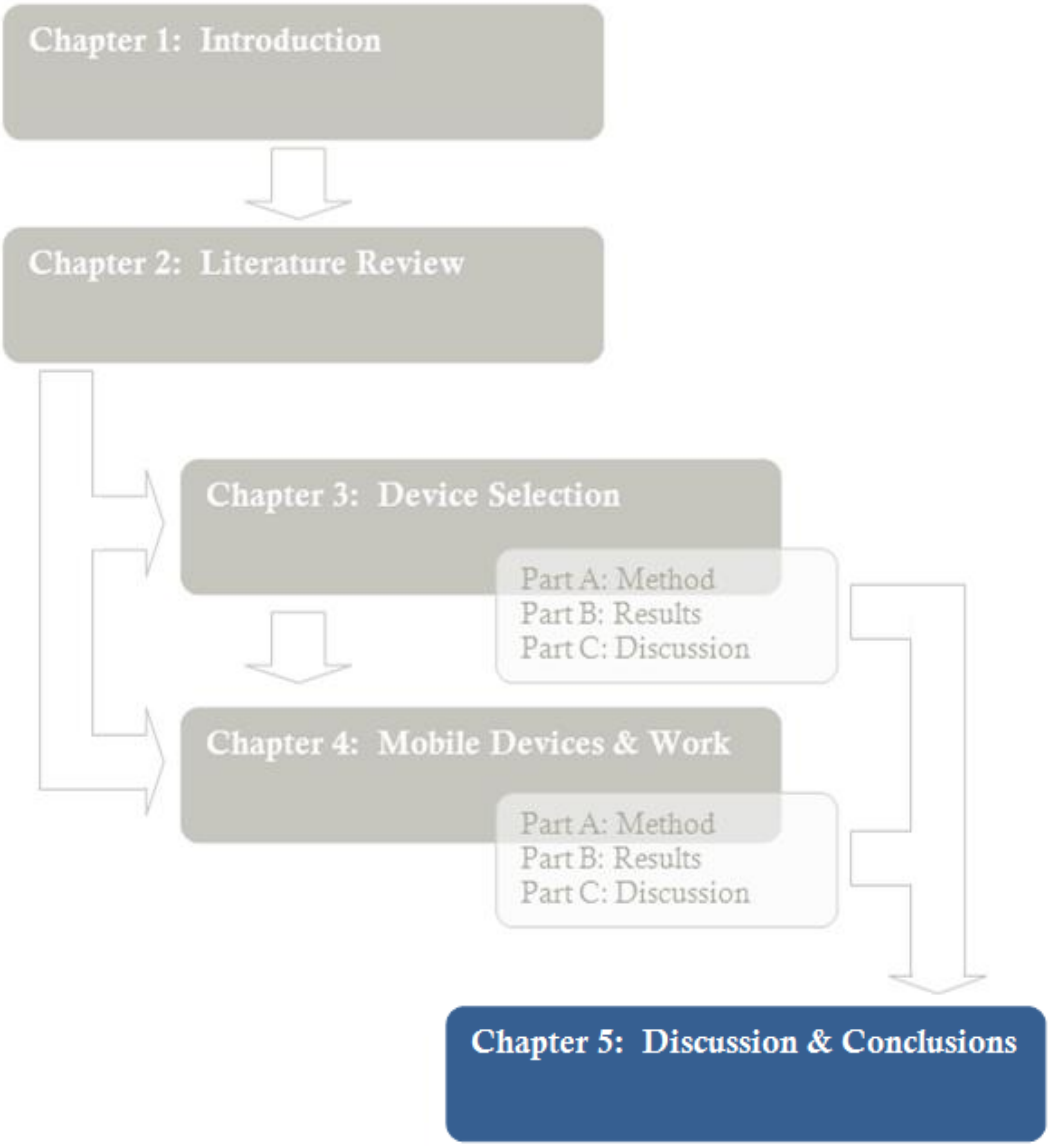
Another limitation of this study is that a key benefit of mobile computing devices is that they can be used anywhere, at anytime, including both on and off the ward. Limiting observation of mobile computing device use to within wards meant that opportunities to discover if, and how, mobile computing devices were used to support clinical work outside of wards was missed. This is likely to have limited the assessment of all possible benefits that mobile computing devices provide. For example, doctors at night who move between large numbers of wards may be better supported if using mobile computing devices that they are able to carry with them from one ward to the next. Furthermore, the study wards largely used computer carts, with only a couple of doctors using tablet computers. The findings in this study may have been different if different types of mobile devices were used. This indicates the need for future research that evaluates and compares the use of different types of mobile computing devices to either validate or counter the findings from this study.

4.29. Conclusion

This chapter discussed the second stage of the research, which involved an investigation of how mobile computing devices support clinical work practices on hospital wards. The findings provide evidence validating core assumptions about mobile devices: namely, that they support clinicians' work by facilitating access to information at patients' bedsides. Notably, mobile devices also supported work away from the bedside and whilst clinicians were in transit, allowing continuity in work processes. However,

mobile devices did not provide the best fit for all tasks and additional factors, such as the temporal rhythms of the ward and structure of ward round teams, affected how mobile devices supported work. These key findings from this second stage of the research and those arising from the first stage of the research are drawn together in the following, and final, chapter of this thesis, which discusses the major contributions and implications of the research presented in this thesis.

CHAPTER 5


Chapter 1: Introduction
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Chapter 4: Mobile Devices & Work
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Part B: Results
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Chapter 5. Discussion & Conclusions

5.1. Introduction

The research presented in this thesis set out to generate new knowledge regarding the selection and use of computing devices to support clinical work practices on hospital wards. Stage one of the research investigated the perspectives of individuals involved in the selection of computing devices in order to determine how decision-makers select computing devices and what factors they consider when making decisions about the selection of devices. Stage two of the research investigated clinicians' use of computing devices on hospital wards in order to determine how mobile computing devices support clinical work practices and what factors affect their use. Taken together, these two stages of research provide important contributions to the existing evidence base, which have practical implications for decision-makers responsible for the acquisition of computing devices whose decisions ultimately affect clinicians and their work practices. The purpose of this final chapter is to discuss these contributions and implications, and to highlight opportunities for future research.

5.2. Guidelines for the Selection of Computing Devices

A critical lesson arising from the research presented in this thesis is that the *selection* of computing devices and the *use* of computing devices are intricately related. For computing devices to achieve their intended benefits, the factors upon which decision-

makers base their device selection decisions must correspond with the factors that affect clinicians' use of computing devices in practice. Research, such as that presented in this thesis, which examines both the selection and use of devices is therefore essential to extending our understanding of how best to select computing devices that will adequately support clinical work practices. By first identifying the range of factors that decision-makers consider when selecting computing devices and then examining whether such factors are evident in practice, this research facilitated the development of guiding checklists to aid the selection of computing devices (Table 5.1, Table 5.2, and Table 5.3). Grounded in evidence, these checklists detail the technology, user and task, and environment factors that were found to influence the use of computing devices on hospital wards and represent a unique and valuable contribution to knowledge arising from this research.

Such guidelines are important for decision-makers responsible for the acquisition of computing devices as there is no "one size fits all" solution and the implementation of similar technologies in different settings can render different results. As such, when undertaking device selection decisions, due consideration needs to be given to all the factors that may affect device use as technology can significantly impact the efficiency and effectiveness of clinical work practices; both in intended and unintended ways (Ash et al. 2004; Audet et al. 2005; Buntin et al. 2011; Embi et al. 2004; Eslami et al. 2008; Garg et al. 2005; Poon et al. 2006; Sidorov 2006; Wachter 2006; Zhan et al. 2006). In particular, it is important to identify the environmental nuances that may affect the ideal fit of computing devices.

Table 5.1. Factors to Consider in Device Selection Decisions: Technology Attributes

Factors	Key Queries
Technology Attributes	
☐ Infrastructure	• Is wireless infrastructure available to allow for mobile computing devices? • Is the speed of the wireless network adequate? • Is there sufficient coverage (i.e., access points) to maintain uninterrupted network connectivity throughout the ward/hospital?
☐ Existing Hardware	• Will the mobile device cause interference to existing hardware (e.g., medical devices such as infusion pumps)? • Are electrical outlets available to permanently power fixed computing devices? • Are electrical outlets easily accessible for recharging mobile devices? Are they also accessible at the bedside?
☐ Device Characteristics	• Does the mobile device have wireless capabilities? • Is the battery life adequate? • How long does it take to recharge the battery? • Is the device rugged and robust (in case it is dropped)? • Can the device be sanitised? • What kind of data input mechanism does the device have? • What size is the screen? • How much does the device weigh (can it easily be carried or manoeuvred)?
☐ Software Applications	• Is the device's operating system compatible with the clinical software applications being used or being considered for implementation? • Is the interface of the software application transferable to different screen sizes? • Can the software application be modified or is there a version for mobile devices with smaller screens?

Table 5.2. Factors to Consider in Device Selection Decisions: User and Task Attributes

Factors	Key Queries
User & Task Attributes	
☐ Role of User	• What type of role (doctor, nurse, pharmacist, allied health professional, etc.) will utilise the computing device? • Are tasks performed independently or within a team (i.e., do multiple clinicians need access to devices or to see information on the computer screen at the same time)? • What is the structure of ward round teams? Do they require the use of multiple devices?
☐ Task Type	• Are the tasks that require use of computing devices mobile or desk-based? • Are additional items required to perform tasks (e.g., sphygmomanometers)? Can these items easily be carried while also carrying a handheld device (e.g., tablet computer) or do they need to be stowed and manoeuvred using a portable device (e.g., computer cart)? • What quantity of information do users need in a given location (e.g., at the bedside, in an office)? • Is the device suited to accessing/documenting smaller amounts of information (e.g., displaying a summary of test results, entering a test order) or larger amounts of information (e.g., displaying trends over time, preparing a comprehensive report or discharge summary)?
☐ Location of Task	• Where do users undertake tasks that require access to computing devices (e.g., at the bedside, away from the bedside or in the corridors, in an office)? • Where do users need to access patient information or clinical resources? • Where do users need to document patient information? • Will the computing device allow users to avoid walking between the locations where information access/capture is required and the location of the device?

Table 5.3. Factors to Consider in Device Selection Decisions: Environment Attributes

Environment Attributes	
☐ Ward Type	• What is the patient acuity profile of the ward? • How many clinicians work on the ward? • Does the ward have infection control or isolation rooms that may require devices that can be sanitised?
☐ Space Available	• Is there desktop space or wall space available to permanently install fixed computing devices? • Is there sufficient space available at the patient bedside to install a fixed device without the device being obstructive in an emergency (e.g., patient resuscitation)? • Is there sufficient space to wheel or use computer carts at the bedside? • Is there space available to store and move mobile computing devices (e.g., computer carts) around?
☐ Accessing Dynamics	• How many (what percentage of) paper-based processes have been replaced with electronic processes? • Do users currently need to queue to access a computing device? • What are the temporal rhythms of the ward (i.e., when are ward rounds and medication administration rounds conducted, do they coincide, and what is the average duration of rounds)? • How many users need access to computing devices concurrently during peak accessing times? • Are clinicians able to access fixed computing devices or move mobile computing devices at night without disrupting patients?

5.3. Applicability of the FITT framework

The research presented in this thesis highlights the value of undertaking research informed by a theoretical framework. Utilising a framework not only provides a lens through which to assess study findings but, as frameworks are founded upon existing evidence, their use adds validity (Brennan 2008). Frameworks have been widely used to evaluate the use of technology (Holden & Karsh 2010). Yet, these same frameworks are rarely applied when investigating decisions that precede technology implementation. Ammenwerth et al.'s (2006) FITT is one such framework. FITT has been used in several studies to assess the suitability between technology, users, and clinical work (Honekamp & Ostermann 2011; Schnall et al. 2012; Sheehan et al. 2012; Tsiknakis & Kouroubali 2009). The research presented in this thesis, however, utilised the FITT framework for examining both decisions about the selection of technology as well as the use of technology in practice.

The factors that decision-makers perceived were important to consider when selecting computing devices largely aligned with the FITT dimensions. These factors were also reflected in the observation of clinicians' use of computing devices in practice, demonstrating the applicability of the FITT framework to both decisions about device selection and the use of computing devices. That the same framework can be used when looking at decisions regarding the selection of technology, as well as the use of that technology once it has been implemented is an important finding. For decision-makers, it highlights that studies that have applied the FITT framework to assess the use of computing devices also impart valuable evidence to help inform device selection decisions.

The findings presented in this thesis, however, suggest the need for additions to the framework. While the dimensions of individuals, tasks, and technology were found to be critical in assessing fit, ultimately it was factors within the environment, such as the

temporal rhythms of a ward, the presence of infection control rooms, or the space on the ward, which influenced the optimal use of technology. Presently, the FITT framework enmeshes factors related to the environment (or context) of a setting as part of the user attribute (Ammenwerth et al. 2006). Yet, context is recognised to be a critically important factor affecting the use of technology. Callen et al.'s (2008) Contextual Implementation Model (CIM), which provides a framework to guide the implementation of clinical information systems, specifies the need for implementers of technology to undertake a thorough analysis of context. The authors indicate that the identified contextual factors should be carefully considered and included in implementation project plans. Pawson et al.'s (2005) realist review model similarly underscores the need to discern the circumstances in which an intervention works or, conversely, does not work. Identifying such circumstances is suggested to "enable decision-makers to reach a deeper understanding of the intervention and how it can be made to work most effectively" (p.21).

The addition of a separate and overarching "environment" dimension to the FITT framework would aid in the assessment of factors related to the context in which users, tasks, and technology operate. The distinction of environment as a separate dimension is necessary as it is likely that this is where the key differences between different sites and settings lie. As such, an environment dimension may help to explain why a technology that works in one setting does not show the same success in another setting. This is an important area where further research is required.

5.4. Recommendations for Future Research

Technology is changing rapidly. Even within the time that the research presented in this thesis was conducted the technology landscape has changed immensely. Yet research examining the selection of computing devices and clearly demonstrating how devices

support clinical work practices remains scarce. Technology will continue to evolve and be implemented into hospitals, so it is critical that those responsible for implementing technology have guiding evidence on which to base their decisions. The research presented in this thesis contributes new knowledge that can be utilised by decision-makers responsible for the selection of technology to guide decisions regarding devices that will adequately support clinical work practices. However, additional research would help to validate the findings from this study.

Furthermore, application of the FITT framework needs to be further assessed. When using the FITT framework we are assessing a current set of circumstances into which technology will be implemented. Technology is, however, known to be disruptive. The implemented technology may suit the work practices but work practices will also change because of the new technology (Wears & Berg 2005). The question then becomes how do we account for this in the framework? Future research should assess whether iterative use of the framework might address this.

5.5. Concluding Remarks

The research presented in this thesis makes an important contribution to knowledge by providing insight into the selection and use of computing devices on hospital wards. Perhaps the most significant lesson conveyed through this work is the importance of understanding the multitude of factors that can influence how well computing devices support clinical work. The success of computing devices in supporting clinical work lies in first understanding these factors and considering them during the selection of computing devices. In investigating the selection and use of computing devices this research has also shown that it is possible, and moreover necessary, to apply the same framework to both studies about the selection of computing devices and evaluations of the use of computing devices in practice.

REFERENCES

Aarts J, Doorewaard H, Berg M (2004) Understanding implementation: the case of a computerized physician order entry system in a large Dutch university medical center. Journal of the American Medical Informatics Association. 11(3):207-216.

Adams GL, Campbell PT, Adams JM, Strauss DG, Wall K, Patterson J, Shuping KB, Maynard C, Young D, Corey C, Thompson A, Lee BA, Wagner GS (2006) Effectiveness of prehospital wireless transmission of electrocardiograms to a cardiologist via hand-held device for patients with acute myocardial infarction (from the timely intervention in myocardial emergency, northeast experience [TIME-NE]). American Journal of Cardiology. 98(9):1160-1164.

Ahmad A, Teater P, Bentley TD, Kuehn L, Kumar RR, Thomas A, Mekhjian HS (2002) Key attributes of a successful physician order entry system implementation in a multi-hospital environment. Journal of the American Medical Informatics Association. 9(1):16-24.

Al-Ubaydli M (2004) Handheld computers. British Medical Journal. 328(7449):1181-1184.

Allen SK (1991) Selection and implementation of an automated care planning system for a health care institution. Computers in Nursing. 9(2):61-68.

Alsos OA, Dabelow B, Faxvaag A (2011) Doctors' concerns of PDAs in the ward round situation. Methods of Information in Medicine. 50(2):190-200.

Ammenwerth E, Buchauer A, Bludau B, Haux R (2000) Mobile information and communication tools in the hospital. International Journal of Medical Informatics. 57(1):21-40.

Ammenwerth E, Iller C, Mansmann U (2003a) Can evaluation studies benefit from triangulation? A case study. International Journal of Medical Informatics. 70(2):237-248.

Ammenwerth E, Graber S, Herrmann G, Burkle T, Konig J (2003b) Evaluation of health information systems – problems and challenges. International Journal of Medical Informatics. 71(3):125-135.

Ammenwerth E, Iller C, Mahler C (2006) IT-adoption and the interaction of task, technology and individuals: a fit framework and a case study. BMC Medical Informatics and Decision Making. 6(1):3.

Ammenwerth E, Spotl HP (2009) The time needed for clinical documentation versus direct patient care. Methods of Information in Medicine. 48(1):84-91.

Ampt A, Westbrook J, Creswick N, Mallock N (2007) A comparison of self-reported and observational work sampling techniques for measuring time in nursing tasks. Journal of Health Services Research and Policy. 12(1):18-24.

Andersen HR, Nielsen TT, Rasmussen K, Thuesen L, Kelbaek H, Thayssen P, Abildgaard U, Pedersen F, Madsen JK, Grande P, Villadsen AB, Krusell LR, Haghfelt T, Lomholt P, Husted SE, Vigholt E, Kjaergard HK, Mortensen LS (2003) A comparison of coronary angioplasty with fibrinolytic therapy in acute myocardial infarction. New England Journal of Medicine. 349(8):733-742.

Andersen P, Lindgaard AM, Prgomet M, Creswick N, Westbrook J (2009) Mobile and fixed computer use by doctors and nurses on hospital wards: multi-method study on the relationships between clinician role, clinical task, and device choice. Journal of Medical Internet Research. 11(3):e32.

Anderson C (2010) Presenting and evaluating qualitative research. American Journal of Pharmaceutical Education. 74(8):141.

Anderson G, Frogner B, Johns R, Reinhardt U (2006) Health care spending and use of information technology in OECD countries. Health Affairs. 25(3):819-831.

Appleton JV, King L (1997) Constructivism: a naturalistic methodology for nursing inquiry. Advances in Nursing Science. 20(2):13-22.

Arabadzhiyska PN, Baysari M, Walter S, Day RO, Westbrook J (2013) Shedding light on junior doctors' work practices after hours. Internal Medicine Journal. 43(12):1321-1326.

Armutlu M, Foley ML, Surette J, Belzile E, McCusker J (2008) Survey of nursing perceptions of medication administration practices, perceived sources of errors and reporting behaviours. Healthcare Quarterly. 11(3);58-65.

Arshad U, Mascolo C, Mellor M (2003) Exploiting mobile computing in health-care. Proceedings of Demo Session of the 3rd International Workshop on Smart Appliances. Rhode Island, USA. p.19-24.

Ash JS, Berg M, Coiera E (2004) Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. Journal of the American Medical Informatics Association. 11(2):104-112.

Ash JS, Chin HL, Sittig DF, Dykstra RH (2005) Ambulatory computerized physician order entry implementation. AMIA Annual Symposium Proceedings. p.11-15.

Ash JS, Guappone KP (2007) Qualitative evaluation of health information exchange efforts. Journal of Biomedical Informatics. 40(Supplement 6):S33-S39.

Ash JS, Sittig DF, Poon EG, Guappone K, Campbell E, Dykstra RH (2007a) The extent and importance of unintended consequences related to computerized provider order entry. Journal of the American Medical Informatics Association. 14(4):415-423.

Ash JS, Sittig DF, Dykstra RH, Guappone K, Carpenter JD, Seshadri V (2007b) Categorizing the unintended sociotechnical consequences of computerized provider order entry. International Journal of Medical Informatics. 76(Supplement 1):S21-S27.

Ash JS, Sittig DF, Dykstra R, Campbell E, Guappone K (2009) The unintended consequences of computerized provider order entry: findings from a mixed methods exploration. International Journal of Medical Informatics. 78(Supplement 1):S69-S76.

Audet AM, Doty MM, Shamasdin J, Schoenbaum SC (2005) Measure, learn, and improve: physicians' involvement in quality improvement. Health Affairs. 24(3):843-853.

Australian Health Ministers' Advisory Council (2008) National eHealth strategy summary. Available from: http://www.ahmac.gov.au/cms_documents/National%20E-Health%20Strategy.pdf

Australian Medical Association (1998) AMA safe hours project. Systems of work for junior doctors in public hospitals: an overview of seven case studies. Kingston, ACT: Australian Medical Association. Available from: https://ama.com.au/systems-work-junior-doctors-public-hospitals-overview-seven-case-studies

Australian Medical Association (2009) AMA junior doctor training, education and supervision survey: report of findings. Barton, ACT: Australian Medical Association. Available from: https://ama.com.au/2009-ama-junior-doctor-training-education-supervision-survey-report-findings

Aziz O, Panesar SS, Netuveli G, Paraskeva P, Sheikh A, Darzi A (2005) Handheld computers and the 21st century surgical team: a pilot study. BMC Medical Informatics and Decision Making. 5:28.

Baldwin LP, Low PH, Picton C, Young T (2007) The use of mobile devices for information sharing in a technology-supported model of care in A&E. International Journal of Electronic Healthcare. 3(1):90-106.

Banitsas KA, Georgiadis P, Tachakra S, Cavouras D (2004) Using handheld devices for real-time wireless teleconsultation. Proceedings of the 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. San Francisco, California. p.3105-3108.

Bardram JE (1997) I love the system – I just don't use it! Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work. Phoenix, Arizona. p.251-260.

Bardram JE (2005a) The trouble with login: on usability and computer security in ubiquitous computing. Personal and Ubiquitous Computing. 9(6):357-367.

Bardram JE (2005b) Activity-based computing: support for mobility and collaboration in ubiquitous computing. Personal and Ubiquitous Computing. 9(5):312-322.

Bardram JE, Bossen C (2003) Moving to get ahead: local mobility and collaborative work. Proceedings of the 8th European Conference on Computer Supported Cooperative Work. Helsinki, Finland. p.355-374.

Bardram JE, Bossen C (2005) Mobility work: the spatial dimension of collaboration at a hospital. Computer Supported Cooperative Work. 14(2):131-160.

Barriball KL, While A (1994) Collecting data using semi-structured interview: a discussion paper. Journal of Advanced Nursing. 19(2):328-335.

Bates DW, Boyle DL, Teich JM (1994) Impact of computerized physician order entry on physician time. Proceeding of the Annual Symposium on Computer Application in Medical Care. p.996.

Bates DW, Gawande AA (2003) Improving safety with information technology. New England Journal of Medicine. 348(25):2526-2534.

Baumgart DC (2005) Personal digital assistants in health care: experienced clinicians in the palm of your hand? Lancet. 366(9492):1210-1222.

Baysari M, Westbrook J, Richardson K, Day R (2011a) The influence of computerized decision support on prescribing during ward-rounds: are the decision-makers targeted? Journal of the American Medical Informatics Association. 18(6):754-759.

Baysari M, Westbrook J, Day R (2011b) Medication decision-making on hospital ward-rounds. Studies in Health Technology and Informatics. 169:935-939.

Benkirane RR, Abouqal R, Haimeur CC, S Ech Cherif El Kettani SS, Azzouzi AA, Mdaghri Alaoui AA, Thimou AA, Nejmi MM, Maazouzi WW, Madani NN, R-Edwards I, Soulaymani RR (2009) Incidence of adverse drug events and medication errors in intensive care units: a prospective multicenter study. Journal of Patient Safety. 5(1):16-22

Berg M (1999) Patient care information systems and health care work: a sociotechnical approach. International Journal of Medical Informatics. 55(2):87-101.

Berg M (2001) Implementing information systems in health care organizations: myths and challenges. International Journal of Medical Informatics. 64(2):143-156.

Berner ES, Houston TK, Ray MN, Allison JJ, Heudebert GR, Chatham WW, Kennedy JI Jr., Glandon GL, Norton PA, Crawford MA, Maisiak RS (2006) Improving ambulatory prescribing safety with a handheld decision support system: a randomized controlled trial. Journal of the American Medical Informatics Association. 13(2):171-179.

Blois MS, Shortliffe EH (1990) The computer meets medicine: emergence of a discipline. In: Shortliffe EH, Perreault LE, Wiederhold G, Fagan LM (editors). Medical Informatics: Computer Applications in Health Care. Reading, Massachusetts. Addison-Wesley. p.3-36.

Bloomrosen M, Starren J, Lorenzi NM, Ash JS, Patel VL, Shortliffe EH (2011) Anticipating and addressing the unintended consequences of health IT and policy: a report from the AMIA 2009 Health Policy Meeting. Journal of the American Medical Informatics Association. 18(1):82-90.

Bogdan RC, Biklen SK (1982) Qualitative research for education: an introduction to theory and methods. Boston, US: Allyn and Bacon.

Bogdewie SP (1992) Participant observation. In: Crabtree B, Miller W (editors). Doing Qualitative Research. Second Edition. Thousand Oaks, California: Sage Publications. p.47-70.

Bond CS (2007) Nurses and computers. An international perspective on nurses' requirements. In: Kuhn K, Warren J, Leong T (editors). Medinfo 2007. Proceedings of the Twelfth World Congress on Health (Medical) Informatics. Brisbane, Australia. IOS Press. p.943-947.

Bossen C (2002) The parameters of common information spaces: the heterogeneity of cooperative work at a hospital ward. Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work. p.176-185.

Bowling A (2009) Research methods in health: investigating health and health services. Third Edition. Maidenhead, England: Open University Press.

Bradley EH, Curry LA, Devers KJ (2007) Qualitative data analysis for health services research: developing taxonomy, themes, and theory. Health Services Research. 42(4):1758-1772.

Brender J (2005) Handbook of evaluation methods for health informatics. Aalborg, Denmark: Academic Press.

Brennan PF (2008) Standing in the shadows of theory. Journal of the American Medical Informatics Association. 15(2):263-264.

Britten N (1995) Qualitative interviews in medical research. British Medical Journal. 311(6999):251-253.

Brown C, Lloyd K (2001) Qualitative methods in psychiatric research. Advances in Psychiatric Treatment. 7(5):350-356.

Bryman A (2006) Integrating quantitative and qualitative research: how is it done? Qualitative Research. 6(1):97-113.

Bullard MJ, Meurer DP, Colman I, Holroyd BR, Rowe BH (2004) Supporting clinical practice at the bedside using wireless technology. Academic Emergency Medicine. 11(11):1186-1192.

Buntin MB, Burke MF, Hoaglin MC, Blumenthal D (2011) The benefits Of health information technology: a review of the recent literature shows predominantly positive results. Health Affairs. 30(3):464-471.

Callen J, McIntosh J, Li J (2010) Accuracy of medication documentation in hospital discharge summaries: A retrospective analysis of medication transcription errors in manual and electronic discharge summaries. International Journal of Medical Informatics. 79(1):58-64.

Callen J, Paoloni R, Li J, Stewart M, Gibson K, Georgiou A, Braithwaite J, Westbrook J (2013a) Perceptions of the effect of information and communication technology on the quality of care delivered in emergency departments: a cross-site qualitative study. Annals of Emergency Medicine. 61(2):131-144.

Callen J, Hordern A, Gibson K, Li L, Hains IM, Westbrook JI (2013b) Can technology change the work of nurses? Evaluation of a drug monitoring system for ambulatory chronic disease patients. International Journal of Medical Informatics. 82(3):159-167.

Callen JL, Braithwaite J, Westbrook JI (2008) Contextual implementation model: a framework for assisting clinical information system implementations. Journal of the American Medical Informatics Association. 15(2):255-262.

Camacho J, Favela J, Gonzalez VM (2006) Supporting the management of multiple activities in mobile collaborative working environments. In: Dimitriadis YA, Zigurs I, Gomez-Sanchez E (editors). Groupware: Design, Implementation, and Use. Proceedings of the 12th International Workshop CRIWG. Medina del Campo, Spain. Springer. p.381-388.

Campbell E, Guappone K, Sittig D, Dykstra R, Ash J (2009) Computerized provider order entry adoption: implications for clinical workflow. Journal of General Internal Medicine. 24(1):21-26.

Campbell EM, Sittig DF, Ash JS, Guappone KP, Dykstra RH (2006) Types of unintended consequences related to computerized provider order entry. Journal of the American Medical Informatics Association. 13(5):547-556.

Campbell R, Ash J (2006) An evaluation of five bedside information products using a user-centered, task-oriented approach. Journal of the Medical Library Association. 94(4):435-441.

Cardno EJ (2000) Managing the 'fit' of information and communication technology in community health: a framework for decision making. Journal of Telemedicine and Telecare. 6(Supplement 2):6-8.

Carroll AE, Saluja S, Tarczy-Hornoch P (2001) Development of a personal digital assistant (PDA) based client/server NICU patient data and charting system. AMIA Annual Symposium Proceedings. p.100-104.

Carroll AE, Saluja S, Tarczy-Hornoch P (2002) The implementation of a personal digital assistant (PDA) based patient record and charting system: lessons learned. AMIA Annual Symposium Proceedings. p.111-115.

Carroll AE, Tarczy-Hornoch P, O'Reilly E, Christakis DA (2003) Resident documentation discrepancies in a neonatal intensive care unit. Pediatrics. 111(5):976-980.

Carter JH (2008) What is the electronic health record? In: Carter JH (editor). Electronic Health Records: A Guide for Clinicians and Administrators. Second Edition. USA: American College of Physicians. p.3-20.

Chaiken BP (2007) Eyes wide open: buying clinical IT. Patient Safety and Quality Healthcare. Available from: http://www.docsnetwork.com/articles/BPC07161.pdf

Chaiken BP (2008) Clinician mobility demands seamless connectivity. Indiana Society for Healthcare Engineering Issues. Available from: http://www.isheweb.org/emails/ISHE-6.17.08.pdf

Chan SS, Chu CP, Cheng BC, Chen PP (2004) Data management using the personal digital assistant in an acute pain service. Anaesthesia and Intensive Care. 32(1):81-86.

Chang P, Hsu CL, Lan CF (2009) Is PDA good for complex documentation in healthcare? Studies in Health Technology and Informatics. 146:115-120.

Chantler C, Clarke T, Granger R (2006) Information technology in the English National Health Service. Journal of the American Medical Association. 296(18):2255-2258.

Chaudhry B, Wang J, Wu S, Maglione M, Mojica W, Roth E, Morton SC, Shekelle PG (2006) Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Annals of Internal Medicine. 144(10):742-752.

Chen Y (2010) Documenting transitional information in EMR. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. Atlanta, USA. ACM. p.1787-1796.

Cheng C, Goldstein M, Geller E, Levitt R (2003) The effects of CPOE on ICU workflow: an observational study. AMIA Annual Symposium Proceedings. p.150-154.

Clemmensen P, Sejersten M, Sillesen M, Hampton D, Wagner GS, Loumann-Nielsen S (2005) Diversion of ST-elevation myocardial infarction patients for primary angioplasty based on wireless prehospital 12-lead electrocardiographic transmission directly to the cardiologist's handheld computer: a progress report. Journal of Electrocardiology. 38(4 Supplement):194-198.

Coiera E, Tombs V (1998) Communication behaviours in a hospital setting: an observational study. British Medical Journal. 316(7132):673-676.

Cook DA, Sorensen KJ, Wilkinson JM, Berger RA (2013) Barriers and decisions when answering clinical questions at the point of care: A grounded theory study. JAMA Internal Medicine. 173(21):1962-1969.

Cornell P, Herrin-Griffith D, Keim C, Petschonek S, Sanders AM, D'Mello S, Golden TW, Shepherd G (2010) Transforming nursing workflow, part 1: the chaotic nature of nurse activities. Journal of Nursing Administration. 40(9):366-373.

Creamer GL, Dahl A, Perumal D, Tan G, Koea JB (2010) Anatomy of the ward round: the time spent in different activities. ANZ Journal of Surgery. 80(12):930-932.

Cresswell KM, Bates DW, Sheikh A (2013) Ten key considerations for the successful implementation and adoption of large-scale health information technology. Journal of the American Medical Informatics Association. 20(e1):e9-e13.

Creswell JW (1998) Qualitative inquiry and research design: choosing among five traditions. Thousand Oaks, California: Sage Publications.

Creswell JW, Plano-Clark VL (2007) Designing and conducting mixed methods research. Thousand Oaks, California: Sage Publications.

Creswell JW (2009) Research design: qualitative, quantitative, and mixed methods approaches. Third Edition. Thousand Oaks, California: Sage Publications.

Creswick N, Westbrook J, Braithwaite J (2009) Understanding communication networks in the emergency department. BMC Health Services Research. 9(1):247.

Creswick N, Callen J, Li J, Georgiou A, Isedale G, Robertson L, Paoloni R, Westbrook J (2010) What impact do emergency department information systems have on nurses' access to information? A qualitative analysis of nurses' use and perceptions of a fully integrated clinical information system. In: Hansen D, Schaper L, Rowlands D, (editors). Proceedings of the 18th Annual Health Informatics Conference: Informing the Business of Healthcare. Health Informatics Society of Australia. p.23-27.

Creswick N, Westbrook J (2010) Social network analysis of medication advice-seeking interactions among staff in an Australian hospital. International Journal of Medical Informatics. 79(6):e116-e125.

Creswick N, Hains IM, Westbrook J (2011) Innovation in intensive care nursing work practices with PACS. In: Moen A, Andersen SK, Aarts J, Hurlen P (editors). User Centred Networked Health Care. Proceedings of MIE 2011. Oslo, Norway. IOS Press. p.402-406.

Cummings A, Parker C, Kwapniowski L, Reynolds G (2008) Using mobility technology to improve pharmacist workflow in the PICU rounding process. The Journal of Healthcare Information Management. 22(4):39-43.

Dahl Y, Svanaes D, Nytro O (2006) Designing pervasive computing for hospitals: learning from the media affordances of paper-based medication charts. Pervasive Health Conference and Workshops. p.e1-e10.

Dale O, Hagen KB, Dale O, Hagen KB (2007) Despite technical problems personal digital assistants outperform pen and paper when collecting patient diary data. Journal of Clinical Epidemiology. 60(1):8-17.

Damberg CL, Ridgely MS, Shaw R, Meili RC, Sorbero MES, Bradley LA, Farley DO (2009) Adopting information technology to drive improvements in patient safety: lessons from the agency for healthcare research and quality health information technology grantees. Health Services Research. 44(2 Part2):684-700.

Davies K (2007) The information-seeking behaviour of doctors: a review of the evidence. Health Information and Libraries Journal. 24(2):78-94.

Davis DC (2008) Computer hardware and enabling technologies. In: Carter JH, (editor). Electronic Health Records: A Guide for Clinicians and Administrators. Second Edition. American College of Physicians. p.21-52.

Davis FD (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly. 13(3):319-340.

Davis FD (1993) User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. International Journal of Man-Machine Studies. 38(3):475-487.

Degeling P, Kennedy J, Hill M (2001) Mediating the cultural boundaries between medicine, nursing and management – the central challenge in hospital reform. Health Services Management Research. 14(1):36-48.

Denzin NK, Lincoln YS (2005) The discipline and practice of qualitative research. In: Denzin NK, Lincoln YS (editors). The Sage Handbook of Qualitative Research. Thousand Oaks, California: Sage Publications. p.1-32.

Department of Health (2013) £260 million invested in patient safety plans. Available from: https://www.gov.uk/government/news/260-million-invested-in-patient-safety-plans

Department of Health and Ageing (2012a) $50 million for Medicare locals to help rollout eHealth records. Available from: http://www.health.gov.au/internet/ministers/publishing.nsf/Content/mr-yr12-tp-tp047.htm

Department of Health and Ageing (2012b) Budget delivers certainty for eHealth system. Available from: http://www.health.gov.au/internet/ministers/publishing.nsf/Content/mr-yr12-tp-tp041.htm

Dishaw MT, Strong DM (1999) Extending the technology acceptance model with task–technology fit constructs. Information and Management. 36(1):9-21.

Duffy WJ, Kharasch MS, Du H (2010) Point of care documentation impact on the nurse-patient interaction. Nursing Administration Quarterly. 34(1):e1-e10.

Dykstra RH, Ash JS, Campbell E, Sittig DF, Guappone K, Carpenter J, Richardson J, Wright A, McMullen C (2009) Persistent paper: the myth of "going paperless". AMIA Annual Symposium Proceedings. p.158-162.

Embi PJ, Yackel TR, Logan JR, Bowen JL, Cooney TG, Gorman PN (2004) Impacts of computerized physician documentation in a teaching hospital: perceptions of faculty and resident physicians. Journal of the American Medical Informatics Association. 11(4):300-309.

Eslami S, Keizer NFd, Abu-Hanna A (2008) The impact of computerized physician medication order entry in hospitalized patients – a systematic review. International Journal of Medical Informatics. 77(6):365-376.

Favela J, Tentori M, Castrom LA, Gonzalez VM, Moran EB, Martinez-Garcia AI (2007) Activity recognition for context-aware hospital applications: issues and opportunities for the deployment of pervasive networks. Mobile Networks and Applications. 12(2-3):155-171.

Feilzer MY (2010) Doing mixed methods research pragmatically: implications for the rediscovery of pragmatism as a research paradigm. Journal of Mixed Methods Research. 4(1):6-16.

Feufel MA, Robinson FE, Shalin VL (2010) The impact of medical record technologies on collaboration in emergency medicine. International Journal of Medical Informatics. 80(8):e85-e95.

Fischer S, Stewart TE, Mehta S, Wax R, Lapinsky SE (2003) Handheld computing in medicine. Journal of the American Medical Informatics Association. 10(2):139-149.

Fisher J, Dawson L, Weeding S, Heslop L (2006) Implementing a mobile wireless environment in a hospital ward: encouraging adoption by nursing. 19th Bled eConference. p.e1-e10.

Fitzpatrick G (2000) Understanding the paper health record in practice: implications for EHRs. In: Pradhan M, Warren J, Chu S, Coiera E, Zelmer ACL (editors). HIC 2000: Proceedings. Health Informatics Society of Australia. p.323-331.

Fontaine BR, Speedie S, Abelson D, Wold C (2000) A work-sampling tool to measure the effect of electronic medical record implementation on health care workers. The Journal of Ambulatory Care Management. 23(1):71-85.

Fossey E, Harvey C, McDermott F, Davidson L (2002) Understanding and evaluating qualitative research. Australian and New Zealand Journal of Psychiatry. 36(6):717-732.

Free C, Phillips G, Watson L, Galli L, Felix L, Edwards P, Patel V, Haines A (2013) The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. PLoS Medicine. 10(1):e1001363.

Friedman C, Wyatt JC (1997) Subjectivist approaches to evaluations. In: Friedman C, Wyatt JC (editors). Evaluation Methods in Medical Informatics. New York, USA: Springer. p.205-222.

Fuchs C, Quinzio L, Benson M, Michel A, Rohrig R, Quinzio B, Hempelmann G (2006) Integration of a handheld based anaesthesia rounding system into an anaesthesia information management system. International Journal of Medical Informatics. 75(7):553-563.

Fuchter E, Herlihy R, Shalloo N (2008) Managing a state-wide eMR clinical transformation. In: Grain H (editor). HIC 2008. Australia's Health Informatics Conference. Health Informatics Society of Australia. p.e1-e6.

Gage NL (1989) The paradigm wars and their aftermath: a "historical" sketch of research on teaching since 1989. Educational Researcher. 18(7):4-10.

Gallego G, Fowler S, van Gool K (2008) Decision makers' perceptions of health technology decision making and priority setting at the institutional level. Australian Health Review. 32(3):520-527.

Gandsas A, McIntire K, Montgomery K, Bumgardner C, Rice L (2004) The personal digital assistant (PDA) as a tool for telementoring endoscopic procedures. Studies in Health Technology and Informatics. 98:99-103.

Garg AX, Adhikari NKJ, McDonald H, Rosas-Arellano P, Devereaux PJ, Beyene J, Sam J, Haynes RB (2005) Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. Journal of the American Medical Association. 293(10):1223-1238.

Garritty C, El Emam K (2006) Who's using PDAs? Estimates of PDA use by health care providers: a systematic review of surveys. Journal of Medical Internet Research. 8(2):e7.

Garwood J (2006) Structured observation. In: Jupp V (editor). The SAGE Dictionary of Social Research Methods. London: Sage Publications. p.292-293.

Glaser B, Strauss A (1967) Theoretical sensitivity. Mill Valley, California: Sociology Press.

Goodhue DL, Thompson RL (1995) Task-technology fit and individual performance. MIS Quarterly. 19(2):213-236.

Goodhue DL (1998) Development and measurement validity of a task-technology fit instrument for user evaluations of information system. Decision Sciences. 29(1):105-138.

Gosling AS, Westbrook JI, Coiera EW (2003) Variation in the use of online clinical evidence: a qualitative analysis. International Journal of Medical Informatics. 69(1):1-16.

Grasso BC, Genest R (2001) Use of a personal digital assistant in reducing medication error rates. Psychiatric Services. 52(7):883-886.

Grasso BC, Genest R, Yung K, Arnold C (2002) Reducing errors in discharge medication lists by using personal digital assistants. Psychiatric Services. 53(10):1325-1326.

Greene JC, Caracelli VJ (1997) Defining and describing the paradigm issue in mixed-method evaluation. New Directions for Evaluation. 1997(74):5-17.

Greenhalgh T (1997) How to read a paper: papers that summarise other papers (systematic reviews and meta-analyses). British Medical Journal. 315(7109):672-675.

Guba EG, Lincoln YS (1994) Competing paradigms in qualitative research. In: Denzin NK, Lincoln YS (editors). Handbook of Qualitative Research. Thousand Oaks, California: Sage Publications. p.105-117.

Gurses AP, Xiao Y (2006) A systematic review of the literature on multidisciplinary rounds to design information technology. Journal of the American Medical Informatics Association. 13(3):267-276.

Hamid NBA, Selvaraju DS, Din SHM, Kola T (2010) Mobile clinical assistant in hospital information system (HIS) environment: are we ready? In: Safran C, Marin H, Reti S (editors). Medinfo 2010. Proceedings of the Thirteenth World Congress on Medical and Health Informatics. Cape Town, South Africa. IOS Press: Amsterdam. p.1456.

Han YY, Carcillo JA, Venkataraman ST, Clark RSB, Watson RS, Nguyen TC, Bayir H, Orr RA (2005) Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system. Pediatrics. 116(6):1506-1512.

Handel DA, Hackman JL (2010) Implementing electronic health records in the emergency department. The Journal of Emergency Medicine. 38(2):257-263.

Handel DA, Wears RL, Nathanson LA, Pines JM (2011) Using information technology to improve the quality and safety of emergency care. Academic Emergency Medicine. 18(6):e45-e51.

Hannah K, Ball M, Edwards M (2006) Introduction to nursing informatics. New York: Springer.

Hannan T (1991) Medical informatics – an Australian perspective. Australian and New Zealand Journal of Medicine. 21(3):363-378.

Harkke V (2006) Impacts of physicians usage of a mobile information system. International Journal of Electronic Healthcare. 2(4):345-361.

Harrison MI, Koppel R, Bar-Lev S (2007) Unintended consequences of information technologies in health care – an interactive sociotechnical analysis. Journal of the American Medical Informatics Association. 14(5):542-549.

Health Informatics Society of Australia (2008) Scope and definitions. Available from: http://www.hisa.org.au/allied_scope

Health Information and Management Systems Society (2012) 2nd Annual HIMSS Mobile Technology Survey. Available from: http://www.himss.org/files/himssorg/content/files/FINALwithCOVER.pdf

Hendrich A, Chow MP, Skierczynski BA, Lu Z (2008) A 36-hospital time and motion study: how do medical-surgical nurses spend their time? The Permanente Journal. 12(3):25-34.

Hersh W (2009) Information retrieval: a health and biomedical perspective. Third Edition. New York: Springer.

Hewson C (2006) Mixed methods research. In: Jupp V (editor). The SAGE Dictionary of Social Research Methods. London: Sage Publications. p.179-181.

Hoepfl MC (1997) Choosing qualitative research: a primer for technology education researchers. Journal of Technology Education. 9(1):47-63.

Holden RJ, Karsh BT (2010) The technology acceptance model: its past and its future in health care. Journal of Biomedical Informatics. 43(1):159-172.

Holloway I (1997) Basic concepts for qualitative research. Oxford, UK: Blackwell Science.

Honekamp W, Ostermann H (2011) Evaluation of a prototype health information system using the FITT framework. Informatics in Primary Care. 19(1):47-49.

Horng S, Goss FR, Chen RS, Nathanson LA (2012) Prospective pilot study of a tablet computer in an emergency department. International Journal of Medical Informatics. 81(5):314-319.

Ilie V, Courtney JF, Van Slyke C (2007) Paper versus electronic: challenges associated with physicians' usage of electronic medical records. Proceedings of the 40th Annual Hawaii International Conference on System Sciences. IEEE Computer Society. p.142.

Institute of Medicine (2012) Health IT and patient safety: building a safer system for better care. Washington, DC: The National Academies Press.

Johnson RB, Onwuegbuzie AJ (2004) Mixed methods of research: a research paradigms whose time has come. Educational Researcher. 33(7):14-26.

Johnson RB, Onwuegbuzie AJ, Turner LA (2007) Toward a definition of mixed methods research. Journal of Mixed Methods Research. 1(2):112-133.

Junglas I, Abraham C, Ives B (2009) Mobile technology at the frontlines of patient care: Understanding fit and human drives in utilization decisions and performance. Decision Support Systems. 46(3):634-647.

Kaplan A (1964) The conduct of inquiry. New York: Harper and Row.

Kaplan B (1995) The computer prescription: medical computing, public policy, and views of history. Science, Technology, and Human Values. 20(1):5-38.

Kaplan B, Maxwell J (2005) Qualitative research methods for evaluating computer information systems. In: Anderson J, Aydin C (editors). Evaluating the organizational impact of healthcare information systems. New York, USA: Springer. p.30-55.

Kaplan B, Harris-Salamone KD (2009) Health IT success and failure: recommendations from literature and an AMIA Workshop. Journal of the American Medical Informatics Association. 16(3):291-299.

Kawamoto K, Houlihan CA, Balas EA, Lobach DF (2005) Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. British Medical Journal. 330(7494):765-768.

Kermode S, Roberts K (2006) Chapter 9: quantitative data collection and management. In: Taylor B, Kermode S, Roberts K (editors). Research in nursing and health care: evidence for practice. Third Edition. South Melbourne, Victoria: Thomson. p.244-267.

Kho A, Henderson LE, Dressler DD, Kripalani S (2006) Use of handheld computers in medical education: a systematic review. Journal of General Internal Medicine. 21(5):531-537.

Kitto SC, Chesters J, Grbich C (2008) Quality in qualitative research: criteria for authors and assessors in the submission and assessment of qualitative research articles for the Medical Journal of Australia. Medical Journal of Australia. 188(4):243-246.

Klasnja P, Pratt W (2012) Healthcare in the pocket: mapping the space of mobile-phone health interventions. Journal of Biomedical Informatics. 45(1):184-198.

Kleinke JD (2005) Dot-gov: market failure and the creation of a national health information technology system. Health Affairs. 24(5):1246-1262.

Knudsen P, Herborg H, Mortensen AR, Knudsen M, Hellebek A (2007) Preventing medication errors in community pharmacy: root-cause analysis of transcription errors. Quality and Safety in Health Care. 16(4):285-290.

Koppel R, Metlay JP, Cohen A, Abaluck B, Localio AR, Kimmel SE, Strom BL (2005) Role of computerized physician order entry systems in facilitating medication errors. Journal of the American Medical Association. 293(10):1197-1203.

Koppel R, Wetterneck T, Telles JL, Karsh BT (2008) Workarounds to barcode medication administration systems: their occurrences, causes, and threats to patient safety. Journal of the American Medical Informatics Association. 15(4):408-423.

Kossman SP (2006) Perceptions of impact of electronic health records on nurses' work. In: Park HA, Murray P, Delaney C (editors). Consumer-Centered Computer-Supported Care for Healthy People. IOS Press. p.337-341.

Kossman SP, Scheidenhelm SL (2008) Nurses' perceptions of the impact of electronic health records on work and patient outcomes. Computers, Informatics, Nursing. 26(2):69-77.

Kripalani S, Jackson AT, Schnipper JL, Coleman EA (2007) Promoting effective transitions of care at hospital discharge: a review of key issues for hospitalists. Journal of Hospital Medicine. 2(5):314-323.

Kuhn K, Giuse D (2001) From hospital information systems to health information systems: problems, challenges, perspectives. Methods of Information in Medicine. 40(4):275-287.

Kuhn TS (1962) The structure of scientific revolutions. Chicago: University of Chicago Press.

Kuhn TS (1970) The structure of scientific revolutions. Second Edition. Chicago: University of Chicago Press.

Kukafka R, Johnson SB, Linfante A, Allegrante JP (2003) Grounding a new information technology implementation framework in behavioral science: a systematic analysis of the literature on IT use. Journal of Biomedical Informatics. 36(3):218-227.

Kuper A, Lingard L, Levinson W (2008) Critically appraising qualitative research: six key questions will help readers to assess qualitative research. British Medical Journal. 337(7671):687-689.

Kushniruk A, Borycki E, Kuwata S, Kannry J (2006) Predicting changes in workflow resulting from healthcare information systems: ensuring the safety of healthcare. Healthcare Quarterly. 9(Special Issue):114-118.

Kushniruk A, Beuscart-Zéphir M-C, Grzes A, Borycki E, Watbled L, Kannry J (2010) Increasing the safety of healthcare information systems through improved procurement: toward a framework for selection of safe healthcare systems. Healthcare Quarterly. 13(Special Issue):53-58.

Kushniruk AW, Borycki EM, Myers K, Kannry J (2009) Selecting electronic health record systems: development of a framework for testing candidate systems. Studies in Health Technology and Informatics. 143:376-379.

Kuziemsky CE, Laul F, Leung RC (2005) A review on diffusion of personal digital assistants in healthcare. Journal of Medical Systems. 29(4):335-342.

Kwankam SY (2004) What eHealth can offer. Bulletin of the World Health Organization. 82(10):800-802.

Lærum H, Ellingsen G, Faxvaag A (2001) Doctors' use of electronic medical records systems in hospitals: cross sectional survey. BMJ. 323(7325):1344-1348.

Lærum H, Karlsen TH, Faxvaag A (2004) Use of and attitudes to a hospital information system by medical secretaries, nurses and physicians deprived of the paper-based medical record: a case report. BMC Medical Informatics and Decision Making. 4(18):e1-e10.

Lau F, Yang J, Pereira J, Daeninck P, Aherne M (2006) A survey of PDA use by palliative medicine practitioners. Journal of Palliative Care. 22(4):267-274.

Leape LL (1997) A systems analysis approach to medical error. Journal of Evaluation in Clinical Practice. 3(3):213-222.

Leontjev A (1978) Activity, consciousness, and personality. Englewood Cliff, New Jersey: Prentice-Hall.

Leontjev A (1981) Problems of the development of mind. Moscow: Progress Publishers.

Lepanto L, Sicotte C, Lehoux P (2011) Assessing task–technology fit in a PACS upgrade: do users' and developers' appraisals converge? Journal of Digital Imaging. 24(6):951-958.

Lewis PJ, Tully MP (2009) Uncomfortable prescribing decisions in hospitals: the impact of teamwork. Journal of the Royal Society of Medicine. 102(11):481-488.

Lincoln YS, Guba EG (1985) Naturalistic inquiry. London, UK: Sage Publications.

Linder JA, Schnipper JL, Tsurikova R, Melnikas AJ, Volk LA, Middleton B (2006) Barriers to electronic health record use during patient visits. AMIA Annual Symposium Proceedings. p.499-503.

Lindquist MA, Johansson EP, Petersson IG, Saveman BI, Nilsson CG (2008) The use of the personal digital assistant (PDA) among personnel and students in health care: a review. Journal of Medical Internet Research. 10(4):e31.

Littlejohns P, Wyatt JC, Garvican L (2003) Evaluating computerised health information systems: hard lessons still to be learnt. British Medical Journal. 326(7394):860-863.

Lorenzi N, Kouroubali A, Detmer D, Bloomrosen M (2009) How to successfully select and implement electronic health records (EHR) in small ambulatory practice settings. BMC Medical Informatics and Decision Making. 9(1):15.

Lu YC, Lee JK, Xiao Y, Sears A, Jacko JA, Charters K (2003) Why don't physicians use their personal digital assistants? AMIA Annual Symposium Proceedings. p.405-404.

Lu YC, Xiao Y, Sears A, Jacko JA (2005) A review and a framework of handheld computer adoption in healthcare. International Journal of Medical Informatics. 74(5):409-422.

Luff P, Heath C, Greatbatch D (1992) Tasks-in-interaction: paper and screen based documentation in collaborative activity. Proceedings of the 1992 ACM Conference on Computer Supported Cooperative Work. Ontario, Canada. p.163-170.

Luff P, Heath C (1998) Mobility in collaboration. Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work. Seattle, Washington. p.305-314.

Lunin LF, Hersh WR (1995) Introduction and overview. Journal of the American Society for Information Science. 46(10):725-728.

Martinez F (2012) Developing a full-cycle mHealth strategy. Frontiers of Health Services Management. 29(2):11-20.

Martins HMG, Jones MR (2004) Implementing mobile computing to support service delivery at the point of care: review of issues involved. Current Perspectives in Healthcare Computing. 196-202.

Martins HMG, Jones MR (2005a) What's so different about mobile information communication technologies (MICTs) for clinical work practices? A review of selected pilot studies. Health Informatics Journal. 11(2):123-134.

Martins HMG, Jones MR (2005b) Mobility in the round: use of wireless laptop PCs in clinical rounds. In: Sorensen C, Yoo Y, Lyytinen K, DeGross JI (editors). Designing Ubiquitous Information Environments: Socio-Technical Issues and Challenges. IFIP TC8 WG 82 International Working Conference. Cleveland, Ohio. Springer. p.93-108.

Martins HMG, Nightingale P, Jones MR (2005) Temporal and spatial organization of doctors' computer usage in a UK hospital department. Medical Informatics and the Internet in Medicine. 30(2):135-142.

Mays N, Pope C (2000) Qualitative research in health care: assessing quality in qualitative research. British Medical Journal. 320(7226):50-52.

McAlearney AS, Schweikhart SB, Medow MA (2004) Doctors' experience with handheld computers in clinical practice: qualitative study. BMJ. 328(7449):1162-1166.

McCord G, Smucker WD, Selius BA, Hannan S, Davidson E, Schrop SL, Rao V, Albrecht P (2007) Answering questions at the point of care: do residents practice EBM or manage information sources? Academic Medicine. 82(3):298-303.

Mejia DA, Moran AL, Favela J (2007) Supporting informal co-located collaboration in hospital work. Proceedings of the 13th International Conference on Groupware: Design Implementation, and Use. Bariloche, Argentina. Springer. p.255-270.

Merton RK (1967) On theoretical sociology. New York: Free Press.

Milian M (2010) Screen size: for smartphone buyers, size may not matter. Available from: http://articles.cnn.com/2010-12-09/tech/screen.sizes_1_smartphones-htc-s-evo-4g-screen?_s=PM:TECH

Mooney BL, Boyle AM (2011) 10 steps to successful EHR implementation. Medical Economics. 88(9):S4-S11.

Moran EB, Tentori M, Gonzalez VM, Favela J, Martinez-Garcia AI (2006) Mobility in hospital work: towards a pervasive computing hospital environment. International Journal of Electronic Healthcare. 3(1):72-89.

Morgan DL (2007) Paradigms lost and pragmatism regained: methodological implications of combining qualitative and quantitative methods. Journal of Mixed Methods Research. 1(1):48-76.

Morrison C, Fitzpatrick G, Blackwell A (2011) Multi-disciplinary collaboration during ward rounds: embodied aspects of electronic medical record usage. International Journal of Medical Informatics. 80(8):e96-e111.

Mosa AS, Yoo I, Sheets L (2012) A systematic review of healthcare applications for smartphones. BMC Medical Informatics and Decision Making. 12(1):67.

Moustakas C (1994) Phenomenological research methods. Thousand Oaks, California: Sage Publications.

Mulhall A (2003) In the field: notes on observation in qualitative research. Journal of Advanced Nursing. 41(3):306-313.

Murphy J (2008) Promises and problems: mobility and electronic health records. Journal of Healthcare Information Management. 22(4):8-9.

Nagle LM (2008) Considering the human factor. Nursing Leadership. 21(2):34-37.

Neilsen J (1993) Usability engineering. San Diego, California: Academic Press.

Newcombe RG (1998) Interval estimation for the difference between independent proportions: comparison of eleven methods. Statistics in Medicine. 17:873-890.

Newton CA, Smiley D, Bode BW, Kitabchi AE, Davidson PC, Jacobs S, Steed RD, Stentz F, Peng L, Mulligan P, Freire AX, Temponi A, Umpierrez GE (2010) A comparison study of continuous insulin infusion protocols in the medical intensive care unit: computer-guided vs. standard column-based algorithms. Journal of Hospital Medicine. 5(8):432-437.

NHMRC (2007) National statement on ethical conduct in human research. Canberra: Australian Government. Available from: http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf

NHS England (2013) Safer hospitals, safer wards: achieving an integrated digital care record. Available from: http://www.england.nhs.uk/wpcontent/uploads/2013/07/safer-hosp-safer-wards.pdf

Niazkhani Z, Pirnejad H, Berg M, Aarts J (2009) The impact of computerized provider order entry systems on inpatient clinical workflow: a literature review. Journal of the American Medical Informatics Association. 16(4):539-549.

Novak LL, Anders S, Gadd CS, Lorenzi NM (2012) Mediation of adoption and use: a key strategy for mitigating unintended consequences of health IT implementation. Journal of the American Medical Informatics Association. 19(6):1043-1049.

NSW Department of Health (2005) Corporate governance and accountability compendium for NSW Health. North Sydney, NSW: NSW Department of Health.

NSW Department of Health (2010a) NSW Department of Health annual report 2009-10. North Sydney, NSW: NSW Department of Health.

NSW Department of Health (2010b) Technology standards: standard technology product acquisition guide. North Sydney, NSW: NSW Department of Health.

NSW Department of Health (2011a) Future arrangements for governance of NSW Health: report of the director-general. North Sydney, NSW: NSW Department of Health.

NSW Department of Health (2011b) About the eMR. Available from: http://www.emr.health.nsw.gov/about-the-emr

NSW Department of Health (2011c) Frequently asked questions on eMR. Available from: http://www.emr.health.nsw.gov/_documents/faqs/emr_faq.pdf

NSW Health Support Services (2012) About CIAP. Available from: http://www.ciap.health.nsw.gov.au/aboutciap/index.html

NSW Procurement (2011) Contract ITS 2007: personal computers, notebook computers and associated services for whole of NSW Government. Sydney, NSW: NSW Government.

Oder K, Nauseda S, E C, Llewellyn J, Brown F, Catrambone C, Fogg L, Garcia B (2010) How to select end user clinical data entry devices: Rush University Medical Center develops tool to identify the quantity of devices needed for the implementation of a new EMR and CPOE system. Journal of Healthcare Information Management. 24(3):65-69.

OECD (2010) OECD information technology outlook 2010. OECD Publishing. Available from: http://www.oecd.org/internet/ieconomy/oecdinformationtechnologyoutlook2010.htm

Orwat C, Graefe A, Faulwasser T (2008) Towards pervasive computing in health care: a literature review. BMC Medical Informatics and Decision Making. 8(1):26.

Ozdalga E, Ozdalga A, Ahuja N (2012) The smartphone in medicine: a review of current and potential use among physicians and students. Journal of Medical Internet Research. 14(5):e128.

Park J, Tymitz K, Engel A, Welling RE (2007) Computerized rounding in a community hospital surgery residency program. Journal of Surgical Education. 64(6):357-360.

Patton MQ (1982) Practical evaluation. Beverly Hills, California: Sage Publications.

Patton MQ (1990) Qualitative evaluation and research methods. Second Edition. Beverly Hills, California: Sage Publications.

Pawson R, Greenhalgh T, Harvey G, Walshe K (2005) Realist review – a new method of systematic review designed for complex policy interventions. Journal of Health Services Research Policy. 10(Supplement 1):21-34.

Payne KFB, Wharrad H, Watts K (2012) Smartphone and medical related app use among medical students and junior doctors in the United Kingdom (UK): a regional survey. BMC Medical Informatics and Decision Making. 12(1):121.

Peute LW, Aarts J, Bakker PJM, Jaspers MWM (2010) Anatomy of a failure: a sociotechnical evaluation of a laboratory physician order entry system implementation. International Journal of Medical Informatics. 79(4):e58-e70.

Pham JC, Story JL, Hicks RW, Shore AD, Morlock LL, Cheung DS, Kelen GD, Pronovost PJ (2011) National study on the frequency, types, causes, and consequences of voluntarily reported emergency department medication errors. Journal of Emergency Medicine. 40(5):485-492.

Polgar S, Thomas SA (2000) Introduction to research in the health sciences. Fourth Edition. Sydney, Australia: Elsevier.

Poon EG, Cina JL, Churchill W, Patel N, Featherstone E, Rothschild JM, Keohane CA, Whittemore AD, Bates DW, Gandhi TK (2006) Medication dispensing errors and potential adverse drug events before and after implementing bar code technology in the pharmacy. Annals of Internal Medicine. 145(6):426-434.

Pope C, Mays N (1995) Reaching the parts other methods cannot reach: an introduction to qualitative methods in health and health services research. British Medical Journal. 311(6996):42-45.

Pope C, van Royen P, Baker R (2002) Qualitative methods in research on healthcare quality. Quality and Safety in Health Care. 11(2):148-152.

Reddy MC, McDonald DW, Pratt W, Shabot MM (2005) Technology, work, and information flows: Lessons from the implementation of a wireless alert pager system. Journal of Biomedical Informatics. 38(3):229-238.

Redwood S, Rajakumar A, Hodson J, Coleman J (2011) Does the implementation of an electronic prescribing system create unintended medication errors? A study of the sociotechnical context through the analysis of reported medication incidents. BMC Medical Informatics and Decision Making. 11(1):29.

Rescorl DJ (2006) Emergency department: computerized provider order entry. Nurse Leader. 4(2):34-38.

Rodriguez NJ, Borges JA, Soler Y, Murillo V, Colon-Rivera CR, Sands DZ, Bourie T (2003) PDA vs. laptop: a comparison of two versions of a nursing documentation application. Proceedings of the 16th IEEE Symposium on Computer-Based Medical Systems. p.201-206.

Ross S, Hamilton L, Ryan C, Bond C (2012) Who makes prescribing decisions in hospital inpatients? An observational study. Postgraduate Medical Journal. 88(1043):507-510.

Rothschild JM, Lee TH, Bae T, Bates DW (2002) Clinician use of palmtop drug reference guide. Journal of the American Medical Informatics Association. 9(3):223-229.

Rudkin SE, Langdorf MI, Macias D, Oman JA, Kazzi AA (2006) Personal digital assistants change management more often than paper texts and foster patient confidence. European Journal of Emergency Medicine. 13(2):92-96.

Russ AL, Zillich AJ, McManus MS, Doebbeling BN, Saleem JJ (2009) A human factors investigation of medication alerts: barriers to prescriber decision-making and clinical workflow. AMIA Annual Symposium Proceedings. p.548-552.

Sackett D, Straus S (1998) Finding and applying evidence during clinical rounds: the "evidence cart". The Journal of the American Medical Association. 280(15):1336-1338.

Schnall R, Smith AB, Sikka M, Gordon P, Camhi E, Kanter T, Bakken S (2012) Employing the FITT framework to explore HIV case managers' perceptions of two electronic clinical data (ECD) summary systems. International Journal of Medical Informatics. 81(10):e56-e62.

Sellen AJ, Harper RHR (2002) The myth of the paperless office. Cambridge, Massachusetts: MIT Press.

Senior T (2006) Paper to EMR: A successful transition. Health Management Technology. 27(10):40-45.

Shachak A, Reis S (2009) The impact of electronic medical records on patient–doctor communication during consultation: a narrative literature review. Journal of Evaluation in Clinical Practice. 15(4):641-649.

Shannon T, Feied C, Smith M, Handler J, Gillam M (2006) Wireless handheld computers and voluntary utilization of computerized prescribing systems in the emergency department. Journal of Emergency Medicine. 31(3):309-315.

Sheehan B, Lee Y, Rodriguez M, Tiase V, Schnall R (2012) A comparison of usability factors of four mobile devices for accessing healthcare information by adolescents. Applied Clinical Informatics. 3(4):356-366.

Sheikh A, McLean S, Cresswell K, Pagliari C, Pappas Y, Car J, Black A, Hemmi A, Nurmatov U, Mukherjee M, McKinstry B, Procter R, Majeed A (2011) The impact of ehealth on the quality and safety of healthcare: an updated systematic overview and synthesis of the literature. Imperial College London/University of Edinburgh. Report No.: NHS CFHEP 001. Available from: http://www.birmingham.ac.uk/Documents/college-mds/haps/projects/cfhep/projects/001Extension/CFHEP001FinalReport-March2011.pdf

Shekelle P, Morton S, Keeler E (2006) Cost and benefits of health information technology. Evidence report/technology assessment no.132. Rockville, MD: Agency for Healthcare Research and Quality. Report No.: AHRQ Publication No. 06-E006. Available from: http://www.ahrq.gov/research/findings/evidence-based-reports/hitsys-evidence-report.pdf

Shekelle PG, Goldzweig CL (2009) Cost and benefits of health information technology: an updated systematic review. London: The Health Foundation. Available from: http://www.health.org.uk/public/cms/75/76/313/564/Costs%20and%20benefits%20of%20health%20information%20technology.pdf?realName=urByVX.pdf

Shortliffe EH (2005) Strategic action in health information technology: why the obvious has taken so long. Health Affairs. 24(5):1222-1233.

Shu K, Boyle D, Spurr C, Horsky J, Heiman H, O'Connor P, Lepore J, Bates DW (2001) Comparison of time spent writing orders on paper with computerized physician order entry. Studies in Health Technology and Informatics. 84(Part 2):1207-1211.

Sidorov J (2006) It ain't necessarily so: the electronic health record and the unlikely prospect of reducing health care costs. Health Affairs. 25(4):1079-1085.

Singer E (2009) A digital health-care revolution: twenty billion dollars might finally turn the U.S. health-care system digital. Available from: http://www.technologyreview.com/news/411795/a-digital-health-care-revolution/

Sintchenko V, Iredell JR, Gilbert GL, Coiera E (2005) Handheld computer-based decision support reduces patient length of stay and antibiotic prescribing in critical care. Journal of the American Medical Informatics Association. 12(4):398-402.

Sittig DF, Jimison HB, Hazlehurst BL, Churchill BE, Lyman JA, Mailhot MF, Quick EA, Simpson DA (2000) Techniques for identifying the applicability of new information management technologies in the clinical setting: an example focusing on handheld computers. AMIA Annual Symposium Proceedings. p.804-808.

Sittig DF, Hazlehurst BL, Palen T, Hsu J, Jimison H, Hornbrook MC (2002) A clinical information system research landscape. The Permanente Journal. 6(2):62-68.

Smith R (1996) What clinical information do doctors need? BMJ. 313(7064):1062-1068.

Sofaer S (1999) Qualitative methods: what are they and why use them? Health Services Research. 34(5):1102-1118.

Sorby ID, Melby L, Dahl Y, Seland G, Toussaint P, Nytrø Ø, Faxvaag A (2010) The MOBEL project: experiences from applying user-centered methods for designing mobile ICT for hospitals. In: Khoumbati K, Dwivedi YK, Srivastava A, Lal B (editors). Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies. IGI Global. p 52-73.

Stengel D, Bauwens K, Walter M, Kopfer T, Ekkernkamp A (2004) Comparison of handheld computer-assisted and conventional paper chart documentation of medical records: a randomized controlled trial. Journal of Bone and Joint Surgery (American). 86(3):553-560.

Stoop A, Berg M (2003) Integrating quantitative and qualitative methods in patient care information system evaluation: guidance for the organizational decision maker. Methods of Information in Medicine. 42(4):458-462.

Strauss A, Corbin J (1990) Basics of qualitative research: grounded theory procedures and techniques. Newbury Park, California: Sage Publications.

Strickland J (2009) What's the difference between notebooks, netbooks, and ultra-mobile PCs? Available from: http://computer.howstuffworks.com/notebook-vs-netbook-vs-ultra-mobile-pc.htm

Sutton R, Staw B (1995) What theory is not. Administrative Science Quarterly. 40(3):371-384.

Svanæs D, Alsos OA, Dahl Y (2010) Usability testing of mobile ICT for clinical settings: Methodological and practical challenges. International Journal of Medical Informatics. 79(4):e24-e34.

Tang C, Carpendale S (2008) Evaluating the deployment of a mobile technology in a hospital ward. Proceedings of the 2008 Conference on Computer Supported Cooperative Work. San Diego, California. ACM. p.205-214.

Taylor P (2006) From patient data to medical knowledge: the principles and practice of health informatics. Oxford, UK: Blackwell Publishing.

Teddlie C, Tashakkori A (2003) Major issues and controversies in the use of mixed methods in the social and behavioral sciences In: Tashakkori A, Teddlie C (editors). Handbook of Mixed Methods in Social and Behavioral Research. Thousand Oaks, California: Sage Publications. p.3-50.

Teddlie C, Tashakkori A (2009) Foundations of mixed methods research: integrating quantitative and qualitative approaches in the social and behavioral sciences. Thousand Oaks, California: Sage Publications.

Thomas DR (2006) A general inductive approach for analyzing qualitative evaluation data. American Journal of Evaluation. 27(2):237-246.

Thomas S, Overhage J, Warvel J, McDonald C (2001) A comparison of a printed patient summary document with its electronic equivalent: early results. AMIA Annual Symposium Proceedings. p.701-705.

Thrope R (2008) Field notes. In: Thorpe R, Holt R (editors). The SAGE Dictionary of Qualitative Management Research. London: Sage Publications. p.97-99.

Tierney WM, Miller ME, Overhage J, McDonald CJ (1993) Physician inpatient order writing on microcomputer workstations: effects on resource utilization. Journal of the American Medical Association. 269(3):379-383.

Tong A, Sainsbury P, Craig J (2007) Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. International Journal for Quality in Health Care. 19(6):349-357.

Tsiknakis M, Kouroubali A (2009) Organizational factors affecting successful adoption of innovative eHealth services: a case study employing the FITT framework. International Journal of Medical Informatics. 78(1):39-52.

van Manen M (1990) Researching lived experience: human science for an action sensitive pedagogy. London, Ontario: Althouse Press.

van Rosse F, Maat B, Rademaker CMA, van Vught AJ, Egberts ACG, Bollen CW (2009) The effect of computerized physician order entry on medication prescription errors and clinical outcome in pediatric and intensive care: a systematic review. Pediatrics. 123(4):1184-1190.

van Teijlingen E, Forrest K (2004) The range of qualitative research methods in family planning and reproductive health care. Journal of Family Planning and Reproductive Health Care. 30(3):171-173.

VanDenKerkhof EG, Goldstein DH, Lane J, Rimmer MJ, Van Dijk JP (2003) Using a personal digital assistant enhances gathering of patient data on an acute pain management service: a pilot study. Canadian Journal of Anaesthesia. 50(4):368-375.

Visvanathan A, Gibb AP, Brady RR (2011) Increasing clinical presence of mobile communication technology: avoiding the pitfalls. Telemedicine Journal and eHealth. 17(8):656-661.

Vygotskij LS (1978) Mind and society. Cambridge, Massachusetts: Harvard University Press.

Wachter RM (2006) Expected and unanticipated consequences of the quality and information technology revolutions. Journal of the American Medical Association. 295(23):2780-2783.

Wager KA, Schaffner MJ, Foulois B, Swanson Kazley A, Parker C, Walo H (2010) Comparison of the quality and timeliness of vital signs data using three different data-entry devices. Computers Informatics Nursing. 28(4):205-212.

Wagner J, Moore DL (2011) Pilot testing of mobile tablet computers in multiple departments in a hospital setting. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 55(1):818-822.

Wallen NE, Fraenkel JR (2001) Educational research: a guide to the process. Mahwah, New Jersey: Lawrence Erlbaum Associates Publishers.

Wears Rl, Berg M (2005) Computer technology and clinical work: still waiting for godot. Journal of the American Medical Association. 293(10):1261-1263.

Weathers AL, Esper GJ (2013) How to select and implement an electronic health record in a neurology practice. Neurology Clinical Practice. 3(2):141-148.

Weigl M, Muller A, Zupanc A, Angerer P (2009) Participant observation of time allocation, direct patient contact and simultaneous activities in hospital physicians. BMC Health Services Research. 9(1):110.

Weiner BJ, Savitz LA, Bernard S, Pucci LG (2004) How do integrated delivery systems adopt and implement clinical information systems? Health Care Management Review. 29(1):51-66.

West DM (2012) How mobile devices are transforming healthcare. Issues in technology innovation. Washington DC: The Brookings Institution.

Westbrook J, Ampt A (2009) Design, application and testing of the Work Observation Method by Activity Timing (WOMBAT) to measure clinicians' patterns of work and communication. International Journal of Medical Informatics. 78(Supplement 1):S25-S33.

Westbrook J, Ampt A, Kearney L, Rob MI (2008) All in a day's work: an observational study to quantify how and with whom doctors on hospital wards spend their time. The Medical Journal of Australia. 188(9):506-509.

Westbrook J, Ampt A, Williamson M, Nguyen K, Kearney L (2007) Methods for measuring the impact of health information technologies on clinicians' patterns of work and communication. In: Kuhn K, Warren J, Leong T (editors). Medinfo 2007. Proceedings of the Twelfth World Congress on Health (Medical) Informatics. Brisbane, Australia. IOS Press. p.1083-1087.

Westbrook J, Duffield C, Li L, Creswick N (2011) How much time do nurses have for patients? a longitudinal study quantifying hospital nurses' patterns of task time distribution and interactions with health professionals. BMC Health Services Research. 11(1):319.

Westbrook J, Gosling AS, Westbrook MT (2005) Use of point-of-care online clinical evidence by junior and senior doctors in New South Wales public hospitals. Internal Medicine Journal. 35(7):399-404.

Westbrook J, Li L, Georgiou A, Paoloni R, Callen J (2013) Impact of an electronic medication management system on hospital doctors' and nurses' work: a controlled pre-post, time and motion study. Journal of the American Medical Informatics Association. 12(5):505-516.

Wilton R, Pennisi AJ (1994) Evaluating the accuracy of transcribed computer-stored immunization data. Pediatrics. 94(6):902-906.

Wolf LD, Potter P, Sledge JA, Boxerman SB, et al. (2006) Describing nurses' work: combining quantitative and qualitative analysis. Human Factors. 48(1):5-14.

Zhan C, Hicks RW, Blanchette CM, Keyes MA, Cousins DD (2006) Potential benefits and problems with computerized prescriber order entry: Analysis of a voluntary medication error-reporting database. American Journal of Health-System Pharmacy. 63(4):353-358.

APPENDICES

Appendix A. Refereed Publications Arising from the Research

Appendix A.1. Refereed Journal Article

Prgomet M, Georgiou A, Westbrook J (2009) The impact of mobile handheld technology on hospital physicians' work practices and patient care: a systematic review. Journal of the American Medical Informatics Association. 16(6): 792-801.

Appendix A.2. Refereed Conference Poster

Prgomet M, Callen J, Westbrook J (2010) Selecting clinical computing hardware devices for hospital wards: the role of IT vendors. In: Safran C, Marin H, Reti S (editors). Medinfo 2010. Proceedings of the Thirteenth World Congress on Medical and Health Informatics. Cape Town, South Africa. IOS Press: Amsterdam. p.1551.

Review Paper ■

The Impact of Mobile Handheld Technology on Hospital Physicians' Work Practices and Patient Care: A Systematic Review

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Abstract The substantial growth in mobile handheld technologies has heralded the opportunity to provide physicians with access to information, resources, and people at the right time and place. But is this technology delivering the benefits to workflow and patient care promised by increased mobility? The authors conducted a systematic review to examine evidence regarding the impact of mobile handheld technology on hospital physicians' work practices and patient care, focusing on quantification of the espoused virtues of mobile technologies. The authors identified thirteen studies that demonstrated the ability of personal digital assistants (PDAs) to positively impact on areas of rapid response, error prevention, and data management and accessibility. The use of PDAs demonstrates the greatest benefits in contexts where time is a critical factor and a rapid response crucial. However, the extent to which these devices improved outcomes and workflow efficiencies because of their mobility was largely absent from the literature. The paucity of evidence calls for much needed future research that asks explicit questions about the impact the mobility of devices has on work practices and outcomes.

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Introduction

Mobility is a central feature of health care delivery.[1] Clinical work, conducted in multiple locations, requires physicians to communicate and collaborate with different individuals and to move between patients, wards, clinics, laboratories, operating theaters, and offices.[2–4] Physicians require information systems which provide access to data, resources, and people where and when they undertake work.[2] Technology can potentially improve information accessibility.[5] Nevertheless, mismatches between system capabilities, and needs and workflows of physicians may hinder realization of intended benefits.[6]

Clinical systems have only partly delivered upon the promise of providing the right information, about the right patient, at the right time, in the right place.[2] While desktop computers allow easy storage, searching, retrieval, and sharing of patient information,[7] because they are static, they do not support many aspects of mobile work.[2,8,9] In the absence of bedside terminals, physicians must often search to find an accessible computer at a location away from the patient.[10] Traditional portable paper charts, by contrast, support the mobility of physicians,[8,11] but are limited by inefficient information accessibility and their lack of simultaneous access by multiple users.[2,11]

Mobile technologies combine advantages of paper charts and desktop computers in their portability[12] and support for information access anywhere, anytime.[11] Handheld devices, including tablet computers and personal digital assistants (PDAs), are generally small, portable, lightweight computers with wireless network connectivity.[13–15] Since their introduction in the 1990s, their uptake has steadily increased.[12–14,16,17] A review of PDA use by healthcare providers indicated adoption by 45% to 85% of those surveyed, with hospital-based physicians identified as the most likely users.[14]

But do handheld devices deliver benefits to workflow and patient care promised by increased mobility? Existing systematic reviews covered the following: uses of handheld devices and their potential roles in medicine;[13,16,18] features and functionality of handheld devices;[13,16] current adoption rates and the primary healthcare users of these devices;[12,14] opinions about the benefits of handheld devices and barriers to their implementation or adoption;[12,17,19] and the perceived outcomes of handheld device use.[12,18,19] The reviews provide considerable evidence regarding uses of handheld devices for: administrative support (e.g., billing and scheduling); professional activities (e.g., patient tracking and electronic prescribing); documentation; decision support (e.g., clinical and drug references); and education and research. Touted benefits of these devices include enhanced productivity, improved information access, improved communication, reduced medical errors, greater mobility, and improved

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quality of patient care. Paradoxically, few reviewers have examined the extent to which mobile handheld devices produce improved outcomes and work practice efficiencies because of their mobility.

The authors undertook a systematic review of evidence for the impact of mobile handheld technology on hospital physicians' work practices and patient care. The focus went beyond suggestions or conclusions about "potential" impacts of handheld devices to concentrate on quantification of the espoused virtues of mobile technologies.[5,19]

Methods

Search Strategy

We based our systematic review on established Cochrane review principles[20] and the Critical Appraisal Checklist for Systematic Reviews of Health Informatics Evaluations (CASP).[21] We conducted the literature search using multiple search strategies to overcome problems associated with inadequate indexing[13,16,22,23] and to ensure a more exhaustive scope.[20,22–25]

To explore several databases, our initial search used the Medical Subject Heading (MeSH) "computers, handheld" supplemented by keywords we identified as being synonymous with handheld computers. In some databases, we combined these keywords with the MeSH terms physicians, medical staff, or medicine. Table 1, available as an online data supplement at http://www.jamia.org, outlines the search strategy, conducted in January 2008. We also searched by hand the reference lists from systematic review articles to identify additional relevant studies.

Study Selection

The MeSH search yielded 2,292 results. Figure 1 illustrates the selection process. The keyword search generated 360 results (Figure 2, available as an online data supplement at http://www.jamia.org). Two reviewers (MP and AG) independently completed title and abstract reviews. In the absence of an abstract, the full-text article was reviewed. Where study information was unclear or additional information was necessary, we contacted the study authors.

The combined search strategies identified 88 full-text articles, which all three authors assessed. Any disagreements were resolved by in-depth discussion and subsequent consensus. Of the 88 articles, 13 met the criteria for inclusion (below); Figures 1 and 2 list reasons for exclusions.

Inclusion Criteria

The analysis only included articles published between January 2000 and December 2007, available in full-text and in English. While we included experimental, evaluative, and observational studies, we excluded other study designs such as qualitative, beta testing exercises, proof-of-concept research, product descriptions, and usability studies (software- or hardware-oriented). We also excluded surveys of patient opinions, physician usage patterns, and physicians' impressions regarding ease of use. Due to the heterogeneous nature of the studies, formal meta-analysis was not possible.

Analysis Framework

We categorized the included studies based on themes from Bates and Gawande[26] regarding use of information technology to support safe healthcare delivery processes. We used these categories as a structured framework to present our

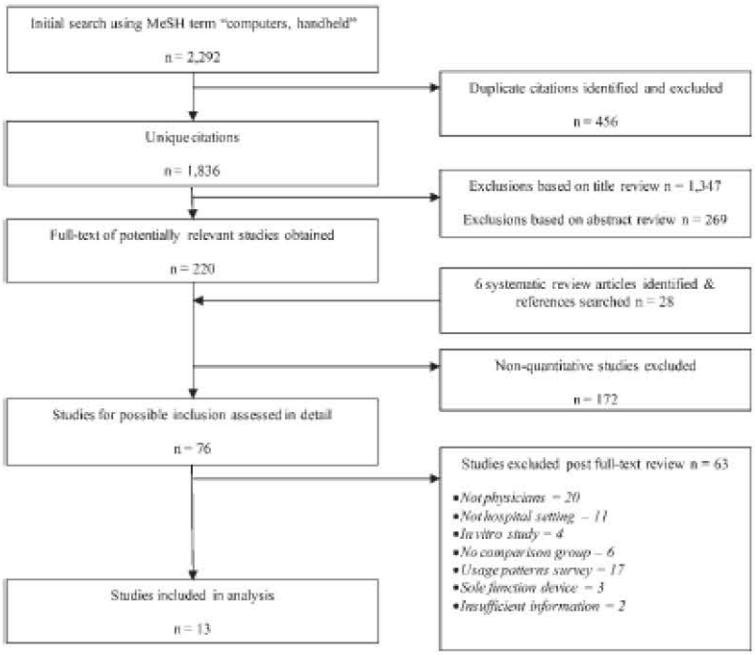

Figure 1. MeSH search and selection process.

results. The categories included use of handheld devices to facilitate: (1) *rapid response* by allowing physicians to identify patient needs, provide prompt intervention, and improve modes of communication; (2) *medication error prevention* by providing physicians with point-of-care decision support with accessible reference information and by eliminating illegibility and decreasing transcription errors; and (3) *data management and accessibility* by enabling physicians to access up-to-date patient information in electronic medical records at the point of care, to assist with monitoring and documentation.

We also assessed the impact of handheld devices on hospital physicians' work practices in terms of changes in: *who* undertook an activity; *what* was done or *what* resources were used in the activity; *when* the activity happened; *where* the activity was performed; and *how* the activity was realized. These were derived from levels of activity (objectives), levels of action (results) and levels of operation (conditions) outlined by Bardram.[27] One author (MP) classified the findings in accordance with the analysis framework and the other two authors validated this.

Results

The thirteen included studies were published between 2000 and 2006, with the largest number originating from the United States ($n = 6$) and the remaining ($n = 7$) from the UK, Australia, Canada, Denmark, Finland, Germany, and Hong Kong. The handheld devices used within the studies were all identified as PDAs. Study methodologies included randomized controlled trials (RCTs) ($n = 2$) and observational studies ($n = 11$). Five of the thirteen were pilot studies and only one involved more than one study site. Most studies measured the impact of the intervention either immediately after implementation (i.e., within 2 mo) ($n = 5$) or over/after a longer period (i.e., greater than 6 mo) ($n = 5$). Only one of the studies stated specifically where within the study site physicians used the handheld device, and four concluded that the mobility of the device had an impact on the study outcomes.

Handheld Devices Facilitating Rapid Response

Four studies evaluated handheld devices that aimed to facilitate physicians' responses to clinical situations in a timely manner (see Table 2, available as an online data supplement at http://www.jamia.org). Of the four, three[28–30] studies examined provision of prompt treatment, and one[31] examined the enhancement of interprofessional communication.

Prompt Treatment

Three emergency medicine studies[28–30] involved the wireless transmission of investigatory images [electrocardiographs (ECGs) or computerized tomography (CT) scans] to physicians' handheld devices to promote faster treatment through earlier notification, assessment, and interpretation. Adams et al.[28] and Clemmensen et al.[29] investigated wireless transmission of prehospital ECGs to a cardiologist's PDA to enable improved door-to-treatment times. Adams et al.[28] compared 17 months of preintervention data, during which 48 patients with acute coronary occlusion were transported to the study site by emergency medical services, with 24 months of intervention data, during which 24 patients with successful prehospital ECG transmission were transported by emergency medical services. In the intervention phase, prehospital ECGs were transmitted to a desktop computer located at the study site. This allowed the Emergency Department (ED) nurses to wirelessly forward the ECG images to a cardiologist's PDA. In nineteen cases, prehospital transmission of ECGs failed, thus this group was used as concurrent controls alongside the 101 patients who self-transported to the ED during the intervention phase. The study findings demonstrated a significantly shorter median door-to-reperfusion time with successful ECG transmission (50 min) compared with: the preintervention time (101 min) ($p < 0.0001$); those who self-transported (96 min) ($p < 0.0001$); and those with failed transmission (78 min) ($p < 0.0001$).

Similar findings were identified by Clemmensen et al.[29] who reported 15 months of data, during which 408 prehospital ECGs were transmitted to a desktop computer at the study site and simultaneously to a cardiologist's PDA. The cardiologist subsequently notified ambulance personnel as to whether the patient needed to be transported to a noninvasive hospital (295 patients) or redirected to a hospital with invasive facilities for primary percutaneous coronary intervention (pPCI) (113 patients). Results showed that redirected patients (pPCI) took significantly longer to arrive at their designated hospital than non-PCI patients [mean time of 17 min compared with 10 min ($p = 0.005$)]. However, there was a substantial reduction of 54 minutes in door-to-treatment times for pPCI patients compared with historical controls[32] [average time of 40 min compared with 94 min ($p < 0.01$)].

Reponen et al.[30] explored data accuracy achievable on handheld technology by assessing CT image quality. They rated the suitability for diagnosis of twenty-one CT scans on a PDA by comparing these reports to reference reports based on the original films. During the study, CT images were stored on a teleradiology server from which physicians could download images to a handheld device. The process averaged 90 seconds per image. Image quality was rated as suitable for diagnosis in all cases. Report compatibility showed good agreement with eighteen (86%) handheld image reports identical to the reference reports. Three cases had minor differences, which were of no clinical importance, while in one case an additional diagnosis was noted via the handheld images that had not been documented in the reference reports.

Although all three studies[28–30] demonstrated positive findings using handheld devices, none explicitly discussed the impact that the mobility of the device had on the study outcomes. For example, similar results may have been derived from the transfer of data to fixed computers. The impact of handheld devices in these studies focused on *when* investigatory images were accessible by the physician, and *how* these images could be accessed. The studies did not examine how well mobile devices facilitated easier and more frequent access to information from different work locations.

Communication

Aziz et al.[31] examined the use of handheld devices to facilitate interprofessional communication. Eight hospital-based physicians received, on alternate weeks during the 6 week study period, either a PDA with mobile phone func-

tionality, or alternatively, a conventional pager. The study compared communication efficiency by measuring call response times for each device for random calls initiated by the researchers. After a 5-minute response interval, it was considered that physicians had failed to respond. The average response times were lower, and failures to respond occurred less often, using the PDA compared with the pager. The authors suggested that the PDA's mobile phone function can improve upon pagers, which require physicians to locate a phone to return a call. As such, the mobility of the handheld device directly impacted on physician work practices, specifically *when* a physician is able to respond to a call.

Handheld Devices Facilitating Medication Error Prevention

Five studies evaluated how handheld devices could allow hospital-based physicians to prescribe medications more safely and effectively (see Table 3, available as an online data supplement at http://www.jamia.org). Three of the five[33–35] assessed the impact of handheld decision support on prescribing practices, while two[36,37] examined use of handhelds for generating medication lists and prescriptions.

Decision Support

Berner et al.,[33] Rudkin et al.,[34] and Sintchenko et al.[35] conducted studies where the use of a decision support system (DSS), via a PDA, was designed to improve patient management by reducing unsafe or unnecessary prescribing. In all three studies, the handheld device primarily served as an information and decision support resource for use at the physicians' discretion. Subjects carried out documentation and prescribing separately. Berner et al.[33] evaluated the effectiveness of a DSS on the prescribing safety of nonsteroidal anti-inflammatory drugs (NSAIDs). They conducted an RCT with 31 physicians assigned to the intervention arm and 28 to the control arm. All physicians were given an author-developed, PDA-based DSS, with the intervention group receiving an additional NSAID-related risk assessment with real-time treatment recommendations. Standardized patients, trained to portray clinical conditions that could result in adverse outcomes with inappropriate NSAID prescription, presented to each participant at least once during 6-month baseline data collection, and once during 8 month follow-up. Safe and unsafe prescribing and documentation of key risk factors were determined through chart review by two clinicians blinded to participant group assignment. At baseline, unsafe prescribing was similar for the intervention and control groups [mean proportion of unsafe prescribing cases per physician 0.27 and 0.29 respectively ($p > 0.05$)]. The intervention rule significantly affected error rates [0.23 in the intervention group compared with 0.45 ($p < 0.05$)]. However, this was attributed to performance degradation in the control group, rather than a substantial improvement in the intervention group, whose performance remained relatively constant. The authors observed a significant association between obtaining key risk factors and safe prescribing. Intervention physicians who obtained this information provided no unsafe prescriptions.

Rudkin et al.[34] conducted a time-motion study that assessed physicians' accesses to resources and rates of change in patient management. Thirty physicians were observed on two occasions—once while using electronic resources via a PDA and once while using paper text resources. Physicians accessed electronic resources ($n = 181$) more often than paper resources ($n = 131$) (OR 1.99; CI 1.41–2.80), with similar average access times (9.3 and 9.4 secs respectively). Access times only reflected the time it took for physicians to find the necessary information within the relevant resource; time required to locate and obtain paper resources was not recorded. Changes in patient management were significantly higher using electronic resources [29.8% compared with 17.6% (OR 2.00; CI 1.11–3.60)], particularly for changes in drug type [21.5% compared with 13.0% (OR 1.84; CI 0.95–3.59)]. This result may reflect differences in information content available electronically versus in paper resources, such as drug interaction information, which was not available in paper format.

Sintchenko et al.[35] assessed the impact of information accessible via a handheld device on patient management. The authors conducted a 6 month prospective study during which twelve physicians received PDAs loaded with locally developed guidelines and site-specific laboratory data. The rate of antibiotic use and outcomes of patients in ICUs during the intervention period were compared with 6 months of historical data, during which no computerized DSS was available. The findings showed that on average the DSS was used four times per day during the study period, primarily to access laboratory data. A significant decrease of antibiotics used occurred. The preintervention consumption rate was 1,925 defined daily doses per 1,000 patient days, and decreased to 1,606 in the intervention period ($p = 0.04$). The average patient length of stay decreased significantly during DSS use [6.22 bed days compared with 7.15 bed days ($p = 0.02$)]. Registrars had higher levels of DSS use compared with consultants. Rudkin et al.[34] also noted a similar finding with less experienced physicians accessing information more frequently than their more senior colleagues.

Among these studies,[33–35] handhelds affected hospital physicians' work practices primarily through *what* information was accessible to them for informed decision making.

Medication Safety

Grasso et al.[36] and Shannon et al.[37] studied the impact of handheld devices on the electronic documentation of medications. Grasso et al.[36] compared error rates when nurses transcribed physicians' handwritten medication orders with those occurring when physicians directly entered medication orders into a PDA to generate patient discharge medications lists. The 110 hand transcribed lists and the 90 electronically generated medication lists were retrospectively reviewed for errors by a pharmacist. The findings showed significantly fewer errors with the electronically generated discharge lists (8%) compared with the hand transcribed lists (22%) ($p < 0.05$). The errors identified in the handheld-generated lists all involved erroneous exclusion of medications, while transcription errors were eliminated.

Medication error reduction, such as eliminating illegibility, was the impetus for a study by Shannon et al.[37] The authors attempted to increase electronic prescribing among nine emergency physicians by giving them handheld devices that could access the hospital's clinical information system. During the 3 month preintervention phase, handwritten and fixed computer prescribing were available. In the 1-week

intervention period the additional method of prescribing via a handheld device was made available. The researchers hypothesized that leaving the patient's bedside to access a fixed computer and enter a prescription was inconvenient and thus hindered electronic prescribing. Seventy-eight pre-intervention prescriptions and 89 intervention prescriptions were reviewed. Introduction of handhelds significantly increased the average rate of electronic prescribing [64% intervention prescriptions v. 52% preintervention ($p = 0.03$)]. Half of the electronic prescriptions generated during the intervention period came from handheld devices, and half from the fixed computer. The study found a high degree of variability among individual physicians in the rate of electronic prescribing, ranging from none to all. The authors found that, rather than a preference for handwriting predicting handheld use, a prior preference for electronic prescribing via the fixed computer predicted subsequent handheld prescribing.

The Grasso et al.[36] and Shannon et al.[37] studies showed positive effects for use of handheld devices, with the impact of the handheld devices on hospital physicians' work practices focusing on *how* medications could be documented or prescribed to prevent errors and *who* performs these tasks.

Handheld Devices Facilitating Data Management and Accessibility

Four studies evaluated how handheld devices could facilitate hospital-based physicians in improving documentation of, and accessibility to, patient data during daily clinical routines (see Table 4, available as an online data supplement at http://www.jamia.org). Stengel et al.,[38] Carroll et al.,[39] Chan et al.,[40] and VanDenKerkhof et al.[41] conducted studies in inpatient settings that compared standard paper documentation with electronic documentation via a handheld device. Two of the studies[38,39] investigated the impact of handheld devices on the quality of patient data documentation, while two[40,41] assessed the use of handheld devices for managing patient information.

Documentation and Information Access

Stengel et al.[38] conducted an RCT to determine whether handheld devices could beneficially impact the quantity and quality of documentation and coding of patient diagnoses. During the study, four physicians performed either conventional paper documentation or electronic documentation via a PDA for patients' history, clinical findings and treatments. Documented diagnoses were translated into standardized codes, manually for paper documentation but automated with electronic documentation. Thirty-nine patients were randomized to conventional paper documentation, and 38 to electronic documentation. Documentation via the handheld device recorded significantly more diagnoses per patient (median diagnoses = 9) compared with paper documentation (median = 4) ($p < 0.0001$). However, the rate of false or redundant codes was also higher with handhelds (11.7 vs. 4.5%). The findings remained significant even after the false codes were removed ($p < 0.0001$). Documentation quality was rated based on: regularly performed data entry; detailed depiction of clinical findings; and correct assessment of patients' progress and translation into standardized codes. The handheld device was rated as significantly better than conventional paper documentation on all aspects of data quality (respectively $p = 0.004$; $p = 0.0045$; and $p = 0.0026$).

Carroll et al.[39] conducted a before and after trial in a neonatal intensive care unit to determine whether a handheld-based patient record and charting system could reduce the prevalence of documentation discrepancies in daily progress notes. The authors analyzed 339 paper progress notes and 432 handheld-generated progress notes. They examined information about patients' weights, medications and vascular lines. A documentation discrepancy occurred when the information documented on the progress note did not match the information noted in the nursing flow sheet, assessment sheet or pharmacy medication administration record. Documentation via the handheld device resulted in significantly fewer documentation discrepancies of patient weight [14.4% compared with 4.4% (OR 0.29; CI 0.15–0.56)]. However, there were no significant changes in the number of progress notes with medication discrepancies [27.7% compared with 17.1% (OR 0.63; CI 0.35–1.13)] or vascular line discrepancies [33.6% compared with 36.1% (OR 1.11; CI 0.66–1.87)].

Chan et al.[40] and VanDenKerkhof et al.[41] assessed the use of handheld devices to document and access patient information during ward rounds in acute pain service settings. They compared duration of rounds pre- and post-implementation of electronic documentation. Chan et al.[40] provided one PDA for use among a clinical team. The device replaced the paper process, where physicians recorded demographic and clinical data on a form that was subsequently transcribed into a computer database. The PDA was synchronized daily with a fixed computer to transfer information to and from the database. The electronic data collection forms included prompts to ensure all mandatory data were entered. The study compared 60 paper documented visits to 68 electronically documented visits during a 3 month study period. No significant change occurred in the average duration of patient encounters [7.0 min for handhelds, compared with 8.8 min for paper processes ($p = 0.151$)].

Unlike Carroll et al.[39] and Chan et al.,[40] who compared structured paper forms with structured electronic forms, VanDenKerkhof et al.[41] assessed the use of structured pain assessment forms on a handheld device and compared the encounter time and the comprehensiveness of the documentation with the standard unstructured paper process. Throughout the 3 week study period one physician performed 100 assessments on 44 patients using paper, where documentation was completed outside the patients' rooms. A further 94 assessments on 30 patients were performed using a PDA, during which documentation was completed at the patient's bedside. Completeness of documentation was assessed using the frequency of recorded pain variables (characterization, location and duration of pain) and the ten most common medication side effects. The median encounter time for each patient was significantly shorter with handheld documentation (227 secs, vs. 301 secs for paper) ($p < 0.001$). The frequency of documented side effects ranged from 5 to 100% for paper charting and 98% to 100% for recording via the handheld device. Pain variables were also more frequently documented via handhelds. The authors suggested that the difference in the comprehensiveness of the documentation might have occurred due to the location of the recording and the structure of the forms.

Although all four studies[38–41] demonstrated positive findings using handheld devices for documentation during daily clinical routines, only VanDenKerkhof et al.[41] explicitly stated that the mobility of the handheld device contributed to the study outcomes. The impact of handheld devices on hospital physicians' work practices in the VanDenKerkhof, et al[41] study focused on *where* documentation of patient data were completed. Stengel et al.,[38] Carroll et al.,[39] and Chan et al.[40] focused on *how* documentation could be performed to improve data quality.

Technical Features of Handheld Devices

Details about handheld devices provided in the studies varied widely (see Table 5, available as an online data supplement at http://www.jamia.org). Reported device manufacturers included: Nokia (n = 2); Palm (n = 2); Handspring (n = 1); Sony (n = 1); Psion (n = 1); Compaq (n = 1); and Handera (n = 1). Seven studies used devices that ran on the Palm Operating System (Palm OS), while three reported using Windows Embedded Compact (Windows CE) systems. Data transfer speeds showed substantial improvements over the 6-year period, from 9600 bit/sec in 2000[30] to 2 MB/sec in 2006.[37]

Study authors developed the tested handheld software (or modified existing software) in seven of the 13 studies. The majority (n = 8) of studies documented technical difficulties, including: failed transmissions (n = 3); battery issues (n = 2); synchronization problems (n = 1); hospital network failure (n = 1); and device breakdown (n = 1). Touchscreen techniques (including stylus handwriting recognition capabilities, onscreen keyboard, drop down menus and check boxes) were the only type of data entry methods reported (n = 7). Some form of user training was provided in seven studies, including one study[37] where participants were only provided with brief instructions on device use.

Discussion

The Impact of Mobile Handheld Technology on Hospital Physicians' Work Practices and Patient Care

This systematic review reveals that the handheld technology may be beneficial in supporting hospital physicians' work practices and patient care through facilitation of (a) rapid response, (b) medication error prevention, and (c) data management and accessibility. Many of the benefits reported could also occur when desktop workstations are available.

In the area of rapid response, over half of the studies were conducted in emergency or critical care settings, where time delays can constrain treatment options and impact on patients' chances of recovery or even survival.[27,42] The studies showed that wireless transmission of investigatory patient data to the relevant physicians' handheld device was feasible for diagnosis[30] and could expedite treatment by allowing earlier notification, resource preparation and mobilization of staff.[28,29] Similar efficiency gains may be realized through the facilitation of interprofessional communication using handheld devices. The mobile phone functionality and multidirectional nature of PDAs overcame limitations of pagers.[31] Given the mobile and collaborative nature of medical work,[6,43–45] PDAs can help to improve accessibility to coworkers[31] and thus coordination of patient care.

The literature also showed improvements in patient management decisions through the use of electronic resources on handheld devices. Physicians accessed electronic resources more often than paper resources, possibly because physicians are limited in the types of paper resources they can feasibly carry.[33,34] A handheld device offers greater portability and provides a greater scope of up-to-date information, including drug interaction information, that may be more rapidly accessed from any location.[13–15,33,34] Thus, by providing information and decision support access at the point-of-need, which supports informed treatment decisions,[33,34] improved patient outcomes may be achieved.[35]

The findings also indicated that medication error prevention could be facilitated by addressing problems of drug order illegibility and errors in transcription.[36,37] Direct input of medications onto a handheld device reduced errors in medication documentation and eliminated transcription errors.[36,37] Although similar results could be achieved through the direct input of medications onto a fixed computer they are generally not located near the patient's bedside. Researchers suggest that the inconvenience of leaving the bedside to locate an available computer hinders a physician's decision to use direct input via a desktop computer.[5,36,37] However, when provided with a choice of input method—paper, fixed computer, or handheld device—some physicians preferred to use a fixed desktop computer located away from the patients bedside rather than using a handheld device at the point of care.[36,37] Evidence showing that entering data onto a PDA via a stylus is slower, more erroneous and less satisfactory for users than entering data via a QWERTY keyboard[46] may explain this preference.

Nonetheless, in the area of data management and accessibility, the evidence showed the use of handheld devices to be at least as effective and efficient as paper processes.[38–41] The studies demonstrated improvements in documentation quality with an increased recording of diagnoses[38] and a reduction in documentation discrepancies.[39] As most patient information is obtained at the bedside[3,8,11,47] providing physicians with devices that allow data entry at the point of care can promote more complete documentation[41] and decrease the length of patient encounters.[40,41] These findings are important given that decision-making may be compromised not only by incorrect data, but also data not entered in a timely fashion.[5] Therefore, having portable, complete, accurate and up-to-date patient specific information could facilitate more complete, accurate and timely patient management.[48,49]

Ability of Handheld Devices to Support Mobile Work Practices

In 2003, Fischer et al.[16] sought to raise physician awareness of handheld computers in medicine, but also noted the lack of substantial evidence about the use of these devices and their impact on health care delivery.[16] The continuing paucity of evidence in this area was identified in three subsequent reviews.[12,50,51] The current review is the first to focus on evidence of the role of handheld devices in supporting the mobile work practices of hospital physicians. We identified only four of 13 studies where the role of device mobility was

Figure 3. Key areas of handheld technology impact as they relate to issues of mobility in the clinical workplace.

directly commented upon by researchers. Thus, we adopted a broad analysis framework to carefully examine and identify contextual factors (either implicit or explicit) impacting on physician mobile work practices that can improve understanding of the areas that mobile technology affects.[52,53] We used the definition of Badram et al.[3] of mobility as the "work needed to achieve the right configuration of people, resources, knowledge and place" as a prism through which to examine and identify domains of physician work mobility (i.e., what is being done, when is it occurring, how is it being done and where is it happening).

Hospitals are complex and busy places involving constant shifts and movement of people and things (resources, information) that are distributed within different areas at different times for diverse requirements.[2] Figure 3 illustrates the interconnectedness of these factors, recognized as important to clinical workflow,[54] and identifies their relationship with key themes uncovered in this review. The studies that focused on prompt treatment of patients within the ED, addressed issues related to the impact of handheld technology on the timing or availability (*when*) of accessible images with a corresponding focus on the available resources (*how*) that allowed these images to be accessible.[28–30] The Aziz et al.[31] study, which concentrated on the use of PDAs to accentuate interprofessional communication, dealt with issues related to the availability (*when*) of a given resource. Conversely, decision support facets of handheld technology primarily addressed issues related to the accessibility of knowledge (*what*) resources[33–35] and medication safety elements were related to medication documentation processes (*how*) and responsibility (*who*).[36,37] The studies that addressed data management focused either on issues related to the location (*where*) documentation occurred[41] or the method (*how*) of documentation.[38–41] Using this framework it is interesting (and somewhat ironic) that only one of the included studies[41] expressly observed *where* handheld device use occurred and addressed the subsequent impact the location had on the study outcomes.

Although many studies alluded to the mobility of the handheld device for "point-of-care",[33,39] "bedside",[34,37] or "just in time"[35] use, none of these studies specifically measured whether the devices were used in this manner. The extent to which handheld devices support mobile work processes was often not clearly portrayed. Many studies also failed to distinguish the benefits of providing physicians with a mobile handheld device over a desktop computer platform, with less than one third of studies explicitly stating that the mobility of the handheld device contributed to the study outcomes. Sintchenko et al.[35] adequately summarize the shortcomings of many studies on handheld devices when referring to their own inability "to identify the specific contributions of using a handheld platform over [a] fixed platform to the study results."

The Status of Handheld Devices in Clinical Practice

Handheld devices possess the advantages of being portable[12] and allowing access to information anywhere and at any time.[11] But does this mobility of information and resources lead to improved outcomes, and if so when and in what context? The available evidence suggests that mobile handheld devices demonstrate the greatest benefits in contexts where time is a critical factor and a rapid response is crucial, for example prehospital notification of vital patient data.[28,29] They are also beneficial in connecting spatially distributed coworkers. Health care work is highly interconnected and health care practitioners are dependent on their coworkers skills, knowledge, and expertise.[54] Thus, improving communication with and accessibility to coworkers allows physicians to deliver "faster, more efficient patient care"[31] with potential benefits to patient outcomes.

Mobile handheld devices are also effective for overcoming difficulties created by inadequate numbers of available of fixed desktop computers. Fixed computers provide access to electronic information systems but, due to the highly mobile nature of hospital work, physicians are limited in their ability to regularly check information only available on fixed computers. Electronic messages or decision support alerts will be ineffective if physicians do not receive them.[54] Additionally, fixed computers located away from patients' bedsides may result in workflow interruptions,[54] additional work such as duplicate documentation (first on paper then on the computer)[40,54] or less comprehensive data collection.[41] Mobile handheld devices potentially provide a solution allowing both direct input and viewing of data at the point of care, increasing the opportunities for physicians to gain value from electronic information systems. However, as this review has demonstrated, there is little evidence to confirm that mobile devices will be used at this location and in the ways expected. A recent observational study of physicians' use of tablet computers during ward rounds demonstrated that while the tablet computers provided the ability to access and document information at a patient's bedside, physicians chose to complete most computer tasks on the tablet in the corridor of the ward.[55] Such results challenge assumptions about how physicians will use mobile technologies in situ.

Mobile handheld devices have some limitations. Their smaller screens are designed for individual use[56,57] which can make collaboration difficult[3,11] and they present challenges in easily viewing and entering data.[46,55] The limitations and potentially error-inducing features of computer screens, which may include limiting a full overview of patient information, or hiding important information behind

menus,[58] will be exacerbated on a PDA screen. Nonetheless, available evidence suggests that handheld devices have some advantages over both paper and fixed computers in supporting physician hospital work practice in situations when: rapid information exchange is required and will influence patient care decisions; where physicians are undertaking highly mobile work which reduces their ability to spend periods in a fixed place where they can access electronic resources via fixed computers; and where data entry or access is required at the point of care and that the absence of these capabilities will reduce the efficiency or effectiveness of care delivery.

Mobile technology is still an emerging and rapidly developing area of study.[12] Existing literature has a tendency to view the mobility of any device as inherently beneficial without clear evidence demonstrating how, why or in what circumstances this mobility provides value. What is required is a more evidence-based approach to the use and evaluation of mobile technologies to understand if, and when, they are useful in supporting clinical practice and improvements in care delivery. The framework that we used to examine and identify domains of physician work mobility provides a useful lens by which to assess the role of mobile technology in supporting improved health care delivery and understanding what will work, for whom, where, and in what circumstances.[59] The results from this review contribute to providing a foundation upon which to refocus future studies of mobile technologies.

Those seeking to implement mobile handheld technologies in a hospital setting should consider questions of why and how the mobile device is expected to improve care delivery because of its core "mobility" asset. Further, how handheld devices might compare with other mobile devices, such as laptops or computers on wheels, should be considered. It is likely that securing the integration of the "right" combination of mobile, fixed and paper information sources is required to achieve the best outcomes for both health care staff and their patients.[3,8,11,47] This requires understanding and acknowledging both the advantages and disadvantages of various technologies, how they are used in real-work clinical situations, and the contextual factors which determine their use.

Technical Features of Handheld Devices

The outcomes associated with the implementation of ICT systems within the context of one institution may not always be applicable to another healthcare setting.[5] To address such issues studies assessing ICT systems should aim to clearly describe the IT artifact being evaluated.[60] The level of detail regarding the handheld devices used within the included studies varied considerably. Information regarding intended and actual use, functionality, and infrastructure was limited across the studies, however most provided software and hardware details, and information about the number of users, their experience and training. The benefits of handheld devices to hospital physicians will be influenced by the extent to which they are stand alone, connected to the Internet or to the hospital's electronic information systems. Few studies in the review revealed such details, but such information is important to allow comparisons of the impact of different devices or features.

Limitations

Despite a comprehensive search only a limited number of quantitative articles which investigated the impact of handheld devices on hospital physicians' work practices and patient care were identified. We sought to include tablet computers in the review but found no studies investigating this mobile handheld technology that met the review criteria, further demonstrating the dearth of research on this topic. We did not exclude articles based on an assessment of their quality and thus the limitations associated with the literature included in this review may impede the conclusions drawn. The heterogeneity of the outcome measures assessed within the included literature made synthesis difficult and precluded the use of meta-analysis techniques. Despite the rapidly evolving nature of handheld technology the central themes identified in this review, in particular the need to more specifically address how any new handheld device actually delivers upon its goal of supporting mobile health care work, remain current.

Conclusions

This review identified evidence about the ability of mobile handheld technology to positively impact rapid response, error prevention, information accessibility, and data management in healthcare settings. The study findings support claims of the potential beneficial impact of this technology on aspects of healthcare delivery. However, the extent to which handheld devices provide benefits due to their mobility has been significantly underinvestigated. The mobility framework applied in this review is grounded in the reality of everyday clinical practice where people are involved in the constant pursuit of achieving the optimal mix of individuals, resources, and knowledge, at the desired time.[2] We believe this framework provides a useful lens by which to assess the role of handheld device use in supporting improved healthcare delivery and better patient outcomes. Prior to widespread adoption of mobile technologies in hospitals, implementers and adopters should address explicit questions about why and how the mobility of these devices is expected to improve care delivery. Pilot observational studies should test assumptions about how mobile technologies will be used in practice to support the work of physicians.

References ■

1. Bardram JE. Activity-based computing: Support for mobility and collaboration in ubiquitous computing. Pers Ubiquit Comput 2005;9(5):312–22.
2. Bardram JE, Bossen C. Mobility work: The spatial dimension of collaboration at a hospital. Comput Support Coop Work 2005; 14(2):131–60.
3. Ammenwerth E, Buchauer A, Bludau B, Haux R. Mobile information and communication tools in the hospital. Int J Med Inform 2000;57(1):21–40.
4. Banitsas KA, Georgiadis P, Tachakra S, Cavouras D. Using handheld devices for real-time wireless teleconsultation. Conf Proc IEEE Eng Med Biol Soc 2004;4:3105–8.
5. Baldwin LP, Low PH, Picton C, Young T. The use of mobile devices for information sharing in a technology-supported model of care in AE. Int J Electron Healthc 2006;3(1):90–106.
6. Reddy MC, McDonald DW, Pratt W, Shabot MM. Technology, work, and information flows: Lessons from the implementation of a wireless alert pager system. J Biomed Inform 2005;38(3):229–38.

7. Sellen AJ, Harper RHR. The Myth of the Paperless Office, Cambridge, MA: MIT Press, 2002.
8. Luff P, Heath C. Mobility in collaboration. Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Works: Seattle, WA, 1998;305–14.
9. Bardram JE, Bossen C. Moving to get ahead: Local mobility and collaborative work. Proceedings of the 8th European Conference on Computer Supported Cooperative Works: Helsinki, Finland, 2003;355–74.
10. McCord G, Smucker WD, Selius BA, et al. Answering questions at the point of care: Do residents practice EBM or manage information sources? Acad Med 2007;82(3):298–303.
11. Dahl Y, Svanaes D, Nytro O. Designing pervasive computing for hospitals: Learning from the media affordances of paper-based medication charts. Pervasive Health Conference and Workshops, 2006;1–10.
12. Kuziemsky CE, Laul F, Leung RC. A review on diffusion of personal digital assistants in healthcare. J Med Syst 2005;29(4): 335–42.
13. Baumgart DC. Personal digital assistants in health care: Experienced clinicians in the palm of your hand? Lancet 2005; 366(9492):1210–22.
14. Garritty C, El Emam K. Who's using PDAs? Estimates of PDA use by health care providers: A systematic review of surveys. J Med Internet Res 2006;8(2):7.
15. Cole E, Pisano ED, Clary GJ, et al. A comparative study of mobile electronic data entry systems for clinical trials data collection. Int J Med Inform 2006;75(10–11):722–9.
16. Fischer S, Stewart TE, Mehta S, Wax R, Lapinsky SE. Handheld computing in medicine. J Am Med Inform Assoc 2003;10(2): 139–49.
17. Lu YC, Xiao Y, Sears A, Jacko JA. A review and a framework of handheld computer adoption in healthcare. Int J Med Inform 2005;74(5):409–22.
18. Lindquist MA, Johansson EP, Petersson IC, Saveman BI, Nilsson CG. The use of the personal digital assistant (PDA) among personnel and students in health care: A review. J Med Internet Res 2008;10(4):31.
19. Martins HMG, Jones MR. What's so different about mobile information communication technologies (MICTs) for clinical work practices? A review of selected pilot studies. Health Inform J 2005;11(2):123–34.
20. Jackson N, Waters E. Criteria for the systematic review of health promotion and public health interventions. Health Promot Int 2005;20(4):367–74.
21. Car J, Black A, Anandan C, et al. The impact of eHealth on the quality and safety of healthcare: A systematic overview and synthesis of the literature, London: University of Edinburgh and the Imperial College London; 2008.
22. Counsell C. Formulating questions and locating primary studies for inclusion in systematic reviews. Ann Intern Med 1997;127(5): 380–7.
23. Whittemore R, Knafl K. The integrative review: Updated methodology. J Adv Nurs 2005;52(5):546–53.
24. Crowther MA, Cook DJ. Trials and tribulations of systematic reviews and meta-analyses. Hematology 2007, 2007;1:493–7.
25. Greenhalgh T. How to read a paper: Papers that summarise other papers (systematic reviews and meta-analyses). BMJ 1997; 315(7109):672–5.
26. Bates DW, Gawande AA. Improving safety with information technology. N Engl J Med 2003;348(25):2526–34.
27. Bardram JEIL. The system—I just don't use it!. Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work: The Integration Challenges, Phoenix, AZ, 1997; 251–60.
28. Adams GL, Campbell PT, Adams JM, et al. Effectiveness of prehospital wireless transmission of electrocardiograms to a cardiologist via hand-held device for patients with acute myocardial infarction (from the timely intervention in myocardial emergency, northeast experience (TIME-NE)). Am J Cardiol 2006;98(9):1160–4.
29. Clemmensen P, Sejersten M, Sillesen M, et al. Diversion of ST-elevation myocardial infarction patients for primary angioplasty based on wireless prehospital 12-lead electrocardiographic transmission directly to the cardiologist's handheld computer: A progress report. J Electrocardiol 2005;38(4) (Suppl): 194–8.
30. Reponen J, Ilkko E, Jyrkinen L, et al. Initial experience with a wireless personal digital assistant as a teleradiology terminal for reporting emergency computerized tomography scans. J Telemed Telecare 2000;6(1):45–9.
31. Aziz O, Panesar SS, Netuveli G, et al. Computers and the 21st century surgical team: A pilot study. BMC Med Inform Decis Mak 2005;5:28.
32. Andersen HR, Nielsen TT, Rasmussen K, et al. A comparison of coronary angioplasty with fibrinolytic therapy in acute myocardial infarction. N Engl J Med 2003;349(8):733–42.
33. Berner ES, Houston TK, Ray MN, et al. Improving ambulatory prescribing safety with a handheld decision support system: A randomized controlled trial. J Am Med Inform Assoc 2006;13(2): 171–9.
34. Rudkin SE, Langdorf MI, Macias D, Oman JA, Kazzi AA. Personal digital assistants change management more often than paper texts and foster patient confidence. Eur J Emerg Med 2006;13(2):92–6.
35. Sintchenko V, Iredell JR, Gilbert GL, Coiera E. Handheld computer-based decision support reduces patient length of stay and antibiotic prescribing in critical care. J Am Med Inform Assoc 2005;12(4):398–402.
36. Grasso BC, Genest R, Yung K, Arnold C. Reducing errors in discharge medication lists by using personal digital assistants. Psychiatr Serv 2002;53(10):1325–6.
37. Shannon T, Feied C, Smith M, Handler J, Gillam M. Wireless handheld computers and voluntary utilization of computerized prescribing systems in the emergency department. J Emerg Med 2006;31(3):309–15.
38. Stengel D, Bauwens K, Walter M, Kopfer T, Ekkernkamp A. Comparison of handheld computer-assisted and conventional paper chart documentation of medical records: A randomized controlled trial. J Bone Joint Surg 2004;86(3):553–60.
39. Carroll AE, Tarczy-Hornoch P, O'Reilly E, Christakis DA. Resident documentation discrepancies in a neonatal intensive care unit. Pediatrics 2003;111(5):976–80.
40. Chan SS, Chu CP, Cheng BC, Chen PP. Data management using the personal digital assistant in an acute pain service. Anaesthesiol Intens Care 2004;32(1):81–6.
41. VanDenKerkhof EG, Goldstein DH, Lane J, Rimmer MJ, Van Dijk JP. Using a personal digital assistant enhances gathering of patient data on an acute pain management service: A pilot study. Can J Anesth 2003;50(4):368–75.
42. Ikeya N. Practical management of mobility: The case of the emergency medical system. Environ Plann A 2003;35(9):1547–64.
43. Coiera E, Tombs V. Communication behaviours in a hospital setting: An observational study. BMJ 1998;316(7132):673–6.
44. Eisenstadt S, Wagner M, Hogan W, et al. Mobile workers in healthcare and their information needs: Are 2-way pagers the answer? AMIA Annu Symp Proc 1998:135–9.
45. Reddy MC, Pratt W, McDonald DW, Shabot MM. Challenges to physicians' use of a wireless alert pager. AMIA Annu Symp Proc 2003:544–8.
46. Haller G, Haller DM, Courvoisier DS, Lovis C. Handheld versus laptop computers for electronic data collection in clinical research: A cross-over randomized trial. J Am Med Inform Assoc. JAMIA PrePrint: Jun 30, 2009;doi: 10.1197/jamia.M3041.

47. Moran EB, Tentori M, Gonzalez V, et al. Mobility in hospital work: Towards a pervasive computing hospital environment. Int J Electron Healthc 2006;3(1):72–89.
48. Lau F, Yang J, Pereira J, Daeninck P, Aherne M. A survey of PDA use by palliative medicine practitioners. J Palliat Care 2006;22(4):267–74.
49. Criswell DF, Parchman ML. Handheld computer use in US family practice residency programs. J Am Med Inform Assoc 2002;9(1):80–6.
50. Kho A, Henderson LE, Dressler DD, Kripalani S. Use of handheld computers in medical education: A systematic review. J Gen Intern Med 2006;21(5):531–7.
51. Mendonça EA, Chen ES, Stetson PD, et al. Approach to mobile information and communication for health care. Int J Med Inform 2004;73(7–8):631–8.
52. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist review—A new method of systematic review designed for complex policy interventions. J Health Serv Res Policy 2005;10 (Suppl 1):21–34.
53. Greenhalgh T, Kristjansson E, Robinson V. Realist review to understand the efficacy of school feeding programmes. BMJ 2007;335(7625):858–61.
54. Niazkhani Z, Pirnejad H, Berg M, Aarts J. The impact of computerized provider order entry systems on inpatient clinical workflow: A literature review. J Am Med Inform Assoc 2009;16(4):539–49.
55. Andersen P, Lindgaard A-M, Prgomet M, Creswick N, Westbrook J. Is selection of hardware device related to clinical task? A multi-method study of mobile and fixed computer use by doctors and nurses on hospital wards. J Med Internet Res 2009;11(3):e32.
56. Gurses AP, Xiao Y. A systematic review of the literature on multidisciplinary rounds to design information technology. J Am Med Inform Assoc 2006;13(3):267–76.
57. Dryer DC, Eisbach C, Ark WS. At what cost pervasive? A social computing view of mobile computing systems. IBM Syst J 1999;38(4):652–76.
58. Koppel R, Wetterneck T, Telles J, Karsh B. Workarounds to barcode medication administration systems: Their occurrences, causes, and threats to patient safety. J Am Med Inform Assoc 2008;15(4):408–23.
59. Pawson R, Tilley N. Realistic Evaluation, London: Sage Publications, 1997.
60. Ammenwerth E, Graber S, Herrmann G, Burkle T, Konig J. Evaluation of health information systems—Problems and challenges. Int J Med Inform 2003;71(3):125–35.

Selecting Clinical Computing Hardware Devices for Hospital Wards: The Role of IT Vendors

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Abstract and Objective

There is limited evidence available to inform decision making processes for selecting clinical computing hardware devices for implementation on hospital wards. We undertook a study to determine the role of IT vendors in this decision making process and to ascertain the factors that vendors deem important to consider in the selection of computing devices. Interviews were conducted with twelve vendors who provide hardware and/or software products to hospitals. Interviews were recorded and the transcripts were analyzed by coding of key concepts. The results highlight the need to assess information about a number of technology, workflow and environmental factors. The study provides a basis for developing a framework to assist decision makers in identifying the ideal devices to adequately support clinical work practices.

Keywords:

Computers, Computer systems, Decision making, Hospitals

Introduction

Frameworks to guide decisions in selecting computing hardware devices are largely absent from the literature. This fundamental gap in evidence may pose significant challenges for decision makers and implementers of computing devices. As part of a larger study, examining the perspectives of various groups involved in hardware selection decision making processes, this study takes the first step in contributing to such a framework by examining IT vendor perspectives.

Methods

Semi-structured interviews were conducted with twelve vendors, from eleven IT companies, in August 2009, during a national informatics conference where vendors, who provide technologies to the Australian and (in most cases) international health sectors, showcased their products. All vendors who were approached agreed to participate in the study. Interviews were transcribed and analysed independently by two researchers (MP and JC). The study was approved by the University of Sydney Ethics Committee and the conference coordinator.

Results

Vendors described their role in decision making processes as a consulting or advisory role. When selecting computing devices for hospital wards vendors perceived it important to consider a number of technology, workflow, and environmental factors.

Technology factors included: infrastructure capabilities; existing devices; device characteristics (e.g. robustness, battery life, wireless capabilities etc.); and software applications (e.g. transferability of the application onto smaller screen sizes).

In evaluating workflow, factors influencing device selection included: the user's role; type of tasks users undertake; level of information users need to access/capture; location where users need to access/capture information; and user preferences.

The environmental factors included: the type of ward; space/ward configuration; levels of concurrency (i.e. the number of users who will be operating the available devices at concurrent times); and clinician buy-in.

Conclusion

The complexity of decision making processes in selecting computing devices necessitates the need for a framework to inform such decisions. By examining the technology, workflow and environmental attributes of a ward, decision makers can more clearly identify devices to adequately support clinical work practices. These factors are important to ensure that the right device is available to the right person, to support the task they are conducting, in the location that it is needed [1].

Acknowledgments

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References

[1] Andersen P, Lindgaard A-M, Prgomet M, Creswick N, Westbrook J. Mobile and fixed computer use by doctors and nurses on hospital wards: multi-method study on the relationships between clinician role, clinical task, and device choice. J Med Internet Res 2009;11(3):e32.

Appendix B. Participant Information Statements and Consent Forms

Appendix B.1. Device Selection Study: Participant Information Statement and Consent Form

The device selection study participant information statement and consent form was provided to all potential participants that were approached to take part in the first stage of the research.

Appendix B.2. Mobile Devices and Work Study: Participant Information Statement and Consent Form

The mobile devices and work study participant information statement and consent form was provided to all potential participants that were approached to take part in the second stage of the research.

Appendix B.1. Device Selection Study: Participant Information Statement and Consent Form

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RESEARCH STUDY INVESTIGATING HOW CLINICAL COMPUTING DEVICE SELECTION DECISIONS ARE MADE

INFORMATION FOR PARTICIPANTS

Introduction
You are invited to take part in a research study investigating how clinical computing device selection decisions are made. The aim of this study is to identify how decisions are made about the type and mix of fixed and mobile clinical computing devices for use on hospital wards. By fixed computing devices we mean stationary computers at central work stations or at a patient's bedside. Mobile computing devices include personal digital assistants (PDAs), tablet computers, laptops, or computers on wheels/trolleys. The study is being conducted by Mirela Prgomet, *Research Student*, and will form the basis for the degree of Doctor of Philosophy at the University of Sydney under the supervision of Professor Johanna Westbrook, *Director, Health Informatics Research and Evaluation Unit.*

Procedures
If you agree to participate in this study, you will be interviewed regarding your role and experience with the clinical computing decision-making process. Interviews will be scheduled for a time and place convenient for you. The interview is expected to last approximately 20 minutes. It will be audio taped to ensure accuracy, and later transcribed for analysis. The researcher will suspend the interview at any time you request.

Risks and Benefits
This study should not expose you to any foreseeable risks. Should you have any concerns please feel free to discuss them with the researcher. We cannot guarantee that you will receive any direct benefits from this study.

Costs
Participation in this study will not cost you anything, nor will you be paid.

RESEARCH STUDY INVESTIGATING HOW CLINICAL COMPUTING DEVICE SELECTION DECISIONS ARE MADE

Confidentiality
If you consent to take part in this study, please be assured that any identifiable details will remain strictly confidential. Access to data will be limited to the research student involved in the collection process and the Chief and Associate Investigators. All information collected will be de-identified. A report of this study may be submitted for publication, but individual participants will not be identifiable in such a report. All data will be stored in locked cabinets and on a password protected PC for a minimum of seven years and then disposed of by shredding or erasure.

Withdrawal from the study
Participation in this study is entirely voluntary. You are in no way obliged to participate and - if you do participate - you can withdraw at any time and request that data relating to you also be withdrawn. Whatever your decision you will not be disadvantaged or prejudiced in any way.

Further Information
When you have read this information, Mirela Prgomet will discuss it with you further and answer any questions you may have. If you would like to know more at any stage, please feel free to contact Professor Johanna Westbrook, on (02) 9351 9677.

Any person with concerns or complaints about the conduct of a research study can contact the Manager, Office of Ethics Administration, University of Sydney on (02) 8627 8175 (Telephone); (02) 8627 8180 (Facsimile) or gbriody@usyd.edu.au (Email).

This information sheet is for you to keep.

The University of Sydney

Health Informatics Research and Evaluation Unit

ABN 15 211 513 464

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Director

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RESEARCH STUDY INVESTIGATING HOW CLINICAL COMPUTING DEVICE SELECTION DECISIONS ARE MADE

PARTICIPANT CONSENT FORM

I, ...[name]

have read and understood the Information for Participants for the above named study and give consent to my participation in the research project.

In giving my consent I acknowledge that:

- I have been made aware of the procedures involved in the study, including any known or expected inconvenience, risk, discomfort or potential side effect and of their implications as far as they are currently known by the researchers.
- I have read the Participant Information Statement and have been given the opportunity to discuss the information and my involvement in the project with the researcher.
- I freely choose to participate in this study and understand that I can withdraw at any time.
- I also understand that the research study is strictly confidential.
- I consent to the interview being audio taped and understand that I can stop the interview at any time if I do not wish to continue. The audio taping will be erased and the information provided will not be included in the study.

Name (Please Print):.....

Signature:..... **Date:** .....

Signature:..... **Date:** .....
(of person who conducted informed consent discussion)

UNSW

PARTICIPANT INFORMATION SHEET AND CONSENT FORM

Research Study on the Use and Impact of Computing Devices on Work Practices

Invitation

You are invited to participate in a research study into the use and impact of computing devices on clinical work practices. The study is being conducted by Mirela Prgomet, Research Student, and will form the basis for the degree of Doctor of Philosophy at the University of New South Wales. The student is supervised by Professor Johanna Westbrook, Director, Centre for Health Systems and Safety Research [redacted]

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

1. 'What is the purpose of this study?'

This study will focus on understanding how computing devices (e.g. desktop computers, computers-on-wheels and/or mobile computers) are used to support work practices. Data about how and when devices are used will be obtained through observations and brief interviews with participating clinical staff.

2. 'Why have I been invited to participate in this study?'

You are being asked to take part as a possible participant because you are a member of the clinical staff whose work may be impacted by the use of computing devices.

3. 'What if I don't want to take part in this study, or if I want to withdraw later?'

Participation in this study is voluntary. It is completely up to you whether or not you participate. If you decide not to participate, it will not affect your relationship with the researcher or the University of New South Wales. If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason.

4. 'What does this study involve?'
If you agree to participate in this study, you will be asked to sign the Participant Consent Form. The researcher will observe your work activities for up to two hours at a given time, for a maximum total of ten hours, spread over a couple of weeks. The researcher will record your use of various computing devices for completing your work. You may also be asked to participate in a brief interview (approximately ten minutes) in order to further understand your computing device preferences. The interview will be audio taped, and later transcribed for analysis.

5. 'How is this study being paid for?'
The researcher is sponsored by an Australian Postgraduate Award scholarship.

6. 'Are there risks to me in taking part in this study?'
The researcher acknowledges that you may feel uncomfortable having someone watch you closely as you work or interview you. The researcher will make every effort to be unobtrusive and put you at ease. If you have any concerns please advise the researcher.

7. 'What happens if I suffer injury or complications as a result of the study?'
Every reasonable precaution will be taken to ensure your safety during the course of the study. In the unlikely event that you suffer any injury as a result of participating in this research project, hospital care and treatment will be provided at no extra cost to you.

8. 'Will I benefit from the study?'
While we intend that this research furthers knowledge, we cannot guarantee that you will receive any direct and immediate benefits from this study. However, it is anticipated that the results of the project will improve our understanding of the ways that information technology devices can be effectively integrated into clinical work processes to support care delivery.

9. 'Will taking part in this study cost me anything, and will I be paid?
Participation in this study will not cost you anything, nor will you be paid.

10. 'How will my confidentiality be protected?'
Only Mirela Prgomet will know whether or not you are participating in this study. Any identifiable information that is collected about you in connection with this study will remain confidential. Only the researcher named above will have access to your details and results that will be held securely at the University of New South Wales.

11. 'What happens with the results?'
The results may be disseminated by reports and feedback to participants, peer-reviewed journals, and seminars and conference presentations and proceedings. In any publication, information will be provided in such a way that you cannot be identified. By signing the Consent Form, you are giving permission for this to be done. Results of the study will be provided to you, if you wish.

12. 'What should I do if I want to discuss this study further before I decide?'
When you have read this information, the researcher, Mirela Prgomet, will discuss it with you and any queries you may have. If you would like to know more at any stage, please do not hesitate to contact her at m.prgomet@unsw.edu.au or on 02 9385 8217.

13. 'Who should I contact if I have concerns about the conduct of this study?'
This study has been approved by [redacted] Hospital HREC. Any person with concerns or complaints about the conduct of this study should contact the Research Office who is nominated to receive complaints from research participants. You should contact them on [redacted]

Thank you for taking the time to consider this study.
If you wish to take part in it, please sign the attached consent form.
This information sheet is for you to keep.

UNSW

Research Study on the Use and Impact of Computing Devices on Work Practices

REVOCATION OF CONSENT

I hereby wish to **WITHDRAW** my consent to participate in the study described above and understand that such withdrawal **WILL NOT** jeopardise any treatment or my relationship with the University of New South Wales or [redacted]

Signature ..... Date .....

Please PRINT Name .....

The section for Revocation of Consent should be forwarded to:

Mirela Prgomet
Centre for Health Systems and Safety Research
Australian Institute of Health Innovation
Faculty of Medicine
Level 1, AGSM Building
University of New South Wales, NSW, 2052

PARTICIPANT CONSENT FORM

Research Study on the Use and Impact of Computing Devices on Work Practices

1. I,.....(name) of.....(ward) agree to participate as a participant in the study described in the Participant Information Sheet attached to this form.
2. I acknowledge that I have read the Participant Information Sheet, which explains why I have been selected, the aims of the study and the nature and the possible risks relating to the study, and the information sheet has been explained to me to my satisfaction.
3. Before signing this consent form, I have been given the opportunity of asking any questions relating to any possible physical and mental harm I might suffer as a result of my participation and I have received satisfactory answers.
4. I understand that I can withdraw from the study at any time without prejudice to my relationship with the University of New South Wales or [redacted]
5. I agree that research data gathered from the results of the study may be published, provided that I cannot be identified.
6. I understand that if I have any questions relating to my participation in this research, I may contact Mirela Prgomet at m.prgomet@unsw.edu.au or on 02 9385 8217, who will be happy to answer them.
7. I acknowledge receipt of a copy of this Consent Form and the Participant Information Sheet.

Complaints may be directed to the, Research Office, [redacted]

Signature of participant	Please PRINT name	Date
_____		
Signature of witness	**Please PRINT name**	**Date**
_____		
Investigator	**Please PRINT name**	**Date**
_____		

Appendix C. Data Collection Tools

Appendix C.1. Health Service Representatives Interview Guide

The Health Service Representatives interview guide was used during interviews conducted with the Area Health Service and NSW Department of Health participants during the first stage of the research.

Appendix C.2. IT Vendors Interview Guide

The IT vendors interview guide was used during interviews conducted with the IT vendors during the first stage of the research.

Appendix C.3. Observation Data Collection Protocol

During the second stage of the research, data collection was guided by a protocol that outlines definitions and rules for the recording of each variable of interest.

Appendix C.1. Health Service Representatives Interview Guide

AN INVESTIGATION OF HOW CLINICAL COMPUTING DEVICE SELECTION DECISIONS ARE MADE

INTERVIEW GUIDE – HEALTH SERVICE REPRESENTATIVES

INTRODUCTION

The aim of this study is to identify how decisions about the selection of fixed and mobile clinical computing devices for implementation in hospital wards are made.

INTERVIEW PROTOCOL

Participants are to be provided with a Participant Information Statement and Consent Form. Participants should be reassured that:

- They may stop the interview at any time
- They may ask questions at any time
- Their answers will be kept confidential
- All data will be de-identified

Participants must be informed that the interview will be taped. Consent must be obtained from the participant prior to proceeding with the interview and this consent should be recorded as part of the interview.

PREAMBLE

We are interested in understanding how decisions are made about the type and mix of fixed and mobile clinical computing devices for use on hospital wards. By fixed computing devices we mean stationary computers at central work stations or at a patient's bedside. Mobile computing devices can include personal digital assistants (PDAs), tablet computers, laptops, or computers on wheels/carts.

QUESTIONS

1. What is you role?

2. Can you describe the types of fixed and mobile clinical computing devices that are used in health care facilities within your organisation?

3. How have decisions about the selection of those device been made in the past?

4. Who contributes to the decision making process and who is ultimately responsible for making the final decisions?

5. a) What are the types of information or factors you think are generally considered when making such decisions?
   b) Do you think there are factors which are not often consider in this process that perhaps should be included? Why?

6. a) Do you think there is a standardised process for making such decisions or do you think it is more ad hoc in most facilities?
   b) On a scale of 1 to 10, 1 being completely ad hoc and 10 being a formalised, standardised, protocol-driven procedure, how do you think most hospitals make decisions about the best mix of fixed and mobile clinical computing devices?

7. Is there policy/guidelines within your organisation to inform/steer the decision making process?

8. How do you think having mobile computing devices on the ward will/do impact on clinical care? *(prompt - e.g. what improvements will they provide? what clinical tasks will they be beneficial for?)*

Thank you very much for your time.

AN INVESTIGATION OF HOW CLINICAL COMPUTING DEVICE SELECTION DECISIONS ARE MADE

INTERVIEW GUIDE – IT VENDORS

INTRODUCTION

The aim of this study is to identify how decisions about the selection of fixed and mobile clinical computing devices for implementation in hospital wards are made.

INTERVIEW PROTOCOL

Participants are to be provided with a Participant Information Statement and Consent Form. Participants should be reassured that:

- They may stop the interview at any time
- They may ask questions at any time
- Their answers will be kept confidential
- All data will be de-identified

Participants must be informed that the interview will be taped. Consent must be obtained from the participant prior to proceeding with the interview and this consent should be recorded as part of the interview.

PREAMBLE

Thank you for agreeing to take part in this study. I am interested in understanding how decisions are made about the type and mix of fixed and mobile computing devices for use on hospital wards – and the role of IT vendors in the decision-making process. By fixed computing devices I mean stationary computers at central work stations or at a patient's bedside. Mobile computing devices can include personal digital assistants (PDAs), tablet computers, laptops, or computers on wheels/carts.

QUESTIONS

1. Could you briefly explain your position and role within your organisation?

2. Can you briefly describe the types of clinical computing *[hardware devices/ software]* that your organisation provides to hospitals (within Australia)?

Thinking about instances when a hospital (or Area Health Service) has approached your organisation regarding the potential implementation of new computing devices:

3. What is your organisation's contribution to the decision-making process about the type/mix of computing devices needed?

4. Is there policy/guidelines within your organisation to inform/steer the decision-making process about the type of devices which may be most suitable for hospital wards?

5. a) What kind of information or factors do you think are generally considered when making decisions about the type/mix of devices needed?
   b) Do you think there are factors which are not often consider in this process that perhaps should be included? Why?

6. a) In your experience do you think there is a standardised process for making decisions about the selection of devices or do you think it is more ad hoc in most facilities?
   b) On a scale of 1 to 10, 1 being completely ad hoc and 10 being a formalised, standardised, protocol-driven procedure, how do you think most hospitals make decisions about the best mix of fixed and mobile clinical computing devices?

7. How do you think having mobile computing devices on the ward will/do impact on clinical care? *(prompt - e.g. what improvements will they provide? what clinical tasks will they be beneficial for?)*

Thank you very much for your time.

Data Collection Instrument

The data collection instrument utilised for this study is a structured A4 paper form. The form is designed to aid in the collection of various data points related to the clinician (nurse or doctor) being shadowed and observed during each observation session. The data collection form is split into two sections. The first section allows the capture of work activities and use of devices by the clinician being shadowed and observed. The second section of the form allows the capture of information exchange during ward rounds that the observed clinician may undertake with other individuals during an observation session.

The form contains nine category headings with subcategories listed underneath. The category headings in the first section of the form include: activity; device/resource; location; impede; interact; and task. The category headings in the second section of the form include: exchange; person; and period. When observing a clinician, each time one of these metrics change (be that a change in the device/resource being used, a change in the location, a change in the task being conducted, etc.) a new row on the form is completed. Additional information regarding changes in tasks is outlined under the task definitions (points 6.1. to 6.15.).

The definitions of each of the nine category headings and subcategories are outlined below. Instructions on how to record each subcategory on the form are illustrated in a shaded box following each definition. The other data points appearing on the form, including date, ward, session identification, participant identification, start time, end time, notes and page number, are also defined below.

Data Points and Definitions

Date – Day, month, and year when the data collection observation session occurred.

Ward – Ward on which the data collection observation session occurred.

Session ID – A unique session identification number allocated to each data collection observation session.

Participant ID – A unique participant identification number allocated to each clinician observed throughout the data collection observation sessions.

Start Time – Hour and minute at which the data collection observation session began.

End Time – Hour and minute at which the data collection observation session ceased.

Work Activities and Use of Devices Section

1. **Activity** – The activity that the clinician being shadowed and observed is undertaking during the observation session. For this study, ward rounds and medication administration rounds are of particular interest, however, clinicians may also be observed while conducting activities outside of rounds.

   Note: Observation sessions may begin and end at any point of an activity as individuals are shadowed and observed for up to 2 hours at any one time. Thus, the entire duration of an activity, i.e. from the beginning of a medication administration round right through to the end of the medication administration round, may not be captured in a single observation session. Alternatively, two types of activities may be captured during a single observation session, e.g. a doctor may be observed while participating in a ward round and, after the ward round concludes, the doctor may be observed conducting activities outside of the round.

   1.1. **W – Ward Round** – A team of clinicians conducting consecutive reviews (examination/diagnosis/treatment/progress) of patients on the ward.

   ☑ Tick box 'W'

   Note: For ward rounds, record the primary device/resource that the doctor leading the rounding team is utilising. This information is recorded in the shaded box appearing in the "Task Codes" panel.

   Note: Only one clinician in the team is the individual that is shadowed and observed, thus only interactions directly related to that individual are recorded. Interactions that occur between other clinicians in the team, which are not directly related to the clinician being observed, are not recorded. For example, where a resident within the team is the clinician being shadowed but the consultant within the team is involved in an interaction and exchange of information with an intern from within the team, this interaction would not be recorded.

1.2. **M – Medication Administration Round** – A nurse, or nurses, preparing and administering the necessary medications to consecutive patients on the ward. A medication administration round is considered as having commenced from the time the nurse being shadowed and observed visits the first of the consecutive patients that they need to prepare and administer medication to. The medication administration round is considered as having ceased from the time the nurse being observed finishes documenting the administration of medication to the last of the consecutive patients they visited during the medication administration round.

☑ Tick box 'M'

Note: Although multiple nurses may conduct medication administration rounds simultaneously, only one nurse is shadowed and observed per observation session.

1.3. **O – Outside of Rounds** – Clinicians undertaking tasks outside of ward rounds or medication administration rounds (e.g., clinical handover, general patient review, or administrative activities).

☑ Tick box 'O'

2. **Device/Resource** – The computing device, paper, or other resource that the clinician being shadowed and observed utilises during an observation session.

2.1. **F – Fixed Desktop PC** – A fixed computing device sitting stationary on a desktop or bench space. Generally comprised of a monitor, a hard drive, a QWERTY keyboard, and an optical/laser mouse.

☑ Tick box 'F'

2.2. **CC – Computer Cart** – A laptop or integrated monitor sitting atop a trolley.

☑ Tick box 'CC'

2.3. **OC – Other Computing Device** – Other computing devices that may be used include a wall-mount computer, a tablet computer, or a PDA/smartphone.

☑ Tick box 'OC' and record name of other computing device in the blank row

2.4. **PR – Paper Record** – The permanent hospital paper-based medical record, which could be used as the entire folder or as separate parts of the paper record. ☑ Tick box 'PR'

2.5. **OP – Other Paper** – Temporary paper documents that do not form part of the permanent paper-based medical record, such as a printed handover sheet, post-it note, or a scrap piece of paper.
☑ Tick box 'OP'

2.6. **O – Other** – Other resources that may be used include writing a note on the back of the hand or memorising information.
☑ Tick box 'O' and record the name of other resource in the blank row

Note: An example of memorising information is where the nurse being shadowed is observed reading the name of a medication at the patient bedside, which the nurse then needs to retrieve from the medication room. If the device/resource from which the nurse obtained the name of the medication is not taken to the medication room, if the nurse does not document the name of the medication on an alternative device/resource (e.g., a post-it note), or if the nurse does not log into another device in the medication room to confirm the name of the required medication, then the nurse is considered to have memorised the information. The memorising of information may also be observed where a nurse, for example, repeats the name of the medication aloud to him-/herself until the medication is obtained.

3. **Location** – The location on the ward where the clinician being shadowed and observed is utilising the indicated device/resource.

Note: This data point is only recorded for the specific location where a device/resource is used. If the device/resource is in transit from one location to another but it is not actually used by the clinician being shadowed and observed, then "in transit" is not recorded. For example, if the clinician being shadowed is observed accessing patient information on a computer cart in the medication room, then wheeling the cart through the corridor without accessing information during the transit, but upon arriving at the patient bedside again utilises the cart to access patient information: the medication room would be recorded, as would the patient bedside, however, in transit would not be recorded. If the clinician being shadowed were to utilise the

computer cart to access or document patient information while wheeling the cart through the corridor, the location of "in transit" would then be recorded on the data collection form.

3.1. **B – Patient Bedside** – The location is considered as being at the "patient bedside" when the device/resource used is located directly beside the bed of the patient that is being attended to.

☑ Tick box 'B'

Note: "Directly beside the bed" is regarded as the device/resource being within approximately one metre of the sides or foot of the bed of the patient being attended to.

3.2. **R – Patient Room** – Where the device/resource is beyond the parameters of what is defined as the "patient bedside" but is still within the room of the patient that is being attended to.

☑ Tick box 'R'

Note: If the device/resource being utilised by the clinician being observed is located at the bedside of a patient, which the clinician is not attending to at that time, but the clinician is attending to another patient within that same room the location is considered as "patient room".

3.3. **C – Corridor** – The corridors, or hallways, of the ward.

☑ Tick box 'C'

3.4. **W – Workbay** – Specific areas within the ward with a desk and office chair, where desktop computers are generally stationed.

☑ Tick box 'W'

3.5. **M – Medication Room** – A room located in the ward where various medications are stored.

☑ Tick box 'M'

3.6. **T – In Transit** – If the clinician being shadowed and observed is utilising a device/resource to access or document patient information while walking between locations.

☑ Tick box 'T'

3.7. **S – Shared Office Area** – A room located in the ward, which had multiple desks and chairs, where clinicians could perform activities.
☑ Tick box 'S'

3.8. **O – Other** – Other locations on the ward (e.g., nurse unit manager's office, a meeting room, or staff break room).
☑ Tick box 'O' and record the name of the other location in the blank row

4. **Impede** – The reason impeding use of a mobile computing device at the patient bedside in instances where the clinician being shadowed and observed tends to a patient but does not utilise the mobile computing device at the patient bedside.
Note: This data point is only applicable when a mobile computing device was being used for the immediately preceding task but was then not able to be used at the bedside due to an impeding reason. Mobile computing devices can include computer carts, tablet computers, and PDAs/smartphones.

4.1. **S – Lack of Space** – If the clinician being shadowed and observed is unable to utilise a mobile computing device at the patient bedside due to a limited availability of space.
☑ Tick box 'S'
Note: The limited space may be attributable to the size of the room, the number of existing medical devices and furnishings within the room or surrounding the patient bedside, or the number of individuals within the room or surrounding the patient bedside.

4.2. **IC – Infection Control Room** – If the clinician being shadowed and observed is unable to utilise a mobile computing device at the patient bedside as it is a restricted or quarantined area.
☑ Tick box 'IC'
Note: A patient room may be restricted or quarantined due to the nature of the patient's medical condition or if the patient has contracted a bacterial infection, such as Methicillin-resistant Staphylococcus aureus (MRSA).

4.3. **P – Power Issue** – If the clinician being shadowed and observed is unable to utilise a mobile computing device at the patient bedside as they require a power outlet to plug in and power the device, but a power outlet is either not available or not easily accessible at the patient bedside.

☑ Tick box 'P'

4.4. **O – Other** – Other reasons for why the clinician being shadowed and observed is unable to utilise a mobile computing device at the patient bedside (e.g. poor or no wireless network signal).

☑ Tick box 'O' and record the name of the other reason in the blank row

5. **Interact** – Where the clinician being shadowed is observed discussing clinical information with another individual while utilising a device/resource.

Note: The device or resource must be part of the interaction. For example, the clinician being shadowed is utilising a computer cart and is observed pointing out and discussing information displayed on the screen of the cart with another individual.

5.1. **D – Doctor** – If the other individual involved in the interaction with the clinician being shadowed and observed is a doctor.

☑ Tick box 'D'

5.2. **N – Nurse** – If the other individual involved in the interaction with the clinician being shadowed and observed is a nurse.

☑ Tick box 'N'

5.3. **M – Pharmacist** – If the other individual involved in the interaction with the clinician being shadowed and observed is a pharmacist.

☑ Tick box 'M'

5.4. **P – Patient** – If the other individual involved in the interaction with the clinician being shadowed and observed is the patient.

☑ Tick box 'P'

5.5. **O – Other** – Other individuals involved in interactions with the clinician being shadowed and observed (e.g., relatives of the patient or other health care

practitioners, such as a physiotherapist).

☑ Tick box 'O' and record the type of other individual in the blank row

6. **Task** – The clinical task undertaken by the clinician being shadowed and observed while utilising a device or resource.

   6.1. **RS – Review Summary Information** – If the clinician is observed reading a summary/overview of information.

   Record code 'RS'

   Note: To be considered a summary/overview it must include information regarding multiple patients (e.g., the summary of patients' information presented on a handover sheet).

   6.2. **RR – Review Patient Record** – If the clinician is observed reading over information contained in a patient's electronic or paper-based medical record.

   Record code 'RR'

   Note: If the clinician being observed is flicking through and reading the different parts of the paper -based medical record it is considered one task. If the clinician is flicking through the paper-based medical record and then looks through the electronic medical record, this is recorded as two tasks as the clinician would require the use of different devices/resources.

   6.3. **PM – Prepare Medication** – If the clinician is observed reading a patient's medication order (or recalling a medication order that they had memorised) to obtain the necessary medication for preparation and administration to the patient.

   Record code 'PM'

   Note: A new task is recorded for each medication prepared.

   6.4. **AM – Administer Medication** – If the clinician is observed documenting that the necessary medication has been administered to the patient.

   Record code 'AM'

   Note: A new task is recorded for each medication administered.

6.5. **WM – Witness Medication** – If the clinician is observed documenting confirmation that they have checked the preparation of a medication by another clinician.

Record code 'WM'

Note: The preparation of certain medications, such as intravenous antibiotics, is often required to be witnessed by a second clinician. "Witness medication" is only recorded where the clinician being observed is the one that documents that they have acted as a witness to another clinicians preparation of medications. Where the clinician being shadowed and observed has prepared the medication and another clinician documents confirmation that they have witnessed the preparation, only the "prepare medication" task is recorded (as only it directly relates to the observed clinician) and the interaction on the device/resource with the other clinician is recorded under the "interact" category. A new task is recorded for each medication witnessed.

6.6. **OM – Order Medication** – If the clinician is observed documenting a medication order.

Record code 'OM'

Note: A new task is recorded for each medication ordered.

6.7. **CM – Modify Medication** – If the clinician is observed: documenting a change in the medication, for example altering the frequency of medication administration; documenting a cancelation, for example where the patient refuses a medication; or documenting the cessation of a medication.

Record code 'CM'

Note: A new task is recorded for each medication that is modified.

6.8. **IM – Lookup Medication Information** – If the clinician is observed seeking and accessing information regarding a medication (e.g., instructions on how to administer the medication or potential drug interactions).

Record code 'IM'

Note: A new task is recorded for each medication. Information may be sought from electronic or paper resources. Whether the information is electronic or paper will be reflected in the subcategory recorded under "device/resource". Looking up medication information only relates to information that the clinician being shadowed has actively sought. If a decision support information window pops-up while the clinician is

prescribing medication it is not considered to constitute "lookup medication information".

6.9. **OT – Order Test** – If the clinician is observed documenting an order for a test.

Record code 'OT'

Note: A new task is recorded for each test order form.

6.10. **RT – Review Test Results** – If the clinician is observed accessing and reading test result information.

Record code 'RT'

Note: A new task is recorded for each results report reviewed. For example, accessing and reading a pathology report, and accessing and reading a radiology report would be recorded as two tasks.

6.11. **DV – Document Vitals/Observations** – If the clinician is observed documenting information regarding a patient's vital signs, observations, or other statistics, such as blood pressure, pulse, respiratory rate, temperature, blood glucose, weight, height, or medication allergies.

Record code 'DV'

Note: A new task is recorded for each form.

6.12. **DP – Document Progress Notes** – If the clinician is observed documenting information regarding a patient's review (examination/ diagnosis/treatment/progress).

Record code 'DP'

Note: A new task is recorded for each form.

6.13. **DI – Lookup Disease Information** – If the clinician is observed seeking and accessing information regarding a disease, such as the pathophysiologic mechanism of a disease, the signs and symptoms, the diagnosis of a disease, and the treatment options.

Record code 'DI'

Note: A new task is recorded for each disease. Where the clinician being observed is reviewing information on the treatment options for a disease, if medications were a treatment option and the clinician looks further into information regarding the various medications this would then be considered "lookup medication information".

6.14. **DS – Document Discharge Summary** – If the clinician is observed generating a discharge summary document.

Record code 'DS'

Note: A new task is recorded for each form.

6.15. **O – Other Task** – Other tasks that the clinician being shadowed and observed may undertake while utilising a device or resource (e.g., documenting self-reminder notes or telephoning another clinician).

Record code 'O' and record the name of other task in the blank row

Information Exchange Section

7. **Information Exchange** – The exchange of information between two individuals during a ward round, where one of those individuals is the clinician being shadowed and observed. To constitute an information exchange an individual must request information from the clinician being shadowed AND the clinician being shadowed must provide a response to that request from information that is accessed and obtained via a computing device or paper resource.

Note: In an information exchange the requesting person is not required to interact on the device/resource with the clinical being shadowed and observed. As with ward rounds, only one clinician is the individual that is shadowed and observed, thus only information exchanges directly related to that individual are recorded. Exchanges of information that occur between other individuals, which are not directly related to the clinician being observed, are not recorded.

7.1. **M – Medications** – If the information that has been requested and provided in response to that request is related to medications.

☑ Tick box 'M'

7.2. **T – Test Results** – If the information that has been requested and provided in response to that request is related to diagnostic tests or test results.

☑ Tick box 'T'

7.3. **D – Diagnosis** – If the information that has been requested and provided in response to that request is related to a diagnosis or disease, such as the pathophysiologic mechanism of a disease, the signs and symptoms, the diagnosis of a disease, and the treatment options.
☑ Tick box 'D'

7.4. **H – General Health** – If the information that has been requested and provided in response to that request is related to the general health of a patient, such as the patient's progress, vital signs, or prognosis.
☑ Tick box 'H'

7.5. **O – Other** – Other information that an individual may request and that the clinician being shadowed and observed provides in response to that request.
☑ Tick box 'O' and record the name of the other information in blank row

8. **Person** – The individual requesting information and receiving the responding information from the clinician being shadowed.

8.1. **D – Doctor** – If the other individual involved in the information exchange with the clinician being shadowed and observed is a doctor.
☑ Tick box 'D'

8.2. **N – Nurse** – If the other individual involved in the information exchange with the clinician being shadowed and observed is a nurse.
☑ Tick box 'N'

8.3. **M – Pharmacist** – If the other individual involved in the information exchange with the clinician being shadowed and observed is a pharmacist.
☑ Tick box 'M'

8.4. **P – Patient** – If the other individual involved in the information exchange with the clinician being shadowed and observed is the patient.
☑ Tick box 'P'

8.5. **O – Other** – Other individuals involved in information exchange with the clinician being shadowed and observed (e.g., relatives of the patient or other health care practitioners, such as a physiotherapist).
☑ Tick box 'O' and record the type of other individual in the blank row

9. **Period** – The time period from which the information was requested and from which the response was provided.
Note: In instances where the time period between the requested information and the information being provided in response does not correspond, record the time period of the information being provided in response to the request and document the discrepancy in the blank row.

9.1. **L – Latest** – Information that is requested and provided from the previous 24 hour time period.
☑ Tick box 'L'

9.2. **C – Current Attendance** – Information that is requested and provided from the current attendance and that is more than 24 hours old.
☑ Tick box 'C'

9.3. **P – Past Attendance** – Information that is requested and provided from a previous attendance, including admissions, emergency episodes, or outpatient visits.
☑ Tick box 'P'

Notes – Additional information of interest regarding the work activities, use of devices, or information exchanges related to the clinician being shadowed and observed.

Page Number – Individual page number and total number of pages for each observation session.

Appendix D. Method Reporting Checklist

Appendix D.1. Consolidated Criteria for Reporting Qualitative Studies (COREQ) Checklist

The consolidated criteria for reporting qualitative research (COREQ), was used to guide the exposition of the first stage of the research.

Appendix D.1. Consolidated Criteria for Reporting Qualitative Studies (COREQ) Checklist

Appendix E. Ethical Approvals

Appendix E.1. Device Selection Study: Ethical Approval Letter

Ethical and scientific approval for the first stage of the research was granted by The University of Sydney Human Research Ethic Committee (reference number 08-2009/12017) (7 August 2009).

Appendix E.2. Mobile Devices and Work Study: Ethical Approval Letters

Ethical and scientific approval for the second stage of the research was granted by a NSW Health lead Human Research Ethics Committee (4 February 2011) and was ratified by The University of New South Wales Human Research Ethics Committee (14 March 2011). Authorisation to commence the research within the study site was granted by the Executive Director of the hospital (16 June 2011).

Appendix E.1. Device Selection Study: Ethical Approval Letter

The University of Sydney

Human Research Ethics Committee
Web: http://www.usyd.edu.au/ethics/human

ABN 15 211 513 464

Gail Briody
Manager
Office of Ethics Administration
Telephone: +61 2 8627 8175
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Marietta Coutinho
Deputy Manager
Human Research Ethics Administration
Telephone: +61 2 8627 8176
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Email: mcoutinho@usyd.edu.au

Mailing Address:
Level 6
Jane Foss Russell Building – G02
The University of Sydney
NSW 2006 AUSTRALIA

Ref: PB/PE

7 August 2009

Professor Johanna Westbrook
Health Informatics Research and Evaluation Unit
Faculty of Health Sciences
Cumberland Campus - C42
The University of Sydney
Email: J.Westbrook@usyd.edu.au

Dear Professor Westbrook

Thank you for your correspondence dated 3 August and 6 August 2009 addressing comments made to you by the Human Research Ethics Committee (HREC). After considering the additional information, the Executive Committee at its meeting on 7 **August 2009** approved your protocol entitled ***"An investigation of how clinical computing device selection decisions are made".***

Details of the approval are as follows:

Ref No.:	***08-2009/12017***
Approval Period:	***August 2009 to August 2010***
Authorised Personnel:	***Professor Johanna Westbrook*** ***Ms Mirela Prgomet*** ***Dr Andrew Georgiou***

The HREC is a fully constituted Ethics Committee in accordance with the *National Statement on Ethical Conduct in Research Involving Humans-March 2007* under *Section 5.1.29*

The approval of this project is **conditional** upon your continuing compliance with the *National Statement on Ethical Conduct in Research Involving Humans.* We draw to your attention the requirement that a report on this research must be submitted every 12 months from the date of the approval or on completion of the project, whichever occurs first. Failure to submit reports will result in withdrawal of consent for the project to proceed.

Chief Investigator / Supervisor's responsibilities to ensure that:

1) All serious and unexpected adverse events should be reported to the HREC as soon as possible.

(2) All unforeseen events that might affect continued ethical acceptability of the project should be reported to the HREC as soon as possible.

(3) The HREC must be notified as soon as possible of any changes to the protocol. All changes must be approved by the HREC before continuation of the research project. These include:-

- If any of the investigators change or leave the University.
- Any changes to the Participant Information Statement and/or Consent Form.

(4) All research participants are to be provided with a Participant Information Statement and Consent Form, unless otherwise agreed by the Committee. The Participant Information Statement and Consent Form are to be on University of Sydney letterhead and include the full title of the research project and telephone contacts for the researchers, unless otherwise agreed by the Committee and the following statement must appear on the bottom of the Participant Information Statement. *Any person with concerns or complaints about the conduct of a research study can contact the Manager, Ethics Administration, University of Sydney, on (02) 8627 8175 (Telephone); (02) 8627 8180 (Facsimile) or gbriody@usyd.edu.au (Email).*

(5) Copies of all signed Consent Forms must be retained and made available to the HREC on request.

(6) It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

(7) The HREC approval is valid for four (4) years from the Approval Period stated in this letter. Investigators are requested to submit a progress report annually.

(8) A report and a copy of any published material should be provided at the completion of the Project.

Yours sincerely,

Associate Professor Philip Beale
Chairman
Human Research Ethics Committee

Copy: Ms Mirela Prgomet m.prgomet@usyd.edu.au

Encl. Approved Invitation to Participate
Approved Participant Information Statement
Approved Participant Consent Form
Approved Interview Guide

4 February 2011

Ms Mirela Prgomet
Centre for Health Systems and Safety Research
AIHI, Faculty of Medicine
Level 1, AGSM Building
Kensington NSW 2052

Dear Mirela

[redacted]

COPY

Project Title: An investigation into the use and impact of mobile information and communication technology on clinical work practices.

[redacted]

Thank you for submitting the above project for ethical and scientific review. The project was first considered by the [redacted] at its meeting held on 1 December 2010. This HREC has been accredited by NSW Department of Health as a lead HREC under the model for single ethical and scientific review.

This lead HREC is constituted and operates in accordance with the National Health and Medical Research Council's *National Statement on Ethical Conduct in Human Research* and the *CPMP/ICH Note for Guidance on Good Clinical Practice*. No HREC members with a conflict of interest were present for review of this project.

I am pleased to advise that the Committee at an Executive meeting on 31 January 2011 has granted ethical and scientific approval of the above multi-centre project.

You are reminded that this letter constitutes *ETHICAL* and *SCIENTIFIC* approval only. You must not commence this research project at a site until separate authorisation from the Chief Executive or delegate of that site has been obtained. A copy of this letter must be forwarded to all site investigators for submission to the relevant Research Governance Officer.

The project is approved to be conducted at the following NSW Public Health sites:

- [redacted]
- [redacted]
- [redacted]
- [redacted]

If a new site(s) is to be added please inform the HREC in writing and submit a Site Specific Assessment Form (SSA) to the Research Governance Officer at the new site.

The following documentation has been reviewed and approved by the HREC:

- Protocol Version 1.1 dated December 2010
- Participant Information Sheet and Consent Form - [redacted] dated January 2011

Please Note: A Master PISC must be submitted for review by the HREC Executive before authorisation at additional sites.

The National Ethics Application Form (NEAF) document reviewed by the HREC was:
[redacted]

Please note the following conditions of approval:

- HREC requires that you furnish it with annual reports on the study's progress beginning in **January 2012.**
- The Co-ordinating Investigator will immediately report anything which might warrant review of ethical approval of the project in the specified format, including unforeseen events that might affect continued ethical acceptability of the project and any complaints made by study participants regarding the conduct of the study.
- Proposed changes to the research protocol, conduct of the research, or length of HREC approval will be provided to the HREC for review, in the specified format.
- The HREC will be notified, giving reasons, if the project is discontinued before the expected date of completion.
- The Co-ordinating Investigator will provide a progress report, in the specified format, annually to the HREC as well as at the completion of the study.
- HREC approval is valid for 5 years from the date of this letter.

Investigators holding an academic appointment (including conjoint appointments) at the University of New South Wales are required to provide a copy of the application form, all approved documents and a copy of this letter to the UNSW HREC for ratification. These documents should be sent to UNSW, Ethics Secretariat, Research Services, Rupert Myers Building, 3rd floor, Kensington 2052.

Please note it is the responsibility of the sponsor or the principal (or co-ordinating) investigator of the project to register this study on a publicly available online registry (eg Australian Clinical Trial Registry www.actr.org.au).

Should you have any queries about your project please contact the Research Office, [redacted] The HREC Terms of Reference, Standard Operating Procedures, *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice* and standard forms are available on the Research Office website: [redacted] or internal at [redacted]

Please quote [redacted] in all correspondence.

The HREC wishes you every success in your research.

Yours sincerely

[redacted]
HREC Executive Officer
Research Office
[redacted]
[redacted]

THE UNIVERSITY OF NEW SOUTH WALES

HUMAN RESEARCH ETHICS COMMITTEE (HREC)

14 March 2011

Ms Mirela Prgomet
Centre for Health Systems and Safety Research
AIHI, Faculty of Medicine
Level 1, AGSM Building

Dear Ms Prgomet,

An investigation of the use and impact of mobile information and communication technology on clinical work practices
[redacted]

Thank you for the above application for ratification of the ethics clearance given by the [redacted] Hospital Human Research Ethics Committee to you dated 4 February 2011.

The Executive noted the above protocol at its meeting held on 8 March 2011, and is pleased to advise it is satisfied that this protocol meets the requirements as set out in the National Statement on Ethical Conduct in Human Research*. The Deputy Vice-Chancellor (Research) accepted the ethics Committee's recommendation.

Please note that the UNSW HREC period of approval for this project is valid for the duration of the approval period given by the Primary Ethics Committee.

Yours sincerely,

A Metcalfe

Professor Andrew Metcalfe
Presiding Member
Human Research Ethics Committee

* http://www.nhmrc.gov.au

UNSW SYDNEY NSW 2052
AUSTRALIA
Telephone: +61 (2) 9385 4234
Facsimile: +61 (2) 9385 6648
Email: ethics.sec@unsw.edu.au
Location: Rupert Myers Building
C/o Research Office / Ethics,
Gate 14, Barker Street Kensington
ABN 57 195 873 179

16th June 2011

[redacted]

Project Title: **An investigation into the use and impact of mobile Information and communication technology on clinical work practices.**
[redacted]

Thank you for submitting an application for authorisation of this project. I am pleased to advise that the Executive Director on 5th June 2011 has granted authorisation for the above project to commence at [redacted]

Documents to be used at this site are:

- Protocol Version 1.1 dated December 2011-06-16
- Participant Information Sheet and Consent Form – [redacted] dated January 2011

Please Note: Ms Mirela Prgomet must compile all [redacted] HR requirements before commencement of this project, and she must be supervised at all time by the Principal Investigator.

The following conditions apply to this research project. These are additional to those conditions imposed by the Human Research Ethics Committee that granted ethical approval:

1. Proposed amendments to the research protocol or conduct of the research which may affect the ethical acceptability of the project, and are submitted to the lead HREC for review, are copied to the Research Governance Officer.

2. Proposed amendments to the research protocol or conduct of the research which may affect the ongoing site acceptability of the project are to be submitted to the Research Governance Officer.

Investigators holding an academic appointment (including conjoint appointments) at the University of New South Wales are required to provide a copy of the application form, all approved documents and a copy of the ethics approval letter to the UNSW HREC for ratification. These documents should be sent to UNSW, Ethics Secretariat, Research Services, Rupert Myers Building, 3rd floor, Kensington 2052.

Should you have any queries about your project please contact the Research Office, [redacted] The HREC Terms of Reference, Standard Operating Procedures, *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice* and standard forms are available on the Research Office website: [redacted] or internal at [redacted]

Yours sincerely

[redacted]

Research Governance Officer
Research Office
TRIM Record Number