

**ELECTRONIC MEDICAL RECORDS & COMPUTERIZED  
PHYSICIAN ORDER ENTRY:  
EXAMINING FACTORS AND METHODS THAT FOSTER  
CLINICIAN IT ACCEPTANCE IN PEDIATRIC HOSPITALS**

A Dissertation  
Presented to  
The Academic Faculty

by

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In Partial Fulfillment  
of the Requirements for the Degree  
Ph.D. in the  
School of Industrial & Systems Engineering

Georgia Institute of Technology  
August 2006

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To Mom, Dad, Big Quin, & Poppa  
for their constant love, support, and encouragement

## ACKNOWLEDGEMENTS

I would like to thank my dissertation committee for their advice and support. Specifically, thank you to Drs Christopher Flowers and Jim Jose for providing their clinician and clinical informatics perspective. Thank you to Dr Brani Vidakovic for helping advance my knowledge of statistics and how to apply it. Special thanks to Dr François Sainfort for encouraging my interest in health systems research and giving me the opportunity to be so involved in the ongoing research at Children's. And to Dr Julie Jacko, my advisor, thank you for encouraging me to pursue my Ph.D. and for your mentorship through out graduate school – I have learned so much from you over the past four years!

I would also like to thank the AHRQ grant team at Children's and Emory for their advice and assistance in developing, distributing and collecting the surveys. I would especially like to thank Ellen Hansen and the Clinical Informatics team for their help in collecting the surveys and providing me details on the EMR implementation and feedback from the Department Champions and other users.

Thanks to my fellow students in the CISE lab and the HS graduate program: Katie, Thitima, Kevin, Leon, Ji Soo, Young Sang, Erin, David, Leanne, Sofia, and Vladi. You have been a continual source of support, help, and sanity throughout my graduate career. I've learned so much from all of you. Special thanks to Kevin who has been my partner in crime for the last four years – I don't know what I would have done without you.

Finally, I would like to thank my wonderful family and friends. I could not have made it through graduate school (and especially my dissertation) without their unending support and encouragement. I am truly blessed.

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## LIST OF SYMBOLS AND ABBREVIATIONS

ADE	Adverse Drug Event
Children's	Children's Healthcare of Atlanta, the pediatric hospital system that served as the setting for this study
CPOE	Computerized provider (or physician) order entry
EE	Effort expectancy (a.k.a. ease of use)
EMR	Electronic medical record
Epic	The EMR/CPOE system, developed by Epic Systems, Inc., implemented at Children's
HCI	Human-computer interaction
HIT	Healthcare information technology
ICU	Intensive Care Unit
JAMIA	Journal of the American Medical Informatics Association
MIS	Management information systems
PE	Performance Expectancy (a.k.a. perceived usefulness)
$t_0$	Baseline time period, 8-9 months prior to implementation of Stage 2 of the EMR system at Children's
$t_1$	Second time period examined in the study, 5-6 months after implementation of Stage 2 of the EMD and 8-9 months prior to implementation of CPOE
UCI	User-centered implementation
UCD	User-centered design
UTAUT	Unified Theory of Acceptance and Use of Technology

## SUMMARY

The healthcare industry and others have acknowledged the potential for information technology systems (IT) such as electronic medical records (EMR) and computerized provider order entry (CPOE) to improve quality of patient care and especially patient safety. Thus the US government, businesses, and other groups are advocating adoption of these systems by hospitals and other care providers. This research study endeavors to examine the factors that contribute to clinician acceptance of EMR and CPOE systems and apply this new knowledge to ensure that methods used to implement these systems foster clinician acceptance and other aspects of system success.

A review of lessons from past EMR/CPOE successes and failures demonstrates two factors commonly observed in implementations that achieve positive (versus negative) outcomes: 1) designing a system that is usable by clinicians in the clinical work context, and 2) adequately preparing users to adopt changes associated with the implementation. Based on this, a framework for User-Centered Implementation (UCI) is presented. This framework combines methods from user-centered design and change management to provide an implementation methodology that addresses these factors during implementation and improves the likelihood that positive outcomes are achieved.

Next, this study examines clinician acceptance of an EMR/CPOE system implemented in a pediatric hospital system, Children's Healthcare of Atlanta (Children's). Children's was selected for this research because they have employed an implementation approach founded in user-centered implementation principles and methods. The study examined physician, nurse, and other staff perceptions about the system's usefulness (performance expectancy (PE)) and ease of use (effort expectancy (EE)) both prior to and following system implementation.

The pre- and post-implementation models demonstrate that the factors that influence PE change over time. Compatibility with work practices was important both prior to and following implementation. Prior to implementation, users who perceived a greater need for the system and felt that their needs were represented in the design process also had

higher expectations of the impact the system would have on their job performance. After implementation, PE ratings were influenced primarily by characteristics of the system. These characteristics included how well the system supported clinical decision making, facilitated sharing information, and how easy it was to use (EE). One aspect of the rollout process, the support provided by super users, also had a positive impact on PE and EE after implementation. This finding highlights the importance of having front-line support resources available on the units.

Because Children's employed a UCI-based implementation approach, it was expected that good levels of user acceptance of the EMR/CPOE would be achieved. Study results indicate Children's implementation achieved positive perceptions of system ease of use (EE). However, this ease of use did not consistently translate to favorable ratings of the systems' impact on individual job performance. Post-implementation PE ratings remained neutral or positive for most user subgroups, a finding likely related to the fact that during this intermediate stage of the implementation both the paper chart and EMR must be used. Managing these dual locations for patient information may be contributing to predominantly neutral, rather than positive, PE ratings since this limits the ability of the system to contribute to gains in personal efficiency and effectiveness.

The findings on factors that influence PE and EE, two aspects of technology acceptance, and the PE and EE levels achieved with Children's EMR were applied to provide further guidance for using UCI to achieve clinician acceptance of EMR systems. Designing EMR/CPOE systems that are usable within the clinical work context is important because it enables clinicians to focus time and energy on the patient, rather than on using the system. Accomplishing this in practice is difficult given the complexity of these systems and the dynamic clinical care processes they must support. However, the UCI framework presented here can be effectively applied to EMR/CPOE implementations to ensure the usability, utility, and, consequently, acceptance of these systems.

## INTRODUCTION

The healthcare industry and others have acknowledged the potential for information technology systems (IT) such as electronic medical records (EMR) and computerized provider order entry (CPOE) to improve quality of patient care and especially patient safety. As a result, many healthcare, government, and business groups are encouraging healthcare providers to adopt EMR and CPOE. For example, in the US the federal government, some state governments, and the Leap Frog Group, a consortium of businesses, have adopted strong positions, and in some cases incentives, for adopting these systems (2003).

These groups advocate adoption of EMR and CPOE because research on adoption of these systems demonstrates a number of benefits associated with their implementation. These benefits, reported in a number of studies and reviews (e.g., Poissant, Pereira, Tamblyn, & Kawasumi, 2005; e.g., Rothschild, 2004; van der Meijden, Tange, Troost, & Hasman, 2003; Walker & Prophet, 1997), include:

- Reduction in the incidence of serious medication errors and adverse drug events (ADEs)
- Reduced length of patient stay
- Reduced cost of care (e.g., medication cost)
- Improved compliance with patient care guidelines
- Increased completeness and standardization of patient documentation
- Improved documentation efficiency for nursing staff
- Improved accessibility to/awareness of/interpretation of patient data (with caution about potential for information overload)
- Increased time spent with patients
- Improved communication between departments/professionals

Despite some limitations (Berger & Kichak, 2004; Oren, Shaffer, & Guglielmo, 2003; Rothschild, 2004), the EMR and CPOE literature provides significant evidence of the benefits of implementing these systems. In addition to the reported benefits reviewed previously, these systems provide an infrastructure that truly enables transforming how

healthcare is delivered. EMR/CPOE facilitates standardization based on best practice care processes (Ali et al., 2005) and CPOE has the potential to resolve many current problems in medication prescribing (Schiff & Rucker, 1998). For example, Lesar and colleagues (1997) found that the factors most commonly associated with prescribing errors were:

- Knowledge and the application of knowledge regarding drug therapy (30%)
- Knowledge and use of knowledge regarding patient factors that affect drug therapy (29.2%)
- Use of calculations, decimal points, or unit and rate expression factors (17.5%)
- Nomenclature factors (incorrect drug name, dosage form, or abbreviation) (13.4%)

CPOE, especially CPOE including dose guideline support, can significantly reduce the potential for all of these factors contributing to errors.

Note that while the literature provides evidence of the benefits of EMR/CPOE, these benefits are not reported consistently across all EMR/CPOE implementations. In fact, some implementations have reported negative outcomes. Negative outcomes reported once or more in the literature include:

- Decreased documentation and ordering efficiency for physicians (Bates, Boyle, & Teich, 1994; Poissant, Pereira, Tamblyn, & Kawasumi, 2005; Shu et al., 2001)
- Introduction of IT-related errors into care processes (e.g., selecting wrong item from a menu/list, errors during system downtime, ‘write’ orders in wrong patient record) (Kaushal, Shojania, & Bates, 2003; Koppel et al., 2005; Weiner et al., 1999)
- Increased mortality in some classes of patients (Han et al., 2005)
- Decreased time with patients (Weiner et al., 1999)
- Errors in communication and coordination (Ash, Berg, & Coiera, 2004)
- Increased care coordination load on patient care team (Cheng, Goldstein, Geller, & Levitt, 2003)
- Negative emotional responses from patient care staff (Sittig, Krall, Kaalaas-Sittig, & Ash, 2005)

This indicates that there is significant variability in outcomes achieved in EMR/CPOE implementations. Thus there is a need to understand factors that ensure positive (versus

negative) outcomes and remove barriers to successful adoption of these systems. These barriers include:

- Cost of system implementation (Kuperman & Gibson, 2003)
- Cultural and organizational barriers like resistance to change (Oren, Shaffer, & Guglielmo, 2003; Poon et al., 2004)
- Magnitude of change clinical care personnel must absorb, especially changes to work processes and job responsibilities (Kuperman & Gibson, 2003)
- Logistics challenges like user training, equipment installation & upgrades (Oren, Shaffer, & Guglielmo, 2003)
- System response time and system downtime (Weiner et al., 1999)

While EMR/CPOE have the potential to improve quality of care, their potential for causing negative outcomes and other barriers emphasize that this technology cannot be viewed as a ‘cure-all’. Examples of painful and failed attempts at adopting these systems (e.g., Massaro, 1993b) and of instances in which implementation resulted in some negative patient care outcomes (Han et al., 2005; e.g., Koppel et al., 2005) highlight the need for providers to be cautious when implementing these systems. This is likely a contributing cause for the low number of hospitals that have fully implemented these systems. For example, in 2002 CPOE was fully available in only 9% of US hospitals (Ash, Gorman, Seshadri, & Hersh, 2004). A central question for providers embarking on adoption of these systems, then, is how to ensure that their implementation is a success.

Several studies and reviews highlight important lessons learned from previous EMR/CPOE implementations (e.g., Ash, Berg, & Coiera, 2004; Poon et al., 2004; Sittig & Stead, 1994; van der Meijden, Tange, Troost, & Hasman, 2003). However, translating these lessons into practice has not been fully accomplished. A letter to the editor of JAMIA highlights that hospitals are not learning from past mistakes. In this letter, Patterson (2002) notes:

*“Our travails with FRED [Friggin’ Ridiculous Electronic Device – their clinicians’ nickname for the CPOE system] were reported in the medical literature; the University of Virginia had a similar experience with the*

*same system around the same time (Massaro, 1993b) ...Imagine, therefore, my surprise when I read in the paper by Murff and Kannry that FRED is alive and well and living in New York... this antediluvian system was implemented and its use made mandatory ... almost a decade after the fiasco in our hospital. Predictably, the results of the survey among Mount Sinai house staff closely parallel those of our assessment 10 years earlier.”*

Patterson’s letter demonstrates that, some hospitals are not effectively learning from previous experiences with EMR/CPOE adoption. In order for EMR and CPOE systems to achieve their potential, providers implementing these systems *must* apply what early adopters have learned to achieve incremental improvements in the impact these systems have on patient care. Differences among EMR and CPOE implementations lead to different impacts on hospitals (Weiner et al., 1999). Therefore, it is of critical importance to develop a better understanding of what factors lead to successful adoption of these systems and to apply this knowledge to improve EMR/CPOE implementation methods. Part of the difficulty in applying these lessons might be that they are generally reported at a high level (e.g. ‘address workflow concerns’) with little guidance as to how to translate these lessons learned in detailed implementation plans. Thus, there is a need for more information on how to integrate past lessons with implementation methods and tools to make it easier to apply them in practice.

A review of lessons from past EMR/CPOE successes and failures, presented in the following sections, demonstrates two crucial factors that distinguish implementations that achieve positive outcomes from those that do not: 1) designing a system that is usable by clinicians in the clinical work context (i.e., patient care setting), and 2) adequately preparing users to adopt changes associated with the implementation (i.e., developing computer/system skills, preparing for changes to work practices, etc.). Methods and tools from the Human Computer Interaction (HCI) and Change Management can be applied to address these factors during EMR/CPOE implementation and improve the likelihood that positive outcomes are achieved and that clinicians accept these systems. However, as with lessons learned from previous EMR/CPOE systems, a framework for integrating

these tools into the system implementation lifecycle is needed to ensure that they are effectively applied.

The research presented here endeavors to contribute knowledge in this area by examining the implementation methods employed and outcomes achieved during implementation of an EMR/CPOE in a pediatric hospital system, Children's Healthcare of Atlanta (Children's). Children's was selected for this research because they have employed an implementation approach founded in user-centered implementation principles from HCI and Change Management. In addition, implementing EMR/CPOE in pediatric hospitals can be more difficult than implementations in general/adult care facilities due to the specialized requirements of pediatric care (Cordero, Kuehn, Kumar, & Mekhjian, 2004; Kaushal, Barker, & Bates, 2001). Therefore, implementation methods that achieved successful implementation in pediatrics are likely to translate to general/adult care environments.

The outcome of interest in this research is clinician acceptance of the EMR/CPOE. Clinician acceptance of EMR/CPOE is important to examine because, as front-line care providers, physician and staff are in the best position to observe the effects of its use (Weiner et al., 1999). Additionally, user satisfaction has been identified as an important predictor of system success (Saathoff, 2005). Thus, the objectives of this research are to:

- Identify factors that influence clinicians' pre-implementation expectations and post-implementation acceptance of EMR/CPOE.
- Provide a framework of user-centered implementation methods and tools that can be employed to improve system usability in clinical use contexts and prepare users for change.
- Determine the impact that these user-centered methods have on user expectations and acceptance of an EMR/CPOE implemented in a pediatric hospital system.
- Apply the above knowledge to improve the framework of user-centered implementation methods to ensure that use of these methods leads to improved clinician acceptance of EMR/CPOE systems.

## **BACKGROUND**

### **Electronic Medical Records & Computerized Physician Order Entry**

The amount of medical knowledge available to medical practitioners is growing exponentially. Yet, Weed (1997) notes that the medical industry does not have an IT infrastructure that efficiently connects those who must apply that knowledge with the appropriate knowledge at the point where it needs to be applied. He calls for tools “to extend the human mind’s limited capacity to recall and process large numbers of relevant variables”. EMR and CPOE have been heralded as tools that can help connect healthcare providers with the information they need at the point of care delivery, thus improving the quality of care. To better understand how EMR/CPOE can accomplish this, the following sections describe what these systems are and the impact they have had on care delivery, especially in pediatric inpatient environments.

#### **What are EMR & CPOE?**

EMR and CPOE are types of clinical information systems (CIS), that is, information systems applied to the delivery of clinical care. As is often the case in healthcare and IT, a number of different names and acronyms are associated with Electronic Medical Records (EMR). These names include: Electronic Health Record (EHR), Computer-Based Patient Record (CBPR), Electronic Patient Record (EPR), Electronic Patient Record System (EPRS), and, Patient Care Information Systems (PCIS). According to the Institute of Medicine (IOM), an Electronic *Health* Record is a system that provides the following capabilities:

- 1) *“Longitudinal collection of electronic health information for and about persons, where health information is defined as information pertaining to the health of an individual or health care provided to an individual;*
- 2) *Immediate electronic access to person- and population-level information by authorized, and only authorized, users;*
- 3) *Provision of knowledge and decision-support that enhance the quality, safety, and efficiency of patient care; and*

4) *Support of efficient processes for health care delivery.*” (Committee on Data Standards for Patient Safety, 2003)

This IOM report notes that the key building blocks of an EHR system are EHRs maintained by individual providers (e.g., hospitals, ambulatory settings) and by individuals (i.e., personal health records). The inclusion of personal health records maintained by individual in this definition emphasized that from a content perspective, the concept of EHR is broader than, but inclusive of, that of a traditional paper medical record. Specifically, it complements traditional documentation of healthcare provided to an individual with additional personal health information that is unrelated to a specific interaction with a care provider. So where do Electronic Medical Records (EMRs) fit into this definition? For the purposes of this research EMRs are defined as the portion of the EHR maintained by the healthcare provider (in this case the hospital system), concentrating on patient information required for or resulting from care delivery.

Computerized Provider Order Entry (CPOE) systems are complimentary to EMRs and are often implemented as part of an overall migration from paper records to EMR. CPOE is defined as:

*“The portion of a clinical information system that enables a patient’s care provider to enter an order for a medication, clinical laboratory or radiology test, or procedure. The care provider is most often a physician, but we would also consider it CPOE when a physician assistant (PA) or nurse practitioner (NP) with medication-ordering privileges uses the computer to enter orders. The system then transmits the order to the appropriate department or individuals, so it can be carried out. The most advanced such systems also provide real-time clinical decision support such as dosage and alternative medication suggestions, duplicate therapy warnings, and drug-drug interaction checking.” (Sittig, Krall, Kaalaas-Sittig, & Ash, 2005)*

Note that CPOE is sometimes referred to as Computerized *Physician* Order Entry, however in this paper the broader ‘provider’ term will be used to be more inclusive of all

clinical users of order entry functions. Also, CPOE is sometimes referred to simply as POE, but this represents the same computerized POE systems.

The above definition states that some CPOE systems include clinical decision support functions such as drug-drug interaction checking and clinical guideline recommendations. These functions are typically implemented using alerts, system defaults, order templates, and other features. As such, these features function as a class of clinical decision support system (CDSS). However, CDSS is a broad class of technology used in healthcare inclusive of IT systems independent of EMR/CPOE. The research reported here does not include the broader class of CDSS, but does address CDSS functions, such as drug-drug interaction alerts, that are featured in many EMR/CPOE systems.

### **EMR & CPOE in Pediatrics**

A substantial body of research on EMR and CPOE use in adult and general care settings has been created over the past several decades. However, the literature examining the use of EMR and/or CPOE in pediatric environments is comparatively sparse. Table 1 demonstrates this lack of attention to pediatric hospitals in the EMR/CPOE literature. As Table 1 indicates, a handful of studies have examined the effect of CPOE on patient safety, errors, quality of care, and cost in a pediatric hospital(s). Only three studies have examined user satisfaction of pediatric providers and staff with EMR/CPOE. However these studies examined pediatric units and personnel within a general care hospital setting; none of these studies addressed personnel in pediatric hospitals.

**Table 1. EMR/CPOE Literature Overview**

	<b>Adult/General Care Inpatient</b>		<b>Pediatric Inpatient</b>	
	<b>EMR/Clin Doc</b>	<b>CPOE</b>	<b>EMR</b>	<b>CPOE</b>
<b>Errors/Patient Safety</b>	Ash et al. (2004)	Ash et al. (2004), Bates et al. (1998, 1999), Cheng et al. (2003), George & Austin-Bishop (2003), Koppel et al. (2005), Raschke et al. (1998), Staggers & Kobus (2000)		Cordero et al. (2004), Han et al. (2005), King et al. (2003), Myers et al. (1998), Potts, et al. (2004), Upperman et al. (2005)
<b>Quality of care (e.g. guideline adherence, length of stay)</b>	Walker & Prophet (1997)	Ali et al. (2005), Chertow et al. (2001), Dexter et al. (2001), Mekhjian et al. (2002), Overhage et al. (1997), Teich et al. (2000), Tierney et al. (1993)		Cordero et al. (2004), Myers et al. (1998)
<b>Documentation Quality</b>	Ash et al. (2004), Walker & Prophet (1997)	Ash et al. (2004)		
<b>Efficiency</b>	Roderiguez (2002), Walker & Prophet (1997)	Aarts et al. (2004), Ali et al. (2005), Bates et al. (1994), Shu et al. (2001), Mekhjian et al. (2002), Staggers & Kobus (2000), Tierney et al. (1993) , Weiner et al. (1999)		Cordero et al. (2004)
<b>Cost</b>		Chertow et al. (2001), Mekhjian et al. (2002), Overhage et al. (1997), Raschke et al. (1998), Teich et al. (2000), Tierney et al. (1993)		Myers et al. (1998)
<b>Clinician work climate</b>		Dykstra (2002), Sittig et al (2005)		

**Table 1 (continued)**

	Adult/General Care Inpatient		Pediatric Inpatient	
	EMR/Clin Doc	CPOE	EMR	CPOE
<b>User expectations – Physicians</b>	van der Meijden, et al. (2000, 2001)		Current Study	Current Study
<b>User expectations – Nurses</b>	Dillon, et al. (2005), McLane (2005), Murphy, Maynard, & Morgan (1994), van der Meijden, et al. (2000, 2001),		Current Study	
<b>User acceptance/satisfaction – Physicians</b>	Gardner & Lundsgaarde (1994), Lærum et al. (2001, 2004), Matsumura et al. (2001), Nightingale, Richards, & Peters (2000), Roderiguez (2002) †, Weir (2000)	Aarts et al. (2004), Dykstra (2002), Massaro (1993), Murff & Kannry (2001), Nightingale, Richards, & Peters (2000), Sittig (2005), Tierney et al. (1993) †, Lee et al. (1996), Weiner et al. (1999), Wilson et al. (2000) <sup>+</sup>	Mikulich et al. (2001)*†	Murff & Kannry (2001)*,
<b>User acceptance/satisfaction – Nurses</b>	Gardner & Lundsgaarde (1994), Lærum et al. (2004), Murphy, Maynard, & Morgan (1994), Nightingale, Richards, & Peters (2000), Weir (2000), <i>RN doc only:</i> Ammenwerth et al. (2003), Burkle (1999), Dennis et al. (1993), Gugerty et al. (2000), Lee at al. (2002, 2004a, 2004b, 2005),	Lee et al. (1996), Nightingale, Richards, & Peters (2000), Staggers & Kobus (2000), Weiner et al. (1999),	Ammenwerth et al. (2003)* (RN doc only)  Current Study	

\*Pediatric unit/clinicians in a general care hospital/hospital system

†Only included interns and/or residents

The comparative lack of knowledge regarding EMR/CPOE use in a pediatric environment may be due in part to the fact that children's hospitals account for less than 5% of all hospitals (NACHRI, 2006). However, children's healthcare is a critical component of the healthcare system. In 2001 (NACHRI), children's hospitals accounted for 39% of admissions, 49% of inpatient days, and 59% of costs for children hospitalized in the US – accounting for 10 billion dollars of care annually. Another fact that highlights the need for, and a key challenge in operating, children's hospitals is that they provide care regardless of the family's ability to pay for care. Consequently, more than 45% of inpatient days at most children's hospitals are accounted for by Medicaid, which on average pays only 85% of the cost of their care (NACHRI, 2001). In addition to this financial challenge, the methods and type of care provided at children's hospitals differs from that provided in general care hospitals (NACHRI, 2001):

- Children's healthcare requires extra time and monitoring; an estimated 40% more nursing care is required to attend to the special medical and psychological needs of children under the age of 2
- Children's hospitals provide most of the highly specialized care required to treat complex and rare conditions in children
- On average, children's hospitals devote 26% of their beds to ICU versus only 9% in general hospitals

Some of the factors that make Children's hospitals different make implementing effective CPOE in pediatrics more difficult than implementing CPOE in an adult care environment (Cordero, Kuehn, Kumar, & Mekhjian, 2004; Kaushal, Barker, & Bates, 2001; Kaushal et al., 2001). This is due to complexities in pediatric care, especially regarding pediatric dosing. Most pediatric medication dosing is weight- and age- dependent. This combined with the absence of prepared medications in pediatric care means that prescribing for pediatrics is more calculation-intensive than adult prescribing (Cordero, Kuehn, Kumar, & Mekhjian, 2004). Thus to provide effective decision support for medication ordering, pediatric CPOE's must enable easy updating of a patient's weight and other clinical factors and integrate that information into complex dosing formulas. For example,

Waitman and colleagues (2003) describe some of the complex functions required to support drug dosing and fluid management in a neonatal intensive care unit (NICU). Neonates require precise and highly specialized drug dosing. To support these specialized patient care needs, the system must provide functions for individualized dosing and instructions based on the patient's age, gestational age, dosing weight, & body surface area. The system must also support total parenteral nutrition (TPN) ordering. TPNs contain multiple components and are compounded daily, which requires a unique workflow and complex order entry requirements. To meet these special needs, Waitman and colleagues had to develop an IV fluid management advisor to support ordering replacement and maintenance fluids.

The complexity in pediatric dosing, however, is one of the major reasons that CPOE with decision support is so crucial to improving patient safety in pediatric hospitals. In their review, (Kaushal, Barker, & Bates, 2001) note that in four pediatric hospitals studied, medication error rates ranged from 0.45 to 6 of every 100 orders. While error rates in two of these hospitals were comparable with adult hospitals (6 per 100 orders), potential adverse drug events (ADEs) occur about 3 times as often in pediatric settings, especially in the NICU (Kaushal et al., 2001). Compared to adults, children are more prone to ADEs because they have less physiologic reserves with which to buffer the effects of medical errors such as overdoses (Fortescue et al., 2003). In addition, young children often lack the communication skills to warn clinicians about potential medication administration mistakes (Kaushal et al., 2001). In a study examining medication errors and ADEs in pediatric inpatients Fortescue and colleagues (2003) found that 74% of errors occurred at the ordering stage. In their detailed examination of potentially harmful errors, they determined that 76% could have been prevented by CPOE with decision support. Many of these preventable dosing errors stem from the complexities associated with pediatric dosing including:

- Drug dosages must often be calculated individually, creating a high risk of 10-fold errors in the calculated dose
- In children, especially neonates, weights can change rapidly and dramatically over time, creating the need to frequently recalculate the appropriate dose

Use of automated dose calculations and automated dose-guideline checking (e.g. periodic recalculation and checking of doses) in CPOE can help prevent these types of dosing errors. When combined with electronic medication administration documentation functions provided in EMRs intended to improve timeliness and accuracy of documenting when medications are due and administered, the ability to reduce medication errors across the life cycle of a medication order is even greater.

This demonstrates the need for using EMR and CPOE in pediatric hospitals to improve patient safety. However, due to the complexities in providing pediatric care and the significant differences between children's healthcare and adult care, examining EMR/CPOE implementations in pediatric hospitals is not only warranted, but critical to ensuring that these systems have a positive impact on the quality and sustainability of providing children's healthcare.

The following section summarizes the limited research to date that has examined the use of EMR and/or CPOE in pediatric hospitals. This section reviews studies examining objective outcomes related to patient safety and delivery and quality of care. Several of these studies highlight the potential that these systems have for improving patient safety and quality in pediatric care. However, neutral and negative outcomes observed in some cases emphasize that these systems are not a cure-all. These instances highlight the need to use proven, effective IT implementation methods to ensure that intended improvements in quality of care are achieved when implementing these systems.

#### Impact on patient care outcomes

A review of the literature identified five studies that have examined the effect of CPOE on patient care outcomes in pediatric hospital environments. No studies were found examining the effects of other EMR functions (e.g., clinical documentation) on patient care outcomes. The results of the CPOE studies are summarized in Table 2. These studies indicate mixed results regarding the effect of CPOE on quality of patient care in pediatric hospitals.

**Table 2. Effects of CPOE in pediatric hospitals**

<b>Hospital</b>	<b>Setting</b>	<b>System</b>	<b>Medication Errors</b>	<b>ADEs</b>	<b>Other</b>	<b>Reference</b>
Ronald McDonald Children's Hospital, Loyola University (RMCH)	Neonatal Intensive Care Unit (NICU)	Medical Information System (ordering module)	(+) Reduced from 3.2 to 0.6 errors per 1000 patient days		No sig. effect on neonatal survival rates (+) Decreased avg. hospital cost per infant and (+) decreased avg. length of stay for infants whose birth weights were less than 1001 gm	Myers, Venable et al. (1998)
Children's Hospital of Eastern Ontario (CHEO)	Medical wards	Commercial CPOE (Eclipsys Sunrise Clinical Manager)	(+) Reduced from 4.5 to 3.1 per 1000 patient days (40% reduction)*	No sig. effect on ADEs*	N/A	King, Paice et al. (2003)
Ohio State University Medical Center	NICU	Commercial CPOE (Siemens Invision 24)	(+) Over- and under-dosages of gentamicin eliminated		(+) Medication and radiology turn around time reduced; (+) Survival rate increased from 86 to 91%	Cordero, Kuehn et al. (2004)

**Table 2 (continued)**

<b>Hospital</b>	<b>Setting</b>	<b>System</b>	<b>Medication Errors</b>	<b>ADEs</b>	<b>Other</b>	<b>Reference</b>
Vanderbilt Children's Hospital	Pediatric Critical Care Unit (PCCU)	Proprietary CPOE (WizOrder, precursor to McKesson Horizon)	(+) Prescribing errors (e.g. illegible) reduced from 30.1 to 0.2 per 100 orders;	Potential ADES reduced from 2.2 to 1.3 per 100 orders	(+) Rule violations (e.g., wrong abbreviation) reduced from 6.8 to 0.1 per 100 orders	Potts, Barr et al. (2004)
Children's Hospital of Pittsburgh (CHP)	Hospital-wide	Commercial CPOE (Cerner PowerOrders)	N/A	No sig. effect on all ADEs, (+) harmful ADEs reduced from 0.05 to 0.03 per 1000 doses*	N/A	Upperman, Staley et al.(2005)
Children's Hospital of Pittsburgh (CHP)	Critical Care Transport patients	Commercial CPOE (Cerner PowerOrders)	N/A		(-) <i>Increased mortality from 2.8% to 6.6% for a subclass of patients</i> (-) Anecdotal evidence of increased medication order turn-around time	Han, Carcillo et al. (2005)

\* Medication error and/or ADE data from clinician self-reports.

In terms of the impact on hospital operations, the Ohio State study, which used NICU-specific order sets, demonstrates that CPOE is an effective tool for reducing response time/improving efficiency of ancillary services and pharmacy for the NICU environment (Cordero, Kuehn, Kumar, & Mekhjian, 2004). However, the Han CHP study, which did not utilize critical care-specific order sets, provides anecdotal evidence that response time of pharmacy orders was increased (Han et al., 2005). This highlights the importance of implementing unit-specific order sets prior to go-live to ensure that efficiency goals for care delivery are met. In addition to the effect on efficiency, the RMCH study demonstrates that CPOE can result in decreased cost of care and length of stay for certain categories of patients (Myers, Venable, & Hansen, 1998).

Four studies reported reductions in medication and/or medication prescribing errors. However, this reduction in errors did not always translate better patient outcomes. In the CHEO study, no change in ADE rates on medical wards was reported (King, Paice, Rangrej, Forestell, & Swartz, 2003). The Upperman CHP study (2005), reported no change in overall ADE rates, but a small decrease in the rate of harmful ADEs. Alarming, the Han study (2005), which also took place at CHP, reported increased mortality for critical care transfer patients after introduction of the same CPOE system that resulted in reduced harmful ADEs in the hospital overall. Han and colleague propose that this increased mortality was not due to increased errors, but rather to delays in providing care resulting from the increased order entry time and other procedural changes (e.g., centralized pharmacy) associated with the CPOE implementation. This demonstrates that to get a complete picture of the impact of CPOE and other technologies on quality of patient care, hospitals must look at more than just error and ADE rates. It is important to use other metrics that give additional insight into how these technologies affect quality of patient care. For example, this additional insight can be obtained by examining clinical staff perceptions about the technology and its impact on their work and quality of patient care. As the front line care providers and system users, they are in the best position to understand both how these systems improve quality of care and when and how they introduce problems that could degrade quality of care.

The results observed at CHP (Han et al., 2005; Upperman, Staley, Friend, Benes et al., 2005; Upperman, Staley, Friend, Neches et al., 2005) highlight several issues of note related to implementing EMR/CPOE. First, Upperman et al. (2005) emphasize that implementing CPOE is more than a technology change; it is a major paradigm shift that, in order to be successful, requires redesigning complex clinical processes to integrate the technology into care processes to optimize care. The change management and HCI literature provide information on best practices for successfully implementing technology changes of this magnitude. Based on the description of CHP's implementation process (provided in Upperman, Staley, Friend, Benes et al., 2005), it sounds, at least at a high level, as if this hospital used a sound organizational change and IT implementation approach. This approach included having a leadership kick-off, getting physicians involved, and doing workflow design – items often mentioned in EMR/CPOE lessons learned. This makes the increased mortality observed in the critical care patients even more alarming. If they used a sound implementation process, how could there still be bad patient outcomes in this hospital area?

The problem in this case likely stemmed from a general system and workflow design that did not account for the special needs of particular patient care environments, specifically, critical care units. The drastically different patient needs in the critical care unit created different system requirements necessary to meet their patients' care needs. In this case, the large number of medication orders typical of critically ill transfer patients made providing order sets necessary to adequately meet patient care needs. On general care units where patients typically received fewer medications, physicians might be annoyed by longer order entry times, but compared to the critical care physicians this increased order entry time is not as significant for them and their patients because that time is not multiplied by the large number of drugs ordered for incoming ICU patients. Similar differences in order entry times between different medical specialties has also been observed in general care hospital environments (Bates, Boyle, & Teich, 1994). This highlights the need for the implementation team to examine care practices in each unit and specialty to identify and address any special care needs. Understanding and designing

the system to support these special needs helps to ensure that clinicians can focus on delivering high quality patient care as they begin using the new system.

In considering the effect of a vendor CPOE system on care in a critical care environment, the results from Han et al. at CHP (2005) appear to conflict with those observed by Cordero and colleagues at Ohio State (2004). The Cordero study reported improved quality of care in the NICU: medication turn-around times decreased, over- and under-dosages in gentamicin were eliminated, and radiology response time decreased. They also reported a 5% *decrease* in mortality following implementation of CPOE. (They reported a 86% survival rate before CPOE versus 91% after CPOE). In contrast, Han et al. reported that unadjusted mortality rate *increased* 3.8% (from 2.8% to 6.6%) for patients admitted to ICU via interfacility transport. Both studies examined CPOE implementations in critical care units; both hospitals used CPOE systems from reputable vendors. So what caused the difference in the observed outcomes? While some of the difference may be accounted for by the difference in study populations, it is unlikely that this accounts for the stark contrast in results. It is most likely that the observed difference in the effect of CPOE on mortality is due to reported differences in the approach used to implement the systems and the resulting system and work process designs. The notable differences in the two studies are outlined below in Table 3.

**Table 3: Comparison of CPOE studies in pediatric critical care units**

	<b>Cordero, et al. (2004)</b>	<b>Han, et al. (2005)</b>
	Neonatal Intensive Care (NICU)	Pediatric Intensive Care (ICU)
Patient Population	Very low birth weight infants (<1500g) selected due to their high morbidity and mortality and critical need for timely radiology and pharmacy response	Patients admitted to the CCU via inter-facility transport because they represented a ‘first encounter’ cohort of patients, requiring immediate processing of admission and stabilization orders

**Table 3 (continued)**

	<b>Cordero, et al. (2004)</b>	<b>Han, et al. (2005)</b>
	Neonatal Intensive Care (NICU)	Pediatric Intensive Care (ICU)
Design/Development	Clinical workgroup developed 18 NICU-specific order sets prior to go-live	No ICU sets at go-live; Entering stabilization orders required an average of 10 clicks (1-2 min) per order
Clinical workflow	<ul style="list-style-type: none"> <li>• Physician enters orders at bedside, immediately printed in pharmacy for processing</li> <li>• Order presented to nurse in computer for electronic medication record</li> <li>• Decentralized pharmacy dispensing for many medications (via Pyxis machine)*</li> </ul>	<ul style="list-style-type: none"> <li>• Physician enters orders at bedside, nurse had to activate orders before they printed in the pharmacy</li> <li>• No orders could be entered prior to patient being admitted</li> <li>• All dispensing moved to centralized pharmacy (no meds dispensed on unit)</li> </ul>
Training	<ul style="list-style-type: none"> <li>• Within 1 month of go-live</li> <li>• Nurse leaders (super users): 16 hrs</li> <li>• Other nurses &amp; clerical staff: 9 hrs</li> <li>• Physicians: 2-4 hrs of individualized training</li> </ul>	<ul style="list-style-type: none"> <li>• Within 3 months of go-live</li> <li>• 3 hour computer tutorial and practice session</li> </ul>
Support	<ul style="list-style-type: none"> <li>• Nurse leader support for physicians</li> <li>• 24hr IT staff support</li> </ul>	<ul style="list-style-type: none"> <li>• CPOE experts on the unit during go-live</li> <li>• Telephone support after go-live</li> </ul>

\* Turn-around times reported were for a medication that is dispensed by the central pharmacy, not the Pyxis on the unit.

Comparing these two studies, it is apparent that the primary differences in these two implementations are related to system usability and the workflow for placing orders in using the system. Regarding system usability, in the Cordero study, ICU-specific order sets were developed prior to go-live to ensure that placing orders in the system was simplified and streamlined. In contrast, in the Han study, no ICU-specific order sets were implemented prior to go-live and placing a single order took 1-2 minutes, multiplied by the significant number of orders typical of critically ill transfer patients. In terms of workflow, in the Cordero study, when a physician placed an order, it printed in the pharmacy immediately. This enabled the pharmacy to prepare the medications immediately, even if the nurse had not reviewed the order yet. In addition, many medications were available on the unit through a Pyxis dispensing machine. Both of these workflow factors contributed to clinicians in this hospital being able to quickly start patients on the medications they needed. In contrast, in the Han study, the nurse had to review the order before it could be printed and prepared in the pharmacy. Additionally, when CPOE went live, all pharmacy functions were centralized, so medications were no longer easily accessible on the unit. Both of these workflow factors and the order entry time requirement resulted in delays in getting patients started on needed medications.

The hospital in the Cordero study designed the system and workflow to account for the time-critical nature of the patients and the parallel collaborative task execution required to deliver care as quickly as possible. Consequently, they observed an improvement in mortality after implementing CPOE. In the Han study, they forced a dynamic care process into a linear workflow and failed to use order sets to streamline the order entry process. By failing to consider the unit-specific needs, the opposite effect was observed, with mortality rates increasing instead of decreasing.

The divergent results observed in these studies highlight a crucial point. The usability of the system interface (e.g., efficiency of order entry) and the usability of the system in the context of the clinical work (e.g., printing orders in the lab immediately instead of after nurse review) are crucial to ensuring that EMR/CPOE implementation improves quality of care, instead of reducing it. However, evaluating system usability is challenging,

especially in complex systems like EMR/CPOE. Fortunately, the field of HCI provides a number of methods for evaluating usability and usefulness of systems and using this information to improve their design and, consequently, acceptance. These methods are reviewed in detail in the section on *User-Centered Design*. The research presented here examines clinician (physician and staff) pre-implementation expectations and post-implementation acceptance of EMR/CPOE to inform the development of a framework for applying these methods to improve the utility and acceptance of EMR/CPOE systems. Note that in their EMR/CPOE implementation, the Children's hospital system studied in this research used other methods to measure the success of their implementation (e.g., medication error rates, medication order turn-around time). However, those results are outside the scope of the research presented here and are reported separately.

### **User Acceptance & Satisfaction with IT**

Due to the large investment that organizations make in implementing IT systems such as EMR/CPOE, a considerable body of research in the Management Information Systems (MIS) and HCI literature has examined user satisfaction with and acceptance of IT systems. After all, if users do not use or under utilize an IT system, the gains expected from using the system will not be achieved. Therefore, user acceptance of IT (IT acceptance) is a crucial factor to assess in examining IT success. IT acceptance and user satisfaction with IT systems are closely related, complex, multi-faceted concepts. The body of HCI/MIS research on this topic demonstrates this complexity. Unfortunately common definitions are not always used in this literature (Mahmood, Burn, Gemoets, & Jacquez, 2000). In general, IT acceptance is conceptualized as an individual's perspective on his or her voluntary or intended use of a system (Hu, Chau, Sheng, & Kar Yan, 1999). As such, research on and measures of IT acceptance focus on usage intentions and behavior. In contrast, user satisfaction, is conceptualized as “ the affective reactions of individuals toward usage of computer applications in general” (p. 278, Al-Gahtani & King, 1999). As such, research and measures related to user satisfaction focus more on users feelings toward the system/interface as opposed to their actual or intended use of the system.

Because of the importance of IT acceptance and satisfaction on IT systems success, numerous models of factors that affect both have been presented and tested. More recent research has examined the interrelationships and efficacy of these models (Al-Gahtani & King, 1999; Mahmood, Burm, Gemoets, & Jacquez, 2000; Venkatesh, Morris, Davis, & Davis, 2003). The following sections review this literature and its application to EMR/CPOE systems.

### **User satisfaction**

In a meta-analysis of the literature on user satisfaction, Mahmood and colleagues (2000) found that the following factors influence user satisfaction:

- *Perceived benefits and convenience*: perceived usefulness, ease of use, user expectations
- *User background*: user experience, user skills, user involvement in system development
- *Organizational support*: organizational support, perceived attitude of top management toward the project and user attitude toward the system

They found that the factors that have the biggest affect on user satisfaction were user involvement in systems development, perceived usefulness, user experience, organizational support, and user attitude toward the system. These findings have several important implications for the development of complex systems like EMR/CPOE. First, the effect of user involvement in systems development, user experience, organizational support, and user attitude toward the system highlight the importance of using a user-centered implementation (UCI) approach. UCI approaches will be discussed in a later section. Secondly, it highlights the important role that perceived usefulness plays in creating satisfied users. Perceived usefulness also plays an important role in ensuring user acceptance of IT, which will be discussed in the following section.

Several survey instruments have been developed to assess user satisfaction with IT systems. Two that have become widely accepted and used are the End-User Computing Satisfaction (EUCS) scale, developed and validated by Torkzadeh & Doll (1988; , 1991) and the Questionnaire for User Interface Satisfaction (QUIS) developed by Chin and

colleagues (1988). EUCS has primarily been validated in the context of satisfaction with decision support and database systems and measures overall user satisfaction (Torkzadeh & Doll, 1991). A factor analysis of responses to this survey indicate that satisfaction is a function of five constructs: content, accuracy, format, ease of use, and timeliness (Doll, Xia, & Torkzadeh, 1994). Based on these constructs, satisfaction is a function of both quality of information and presentation/use of information.

QUIS was developed to assess users' subjective evaluation of a system's interface. QUIS includes rating scales addressing five constructs: overall reactions to the system, screens, terminology and system information, learning, and system capabilities. Where EUCS concentrated primarily on satisfaction with quality, presentation, and use of information in the system, QUIS items focus more on screen design, terminology, system messages, learnability of the system and other items that contribute primarily to the system's ease of use. Therefore, EUCS and QUIS are designed to measure slightly different aspects of user interface satisfaction, but both are primarily targeted toward application design topics (i.e., ease of use), rather than the fit of the system with the work context (perceived usefulness).

## **IT Acceptance**

The past several decades have produced several different theoretical models of IT acceptance including the Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), the Theory of Planned Behavior (TPB), and others (Venkatesh, Morris, Davis, & Davis, 2003). Based on their review and testing of eight models related to IT acceptance, Venkatesh and colleagues (2003) developed the Unified Theory of Acceptance and Use of Technology (UTAUT). This model was developed by comparing the effectiveness of the eight theoretical models for four different IT systems in four different industries, including two voluntary and two mandatory systems. They also examined its effectiveness at three different time periods: after training, one month after implementation, and three months after implementation. Based on their analysis of these models, they developed UTAUT, which combines items from the eight original models based on their effectiveness in predicting anticipated and actual system use behavior.

UTAUT proposes that behavioral intention and subsequent use are affected by performance expectancy, effort expectancy, social influence, and facilitating conditions, moderated by experience with the system (i.e., time), voluntariness, gender, and age. (See Table 4 for definitions.) The UTAUT model was further validated by applying it to evaluate systems in two additional organizations and demonstrated good predictive ability ( $r^2=0.36$  when only direct effects were included,  $r^2=0.77$  when both direct and indirect effects were included). Because UTAUT synthesizes previously presented models and has demonstrated good predictive validity, it will serve as the foundation of the theoretical model on which the research presented here is based. See Figure 1 for the complete theoretical model, including UTAUT.

Venkatesh et al.'s UTAUT findings provide insights useful for implementing EMR/CPOE. Most importantly, *performance expectancy*, which encompasses the *perceived usefulness* construct discussed in the section on user satisfaction, demonstrated a much stronger influence on *intention to use* compared to other factors. This finding is consistent with the results observed in a previous study by Venkatesh and Davis (2000). This strong influence persisted across all time periods evaluated, a finding that is also consistent with the previous study by Venkatesh & Davis. *Effort expectancy* also had a strong influence prior to use of the system, but its role diminished with use of the system. Because many EMR/CPOE systems are mandatory when they are introduced, it is also interesting to note UTAUT's findings related to how *voluntariness* (whether or not use of the system was voluntary or mandatory) influences the model. Specifically, Venkatesh et al. found that the effect of *social influence* on *intention to use* differed depending on *voluntariness*. In mandatory settings, *social influence* was a significant predictor of *intention to use*, however in voluntary settings it was not. Also, even in mandatory settings, the role of *social influence* diminished over time and was insignificant once users had three months of experience using the system. *Social influence's* role in forming users' initial *intention to use* highlights the importance of having respected clinicians serve as EMR/CPOE champions in environments where system use will be mandatory. This social influence is important for forming initial positive intentions to use the system.

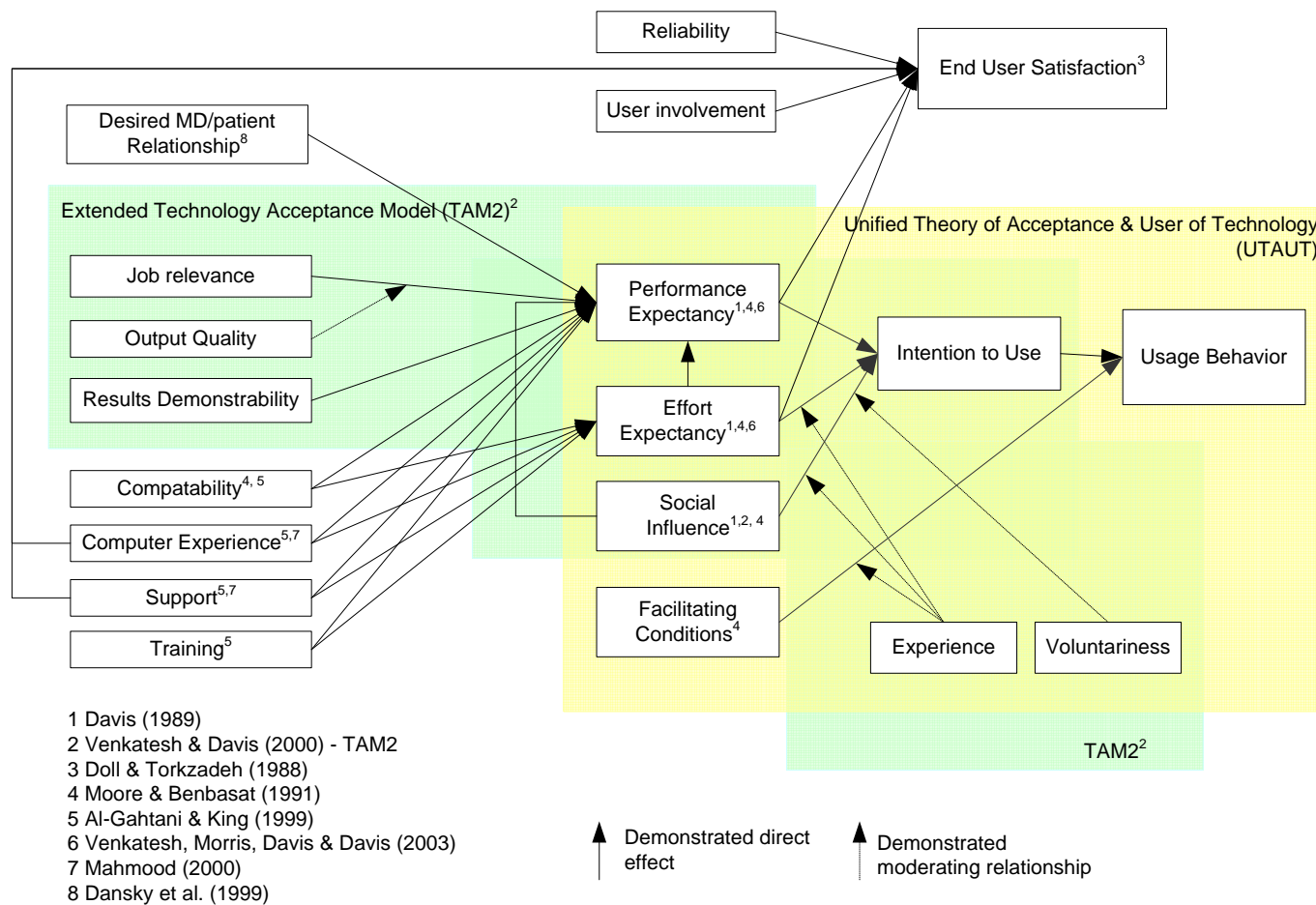
It is also important to note that UTAUT drops the attitude construct that is included in some models (e.g., Al-Gahtani & King, 1999). The authors omitted attitude because their review of previous findings indicated that it is only significant in models where specific constructs related to performance and effort are not included in the model. They conclude ‘any observed relationship between attitude and intention to be spurious and resulting from the omission of the other key predictors (specifically, performance and effort expectancies) on attitude’ (p. 455, Venkatesh, Morris, Davis, & Davis, 2003). Their results also demonstrate that gender and age have moderating effects on the role *performance expectancy, effort expectancy, and social influence* have on *intention to use*.

**Table 4: Definitions of factors related to IT acceptance**

<b>Construct</b>	<b>Model</b>	<b>Same/highly similar concept in other models</b>	<b>Definition</b>	<b>References</b>
Compatibility	M&B		Degree to which the system is perceived as being consistent with the user's existing needs, values, and past experiences.	Moore and Benbasat (1991)
Computer Experience	Mahmood	Al-Gahtani TAM ext.: EUC Experience	Users prior experience and skill level with other computer systems.	Al-Gahtani and King (1999); Mahmood, Burm et al.(2000)
Effort Expectancy (EE)	UTAUT	TAM: Perceived Ease of Use	"Degree of ease associated with the use of the system" (Venkatesh, Morris, Davis, & Davis, 2003, p. 450)	Davis (1989); Venkatesh, Morris et al.(2003)
Experience	UTAUT, TAM2		Amount of hands-on experience with the system (e.g., after training, x-months after system implementation)	Venkatesh and Davis (2000); Venkatesh, Morris et al.(2003)
Facilitating Conditions (FC)	UTAUT	Al-Gahtani TAM ext.: Support	"Degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh, Morris, Davis, & Davis, 2003, p. 453)	Al-Gahtani and King (1999); Venkatesh, Morris et al.(2003)
Job Relevance (JR)	TAM2		Degree to which the system is applicable to the user's job	Venkatesh and Davis (2000)
Output Quality (OQ)	TAM2		User's perception of how well the system performs tasks	Venkatesh and Davis (2000); Venkatesh, Morris et al.(2003)

**Table 4 (continued)**

<b>Construct</b>	<b>Model</b>	<b>Same/highly similar concept in other models</b>	<b>Definition</b>	<b>References</b>
Performance Expectancy (PE)	UTAUT	TAM: Perceived Usefulness M&B: Relative Advantage	“Degree to which an individual believes that using the system will help him or her to attain gains in job performance” (Venkatesh, Morris, Davis, & Davis, 2003, p. 447)	Moore and Benbasat (1991); Venkatesh, Morris et al.(2003)
Results Demonstrability	TAM2, M&B		Degree to which the results of using the technology are tangible (i.e., directly apparent to the user)	Moore and Benbasat (1991); Venkatesh and Davis (2000)
Social Influence (SI)	UTAUT	TAM2: Subjective Norm M&B: Image	“Degree to which an individual perceives that important others believe he or she should use the new system” ” (Venkatesh, Morris, Davis, & Davis, 2003, p. 451)	Moore and Benbasat (1991); Venkatesh, Morris et al.(2003)
Voluntariness	UTAUT, TAM2		Indicator of whether use of the system is voluntary or mandatory	Venkatesh and Davis (2000); Venkatesh, Morris et al.(2003)



**Figure 1: Combined MIS/HCI model of IT acceptance**

## **Performance Expectancy**

The strong relationship *performance expectancy* has with both user satisfaction and IT acceptance highlights the importance of understanding what factors influence users' beliefs regarding how well the system will help them perform their job. One of the models that contributed to the development of UTAUT, the enhanced Technology Acceptance Model (TAM2), has explored these factors (Venkatesh & Davis, 2000). Note that while UTAUT is based in part on TAM/TAM2, discussions of the two can become confusing because they use different terms (performance expectancy and perceived usefulness, respectively) to refer to the same concept. To avoid confusion and be consistent with the remainder of this document, the UTAUT term, *performance expectancy* (PE), will be used. However, a cross-reference of the terminology used in UTAUT, TAM/TAM2, and other acceptance research is provided in Table 4.

The original TAM research (Davis, 1989) established that user perceptions of PE and effort expectancy (i.e., ease of use) were highly correlated with user's current and predicted use of an IT system, a finding which was replicated in the UTAUT research presented previously. Venkatesh and Davis (2000) later extend TAM to TAM2, which is based on Davis' TAM research and related work by Moore & Benbasat (1991). This extended model was based on results from four longitudinal field studies of four different systems in four different industries and includes a number of factors that influence PE. In this extended model, Venkatesh & Davis found that PE, and subsequently intention to use, was related to: social influence (subjective norm and image) moderated by experience, results demonstrability, and job relevance moderated by output quality. (See Table 4 for definitions.)

## **Social Influence**

The TAM2 studies provide several interesting insights into the role social influence (SI) plays in forming PE. As users gained direct experience with the system (from initial training to 3-months after go-live) they continued to judge a system's usefulness (PE) on benefits resulting from system use and relied less on social information in forming those

perceptions and intentions. This is demonstrated by the fact that SI had one of the strongest effects on PE at initial training and by 3-months after go-live this effect had diminished one of the smallest effects, and was insignificant in two of the four studies. This diminishing contribution of SI toward PE was demonstrated in both mandatory and voluntary use settings.

#### Job Relevance & Output Quality

The same study identified an interesting interaction effect between job relevance and output quality. Venkatesh and Davis note “this implies that judgments about a system’s usefulness are affected by an individual’s cognitive matching of their job goals with the consequences of system use (job relevance), and that output quality takes on greater importance in proportion to the system’s job relevance (p. 199)”. EMR/CPOE systems are highly relevant to clinicians’ job since they are integral to completing and documenting patient care tasks (e.g., ordering/administering medications, ordering/reporting lab tests, etc.) Therefore, the interaction effect is not as of much interest in the context of EMR/CPOE systems. However, this interaction effect indicates that because EMR/CPOE facilitates completing crucial patient care tasks, output quality can be expected to take on an important role in forming PE. This finding also highlights the need to understand clinical work practices and design the system so that it effectively supports completing important clinical tasks, therefore ensuring high output quality.

#### Facilitating Conditions

Facilitating conditions incorporate aspects of both organizational and technical support for using the system. The UTAUT study indicated that facilitating conditions had little consistent, significant effect on intention to use and system use. Although, this study did indicate that for older users, facilitating conditions might contribute to usage behavior. However, in examining the role of technical support in IT acceptance, Al-Gahtani & King (1999) found that this aspect of facilitating conditions was a significant contributor to performance expectancy (i.e., relative advantage).

## Compatibility

In UTAUT, the authors conceptually include Moore & Benbasat's *compatibility* construct in the *facilitating conditions* construct along with items from the Theory of Planned Behavior's (TPB) perceived behavioral control and the Model of PC Utilization's (MPCU) facilitating conditions. However, due to the pruning method they selected (highest factor loading) none of the *compatibility* items are accounted for in UTAUT's *facilitating conditions* construct. Examination of the reported factor loadings of the candidate items hints that they might be a separate, but strongly correlated construct. Review of the content of the items provides additional evidence for this hypothesis. The items selected for the *facilitating conditions* construct come from TPB's perceived behavioral control and MPCU's facilitating conditions. The content of these items address the user having the support resources, infrastructure, and knowledge necessary to use the system. For example, "I have the resources necessary to use the system" and "A specific person (or group) is available for assistance with difficulties".

In contrast, Moore & Benbasat's *compatibility* construct includes items that address how well the system fits in with their work context. For example, "Using the system fits into my work style" and "Using the system is compatible with all aspects of my work." Moore & Benbasat's work indicates that *compatibility*'s influence on *intention to use* and subsequent use is moderated through its influence on performance expectancy (i.e., *perceived usefulness*). Because of this difference in content between *facilitating conditions* and *compatibility*, the two are included separately in the theoretical model in Figure 1.

## **MIS models/methods applied to EMR/CPOE**

Because EMR/CPOE systems have a dramatic impact on front-line care providers (i.e., physicians, nurses, and other staff), some studies have examined aspects of user acceptance of these technologies. However, as demonstrated in Table 1, these studies have primarily focused perceptions of staff in general hospitals, not pediatric hospitals. The findings of these studies as they relate to the design and implementation of EMR/CPOE are reviewed in the next section, but it is also of interest to examine the

theoretical basis on which these studies are based. Interestingly, many of the EMR/CPOE studies that evaluated satisfaction did not explicitly link their methods/results to the IT acceptance literature. However, several studies appear to be grounded in this literature. A review of the models and methods employed in these studies provides insight into where these MIS-based models succeed and fall short in understanding user acceptance of HIT like EMR/CPOE.

### TAM/TAM2

Several studies have applied TAM or TAM2 to understand user acceptance of clinical technologies. One study is of particular interest. This study applied TAM to ambulatory care physicians' pre-implementation expectations about EMR's perceived usefulness (i.e., PE) (Dansky, Gamm, Vasey, & Barsukiewicz, 1999). This study examined several factors hypothesized to affect PE, including questions related to their patient care values. However, the researchers in this study adapted the survey items used to assess PE, including adding items related to patient care and clinical work. The results of this study indicated that computer experience and organizational support were positively correlated with PE, and computer anxiety and valuing a close patient relationship were negatively correlated with PE.  $R^2$  values were not reported, so adequacy of model fit could not be determined. However, the significance of valuing a close relationship with their patients in determining PE highlights the importance of developing a better understanding of how IT's perceived impact on aspects of patient care contributes to perceptions of PE. In addition, the researchers' decision to adapt Davis's original TAM PE questions demonstrates that the original PE construct, developed in the context of evaluating a business application (i.e., a spreadsheet application), does not provide a complete view of PE for applications used in healthcare. In fact, the authors note that the PE scale in this study context might be measuring two different sets of physician expectations: 1) contribution to improved patient care, 2) contribution to improved office productivity.

A study by Dillon and colleagues (2005) that examined nurses' attitudes toward an EMR 30-90 days prior to implementation was also based on Davis' early work on TAM.

This study examined the effect of demographic factors (i.e., age, education level, gender, and full/part-time work), computer use, and system image profile on attitude toward the EMR, based on the hypothesis that attitude has a direct effect on system adoption and use. The results indicated that only age and image profile had a significant effect on attitude. However, application of these results are limited since the previously reviewed literature on IT acceptance indicates that attitude is not as good a predictor of actual usage behavior as the specific constructs of PE and EE (Venkatesh, Morris, Davis, & Davis, 2003). In addition, the reported regression model only accounted for 44% of variability in this study, compared to 78% in Davis's study on email that used the same attitude survey instrument. This indicates that Dillon et al.'s theoretical model was missing some key factors needed to understand what factors contribute nurses' perceptions of EMR.

While the above studies were the only EMR/CPOE satisfaction studies that explicitly reported being based on TAM or related research, several other studies have applied TAM to evaluate other healthcare information technologies (HIT):

- Use of Internet-based health applications in pediatrics (Chismar & Wiley-Patton, 2002)
- Emergency Medical Services (EMS) PDA support system (Chang et al., 2004)
- Telemedicine technology (Hu, Chau, Sheng, & Kar Yan, 1999)
- Prototype 3-D system for postural assessment (Van Schaik, Bettany-Saltikov, & Warren, 2002).

The Chismar & Wiley-Patton study is of particular interest since it examined Pediatrician's intention to use general Internet-based health applications. This study directly applied TAM2 to determine which factors had the greatest influence on Pediatricians' intentions to use these systems. Their results indicate that PE was a strong determinant of intention to use ( $\beta=.66$ ), while EE was not, consistent with findings in the general TAM and UTAUT literature. They also found that PE was primarily determined by job relevance and results demonstrability. These results are comparable to the TAM2 findings, where for systems whose use is voluntary, like Internet-based applications,

social influences (subjective norm, image) do not have as strong an influence on intention to use as those factors addressing the specific work the user is trying to accomplish (Venkatesh & Davis, 2000). The presence of job relevance and results demonstrability also make sense given the general Internet context – respondent's PE was related to their perceptions of whether or not those applications were relevant to their job and how well they could see and communicate the benefits of using those applications. It is interesting to note that while the measurement reliability for the TAM2 constructs obtained in this result are good (Cronbach's alpha: 0.72-0.92), the moderate  $R^2$  values for PE ( $R^2=0.62$ ) and intention to use ( $R^2=0.54$ ) indicate that there is still room for improving the TAM2 model's fit when applied to HIT.

Chang and colleagues (2004) applied TAM to assess emergency services physicians' and nurses' perceptions regarding use of a prototype PDA support system. Prior to administering the TAM questionnaires, these researchers validated the content validity of survey items relative to healthcare technology with clinician and information technology managers. Based on this groups' feedback, the question content was modified to ensure content validity in healthcare. While the authors did not examine the relationships among the constructs, they obtained useful information about user perceptions about the system and its anticipated effect on clinical work, which they could directly apply to continued development of the prototype and subsequent system.

In the study applying TAM to evaluate telemedicine, the authors indicated that TAM provided a reasonable depiction of physicians' intention to use telemedicine technology (Hu, Chau, Sheng, & Kar Yan, 1999). Similar to the findings in the study on use of Internet-based healthcare applications (Chismar & Wiley-Patton, 2002), Hu et al.'s results indicated that PE was a significant determinant of *attitude* and *intention to use* the system, but EE was not. This study also demonstrated relatively low  $R^2$  values for intention to use ( $R^2=0.44$ ). Note that this study examined perceptions of telemedicine in general, not a specific application, and at a time when telemedicine was at an early stage of development. Consequently, users were unlikely to have concrete experiences with telemedicine on which to base perceptions. It is likely that variability in user knowledge

about telemedicine and lack of specificity about the application probably contributed to some of the variance not accounted for in the model. However, the authors also conclude that there is a need to incorporate additional factors into the model in order to improve its specificity and utility to healthcare technologies.

Van Schaik and colleagues (2002) used TAM to inform development of a tool to facilitate evidence-based practice in postural assessment. They surveyed clinicians after showing them a demo of a portable posture assessment system. Similar to the previous studies, their results supported the applicability of TAM to understand IT acceptance in healthcare. Their results indicated that EE was a predictor of PE, a relationship observed in other TAM studies (Davis, 1989; Venkatesh & Davis, 2000). Also, similar to the results in two of the previously highlighted studies of TAM in healthcare, Van Schaik et al.'s results indicated that PE, but not EE, was a significant predictor of *intention to use*. The authors speculated that this difference in the role of EE might be due to the subjects' lack of hands on experience with the system (they only saw a demo). This theory is supported by the fact that both the Internet healthcare application and telemedicine studies involved perceptions of future systems as opposed to systems that the subjects had specific hands-on knowledge of. This finding also highlights the importance of Venkatesh & Davis's (2000) finding that the relationships among factors that influence acceptance change as the technology adoption lifecycle progresses, with different factors being important prior to hands-on system use and other factors taking on a greater role as users gain experience using the system. From a methodological standpoint, it is also interesting to note that, similar to the Hu et al. study, the researchers in this study adapted the TAM questionnaire to be more applicable to the stage of development (early prototype) and the target work context (clinical tasks and objectives).

#### Measuring user satisfaction with EMR/CPOE

In addition to the above studies based on the IT acceptance literature, several studies have examined user satisfaction with EMR and/or CPOE. While the findings of these studies will be reviewed in later sections, it is of interest to discuss the theoretical basis for the user satisfaction measures used in these studies as they related to the MIS/HCI models of

IT acceptance. Several of the studies, provided no description of the theoretical basis for the questions used to assess satisfaction (e.g., Lee, Teich, Spurr, & Bates, 1996; e.g., Mikulich, Liu, Steinfeldt, & Schriger, 2001). However, some studies used the QUIS questionnaire (Murff & Kannry, 2001; Staggers & Kobus, 2000), discussed previously, or questions adapted from QUIS (Ammenwerth, Mansmann, Iller, & Eichstadter, 2003). Similarly, several studies used the EUCS survey, also described previously, or questions adapted from EUCS (Lærum, Ellingsen, & Faxvaag, 2001; Lærum, Karlsen, & Faxvaag, 2004; Weir, Crockett, Gohlinghorst, & McCarthy, 2000).

### **User acceptance of and satisfaction with EMR & CPOE**

The literature on IT acceptance demonstrates the importance of understanding user perceptions of the system throughout the system's lifecycle. Examining EMR/CPOE user perceptions throughout the lifecycle by using surveys, interviews, and focus groups are a means of obtaining design input from users. EMR/CPOE researchers have noted the importance of involving users throughout EMR/CPOE design and implementation (e.g., Massaro, 1993b; Snyder, Weston, Fields, Rizo, & Tedeschi, 2005). By assessing user perceptions and expectations prior to implementation, potential barriers to acceptance can be identified and resolved prior to implementation. Assessing user perceptions and acceptance following implementation provides insight into the system's effectiveness in practice, which can be used to continually refine and improve the system's function.

The research presented in this paper uses surveys before and after implementation to develop a better understanding of user expectations and perceptions regarding EMR/CPOE and the factors that affect those expectations and perceptions. To inform this research, the following sections review existing studies examining user's pre-implementation expectations and post-implementation acceptance of EMR/CPOE systems. This review concentrates primarily on findings related to EMR/CPOE in pediatric inpatient environments, but since there is currently little research in this area, these findings are supplemented with findings from general and adult care hospitals.

### **Pre-implementation expectations and readiness**

To develop a better understanding of the dynamic factors and events that lead to the acceptance of EMR/CPOE system requires longitudinal research with data collection before, during, and after implementation (Dansky, Gamm, Vasey, & Barsukiewicz, 1999). Additionally, understanding the attitudes of future users during development and implementation of EMR/CPOE is important to improving final acceptance (van der Meijden, Tange, Troost, & Hasman, 2001). Therefore, it is important to examine clinical users' perceptions and expectations regarding EMR/CPOE prior to system implementation.

Case studies of failed and painful EMR/CPOE implementations highlight this need. For example, in their discussion of the difficulties experienced during the CPOE implementation at University of Virginia, Massaro (1993b) emphasized that to avoid the pain and user dissatisfaction they experienced it is important to get users involved, respond to voiced user concerns, and understand how the system will affect clinical work. Stablein and colleagues (2003) note that "some of the biggest challenges [in implementing CPOE] lie in building or enhancing the relationship between the hospital and the physician community". Pre-implementation surveys of clinicians are one of several mechanisms that can be employed to obtain user input during implementation and, thus contribute to enhancing this relationship. These surveys solicit input from a broad range of clinical users to provide a better understanding of their expectations and concerns. By visibly acting on the information obtained through the surveys, the implementation team can demonstrate to the clinical community that they are actively listening to clinicians' concerns and using that input to improve the design and rollout of the system.

Understanding users' expectations and concerns prior to implementation is crucial for ensuring that the user community accepts these systems. Understanding expectations and concerns enables the EMR and CPOE implementation team to design the system to be effective and usable and to ease the adjustment period during and immediately following go-live. However, there is very little information available on pediatric hospital physician

and staff expectations and perceptions prior to implementing EMR/CPOE. Only one pediatric study reports distributing a readiness survey to employees 7 months prior to CPOE implementation (Upperman, Staley, Friend, Benes et al., 2005). This survey examined personal preference, job impact, effectiveness of training, change imperatives, and perceived rewards/recognition attached to implementation. While the authors did not present detailed results of the survey, they indicated that it provided useful insights into the change process and that, in general, the respondents were satisfied with the project team's preparations to date.

While pre-implementation perceptions have been neglected in the pediatric hospital EMR/CPOE literature, findings from general/adult care hospitals provide some insight into clinicians' expectations and perceptions of EMR/CPOE prior to implementation. Where the literature base examining tangible impacts of these technologies on quality of care (e.g., error rates, ADEs, time to deliver care) tends to focus on CPOE, the literature on technology readiness focuses more on EMRs as a whole, as opposed to CPOE specifically. The results of these studies are presented in Table 5. Note that there are additional studies that examine clinicians' general perceptions regarding use of computers in healthcare and in some cases EMR in general, however only studies that addressed perceptions in the context of planning implementation of a specific EMR/CPOE in the clinicians' specific work environment are included because perceptions regarding computers in healthcare in general may vary substantially from those regarding a system the respondent knows they will be using within a specific timeframe.

**Table 5: Summary of findings on EMR/CPOE pre-implementation perceptions**

<b>Population</b>	<b>Key findings</b>	<b>Setting</b>	<b>Reference</b>
Physicians, residents, & nurses	<ul style="list-style-type: none"><li>• Respondents with Computer Experience more positive, more likely to think EMR could improve quality of care;</li><li>• Those inexperienced with computers were concerned EMR would take a long time to learn</li></ul>	EMR for stroke patients only; Dutch hospital	van der Meijden et. al (2000, 2001)
Nursing staff	<ul style="list-style-type: none"><li>• Large portion of staff had limited computer experience</li><li>• More than 70% believed use of computers leads to increased monitoring</li><li>• 57% concerned about patient confidentiality</li><li>• 23% worried workload would increase</li></ul>	BMT unit at MD Anderson Cancer Center	McLane (2005)
Nursing staff	<ul style="list-style-type: none"><li>• Overall attitudes toward EMR positive</li><li>• Age &amp; system image significant predictors of attitude; work experience, gender, level of education, computer experience not significant</li></ul>	US 450-bed regional hospital	Dillon, Blankenship, & Crews (2005)

van der Meijden and colleagues (2000) found that physicians, residents, and nurses were generally satisfied with paper medical records, with an average satisfaction rating of 3.6-3.8 for data entry and 3.0-3.4 for data retrieval (on a scale of 1 to 5). This presents a challenge to EMR designers, as they have to develop a system that is perceived be an

improvement over a system (i.e., paper records) with which people are generally satisfied. However, noting that these clinicians were less satisfied with paper records on data retrieval tasks, EMR implementation teams should highlight the benefits of EMR on data retrieval tasks and take efforts to address user concerns about the efficiency/quality of data entry tasks. Note that one limitation of this study was that it examined attitudes toward an EMR for stroke patients only, not a full hospital-wide EMR with CPOE, so this may have impacted expectations.

It is interesting to note that in a related study at the same Dutch hospital, few respondents expected the EMR to facilitate better communication or to reduce time on administrative tasks (van der Meijden, Tange, Troost, & Hasman, 2001). These users also did not expect their work routine to change drastically after converting to EMR. This may be a factor of the limited scope of this EMR (for stroke patients only, not hospital wide). However, in hospital-wide implementations, a similar expectation that clinicians' work routines are not going to change after implementation may indicate that they are unaware of how the system will affect their work and may be in for a big surprise at go-live. As such, it should be a red flag to the implementation team, indicating that they need to ensure that correct expectations are set with the users regarding how EMR will impact their day-to-day work routine.

#### *Factors that influence attitudes*

Several studies examined factors that influenced clinician's pre-implementation attitude toward EMR/CPOE. In their survey of physicians, residents, and nurses van der Meijden et al. (2000) found that those with computer experience rated the system more positively (3.6 of 5) than inexperienced respondents (3.0). However, Dillon et al. (2005) also looked at computer experience and found that it did not effect attitudes of nursing staff toward EMR. The difference in these findings may be related to the timing of the surveys. The Dillon surveys were administered much closer to system implementation during the time frame when staff were being trained on the system. The first-hand exposure to the system during training may have moderated the influence of computer experience on attitude.

The Dillon study, did report that age affected attitude toward the system, however the relationship was not linear. Staff in their thirties had the most favorable attitudes toward EMR. Also, not surprisingly, they also reported that the user's image of the system (e.g., threatening, effective, simple) affected their attitude toward the system. In these image profiles, it is interesting to note that negatively worded items were higher rated than positively worded items, indicating that respondents were concerned about the EMR's effect on other staff and patients more than on its individual effects (e.g., on time required). This finding supports the hypothesis that in healthcare, perceptions regarding the impact of the system on performance (PE) are broader than just the impact on the individual user – it also encompasses a broader concept of impact on quality of patient care.

#### *Expected impact on patient care & work processes*

While expected impact on patient care is important to acceptance of EMR/CPOE technologies, it appears that most clinical users had only vague expectations regarding how computer applications would affect health care and their daily work (van der Meijden, Tange, Troost, & Hasman, 2001). Instead the users seemed to be primarily concerned about the accessibility and reliability of these systems. This lack of information about the system's impact on their daily work could result in some unpleasant surprises at go-live. Implementation teams need to work diligently to make sure that prior to go-live, users understand and are prepared for how the system will affect their daily work. By having this dialog prior to go-live, any work impacts that could negatively affect patient care can be identified and resolved prior to go-live. For example, in the Han study (2005) reviewed previously if pre-implementation surveys indicated that they were concerned about the impact the system would have on order entry time, the implementation team could have examined and taken steps to address this concern prior to go-live.

The van der Meijden studies indicate that clinicians expected implementation of EMR to have the following impacts on patient care:

- Improved legibility
- More concise reporting
- Eliminate redundant data entry (no copying data, patient does not have to answer same questions multiple times)
- Access to more information (e.g., overview information, continuing education materials)
- Access to up-to-date information

### *Concerns regarding EMR/CPOE*

Dillon et al. (2005) found that while nursing staff were generally supporting and accepting of the EMR implementation, they had concerns about the impact the system would have on quality of healthcare delivery. These concerns were revealed through the image profiles examined by the researchers. In these image profiles, the highest rated items were: threatening, disgusting, discouraging, risky to use, dehumanizing. The authors noted that the content of these items indicated this was not selfish resistance by the nursing staff, but instead reflected a healthy caution regarding how the new technology would affect patients and care delivery. Similarly, recall that Dansky et al. (1999) found that physicians who valued a close patient relationship had less positive attitudes about EMR. This finding also indicates an underlying concern about the impact of EMR on quality of patient care.

A 1998 study (Gamm et al.) comparing pre- and post-implementation perceptions of an outpatient EMR found that users' experience in many functional areas fell short of their expectations. Consequently, these users' ratings of the utility of the system declined after implementation even though their computer anxiety was lower. This was especially true for physicians. For example, physicians and staff had to spend more time entering data due to the number of screens that had to be accessed. Additionally, respondents' pre-implementation concern about EMR depersonalizing the patient encounter was warranted. After implementation respondents expressed further concern about keeping the patient encounter personal while having to focus on data entry in the exam room.

While the respondents credited the EMR with improving legibility and completeness of records, the increased data entry time and other disappointing features drove the overall utility ratings down.

In addition to this general caution toward the new technology, clinicians often expressed concerns about the affect EMR would have on clinician time. In the van der Meijden study (2000) those with less computer experience expressed concern about the amount of time using EMR would take. Also, in the McLane (2005) study 27% of nursing staff indicated they were concerned about increased workload.

#### *Utility of pre-implementation surveys*

The studies presented here highlight the utility of surveying EMR/CPOE users to examine their pre-implementation perceptions of the system. They demonstrate that such surveys provided valuable information that can be applied during design/implementation to improve the system before to go-live. McLane (2005) noted that “recognition of the attitudes and expectations of the staff prior to implementation of an EMR project offered key information that assisted planners and developers to shape communication and information for the end users (p.91).” She reported that the insights from their survey conducted 18-mths prior to implementation were useful for communication plans, putting design teams together, and delivery of training. For example, because their respondents expressed concerns about patient privacy, training emphasized privacy features in the system.

In addition, pre-implementation surveys can provide insight into features and functions that clinicians consider important. This insight can be used to set priorities during planning for design and implementation. For example, the van der Meijden studies indicated that their clinicians rated reliability, accessibility, speed of data retrieval, ease of use, and ease of learning as important features for an EMR. The previously discussed study of an EMR implementation in ambulatory care (Gamm et al., 1998) highlights the importance of not only understanding user expectations and priorities regarding features and functions, but also acting on that knowledge. Because there were many functional

areas where the users' experience fell short of their expectations, users' perceptions about system utility declined after implementation even though their computer anxiety was lower. This highlights the importance of effectively applying knowledge gained through pre-implementation surveys and other means of obtaining design feedback from users to improve the quality of the system prior to go-live and ensure that EMR/CPOE's are accepted after rollout.

### **Post-implementation acceptance and satisfaction with EMR/CPE**

A survey of physicians at hospitals using CPOE found that 69-75% reported spending more than 60 minutes per day on the system (Murff & Kannry, 2001). Similarly, field studies by Tierney and colleagues (1993) and Shu, et al. (2001) indicated that interns using CPOE spent 9-10% of their time entering orders. These studies indicate that clinicians using EMR and/or CPOE can expect to spend a significant portion of their working day on these systems. Thus, understanding factors that contribute to the acceptance of these systems has important implications related to clinician job satisfaction. For example, there have been several instances in which CPOE and other clinical systems have been met with staunch resistance from physicians, creating an unpleasant, sometimes even hostile, work environment in the hospital (e.g., Massaro, 1993a; Williams, 1992).

Therefore, it is important to understand users' post-implementation perceptions of EMR/CPOE systems and especially the factors that affect their acceptance of these systems. Gaining better insight into clinicians' concerns regarding these systems and the factors that increase their acceptance and satisfaction with the systems will provide system designers with information needed to improve the usability and utility of these systems. As demonstrated in the section on IT acceptance, acceptance and satisfaction are closely related, but different constructs. Recall that acceptance examines actual and anticipated future use whereas satisfaction examines affective reactions to technology. While numerous studies have measured and reported user satisfaction with EMR/CPOE in general care environments, relatively few have explicitly examined acceptance of this technology.

In one study of physician satisfaction with CPOE, Murff & Kannry (2001) note “our results indicate that not all entry systems are equally usable” (p.508). This finding is not surprising to anyone in the technology industry, but the results provide interesting insights into user acceptance of EMR and CPOE systems. The study surveyed a set of physicians who practiced medicine at a community hospital and also spent 1-2 months a year on rotations at a nearby Veterans Affairs (VA) hospital. As such, this set of physicians had the opportunity to interact with two different CPOE systems: 1) the commercially available system used at the community hospital, and 2) the VA’s internally developed system, CPRS. Results from the survey indicated that physicians were satisfied with the VA’s CPOE system (mean score 7.2 out of 10), but dissatisfied with the commercial CPOE system (mean score 3.7 out of 10). This dramatic difference in satisfaction levels highlights that EMR/CPOE users (in this case physicians) are cognizant of the differences between a system that is effective and easy to use and one that is not. System designers need to develop a better understanding of the factors that contribute to users’ acceptance of and satisfaction with these systems so that implementation efforts can concentrate resources and efforts in these areas.

It is also interesting to note that in this case, the physicians interviewed spent more clinical time using the commercial system versus the VA system (10-11 months vs. 1-2 months a year). Given their increased time using the commercial system, HCI theory would hypothesize that greater experience with a particular system would lead to greater satisfaction with that system (compared to the less frequently used system) since they would have more time to figure out tips and tricks that lead to more efficient use. However, the survey results revealed the opposite effect. Users were more satisfied with the VA system, which used a familiar Windows GUI interface (compared to a proprietary text-based interface) and organized the patient record like a standard patient chart, thus using an information presentation paradigm similar to one that users were already familiar with. This study demonstrates that experience with the system cannot overcome certain usability issues inherent to the system design. Therefore, implementation approaches need to employ methods specifically intended to ensure system usability.

Several studies have examined physicians' and nurses' post-implementation satisfaction and/or acceptance of inpatient EMR and CPOE systems. Unfortunately, few examined these perceptions related to EMR/CPOE used in pediatric care. There have been several studies, however, that have examined post-implementation perceptions of pediatric units and/or personnel in general care hospitals. The following sections review the EMR/CPOE satisfaction literature and highlight findings on factors that influence acceptance and satisfaction, highlighting studies that specifically address pediatrics. Because post-implementation perceptions have been studied more extensively in general care hospitals, additional relevant articles from this literature base are included as appropriate to present a more complete picture of the current knowledge in this area.

#### Factors that influence acceptance and satisfaction

A number of studies have measured and reported user satisfaction with EMR/CPOE in general care environments. However, few have explicitly examined acceptance and/or usage. This section begins by reviewing studies examining acceptance or usage since this is particularly relevant in the context of this study, followed by an examination of the satisfaction literature.

A study by Weir and colleagues (2000) explicitly examined relationships between EMR users' (physicians' and nurses') perceptions about the system and their adoption behavior. Specifically, they found that users who viewed the systems as more effective at information tasks (e.g., communication, workload tracking, complex decision making, etc.) were more likely to use more system features and to demonstrate less resistance to adopting EMR. This is consistent with the TAM2 findings in healthcare technology that indicated PE was the strongest indicator of intent to use the system. The authors also found that early adopters had higher affect ratings (i.e., enjoyment of and interest in computers). However, they found no significant correlation between overall satisfaction and these adoption behaviors. The authors noted that this lack of relationship between user satisfaction and usage behavior may be due to the fact that use of the system was mandated. These findings demonstrate the importance of examining specific factors

contributing to IT acceptance instead of general satisfaction, even in mandatory system settings, since these specific factors are better predictors of clinician usage behavior. However, because acceptance and satisfaction are so closely related, examining past findings of EMR/CPOE satisfaction can provide insight into how to revise general models of IT acceptance to improve their fit with acceptance of healthcare IT.

Several studies have examined correlations various factors have with EMR/CPOE user satisfaction. These findings are summarized in Table 6 below. Note that these factors are organized into categories based their content, highlighting items/factors that are part of a previously identified IT acceptance construct (e.g., PE, EE) or other constructs not currently examined in the general IT acceptance literature.

**Table 6: Factors contributing to satisfaction with EMR & CPOE**

User Group	System Type	Factor	Impact on Satisfaction	Reference
<b>PE (Usefulness)</b>				
Physicians & nurses	CPOE	Made user's job easier	Improves $r=0.79$	Weiner, Gress et al.(1999)
Physicians & nurses	CPOE	Increased timeliness of order execution	Improves $r=0.57$	Weiner, Gress et al.(1999)
Physicians, nurses, pharmacy staff	EMR/CPOE, CPOE	Improves productivity	Improves $r=0.69 - 0.73$	Lee, Teich et al. (1996) Wilson, Bulatao et al. (2000)
Physicians, nurses, pharmacy staff	EMR/CPOE	Slows me down	Reduces $r=-0.65 - -0.57$	Lee, Teich et al. (1996) Wilson, Bulatao et al. (2000)

**Table 6 (Continued)**

User Group	System Type	Factor	Impact on Satisfaction	Reference
<b>EE (Effort)</b>				
Physicians, nurses, pharmacy staff	EMR/CPOE, CPOE	Ease of use	Improved $r=0.67 - 0.76$	Lee, Teich et al. (1996), Weiner, Gress et al.(1999), Wilson, Bulatao et al. (2000)
Physicians	CPOE/EMR, CPOE, EMR (outpatient)	Terminology (consistent, related to tasks)	Improved $r=0.50 - 0.72$	Murff & Kannry (2001), Sittig, Kuperman et al. (1999)
Physicians	EMR/CPOE, CPOE, EMR (outpatient)	Screen layout/sequence	Improved $r=0.48-0.68$	Murff & Kannry (2001) Sittig, Kuperman et al. (1999)
Physicians	EMR/CPOE, EMR (outpatient)	Perform tasks in straightforward manner	Improved $r > 0.50$	Murff & Kannry (2001), Sittig, Kuperman et al. (1999)
Physicians	EMR (outpatient)	Correcting mistakes difficult/easy	Improved $r > 0.5$	Sittig, Kuperman et al. (1999)
Physicians	EMR/CPOE, CPOE	Ease of Learning	Improved $r=0.51-0.71$	Murff & Kannry (2001)
<b>Quality of Care</b>				
Physicians & nurses	CPOE	New data from CPOE helpful	Improves $r=0.62$	Weiner, Gress et al.(1999)
Physicians & nurses	CPOE	Decreases ordering errors	Improves $r=0.61$	Weiner, Gress et al.(1999)
Physicians, nurses, pharmacy staff	EMR/CPOE, CPOE	Negative impact on patient care	Reduces $r=-0.65 - -0.73$	Lee, Teich et al. (1996) Wilson, Bulatao et al. (2000)
Physicians, nurses, pharmacy staff	EMR/CPOE, CPOE	Improves quality of care	Improves $r=0.52 - 0.75$	Lee, Teich et al. (1996) Weiner, Gress et al.(1999) Wilson, Bulatao et al. (2000)

**Table 6 (Continued)**

User Group	System Type	Factor	Impact on Satisfaction	Reference
Physicians & nurses	CPOE	Increased time with patients	Improves $r=0.58$	Weiner, Gress et al.(1999)
<b>Support</b>				
Physicians	CPOE/EMR + CPOE	Help & Reference	Improves $r=0.44-0.50$	4: Murff & Kannry (2001)
<b>Other</b>				
Physicians	CPOE/EMR + CPOE	System speed, reliability	Improved $r=0.43-0.57$	Murff & Kannry (2001)
Physicians, nurses, pharmacy staff	EMR/CPOE, CPOE	Reliability	Improved $r=0.52 - 0.56$	Lee, Teich et al. (1996) Wilson, Bulatao et al. (2000)
Physicians, nurses	EMR	Duration/ frequency of system use	Improves $r$ not reported	Gardner & Lundsgaarde (1994)
Nurses	Nursing Doc.	Acceptance of nursing process prior to go-live	Improves $r=0.55$	Ammenwerth et. al (2003)
Nurses	Nursing Doc.	Attitude toward computers	Improves $r=0.43-0.54$	Ammenwerth et. al (2003)

Note that the strong correlations that PE, EE, and Support items have demonstrated with inpatient EMR/CPOE user satisfaction provide evidence that the general IT acceptance model applies to these systems. However, the strong correlation that quality of care and other items have with satisfaction indicates that the general model has a few missing links. Specifically, the general model of IT acceptance needs to be extended to account for the perceived effect these systems have on quality of patient care and patient safety. The current study endeavors to inform the development of this extended model of EMR/CPOE acceptance by examining the relationship between patient safety perceptions and EMR/CPOE acceptance, which is discussed further in the *Proposed Model* section.

The following sections review relevant findings to date on the relationship between EMR/CPOE satisfaction and the above constructs.

### *Performance Expectancy*

The findings of several studies highlight the importance of PE in regards to EMR/CPOE satisfaction, especially where user efficiency is concerned. Murff & Kannry (2001) found that user satisfaction correlated best physicians' ability to use the system to perform the tasks efficiently. Similarly, Lee, et al. (1996) found that physician and nurse satisfaction with CPOE was more correlated with their perception of CPOE's effect on productivity than with its effect on quality of care. These perceptions of clinicians mirror the findings of Kawamoto et al. (2005) who, in a review of trials examining CDSS (including CDSS related to CPOE) concluded, "...findings suggest that an effective [CDSS] must minimize the effort required by clinicians to receive and act on system recommendations (p. 7)."

Qualitative data from clinical users also supports this relationship as well. For example, in the Murff and Kannry study the most frequent comments about CPOE system with lower satisfaction ratings were related to "routine tasks being both cumbersome and taking longer to perform" (2001, p. 505). Similarly, Lee et al. (1996) identified common themes in what physicians and nurses said they liked most about a CPOE system, and many of these items related to their efficiency and effectiveness on the job. For example, physicians liked having off floor/remote access and computer checks/automatic prompts for default dose/frequency while nurse liked that typed orders were easier to read, unambiguous, and had fewer errors and that several of their tasks were quicker and/or easier (e.g., review/check orders, check labs).

These findings support the applicability of the IT acceptance model to EMR/CPOE. The impact of EMR/CPOE on efficiency/productivity is easily observable by clinicians and this impact contributes to PE. Further support for the applicability of PE in understanding EMR/CPOE acceptance is provided by Weiner et al. (1999) who note in their study on physician and nurse views on CPOE: "...those who perform order entry but receive few

tangible benefits from POE are likely to have much less favorable views of the system than those who receive tangible benefits...benefits to distinct user groups and nonuser groups should be formally assessed. (p. 241)”

### *Expected Effort*

In addition to PE, effort expectancy (EE) also plays an important role in EMR/CPOE satisfaction. For example, while the Lee et al. study (1996) discussed above identified several PE-related themes that clinical users liked, it also identified themes in what these users would change about the system. The themes on what users would change where in large part related to EE. Physicians commented on speed/slow response time, and having too many screens and steps between logon and order entry while nurses commented on having to enter ‘keys’ many times, having too many steps required to order and take off meds, and needing more flags to indicate new or pending information (e.g., orders). In another study of user satisfaction with CPOE, Weiner and colleagues (1999) also identify excess work for simple orders, lag time for new admissions, and system response time as barriers to CPOE acceptance. Consequently, they note the need for CPOE designers to reduce the number of screens and clicks required to complete simple orders.

The EE-related findings from the Murff & Kannry (2001) study are also interesting since they compare two systems, one using a GUI interface (VA system) and the other a text-based interface (commercial system). Of the system aspects examined, the commercial system rated lowest on items related to ease of learning (Mean=3.21), whereas the VA system rated high (Mean=7.13) on ease of learning. As such, learning had the highest absolute difference between the two systems, indicating the VA system was easier to learn. An examination of the correlation between the factors and overall satisfaction revealed an interesting difference. Specifically, for the system rated low on ease of learning, items in the learning dimension had the highest correlation with overall satisfaction ( $r=0.67-0.71$ ), followed by items related to terminology ( $r=0.57-0.60$ ) and screen design/layout ( $r=0.48-0.61$ ). In contrast, this finding was reversed in the system that rated highly on ease of learning. For this system, the highest correlation was with items related to terminology ( $r=0.71-0.72$ ) and screen design/layout ( $r=0.67-0.69$ ), and

the strength of the relationship between overall satisfaction and ease of learning was reduced ( $r=0.51-0.63$ ). While the authors did not examine this phenomenon in detail, this finding indicates the systems' ease of learning moderates the relationship between overall satisfaction and EE. For systems that are difficult to learn, ease of learning has a stronger relationship with satisfaction than EE. However, in systems that are easier to learn, aspects of the system's usability that drive EE of ongoing use of the system start to drive overall satisfaction. Further support for this theory is provided in the fact that one item, 'performing tasks in a straight-forward manner', contributes both to the systems' learnability and efficient ongoing use and, consequently, was highly correlated ( $r=0.71$ ) to user satisfaction in both systems.

### *Experience*

Prior computer/system experience plays a lesser role in contributing to overall satisfaction compared to the factors discussed previously (e.g., PE, EE). In fact, Lee et al. (1996) found no correlation between overall satisfaction with CPOE and either self-reported prior experience with computers or attendance of training sessions. Similarly, an evaluation of an EMR system (Gardner & Lundsgaarde, 1994) and an evaluation of two CPOE systems (Murff & Kannry, 2001) found no significant relationship between computer experience and user satisfaction. Interestingly, while general computer experience was not significant in the EMR study, duration/frequency of use was; those who used the system on a routine basis were more satisfied than those who worked in areas where use was only occasional. However, the CPOE study reported no difference in satisfaction between frequent and infrequent CPOE users.

In contrast, one study reported a significant moderate relationship between self-rated computer experience and overall satisfaction with CPOE (Weiner et al., 1999). However, comparing the strength of that relationship ( $r = 0.33$ ) to the size of relationship reported between satisfaction and CPOE's ease of use and impact on the user's job ( $r=.76$ , and  $r=.79$ ), it is clear that computer experience is less influential in driving user satisfaction.

The results of a study comparing a text-based versus a GUI interface for nursing order tasks (create, activate, modify, discontinue) provides additional insight into the complex role of experience on user satisfaction (Staggers & Kobus, 2000). In this study, users who used the GUI system first rated it higher (8) and the text-interface substantially lower (2.5) compared to users who used the text system first (these users rated the text-based interface a 5 and the GUI interface a 7). Users in this study had low-to-moderate depth and breadth of computer experience. Thus these results indicate that as users were exposed to GUI systems, they became less satisfied when presented with a text-based interface. Consequently, as clinical users are exposed to computer systems (clinical or otherwise) with good usability/that are satisfying to use, this will, in effect raise the bar for clinical users' expectations of EMR/CPOE usability and make it more challenging to achieve acceptance of these systems.

#### *Clinical role/work position and compatibility*

A number of studies indicate that a user's clinical role or work position influences user satisfaction. Several studies indicate medical specialty may affect satisfaction while others indicate work position (e.g., physician, nurse) also plays an important role. Detailed findings from these studies indicate that the source of these observed differences in satisfaction is in how well the system fits with the given specialty/work position's care processes/tasks and patient care needs.

For example, Lee et al. (1996) reported that physicians were more satisfied than nurses with the CPOE system used Brigham and Women's Hospital. They note this result may be related to fact that nursing functions (e.g. eMAR) had not yet been implemented at the time the survey was completed. In fact, most of functions implemented at that time targeted physicians. In contrast, Weiner et al. (1999) found that nurses were more satisfied than physicians with the system they examined. They speculated that physician dissatisfaction was related to the fact that they reported spending less time with patients, and the authors speculate, more time generating orders. The nurses, however, reported spending more time with patients, likely because of the CPOE's streamlined system of organizing orders and the fact that they no longer had to spend time interpreting hand-

written orders. In both of these studies, the authors traced the differences in satisfaction back to difference in the system's fit with the clinical work and/or impact on patient care between the two groups of users.

Massaro (1993a) reported that attitudes toward a CPOE varied by professional group relative to the positive impact the system had on their daily work: physicians rated the lowest enhancement to their jobs, followed by nurses, then pharmacists.

Similarly, Lærum and colleagues (2004) found that medical secretaries were more satisfied with an EMR compared to nurses and physicians. The authors concluded that the medical secretaries' higher satisfaction was related to the fact that their EMR tasks were smaller in scope and involved more easily defined information types than the tasks that physicians and nurses had to complete. Also, in this system users reported having difficulty with scanned documents, which the secretaries had less need to use, and secretaries completed tasks in a stationary environment, while physicians and nurses needed more mobility in their work. In another study where both physicians and nurses reported generally positive perceptions of an EMR system (Gardner & Lundsgaarde, 1994), physicians and nurses differed in which system features and information they valued. They also differed in their perceptions of the system's impact on several aspects of patient care (e.g., privacy).

These findings underscore that the different care responsibilities, work practices, and culture of different user groups, especially physicians versus nurses, translate into different needs and perceptions regarding EMR/CPOE system. This again highlights the importance of understanding and addressing the needs of specific user groups and the work that they perform in order to ensure that the system fits well with patient care processes and achieves high levels of user satisfaction and acceptance.

Some results also indicate that different clinical specialties report different levels of satisfaction with CPOE. Lee et al. (1996) found that medical service personnel were more satisfied with a CPOE system than surgical services. The authors hypothesize that this difference in satisfaction is related to the significant increase (73 minutes per day) in the

time required for surgeons to complete orders. Similarly, Weiner et al. (1999) found that Cardiology staff were less satisfied with CPOE compared to other staff. The authors hypothesize this may be due to cardiologists' higher workloads or the increased urgency of their patient's conditions, which leaves them little bandwidth to account for the increased time required to enter orders with CPOE. Physicians in critical care units (not included in their survey) may suffer from similar time and patient acuity constraints. Both of these studies highlight the fact that a system that fits the needs of users in one medical specialty may not meet the needs of and in some cases may significantly increase the workload of users in certain specialties due to differences in patient acuity, ordering patterns, and other differences in work context.

Similar to the specialty differences observed in the Lee study, Ammenwerth and colleagues (2003) found that pediatric nurses were less satisfied with a nursing documentation system compared to nurses on adult units. The authors concluded that one factor contributing to this difference was increased documentation requirements on the pediatric units due to differences in adult versus pediatric care requirement. Differences between documentation of pediatric versus adult care processes contributed to the opposite effect in a 2004 study of physician satisfaction with EMRs (O'Connell, Cho, Shah, Brown, & Shiffman). In this study, residents in pediatrics reported higher satisfaction with the EMR than internal medicine residents. The researchers in this study hypothesize that the observed differences were related to two factors: internal medicine residents also had exposure to another ambulatory EHR, used on their VA clinic rotations, which they may have liked better; and pediatric residents had more previous experience using structured data entry prior to EHR implementation and their patient encounters involved more preventive care, for which structured data entry may be well suited. They also note that the EHR had been used longer in the pediatric clinics and iterative refinements to the system may have improved user interface for that population, further contributing to their more favorable satisfaction ratings.

In contrast to these studies, a study by Gardner & Lundsgaarde (1994) failed to find a significant link between specialty (medical versus surgical) and user satisfaction. While

at first their findings appear contradictory, this study provides further support for the conclusion that implementation approaches need to address specialty-specific needs in order to achieve user satisfaction and acceptance. The Gardner & Lundsgaarde study examined satisfaction with the HELP system, an EMR/CPOE system developed and iteratively improved over a 20 year period at LDS Hospital. Thus, the HELP system is more mature than the systems in previous studies. Iterative evaluation and improvement to HELP through the years have likely identified and addressed specialty-specific needs that might have reduced satisfaction for a particular specialty or clinical user group.

#### *Other User Characteristics*

Several studies examined other user characteristics that could influence user satisfaction with EMR/CPOE. For example, one study reported that age and gender were not correlated with user satisfaction (Lærum, Ellingsen, & Faxvaag, 2001). Similarly, O'Connell et al. (2004) also reported no correlation between gender or age and satisfaction. The Gardner and Lundsgaarde study (1994) of the HELP EMR system indicated that physicians' and nurses' age did not predict satisfaction.

#### Acceptance & Satisfaction in Pediatrics

The Ammenwerth (2003) study and O'Connell et al. study (2004) studies discussed previously highlight that patient care processes in pediatrics differ from those in adult care environments. These studies compared perceptions of clinicians (nurses and physicians, respectively) in a pediatric unit to those in adult units and revealed differences in how well the systems studied fit with pediatric clinical processes and user needs in the two environments and, the consequent effects on user satisfaction with the system. The results of these studies demonstrate that in order to achieve user satisfaction and acceptance of EMR/CPOE in pediatric inpatient environments, EMR/CPOE have to be designed specifically to meet the special needs of pediatric clinicians and care processes.

For example, the Ammenwerth study reported that while acceptance of the nursing process was positive on all units prior to system implementation, those perceptions held

steady on the adult units, but declined considerably in the pediatric unit and nurses on the pediatric unit reported the lowest level of system acceptance. The authors suggest that, among other factors, the following reasons contributed to lower system acceptance on the pediatric unit:

1. Prior to implementation the nursing process was only partially documented; after implementation more documentation was required
2. This unit required more documentation compared to other wards because the young patients need for care required 24-hr/day documentation
3. Due to the location of the computers, nurses in this unit had to document at the unit office instead of at bedside (prior to implementation documentation was completed at the bedside)

This indicates that the pediatric nurses not only had to significantly change their documentation processes (#1 & #3), they also had to do more documentation compared to nurses on other units (#2). Consequently, nurses on the pediatric ward complained about the amount of time needed for documentation and felt burdened by system. However, acceptance increased at the 9-month point after system and process changes were made to reduce the size of care plans, improve documentation workflow, and nurses had gained more experience. The authors note that on the pediatric unit “[the task-technology] fit was far from perfect, because the functionality of the computer-based system did not well support nursing documentation and communication tasks” (p. 82). This study indicates that system’s negative impact on pediatric nurses’ ability to effectively complete documentation tasks (i.e., performance expectancy) led to lower user satisfaction with the system.

Similar to the Ammenwerth study, results reported by Mikulich and colleagues (2001) also indicate that systems designed for adult/general care settings do not always effectively meet pediatric clinician needs. This study evaluated a complaint-specific Emergency Department (ED) charting system, similar to an EMR, used for a subset of ED patients. One of the five complaints supported was febrile children <3 years of age. As such, while the primary users of the system were Emergency Medicine residents

(82%), pediatric interns and residents also used the system, representing 5% of system users. The pediatric module was the least used of the five modules provided. Pediatric medicine users used the system considerably less often than Emergency residents (39% versus 69%). In fact, 54% of pediatric respondents reported they never used the system. In their comparison of highly used modules versus under used modules like the pediatric module, the authors note that for the under used modules “physicians were more comfortable with their own capacities and more skeptical about the rules embedded in the computer (p. 176)”. This highlights the need to develop a better understanding of how to develop EMR/CPOE systems that better meet pediatric clinicians’ needs and, consequently, are more widely accepted by pediatric clinicians.

The previous studies highlight the need to understand and account for pediatric-specific needs in EMR/CPOE implementations in pediatric environments. However, several other studies of clinical systems in pediatric environments report other interesting findings related to pediatric clinicians’ acceptance of IT systems. For example, Rocha, Christenson et al (2001) examined use of a rule-based expert system used in three units of a pediatric hospital (PICU, BMT, & ER). The system generated alerts and reminders to help detect and manage infections in pediatric patients. These alerts and reminders were displayed on a computer near the patient and a paper copy printed on the nearest printer. A survey of physicians and nurses indicated that most had positive attitudes toward the system and indicated they wanted to continue receiving the alerts. However, a before and after comparison of treatment strategies showed no difference in clinician’s treatment strategies as a result of using the system. This highlights the need to examine acceptance of the system (which focuses on system use behavior) instead of just examining satisfaction (an attitude toward the system) since having a positive attitude toward the system does not always result in changes in clinician behavior.

A study examining physician perceptions of EMR implemented in an urban pediatric primary care clinic (Adams, Mann, & Bauchner, 2003) is also of interest. This study found both that physicians reported positive perceptions about the system and chart reviews indicated they changed their behavior, addressing more health maintenance

topics with patients when using the EMR. However, physicians also reported they felt the system increased the duration of patient visits and reduced eye-to-eye contact. Despite these shortcomings, all of the participating physicians agreed the EMR should continue to be used and would recommend its use to other practices. While this study only had a small sample size, it highlights that in addition to ease of use (i.e., EE), pediatric physicians consider how the system affects various aspects of patient care (e.g., quality of documentation, patient-physician interaction) when making judgments about acceptance of these systems. Therefore, to develop a complete understanding of pediatric clinicians' acceptance of technology, it is important to examine both EE and their perceptions of how the system affects their individual performance on patient care tasks and patient care in general.

### **Proposed Model of EMR/CPOE Acceptance**

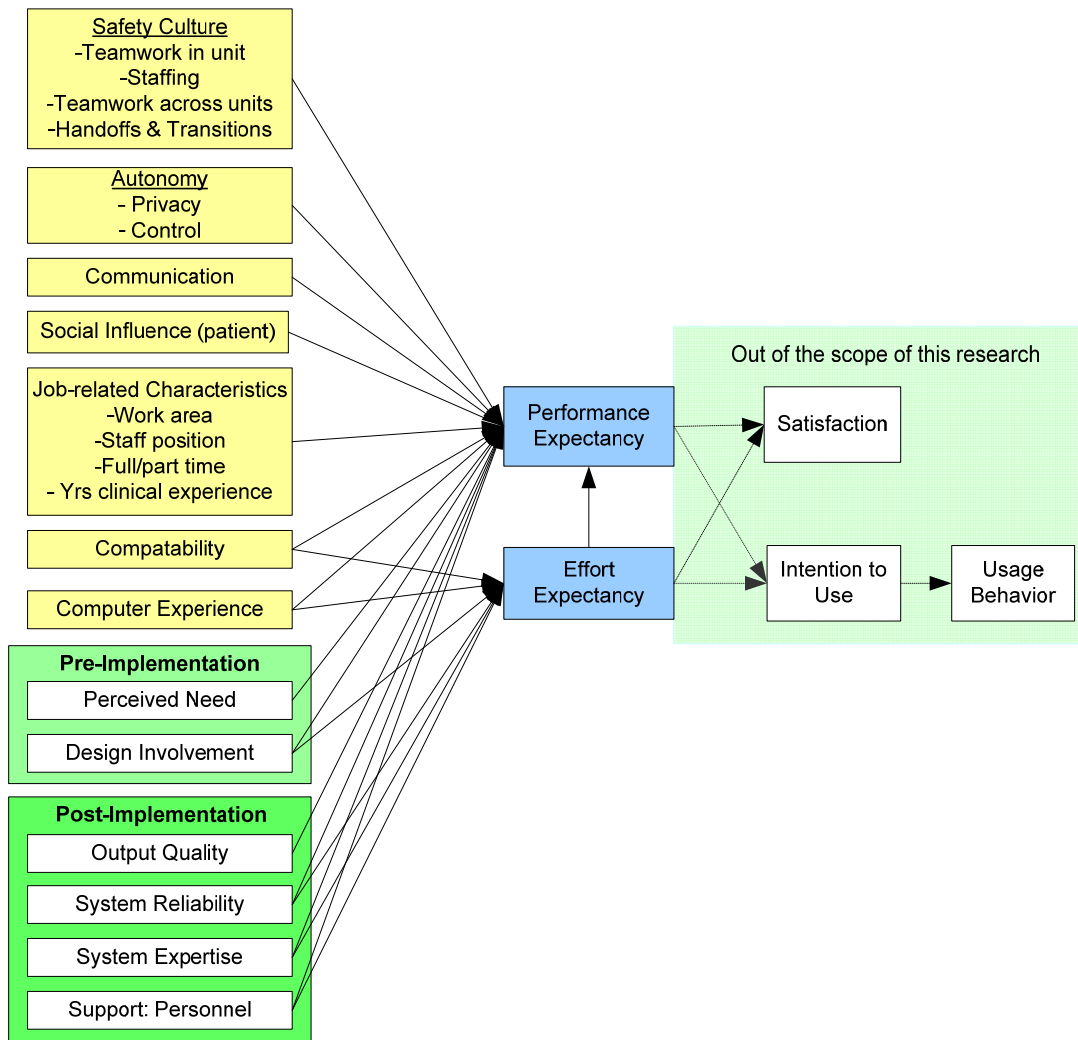
The research on past EMR/CPOE implementations and clinician perceptions of those systems emphasizes both the complexity of these systems and the importance of ensuring that they are designed to be easy for clinicians to use and to work well in the clinical context in which they will be used. Therefore it is important to have a better understanding of how to measure clinicians' acceptance of EMR/CPOE systems and what factors influence EMR/CPOE acceptance at various stages of the systems development lifecycle.

The UTAUT model of IT acceptance from the MIS/HCI literature, based on TAM and related models, provides a strong theoretical foundation for examining EMR/CPOE acceptance. However, application of these models, developed in the context of various business environments and systems, has not been thoroughly tested and applied in the context of healthcare and clinical information systems (CIS). A few studies have applied UTAUT-related models to evaluate acceptance of CIS in healthcare, (e.g., Chismar & Wiley-Patton, 2002; Dansky, Gamm, Vasey, & Barsukiewicz, 1999; Dillon, Blankenship, & Crews, 2005). However, findings from these studies indicate that while this model is useful for examining technology acceptance in healthcare, it needs to be extended to account for healthcare workers' strong focus on quality and safety in patient care in

addition to the factors that are typically relevant in other industries (e.g., output quality, productivity).

Therefore, this research endeavors to extend the MIS/HCI model and measures of IT acceptance to include aspects of quality of care and other factors that previous EMR/CPOE implementations indicate are important to acceptance of these systems. The proposed model is presented in Figure 2. Note that the theoretical model includes performance expectancy (PE) and effort expectancy (EE) and their downstream effects on satisfaction, intention to use, and usage behavior, links that have been well validated in the MIS/HCI literature. Initial results in the healthcare IT field indicate that these relationships hold for healthcare IT as well (Chismar & Wiley-Patton, 2002; Hu, Chau, Sheng, & Kar Yan, 1999). Therefore, further validating these links in the context of EMR/CPOE systems is out of the scope of the current research, and is left for future research. Instead, this research focuses on understanding the components that comprise PE in healthcare IT systems and the factors, including EE, that affect PE for EMR/CPOE systems.

Based on findings in the MIS/HCI literature, the research presented here focuses on users' PE and EE ratings as indicators of technology acceptance. However, much of the existing literature on EMR/CPOE focuses on user satisfaction, as opposed to PE. This research has chosen to focus on PE instead of user satisfaction for two reasons. First, the current research is interested in acceptance of the technology within the broader clinical work context. PE items address the technology's utility and impact on the user's work/job performance. Examining PE in combination with EE (effort) enables examining the fit of the system within the broader work context, and not just satisfaction with specific aspects of the system (e.g., the interface, data quality, etc.). The second reason for focusing on PE and EE as opposed to user satisfaction is that the MIS/HCI literature has demonstrated that PE and EE are more predictive of planned and actual system usage than user satisfaction. Specifically, in a study utilizing both PE and EE measures and EUCS, only the PE and EE measures had a significant effect on system usage (Al-Gahtani & King, 1999).



**Figure 2. Proposed model of EMR/CPOE acceptance**

A study by Weir and colleagues (2000) presents similar results for an EMR system. They found no correlation between overall satisfaction (measured using EUCS) and adoption behavior. Instead, they found that users who viewed the systems as more effective at information tasks (e.g., communication, workload tracking, complex decision making, etc.) were more likely to use more system features and to demonstrate less resistance to adoption of EMR/CPOE. These information tasks are related specifically to the clinical work completed by the users, and thus are specific measures conceptually related to the

general PE construct. Note that in this study, the authors conclude that user satisfaction may be less relevant in their study context since the EMR/CPOE use was mandated. Since EMR/CPOE systems are often initially or eventually mandated, this provides further support for focusing on PE and EE instead of user satisfaction in the proposed research model since these concepts apply in both mandatory and voluntary systems.

Based on the literature reviewed previously, the proposed model (Figure 2) identifies a number of factors that may influence PE and/or EE. These factors are included in the model because findings from the MIS/HCI and EMR/CPOE literature, reviewed previously, support the hypotheses that these factors will affect clinical users' perceptions of PE and/or EE. Further justification for including each factor in the model and details about how each factor will be measured is provided in the *Measures* section.

### **Framework for User-Centered Implementation**

Reviews of EMR/CPOE and IT acceptance literature indicate there is a need for hospitals to take a user-centered approach to implementation in order to ensure success. Specifically, there is both a need to design and implement systems that are usable in the context of the specific clinical work context in which they will be used and a need to ensure that clinicians are prepared for the changes that will accompany the transition to using these systems to support clinical care.

Two existing bodies of research, user-centered design and change management, provide a number of methods and tools that can be applied to meet these needs. Combining these methods and applying them during the systems implementation lifecycle results in a user-centered implementation methodology. The combination of these two approaches enables implementation teams to empower users to effectively use new technology by 1) designing the technology to meet the needs of the user, the work, and the work context, and 2) involving, communicating with, and preparing users for the changes that will occur when the technology is implemented. Best practices from past EMR/CPOE implementations highlight the need for using this combined approach to ensure that these systems are adopted and effectively used. The next section reviews these best practices.

The following sections review literature on user-centered design and change management and the present a framework for user-centered implementation (UCI) that marries these two approaches in order to improve IT acceptance and success.

### **EMR/CPOE best practices: establishing the need for UCI**

While studies demonstrate the potential for EMR and CPOE to dramatically improve the quality of patient care, they must be implemented using a careful, human-centered and patient-centered approach in order to achieve this potential. Previous studies illustrate that EMR and CPOE precipitate a dramatic change to the way that patient care is delivered. A change of this magnitude requires that the implementation address organizational as well as technology issues. Thus, successfully implementing EMR/CPOE is a challenge for any organization. Hospitals previously implementing these systems have identified best practices for EMR/CPOE implementation based on their lessons learned. Table 7 presents an overview of these best practices.

**Table 7. Best practices for EMR/CPOE implementation**

<b>Best Practice</b>	<b>References</b>	<b>Design for usability</b>	<b>Address org. change needs</b>
Provide strong leadership support – both executive and clinical	Ahmed et al. (2002), Ash et al. (2003), Poon et al. (2004), Massaro (1993a), Upperman et al. (2005a)		✓
Assemble a collaborative, cross-disciplinary implementation team	Ahmed et al. (2002), Ash et al. (2003), Kuperman & Gibson (2003), Sittig & Stead (1994), Upperman et al. (2005a),	✓	✓
Empower and involve physicians and other clinical users (e.g., through physician & nursing champions, advisory/governance committees, etc.)	Ahmed et al. (2002), Ash et al. (2003), Ash et al. (2004), Massaro (1993b), Poon et al. (2004), Sittig & Stead (1994), Upperman et al. (2005a)	✓	✓
Establish and measure progress toward achieving goals (e.g., safety, efficiency)	Ash et al. (2004), Poon et al. (2004), Upperman et al. (2005a)		✓
Provide value to users and make the benefits of the system clear to users	Ash et al. (2003), Massaro (1993a), Sittig & Stead (1994)	✓	✓
Understand users' readiness for change and address any anxiety	Massaro (1993a), Upperman et al. (2005a)		✓
Address workflow (practice pattern), job distribution, and efficiency needs, changes and concerns	Ahmed et al. (2002), (Poon et al., 2004), Ash et al. (2003), Kuperman & Gibson (2003), Massaro (1993a), Massaro (1993b), Poon et al. (2004), Sittig & Stead (1994), Upperman et al. (2005a)	✓	✓
Address governance/policy issues that impact the system implementation	Massaro (1993a), Sittig & Stead (1994), Upperman et al. (2005a)	✓	✓

**Table 7 (continued)**

<b>Best Practice</b>	<b>References</b>	<b>Design for usability</b>	<b>Address org. change needs</b>
Communicate (e.g., to set expectations about the implementation, technology)	Ash et al. (2003), Ash et al. (2004), Upperman et al. (2005a)	✓	✓
Provide a consistent, user-friendly interface	Ahmed et al. (2002), Massaro (1993a)	✓	
Provide flexibility/customization to meet diverse needs	Ahmed et al. (2002), Ash et al. (2004), Ash et al. (2005)	✓	
Provide appropriate breadth of order sets	Ahmed et al. (2002), Kuperman & Gibson (2003), Sittig & Stead (1994), Upperman et al. (2005a)	✓	
Provide appropriate user training and accessible initial and on-going user support	Ahmed et al. (2002) , Ash et al. (2003), Kuperman & Gibson (2003), Sittig & Stead (1994), Upperman et al. (2005a)		✓
Provide mechanisms for continuous feedback and improvement	Ash et al. (2003), Ash et al. (2005)	✓	✓

Once implemented, EMR/CPOE systems are complex sociotechnical systems in which behaviors emerge as a result of the behaviors/actions of both individual social (i.e., people) and technical components (Ash, Berg, & Coiera, 2004). The best practices presented above illustrate that these systems are *sociotechnical* as many of the best practices address people and organizational, rather than technical and functional, aspects of the system and its implementation. Consequently, the system needs to be designed to ensure there is a good match between system functions and the real-life patient care context in which users work. In instances where this match is not adequately achieved, latent errors can emerge, usually after the technical system is introduced (Ash, Berg, & Coiera, 2004).

Complexities in healthcare processes (e.g., time pressure, interaction between care team members, interactions with patients) (Ash, Berg, & Coiera, 2004) make achieving this match challenging. However, the identified best practices serve as a high-level guide to how to achieve this match in practice. As Table 7 indicates, most of the best practices identified address one or both of the following areas:

1. *Designing for usability*: Activities and approaches that facilitate designing a system that is usable by clinical users in the clinical work context;
2. *Addressing organizational change needs*: Activities and approaches that address individual and organizational needs to ensure they are adequately prepared to adopt changes associated with the implementation.

In the context of EMR/CPOE best practices, the concept of ‘usability’ is broader than the traditional IT concept of usability. When most people hear ‘usability’, they think of it as how easy the interface is to use. However, in the context of this research, usability refers to a broader concept: the usability of the system *in the work context*. Specifically, in addition to the interface being easy to use, are the functions of the system easy to apply to patient care processes in the real-world environment in which the users work?

Implementing EMR/CPOE causes changes in practice patterns, shifts roles on the patient care team, and can bring inadequate institutional policies to light (Sittig & Stead, 1994).

Thus for the EMR/CPOE to be truly usable, new practice patterns, roles, and policies that accompany its implementation must also be 'usable'. With EMR/CPOE systems, lack of usability can lead to unintended consequences that may negatively impact quality of care such as: entering orders in the wrong patient's record, errors in the communication and coordination of care, disruption of usual care routines, and cognitive fragmentation due to switching between screens during tasks (e.g., order entry) (Rothschild, 2004).

This emphasizes that EMR/CPOE implementation methodologies need to examine clinical user roles, needs, work practices, and concerns regarding the technology and design the system and new roles and work practices to ensure that they enable users to be more effective and efficient in delivering quality care to patients. Fortunately, the fields of HCI and human factors have provided a number methods and tools for user-centered design (UCD) that can be applied during the system development lifecycle to provide a system that is usable within the clinical work context.

However, UCD methods are not designed to specifically address the organizational change needs associated with the changes in practice patterns, shifting roles on the patient care team, and changes to institutional policies. EMR/CPOE best practices indicate that addressing change-related needs is critical to implementation success as well. People are naturally apprehensive about changes of this magnitude (Anton, Petouhoff, & Schwartz, 2003), so organizations must actively manage the shift to use of EMR/CPOE in patient care. Key early processes include ensuring there is strong administrative, clinical, and opinion leader support for the change (Ash, Fournier, Stavri, & Dykstra, 2003) and facilitating effective two-way communication with individuals to set appropriate expectations about benefits and tradeoffs (Dykstra, 2002) and to identify and remove potential barriers to adopting the change. As system rollout approaches, ensuring that users have the knowledge and resources they need to effectively use the system is crucial as well. Fortunately, the field of organizational change has developed a variety of methods and models that can be applied to address organizational change needs during the EMR/CPOE systems development lifecycle.

While the EMR/CPOE literature provides a valuable set of lessons learned and best practices, these are generally at a high-level; they give few details about how to apply these best practices comprehensively in practice. For example, everyone advocates having clinicians involved in design, but how do you get clinicians involved and which design activities do they need to be involved in? The following sections endeavor to fill this gap by reviewing methods in user-centered design and change management. Then a framework for user-centered implementation (UCI), which combines the methods and tools from these two areas and links them with the systems implementation lifecycle is presented.

### **User-Centered Design**

User-centered design (UCD) is “a multidisciplinary design approach based on the active involvement of users to improve the understanding of user and task requirements, and the iteration of design and evaluation” (Mao, Vredenburg, Smith, & Carey, 2005, p. 105). The UCD approach and its methods and tools are reviewed in detail elsewhere (e.g., Leonard, Moloney, & Jacko, 2006; e.g., Noyes & Baber, 1999; UsabilityNet, 2006), so only an introduction is presented here.

Traditional systems development approaches are technology focused. However, traditional approaches often result in gaps between what users want to do and how the system works. From a user action perspective, these gaps are manifested as gulfs of execution and evaluation (Norman, 1990). A gulf of execution occurs when there is a difference between what the user wants to do (i.e., their intention) and the actions allowed by the system. After an action has been taken, the gulf of evaluation represents how much effort it takes for the user to determine whether not they accomplished their intent (i.e., What is the system state? Does it match the state the user intended?) User-centered design was conceptualized as a way to bridge these two gulfs by focusing on the needs of the user and having those needs drive system design (Norman, 1986). Therefore, UCD methods are applied throughout the systems implementation lifecycle to improve the usefulness and usability of the system (Mao, Vredenburg, Smith, & Carey, 2005).

The UCD approach is founded on the following fundamental principles (Gulliksen, Lantz, & Boivie, 1999; Karat & Karat, 2003; Mao, Vredenburg, Smith, & Carey, 2005):

- Early and continual focus on users for a clear understanding of user and task requirements
- Active involvement of users
- Early and continual evaluation to inform iterative design and development
- Appropriate allocation of tasks between user and system
- Integrated, whole-systems design
- Use of a multi-disciplinary approach

To achieve a truly user-centered design, multiple UCD methods are employed at various stages of the systems implementation lifecycle. Use of multiple methods at each stage is required to develop a comprehensive understanding of the users, their work and work context, and their interaction with the system. This comprehensive view is needed because acceptability of a system depends not just on characteristics of the interface, but also how well the system fits in the use context, making usability both complex and context-dependent (Karat & Karat, 2003).

A concept similar to UCD is that of participatory design. While UCD focuses on understanding the needs of the user to inform design, participatory design focuses on user/worker involvement in the design process (Karat & Karat, 2003). Participatory design methods directly involve and consult users throughout the systems implementation lifecycle (Carroll, 1996; Gulliksen, Lantz, & Boivie, 1999). Many of the methods employed in UCD are participatory, therefore there is overlap between participatory design and UCD (Gulliksen, Lantz, & Boivie, 1999). The review presented here focuses on UCD methods, acknowledging that many of these methods are also participatory.

UCD is an iterative process. Through use of UCD methods, several outputs are created and used to inform system design (C. M. Johnson, Johnson, & Zhang, 2005; Zhang, Carey, Te'eni, & Tremaine, 2005):

- *User analysis*. Identifies target users and describes relevant user characteristics such as age, computer experience, domain knowledge, job/task factors, and usage constraints.
- *Context analysis*. Characterizes the organizational, technical, and physical context in which the user will use the system. These factors range from lighting and noise levels in the physical environment to aspects of the organizational culture that may affect attitudes toward the system.
- *Task/work analysis*. Identifies user goals and how those goals are accomplished. Includes both a high-level understanding of goals and task contexts and detailed breakdown of the people, processes, and resources (e.g., tools, information) needed to accomplish each goal.
- *Evaluation metrics*. Defines the metrics that will be used to determine how well a design/system meets the stated business/operational goals.

The user, context, and task analyses serve as inputs to defining system requirements and developing initial design concepts. They also serve as input for defining the metrics used to evaluate each iterative design and the developed system. Iterative design concepts are evaluated using the evaluation metrics. Feedback from evaluations serves as input to improve the design and further develop user, context, and task analyses as more is learned about the user, the work, and the work context. A number of methods have been developed to provide information needed for these analyses and to iteratively evaluate the design/system. An overview of frequently used UCD methods is provided in Table 8. Methods that involve users' participation are highlighted in the right hand column.

Additional information on these and other UCD methods including when they are used and their advantages and disadvantages is available from the following resources:

- <http://www.usabilitynet.org>
- User-Centered Design: An Integrated Approach by Vredenburg et al. (2002)
- "User-centered design of information technology" by Leonard, Moloney, & Jacko in The Occupational Ergonomics Handbook (2<sup>nd</sup> Edition) (2006)
- User-Centered Design of Systems by Noyes & Baber (1999)
- Human-Computer Interaction by Dix et al.(1998)

**Table 8. User-centered design methods and tools**

Method	Description	Example tools/techniques	References	User Involvement
Data collection methods (including evaluation methods)				
Document & artifact review	Review of existing products, systems, procedure/systems documentation, and other artifacts to collect data to inform requirements and design.		Beyer & Holtzblatt (1998); Dix et al. (1998); Leonard et al. (2006); UsabilityNet (2006)	
Field studies/ observations	Researcher observes and documents a representative sample of work activities as they are being completed by the user in their actual work environment.	Ethnography, contextual inquiry, time study, occurrence sampling	Beyer & Holtzblatt (1998); Leonard et al. (2006); Mao et al. (2005); Noyes & Baber (1999); UsabilityNet (2006); Vredenburg et al. (2002)	✓
Focus groups	Face-to-face probes and discussion with a group to solicit information. May be used to gather requirements, obtain feedback on designs/systems, or to obtain iterative feedback on user/task/context models		Noyes & Baber (1999); Leonard et al. (2006); Mao et al. (2005); UsabilityNet (2006)	✓

**Table 8 (continued)**

<b>Method</b>	<b>Description</b>	<b>Example tools/techniques</b>	<b>References</b>	<b>User Involvement</b>
Inspection-based evaluations	Experts inspect the system/design and reports on its usability, identifying where problems in user interaction are likely to occur and the severity of those problems.	Heuristic Evaluation, Cognitive Walkthrough, Error identification methods (e.g., THERP, TAFEI), usability audit, informal expert reviews	Dix et al (1998); Johnson et al. (2005); Leonard et al. (2006); Mao et al. (2005); Noyes & Baber (1999); UsabilityNet (2006); Vredenburg et al. (2002)	
Interviews	Face-to-face probes and discussions with an individual to solicit information. Content of interviews varies based on the lifecycle stage (e.g. requirements vs. on-going use) and objective (e.g., requirements gathering vs. design evaluation)		Dix et al. (1998); Leonard et al. (2006); Mao et al. (2005); Noyes & Baber (1999); UsabilityNet (2006)	✓
Knowledge elicitation methods	Methods used to gather data about user knowledge relevant to system design (e.g., rules, patterns, procedures, etc.) These methods are often employed to collect 'expert' knowledge in a domain.	Card sorting, classification, scenario analysis, verbal protocol analysis, affinity diagrams	Beyer & Holtzblatt (1998); Dix et al. (1998); Leonard et al. (2006); Mao et al. (2005); Noyes & Baber (1999); UsabilityNet (2006)	✓

**Table 8 (continued)**

<b>Method</b>	<b>Description</b>	<b>Example tools/techniques</b>	<b>References</b>	<b>User Involvement</b>
Modeling & simulation	Utilize computer-based models to simulate user interaction with system to predict outcomes of that interaction.	user/activity modeling (e.g., GOMS, CCT, keystroke-level models (KLM)), computer simulations	Dix et al.(1998); Noyes & Baber (1999)	
Participatory design sessions	Developers, end users, and other stakeholders participate in collaborative workshops to define system scope, requirements, and design the system concept.	brainstorming sessions, walk-throughs, talk-throughs, JAD workshops	Leonard et al. (2006); Mao et al. (2005); McConnell (1996); Noyes & Baber (1999) ; UsabilityNet (2006); Vredenburg et al. (2002)	✓
Prototypes	An artifact (e.g., paper, screen mock-up, software) that simulates or visually presents a subset of intended/possible system features, functions, and/or screens.	Low fidelity: storyboards, paper prototypes; Medium fidelity: wizard-of-oz, screen mock-ups; High fidelity: full prototype	Bainbridge (1996); Dix et al.(1998); Leonard et al. (2006); Mao et al. (2005); McConnell (1996); Noyes & Baber (1999); UsabilityNet (2006); Vredenburg et al. (2002)	

**Table 8 (continued)**

<b>Method</b>	<b>Description</b>	<b>Example tools/techniques</b>	<b>References</b>	<b>User Involvement</b>
Surveys & questionnaires	Collect information from users or other stakeholders by posing a number of questions. Questions may be open-ended, multiple-choice, rating scales, or other formats. Question content will vary based on the lifecycle stage (e.g. requirements vs. on-going use) and objective (e.g., requirements gathering vs. design evaluation)	Questionnaire for User Satisfaction (QUIS); End-user Computing Satisfaction scale (EUCS); TAM survey	Dix et al. (1998); Mao et al. (2005); Noyes & Baber (1999); UsabilityNet (2006); Vredenburg et al. (2002)	✓
User testing/ usability evaluation	Collect data on user performance while using the system. Often occurs in a lab/controlled environment. Performance metrics collected may include task completion time, number of errors, etc. Evaluations may be conducted with prototypes of varying levels of fidelity	Comparative evaluation, user trials, verbal protocols, pencil & paper exercises	Bainbridge (1996); Dix et al. (1998); Johnson et al. (2005); Mao et al. (2005); Noyes & Baber (1999); UsabilityNet (2006); Vredenburg et al. (2002)	✓
<b>Data synthesis methods</b>				
Error & critical incident analysis	Retrospective analysis of an error/incident to identify factors contributing to the error/incident and impact of the error/incident on outcomes.		Leonard et al. (2006); UsabilityNet (2006)	

**Table 8 (continued)**

<b>Method</b>	<b>Description</b>	<b>Example tools/techniques</b>	<b>References</b>	<b>User Involvement</b>
Iterative design	Design process that cycles through several designs, iteratively refining/specifying requirements and improving the final product at each pass. Typically utilizes prototypes/simulations increasing in fidelity at each iteration.	Spiral lifecycle model	Dix et al.(1998); Mao et al. (2005); McConnell (1996)	
Task analysis techniques	Systematic analysis of steps required to accomplish a goal. Typically breaks a high-level activity into tasks and subtasks. Frequently includes function allocation (i.e., who or what performs each task/step).	Hierarchical Task Analysis (HTA), cognitive task analysis, workflow diagrams, task analysis for knowledge description (TAKD)	Dix et al. (1998); Mao et al. (2005); Noyes & Baber (1999); UsabilityNet (2006); Vredenburg et al. (2002); Zhang et al. (2005)	
Personas/user profiles	1-2 page profile of realistic, but fictional, user including a general description, behavior patterns, goals, skills, attitudes, & environment		Leonard et al. (2006)	

**Table 8 (continued)**

<b>Method</b>	<b>Description</b>	<b>Example tools/techniques</b>	<b>References</b>	<b>User Involvement</b>
Use cases/scenarios	Narrative description of work scenarios including tasks to perform, steps for each task, system behavior at each step/task	Scenarios that specify how users complete a task in a given context used to inform design and prototype/system usability evaluation.	Beyer & Holtzblatt (1998); Leonard et al. (2006); UsabilityNet (2006); Vredenburg et al. (2002)	
User requirements analysis	Synthesis of user, task, and context knowledge into structured requirements for the system (e.g., function, information, security & other requirements)		Dix et al.(1998); Mao et al. (2005); Noyes & Baber (1999)	

The cost-benefit ratio of applying particular methods is usually considered when choosing the right combination of methods for a given project (Mao, Vredenburg, Smith, & Carey, 2005). Other considerations include the stage in the lifecycle, the objectives for the stage, resource constraints, time constraints, objective vs. subjective data, and level of intrusiveness (Dix, Finlay, Abowd, & Beale, 1998). The goal is to choose a set of complimentary methods that enable developing a comprehensive understanding of the user, task, and context while fitting within project constraints (e.g., time, budget, organizational culture, etc.)

Despite the fact that UCD methods have been available for almost 20 years, these methods are underutilized in practice, in part because their use has been regarded as separate from traditional software implementation lifecycles (Seffah & Metzker, 2004). Additionally, applying UCD in practice is challenging due to difficulties related to user participation (e.g., where, when, how, and who should participate?), project management and work processes (e.g., when do you stop your iterations?), organization (e.g., managing user expectations, avoiding politics), and communication (e.g., who should talk to whom? how do you create shared understandings?) (Gulliksen, Lantz, & Boivie, 1999). Toward that end, UCD methods are continually adapting to meet the changing needs of IT marketplace (Vredeuhurg, Seidman, & Ritsko, 2003).

A recent survey of UCD professionals indicates that UCD is not yet being applied in a rigorous manner (Mao, Vredenburg, Smith, & Carey, 2005). In fact, survey results indicate that only 13% projects engaged full UCD at all stages of the development cycle. Since this survey only considered projects on which UCD professionals worked, the actual number is even lower since, unfortunately, many IT projects do not include a UCD professional on the team. This is especially true on smaller software development teams (Seffah & Metzker, 2004). However, experiences at IBM illustrate that making UCD processes a core part of the systems development lifecycle is central to their effective use in practice (Vredenburg, 2003). Therefore, research that helps software implementation

teams more effectively integrate UCD into the system implementation lifecycle is warranted.

## **Change Management**

The topic of change management has received considerable attention in both the management and social sciences. Change management encompasses a set of models, theories, and tools for managing individual, team, and organizational change (Cameron & Green, 2004; Hiatt & Creasey, 2003). The dictionary defines *change* as a verb that means “to make radically different” (Merriam-Webster, 2006). In a review of literature and best practices in organizational change, the editors of the Change Management Learning Center also emphasize that change is a process (Hiatt & Creasey, 2003).

As such, change management methods and tools are employed to help people move through the five stages of change: awareness, desire, knowledge, ability, and reinforcement (i.e., ADKAR) (Hiatt & Creasey, 2003).

Why do people need help moving through the stages of change? Because people are by nature resistant to change (Anton, Petouhoff, & Schwartz, 2003). This resistance can be caused by any number of reasons including that the change requires effort, may create a burden, may cause personal loss (e.g., of security, authority, money), or due to lack of input into the change. When viewed positively, change is considered an opportunity (Anton, Petouhoff, & Schwartz, 2003); however, when viewed negatively, people tend to respond with fight or flight responses, not cooperation (Lorenzi, Riley, Blyth, Southon, & Dixon, 1997). Thus employing change management in concert with an initiative that causes significant change is a means of mitigating or avoiding risks associated with the initiative (Hiatt & Creasey, 2003).

When a project or initiative changes the job responsibilities, work processes, communication, skill requirements, and/or other aspects of an individual's or team's work, managing the people side of the project becomes crucial, regardless of the type of project or initiative. This is especially the case in large scale IT projects such as

implementation of an EMR. These IT projects affect a variety of stakeholder groups (e.g., management, nurses, physicians, IT, etc.) and each in a different way. In the case of clinical staff, this may be the first time they are required to use computers in their work, which means they may have to acquire new computer skills in order to do their jobs once the system goes live. Additionally, traditional work processes are altered, sometimes drastically, in order to utilize the new technology. This is necessary to achieve the maximum benefit from the technology, but places an additional learning burden on user as they must learn new methods for accomplishing their work. Because of the magnitude of changes stakeholders must absorb, employing methods to help them progress through the stages of change (i.e., awareness, desire, knowledge, ability, and reinforcement) becomes crucial to enabling users to successfully adopt the new technology.

In the Management and Organizational Behavior domains, change management refers to the broad concept of topics and methods for managing change within an organization, whether that change involves technology adoption or not. Unfortunately, in the realm of IT, the term change management is sometimes used to refer to a different concept. In IT, change management sometimes refers to methods for managing software configuration changes (e.g., change request, etc.). For example, wikipedia highlights two ‘change management’ methods in IT implementation: ITIL change management and software configuration (change) management ("Change Management", 2006). Both of these methods are related to managing changes in software, not in the organizational change associated with adoption of a new technology. This use of the same term to refer to different, but related, methods and concepts can cause confusion. However, in the context of the research presented here, *change management* refers to the broader definition addressing organizational change and will be discussed in the context of changes related to large scale technology adoption (i.e., adoption of EMR/CPOE).

Researchers have identified several factors crucial to ensuring that projects that precipitate significant change are successful (Brill & Worth, 1997; Connor & Lake, 1994; Hiatt & Creasey, 2003; Kirkpatrick, 1985; Kotter & Cohen, 2002; Senge, 1999). These factors include:

- *Leadership.* Leadership at various levels of the organization, including executive sponsorship, local line leaders/supervisors/managers, and internal networks/community builders, is needed to foster and maintain support for the change.
- *Communication.* Creating a continuous dialog between the project team, leaders, and employees in order to create buy-in by letting stakeholders know what is going to happen and how it will affect them. Communication is most effective when teams use a combination of methods (e.g., face-to-face, written) to communicate about change.
- *Remove barriers to change.* Identify and address resistance to the change (e.g., from managers/supervisors and others), organizational barriers (e.g., rules & regulations, traditional work practices), and barriers to understanding, accepting, and acting to facilitate the change. Develop and implement plans to remove these impediments to adopting the change.
- *Participation.* Ask stakeholders for their input. Consider and act on that input whenever possible. In instances where that input cannot be acted on, make sure that stakeholders understand why so that they know the team is listening and taking action whenever possible.
- *Learning.* It is crucial to use training *and other learning methods* to help those affected by a change acquire the skills and knowledge they need to ensure they can effectively adopt the change.
- *Goals & measurement.* Establish goals to help people understand why the change is needed. Make sure that the expected benefits are clear to everyone so that they know that making the change is worth the effort. Use measurement to ensure (and communicate) that the goals of the change are being met and the expected benefits are being achieved.
- *Reinforce change.* Create and reward meaningful short-term wins throughout the change process to foster/maintain support for the project.

A number of methods and tools have been developed to help teams ensure that the above factors are addressed on their projects, whether those projects involve technology

adoption or other initiatives. Examples of these tools and the success factors that they help to address are presented in Table 9. The methods are organized based on the stage of the change implementation process at which they are typically employed.

Change management processes and business improvement methodologies work best when integrated from the beginning of a project (Hiatt & Creasey, 2003). Therefore, an important step in managing change for a project is to develop a change management plan at the outset. This includes assessing the scope of the change and readiness of the organization since these drive the change management needs. Connor & Lake (1994) recommend using the following criteria to inform the change management plan, including which methods/tools to employ:

- *Time available*: How much time is available to implement the change?
- *Scope and depth of the change*: How many individuals/groups are affected? How many behaviors need to change in each group? How important are the changes *to the individuals involved*?
- *Favorableness of the change target*: Do individuals who are the recipients of the change see the need for the change? Do they believe that the change should occur? To what degree are they committed to making the change?
- *Favorableness of the change agent*: Do the people responsible for making the change have or have access to the resources, technical skills, and interpersonal skills needed to effect the change?

**Table 9. Change management methods and tools**

Method/Tool	Description	Leadership	Communication	Remove Barriers	Participation	Learning	Goals & Measurement	Reinforce Change	References
<i>Planning for change</i>									
Define vision & goals/expected ROI	Articulate the overall vision and goals in concrete terms (e.g., calculate an expected ROI; identify expected benefits from change; develop a descriptive of what the future looks like)	✓		✓			✓		Anton, Petouhoff, & Schwartz (2003); Bainbridge (1996); Kirkpatrick (1985) ; Kotter & Cohen (2002)
Change management plan	Identify groups/individuals affected by change, magnitude of change for each group and plan change management activities to make sure they are aware of, prepared for, and supportive of the change.			✓					Bainbridge (1996); Cameron & Green (2004); Connor & Lake (1994); Hiatt & Creasey (2003)
Stakeholder analysis	Identify stakeholders and talk to them to identify needs and concerns. This informs the business case for the change, informs resistance management and other plans		✓	✓	✓				Anton, Petouhoff, & Schwartz (2003); Cameron & Green (2004)
Sponsor roadmaps	Business leaders (sponsors) take an active, visible role in promoting the change. Identify activities they need to undertake to promote the change	✓	✓					✓	Hiatt & Creasey (2003)
Training plans	Identify training needs (skills, knowledge, behaviors); develop training program to meet those needs			✓		✓			Hiatt & Creasey (2003)

**Table 9 (continued)**

<b>Method/Tool</b>	<b>Description</b>	<b>Leadership</b>	<b>Communication</b>	<b>Remove Barriers</b>	<b>Participation</b>	<b>Learning</b>	<b>Goals &amp; Measurement</b>	<b>Reinforce Change</b>	<b>References</b>
Communication plans	Analyze audience, key messages, timing of messages. Plan should include communications to create awareness of the need and messages about the change, how change will impact employees, and the project schedule. A variety of communication mechanism should be used to communicate throughout the project.	✓	✓	✓	✓	✓		✓	Hiatt & Creasey (2003); Kirkpatrick (1985)
Social network diagrams	Identify relationships between individuals/groups to understand spheres of influence and apply this information to inform change management plans	✓		✓					Brill & Worth (1997); Cameron & Green (2004)
Create short term wins	Define the project so that short-term wins can be achieved. For example, break the project into a series of achievable project milestones so that visible, meaningful, attainable achievements throughout the project/initiative build toward the long-term vision						✓	✓	Anton, Petouhoff, & Schwartz (2003); Kotter & Cohen(2002)
Transition plan/change timeline	Develop a plan for implementing the change. This timeline should consider organizational and seasonal workload factors to ease the transition.		✓	✓					Connor & Lake (1994); Kirkpatrick (1985)

**Table 9 (continued)**

Method/Tool	Description	Leadership	Communication	Remove Barriers	Participation	Learning	Goals & Measurement	Reinforce Change	References
<i>Preparing for change</i>									
Leadership/coaching skills training	Train supervisors and thought leaders from each stakeholder group on skills and tools to help individuals move through the change process (e.g., communication on change, conflict resolution)	✓	✓						Anton, Petouhoff, & Schwartz (2003); Connor & Lake (1994); Hiatt & Creasey (2003)
Change readiness assessment	Assess people's attitude toward the change (e.g., using surveys, interviews) to identify where action needs to be taken to improve readiness for the change		✓	✓			✓		Chrusciel & Field (2003); Haddad (2002); Jones, Jimmieson, & Griffiths (2005)
Resistance management plans	Identify and understand sources of resistance to the change and develop and implement plans for addressing that resistance		✓	✓					Hiatt & Creasey (2003); Kirkpatrick (1985)
Manage personal transitions/coaching	Diagnose where individuals are in the change process and use focused conversations to help them move through the stages of change. ADKAR or other models can be used for diagnosis and as a communication framework.		✓	✓					Hiatt & Creasey (2003); Kirkpatrick (1985); Senge et al. (1999)

**Table 9 (continued)**

<b>Method/Tool</b>	<b>Description</b>	<b>Leadership</b>	<b>Communication</b>	<b>Remove Barriers</b>	<b>Participation</b>	<b>Learning</b>	<b>Goals &amp; Measurement</b>	<b>Reinforce Change</b>	<b>References</b>
Mentors	Skilled persons work one-on-one with an individual to develop skills.		✓			✓			Senge et al. (1999)
Facilitated/ participative sessions	Use cross-functional workgroups to brainstorm ideas and make decisions related to the change		✓	✓	✓				Brill & Worth (1997); Senge et al. (1999)
Q&A sessions	Provide a forum for frank, open discussion about the need, plans for, expected benefits, and decisions related to the change	✓	✓	✓	✓				Brill & Worth (1997); Kirkpatrick (1985); Kotter & Cohen (2002)
Learning initiatives	Activities that enable people to gain knowledge/skills through experience over time in 'real life' contexts			✓		✓			Senge et al. (1999)
Training	Provide training classes that enable people to develop the skills and knowledge necessary to adopt the change			✓		✓			Bainbridge (1996); Haddad (2002); Senge et al. (1999)

**Table 9 (continued)**

Method/Tool	Description	Leadership	Communication	Remove Barriers	Participation	Learning	Goals & Measurement	Reinforce Change	References
<i>After the Change</i>									
Measure & report outcomes	Measure and report outcomes to demonstrate progress toward stated project goals. (Start with baseline measurement before change.) Act based on reported measures.		✓				✓	✓	Anton, Petouhoff, & Schwartz (2003); Bainbridge (1996); Haddad (2002); Kirkpatrick (1985); Senge et al. (1999)
Celebrations	Celebrate successes (early and on-going), transfer ownership to the organization	✓	✓		✓			✓	Hiatt & Creasey (2003)
Compliance reporting and management	Measure compliance with the change and implement action plans based on results						✓	✓	Kirkpatrick (1985)
Recognition & rewards systems	Utilize formal and informal mechanisms to evaluate the degree to which people adopt the change and recognize & reward them for that behavior			✓			✓	✓	Bainbridge (1996); Connor & Lake (1994); Kirkpatrick (1985); Kotter & Cohen (2002)
Conduct after-action reviews	Conduct reviews after the change to identify the successes, the failures, and what needs to be changed next time.		✓	✓			✓		Senge et al. (1999)

In defining a change management plan, it is important to use a number of methods that together give people within the organization the resources, skills and knowledge needed to sustain the change over time (Kirkpatrick, 1985). Templates and guidelines to assist organizations in applying the methods/tools described above are available from a number of sources including:

- Prosci's Change Management Toolkit (<http://www.change-management.com/change-management-toolkit.htm>).
- Change Management Learning Center's Best Practices in Change Management report (<http://www.change-management.com/best-practices-report.htm>)
- ADKAR worksheet templates (Hiatt & Creasey, 2003)
- Successful People Process (SPP) from LMR Associates ([www.lmrassociates.com](http://www.lmrassociates.com))
- Schwartz-Petouhoff Measure, Market, and Manage Service Model (SP3M) (Anton, Petouhoff, & Schwartz, 2003).
- Guidelines for developing communication plans (Bainbridge, 1996; Kirkpatrick, 1985)
- Guidelines for addressing challenges associated with change (e.g., alleviating time pressures, providing help/support during change, assessing effectiveness, etc.) (Senge, 1999)
- Steps in training program design (Haddad, 2002)

### Change Management & IT Implementations

Because IT implementations often create significant changes for end users and the organizations in which they work, ensuring that the change is managed effectively is crucial to success. Consider that in a review of critical success factors for decisions support systems (DSS) implementations, the majority of the factors identified were related to change management as opposed to technical or system factors (Chrusciel & Field, 2003). The success factors identified included: top management support, user training, comprehensive communication, perception of personal gain, curriculum specifically dealing with change, and organizational readiness to deal with change. Interestingly, these are very similar to the EMR/CPOE best practices presented previously.

Higher pre-implementation levels of readiness for change have been associated with higher levels of post-implementation system usage and improved user satisfaction (Jones, Jimmieson, & Griffiths, 2005). The same study also demonstrated that favorable pre-implementation user perceptions of the organization's capabilities to effectively manage the change were also associated with higher levels of system usage. Thus, there is a need to apply change management models and methods to facilitate IT adoption and improve user acceptance.

Others have recognized this need to integrate change management practices into the IT implementation lifecycle. For example, Cameron & Green (2004) highlight the importance of addressing process changes to ensure change related to IT adoption is successful. Additionally, some IT implementation methodologies highlight the importance of both using communication plans to manage user expectations and developing training/education strategies that teach end users skills needed to use the system (e.g., Kimball, 1998). Others suggest using participatory design methods to help ensure that change related to technology adoption is successful (Haddad, 2002). However, while the need for integrating change management and IT implementation has been recognized, there is little practical advice to practitioners on how to effectively accomplish this. The next section describes a framework for user-centered implementation, which links change management methods and user-centered design approaches during the IT systems lifecycle to ensure that the people side of the technology adoption equation is adequately addressed.

### **Framework for User-Centered Implementation**

User-centered implementation (UCI) applies a human-integrated systems perspective to technology implementation. Specifically, it takes a broad view of the people, technical tools, and other tools that work in concert to achieve work goals. The focus is on designing the work processes and distribution of work so that the technology is an enabler for the people doing the work - taking maximum advantage of what people do best and what technology does best. Implementing new technologies creates a new way of working which often results in substantial changes to the users doing the work. UCI

combines UCD and change management methods to manage the complexity of this change by:

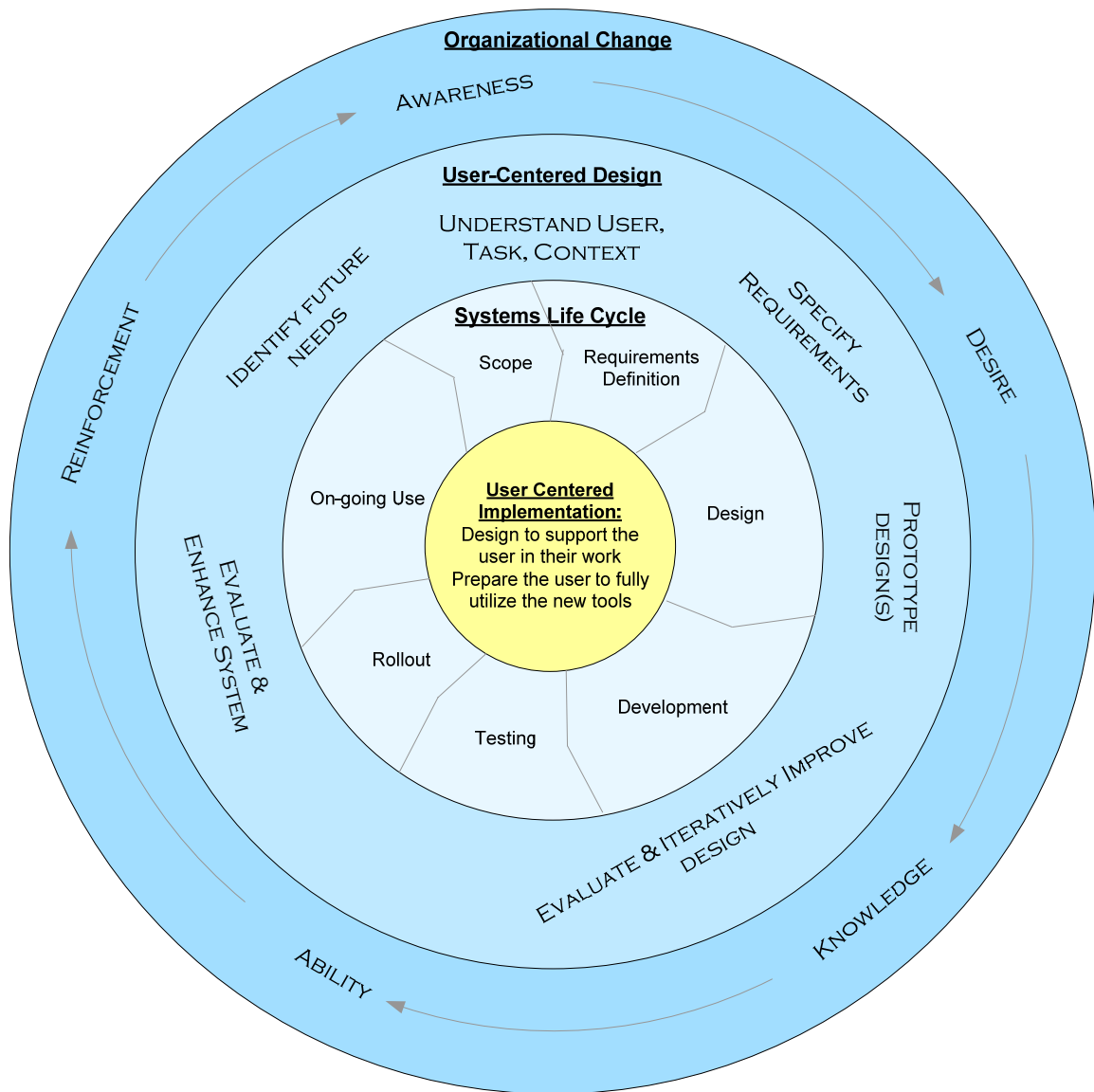
- 1) Making informed decisions about the scope and impact of the change;
- 2) Reducing the learning burden on users by designing technology that is easy to learn and use,
- 3) Designing new processes that take advantage of the technology and make sense in the work context, and
- 4) Engaging users in change and design processes so they feel empowered to effect the change.

There has been a long standing disconnect between IT and the business/user community that they support (Holmes, 2001). This disconnect has been a large contributor to many failed IT projects in the past, emphasizing the need for applying methods to reduce this gap between IT and business or, in the case of EMR/CPOE, clinicians. Both UCD and change management recognize the need to fill this gap. However, both approach this problem from different perspectives and focus on different aspects of the problem. UCD focuses on understanding the user, the work, and the work context to ensure that the technology is designed to effectively support the work. Designing usable technology eases adoption of the technology-related change because it is usually easier to learn and users can more readily see the benefit it has in their work. Additionally, since many UCD methods involve user participation, this user involvement in design helps remove barriers to adoption by increasing the users' knowledge of the system and its potential benefits prior to implementation and giving them a sense of ownership and empowerment related to the change. Change management focuses on acknowledging the scope of the change associated with implementing a new technology (especially related to changes in work practices and roles) and actively managing that change to ensure that the organization can effectively use the technology when it is introduced.

One thing in common is that both fields advocate user engagement and involvement. Therefore, some people mistakenly assume that by, for example, applying UCD in design they are automatically addressing change management needs. Unfortunately, while user participation in design helps to address organizational change needs, it does not fully

address them. Through the years, there has been some cross-pollination between the two fields. However, most of this cross-pollination has occurred at the beginning or end of the UCD design lifecycle. An example of this is completing a stakeholder analysis at the beginning of a project (Leonard, Moloney, & Jacko, 2006). IT project management has also recognized the need to identify an executive sponsor and define a business case at the onset of project. At the end of the lifecycle, both the IT project management and UCD fields have recognized the importance of training and post-rollout support, both vital change management mechanisms for ensuring that users develop the skills they need to adopt the technology. However, just as regarding UCD methods as separate from traditional software implementation lifecycles has resulted in their underutilization (Seffah & Metzker, 2004), regarding change management as separate from UCD processes and the software implementation lifecycle will result in their under use and reduced effectiveness. To maximize the benefit of using each of these approaches, they must be tightly integrated both with each other and the systems implementation lifecycle, as illustrated in

Figure 3. It is only by taking this integrated lifecycle approach that the synergies of these methods can be realized and truly user-centered technology implementation can be achieved.



**Figure 3. User-centered implementation lifecycle**

Others have recognized the need to address both social and technical aspects of the system to optimize performance (Haddad, 2002) and to address work process changes associated with the introduction of new technology to ensure change related to IT adoption is successful (Cameron & Green, 2004). This broader focus during design is warranted because if the system does not meet end user expectations and requirements, the system will have to be reworked, putting the project at risk for substantial delays (McConnell, 1996) and the associated costs.

Bainbridge (1996) provides a general approach to designing for change that illustrates the need for UCI. Bainbridge emphasizes that design is a crucial part of change because it provides a means to: 1) decide how things will work, 2) specify the requirements to make them tangible and visible, 3) specify changes that must be carried out to make the new design a reality, 4) manage and control the number/magnitude of changes to minimize risk, and 5) understand the impact of proposed changes on the organization. Design, therefore, becomes the first element of change – determining what is required and what has to be changed to get there. In fact, similar to UCD, he emphasizes that the desired work process should drive the technology requirements and not visa versa. The concept of design here is not limited to technology. Instead it includes integrating work redesign with technology, organization, and infrastructure design in order to build the people and organizational capabilities to make the change a reality. This includes organization redesign (e.g., team structures, reporting lines, staffing, career paths, etc.) and definition of job roles. An iterative design process is recommended in which the design is continuously improved based on feedback.

Bainbridge provides a useful discussion on the goals and content of designing and implementing new processes and the supporting organization and technology. However, there is no link between his design process and the tools and methods from UCD and change management that can be applied during that process. Instead he gives high-level ‘signposts for success’ at each stage such as ‘keep it simple’ and ‘communicate constantly’. So, once again, the practitioner is left to their own devices to identify methods and tools for putting this approach into practice.

In fact, historically, there has been little specific guidance for practitioners on how to successfully integrate UCD and other HCI methods into the systems implementation lifecycle (Zhang, Carey, Te'eni, & Tremaine, 2005). Zhang and colleagues (2005) proposed the human-centered systems development methodology (HCS DLC) as a means to address HCI concerns during systems development. This high-level methodology highlights the HCI-related deliverables that should be accomplished at each stage

including: context analysis, user analysis, task analysis, evaluation metrics, formative evaluation, and summative evaluation. While, HCSDLC links HCI-deliverables to systems lifecycle stages, it does not provide practitioners with guidance on which user-centered design methods and tools can be employed to achieve those deliverables. Further, HCSDLC does not incorporate concepts from change management to ensure that the system, once developed, is effectively incorporated into the work context and accepted by users.

This lack of detail on how to integrate UCD and change management methods into the systems implementation lifecycle makes it difficult for many implementation teams to incorporate these methods into their project plans, especially when these teams do not have access to a UCD/HCI expert and a change management expert. Therefore, a framework for user-centered implementation (UCI) is presented to provide guidance on which methods can be applied at each stage of the system lifecycle.

The UCI lifecycle is illustrated in Figure 3. This lifecycle emphasizes that both UCD and change management activities should be occurring at *each stage* of system implementation. Figure 3 also emphasizes that at each stage, the purpose of using these methods is different. For example, early in the lifecycle, UCD methods focus on understanding the user, task, and context and identifying requirements. In parallel with this effort, the implementation team should be actively developing awareness of and desire for adoption of the technology throughout the organization in order to address organizational change needs at this stage.

Both UCD and change management best practices highlight the importance of iterative feedback and improvement, thus the UCI lifecycle is iterative. Also note that while many resources on UCD seem to concentrate on custom developed applications, where the project team has complete control over the system design, the methods and tools presented in the UCI framework may also be applied to vendor system implementations, especially when these systems provide a variety of configuration options that enable tailoring the system to specific needs of a particular organization.

Building on the UCI lifecycle presented in Figure 3, Table 10 maps the UCD and change management methods presented previously to the lifecycle stage at which they are typically used. Together, the lifecycle in Figure 3 and lifecycle map of methods in Table 10 provide a framework to help practitioners adopt a truly user-centered implementation methodology. UCI is founded in the following principles:

- Utilizing a multi-disciplinary, collaborative implementation team in which all disciplines are actively engaged at each stage
- Taking a socitechnical system perspective for design encompassing process, people, and technology and how they interact together to accomplish work goals
- User involvement both to improve system/work practice design and develop user buy-in for changes that will accompany adoption of the technology
- Iterative feedback and improvement of the design of both the technology, work processes, and work distribution
- Two-way communication between the implementation team and user community at all stages of implementation so that
- The user community helps the implementation team develop an accurate understanding of user requirements, priorities, needs, and concerns
- The implementation team helps the user community develop accurate expectations regarding the system, future work processes, and the implementation process and timeline

In utilizing UCI, recall that all of these methods and tools are *means to an end*, and not an end in themselves. They are a means to accomplish the goals driving the IT implementation and the changes due to adoption of the technology. Select appropriate methods based on the technology and organizational context of the project. Always ask ‘which method(s) will make the greatest contribution to ensuring that the overall business objectives are achieved?’ Also, practitioners should be flexible and adjust their approach as they see what works and does not within their organization.

**Table 10. Mapping of UCI methods & tools to the system lifecycle**

Lifecycle Stage	Methods and tools		Synergies
	Change management (CM)	User-Centered Design (UCD)	
Scope	Define vision & goals/ROI Stakeholder analysis Change management plan Sponsorship roadmap Communication plan	Field studies/observations Focus groups Interviews Surveys & questionnaires	Use UCD methods to collect data for the vision/ROI and stakeholder analysis. The defined vision and goals and expected ROI should be used to focus project scope and plans. Assemble a multidisciplinary team that encompasses both technical and subject matter expertise. As UCD methods are employed to understand the users, task, and context share what is learned with the CM team as input for change management plans, the sponsorship roadmap, and communication plans.
Requirements	Change readiness assessment Stakeholder interviews Transition plan/change timeline Social network diagrams Develop resistance management plan Leadership/coaching skills training Training plan Facilitated/participative sessions* Communication Q&A sessions	Field studies/observations Focus groups Interviews Surveys & questionnaires Document & artifact review Knowledge elicitation methods Task analysis techniques Participatory design sessions* Personas/user profiles Use cases/scenarios User requirements analysis	As team members interact with users on both UCD and CM activities, they should share observations and findings so that they can be leveraged in both system/process design, CM plans, and implementation plans. Implementation team members should complete leadership/coaching skills training so that each interaction with the user can be used as opportunity to identify and address barriers to adoption. At the end of the requirements stage, the identified requirements should be examined to verify they facilitate achieving the identified vision, goals, & ROI.

**Table 10 (continued)**

Lifecycle Stage	Methods and tools		Synergies
	Change management (CM)	User-Centered Design (UCD)	
Design	Implement resistance management plan Manage personal transitions/coaching Measurement plan Facilitated/participative sessions* Communication Q&A sessions	Focus groups Task analysis techniques Modeling & simulation Participatory design sessions* Iterative design Low & medium fidelity prototypes Inspection-based evaluations Interviews Surveys & questionnaires Knowledge elicitation methods Personas/user profiles Use cases/scenarios User requirements analysis	As team members interact with users during UCD tasks, they should communicate any pockets of resistance or other barriers to adoption that they encounter to project leadership so that they can be incorporated into CM plans. As CM communication and Q&A sessions are conducted, feedback on user questions and concerns should be shared with the design team to ensure that they are addressed. The design team needs to review the measurement plan to ensure both established metrics and the design are based on the same goals/objectives. Each interaction with the users should be used as an opportunity to identify and remove barriers to adoption.

**Table 10 (continued)**

<b>Lifecycle Stage</b>	<b>Methods and tools</b>		<b>Synergies</b>
	<b>Change management (CM)</b>	<b>User-Centered Design (UCD)</b>	
Development	Develop/test training materials Develop rollout plan Manage personal transitions/coaching Baseline measurement of metrics Facilitated/participative sessions* Develop rollout support plan** Communication Q&A session	Medium & high fidelity prototypes Predictive usability evaluations Usability studies Task analysis techniques (for future work processes) Participatory design sessions* Focus groups	Utilize focus groups and participative sessions to get feedback on proposed future work processes in addition to system prototypes. This will help identify process problems that could be barriers to adoption or to achieving stated goals. Also use focus groups and participative sessions to obtain feedback on training materials & plans and identify user needs/concerns regarding rollout support. As focus groups are used to obtain design feedback, use them as an opportunity for Q&A related to the system, future work processes, and the implementation process. Each interaction with the users should be used as an opportunity to identify and remove barriers to adoption.

**Table 10 (continued)**

<b>Lifecycle Stage</b>	<b>Methods and tools</b>		<b>Synergies</b>
	<b>Change management (CM)</b>	<b>User-Centered Design (UCD)</b>	
Testing	Training classes Learning initiatives Manage personal transitions/coaching Prepare for rollout support** Communication Q&A sessions	User testing/usability evaluation User acceptance testing (UAT)† Focus groups Interviews Surveys & questionnaires	As users interact with prototypes and/or the system, difficult or complex interactions should be identified. If they cannot be resolved by design and/or process changes prior to go-live, training and learning initiatives should highlight these activities. Concerns about system functions/work processes voiced in Q&A sessions should be integrated into test plans to identify and resolve potential problems prior to go-live. Also, trainers should provide feedback to the implementation team on identified problems and areas where users are having difficulty. Positive user feedback from user testing/UAT can be integrated into communications to build user support for and excitement about using the system.
Rollout	Learning initiatives Mentors Celebrate Communication Q&A sessions	Field studies/observations Interviews Surveys & questionnaires	Have members of the implementation team (both technical and functional (subject matter experts)) conduct rounds in the field to provide user support, foster learning and observe how the system is being used in practice. In celebrating implementation successes, include both the implementation team and users to foster developing better relationships between IT and the user.

**Table 10 (continued)**

<b>Lifecycle Stage</b>	<b>Methods and tools</b>		<b>Synergies</b>
	<b>Change management (CM)</b>	<b>User-Centered Design (UCD)</b>	
On-going use & support	Conduct after-action reviews Compliance reporting Measure & report outcomes Recognition & rewards systems Communication Update new employee training Learning initiatives	Field studies/observations Focus groups User testing/usability evaluation Error & critical incident analysis Interviews Surveys & questionnaires	Feedback from after-action reviews and outcomes reporting should inform iterative improvements to the system & work processes. Results from focus groups, field studies, etc. should inform the development of learning initiatives to address problematic areas until they can be resolved.

\* Both UCD and CM call for the use of participative sessions around designing the system/change. In practice, these sessions serve both a UCD and CM purpose.

\*\* While the CM literature does not explicitly identify ‘rollout support plan’ as a tool, this is an important tool for ensuring users have the resources they need to adopt the change and learning resources available to help them quickly move through the learning curve.

† While user acceptance testing is not formally discussed in the UCD literature, this testing, in which users interact with the system and ‘sign-off’ on whether or not it meets the established user requirements, is often used in practice to obtain user feedback and buy-in prior to rollout.

## Proposed Research

The literature presented previously demonstrates that while EMR/CPOE systems have the potential to improve quality of patient care, the manner in which these systems are designed and implemented has a substantial affect on the degree to which these potential improvements are achieved. Thus, additional research into implementation methods that can ensure successful outcomes and clinician acceptance of these technologies is warranted. This is especially the case in pediatric inpatient environments, where little research has examined implementation and acceptance of EMR/CPOE systems. This research endeavors to contribute to this knowledge base by examining the following research questions:

1. How do clinical staff perceptions of safety relate to aspects of EMR/CPOE acceptance?

As the theoretical model illustrates, the proposed research hypothesizes that the focus on quality of patient care and, especially, patient safety in pediatric healthcare will alter the model of factors that affect acceptance of healthcare technologies like EMR/CPOE. Specifically, this research hypothesized the following:

*H1.1 Due to the dual priorities in healthcare (quality of care and operational effectiveness), Performance Expectancy will consist of two sub-components: one related to the impact of the technology on patients/patient care, and one on user's individual performance.*

This hypothesis will be tested by completing factor analysis on pre-implementation survey items and post-implementation survey items.

*H1.2 Prior to implementation, staff perceptions regarding aspects of culture of safety in the hospital will contribute to Performance Expectancy and expected ease of learning, an aspect of Effort Expectancy.*

This hypothesis will be tested by completing correlations between components of safety culture, components of Performance Expectancy, and expected ease of learning.

*H1.3 After implementation staff perceptions regarding aspects of culture of safety in the hospital will contribute to Performance Expectancy and Effort Expectancy.*

This hypothesis will be tested by completing correlations between components of safety culture, components of Performance Expectancy, and Effort Expectancy.

*H1.4 Prior to implementation job/user and systems implementation factors in addition to culture of safety will contribute to Performance Expectancy and expected ease of learning, an aspect of EE.*

This hypothesis will be tested by constructing a regression model of PE to determine which factors in addition to culture of safety (e.g., autonomy, communication, work area, computer experience, etc.) influence PE. The size of the effects will be examined to identify the factors with the strongest influence on PE.

*H1.5 After implementation job/user and systems implementation factors in addition to culture of safety will contribute to Performance and Effort Expectancy.*

This hypothesis will be tested by constructing regression models of PE to determine which factors in addition to culture of safety (e.g., autonomy, communication, work area, computer experience, etc.) influence PE and EE. The size of the effects will be examined to identify the factors with the strongest influence on PE and EE.

2. How does the relationship between safety perceptions and aspects of EMR/CPOE acceptance change as users gain experience with the system?

In UTAUT and other IT acceptance research, experience with the system has been demonstrated to moderate the effect that certain factors have on IT acceptance.

Similarly, it is hypothesized that as users gain hands-on experience with EMR/CPOE, the relationship that components of safety culture and other factors have with Performance and Effort Expectancy will change.

*H2.1 The size and, in some cases, the direction of the relationship between components of safety culture and Performance and Effort Expectancy will differ after users gain hands-on experience with the system.*

Correlations and regression models completed in Research Question 1 will be compared to identify similarities and differences.

3. How do perceptions related to EMR/CPOE acceptance change during the implementation life cycle when using a user-centered implementation approach?

Lessons learned from previous implementations of complex IT systems, including multiple examples of EMR and/or CPOE implementations, advocate using a user-centered implementation approach. The hospitals examined in this research used such an approach. One goal of these approaches is to identify user concerns early on and address those concerns prior to rollout. Therefore, if these approaches are successful, perceptions of Performance Expectancy and Effort Expectancy should improve between the early stages of design ( $t_0$ ) and after the initial period of system use ( $t_1$ ). Note that staff subgroup analysis will be included in examining these hypotheses because work practices and design participation vary significantly between hospitals, work areas, and staff position, which may have a moderating effect on the degree of change in each of these areas.

*H3.1 User perceptions of Performance Expectancy will improve between  $t_0$  and  $t_1$ .*

A t-test will examine the effect of time ( $t_0$  vs.  $t_1$ ) on PE overall and for sub-groups of users based on their hospital, work area, position, and other user characteristics.

*H3.2 User perceptions of expected ease of learning, an aspect of EE, will improve between  $t_0$  and  $t_1$ .*

A  $\chi^2$  test will examine the effect of time ( $t_0$  vs.  $t_1$ ) on EE (ease of learning) overall and for sub-groups of users based on their hospital, work area, position, and other user characteristics.

4. Does use of user-centered implementation methods result user acceptance of EMR and CPOE?

Because the goal of UCI is to improve the success of IT systems, it is worthwhile to examine whether or not the application of UCI to an EMR implementation resulted acceptance of the EMR by clinical users. Because Children's used a UCI approach, it is hypothesized that after implementation ( $t_1$ ) perceptions regarding aspects of technology acceptance will be positive. Note that subgroup analysis will be included in examining these hypotheses because work practices and design participation vary

significantly between hospitals, work areas, and staff position, which may have a moderating effect on the degree of acceptance in each of these areas.

*H4.1 User perceptions of Performance Expectancy will be positive (average greater than 3 on a 1 to 5 scale) after implementation ( $t_1$ )*

A t-test will be conducted to determine if average ratings on Performance Expectancy constructs are greater than 3 for each subgroup.

*H4.2 User perception of Effort Expectancy will be positive (average greater than 3 on a 1 to 5 scale) after implementation ( $t_1$ )*

A t-test will be conducted to determine if average ratings on Effort Expectancy constructs are greater than 3 for each subgroup.

Note that if staff subgroup differences exist, potential sources of these differences will be examined to determine if they provide insight into how UCI can be modified to enhance their effectiveness in EMR/CPOE implementation.

5. Based on the staff perceptions observed here, how can UCI be enhanced to improve future implementations of EMR/CPOE and, potentially, other large scale clinical information systems implementations?

To answer this research question, quantitative results in Q1-4 will be examined and qualitative feedback from users and the EMR implementation team will be examined to answer the following questions:

- a. Based on the results in Q1 and Q2, do UCI approaches need to be modified to ensure that user concerns about patient safety are adequately addressed?
- b. Based on the results in Q3 and Q4, are there particular subgroups of clinical staff that have special needs which UCI can be enhanced to address?

## **METHODS**

This research examines clinician acceptance of an EMR/CPOE implemented on two inpatient campuses of a pediatric healthcare system. Details regarding this study context including a description of the healthcare system, the EMR/CPOE system implementation, and the clinician population surveyed are provided below. In addition, the surveys used to measure EMR acceptance and factors influencing acceptance are described along with the survey distribution and collection methods. Finally, data analysis methods employed to test the research hypotheses are identified.

### **Study Context**

This study examines clinician perceptions of an EMR/CPOE system implemented at Children's Healthcare of Atlanta, in an inpatient pediatric healthcare system in Atlanta, Georgia. The study population includes physicians, nurses, ancillary, and other clinical staff. Clinicians were surveyed prior to implementation of each system component (e.g., electronic medication administration, CPOE) to assess pre-implementation expectations and perceptions about the upcoming implementation. Clinicians were surveyed again after implementation to assess their post-implementation acceptance of the system. The following sections provide additional details on the healthcare system and the EMR/CPOE system implementation that provide the context for this research.

#### **Children's Healthcare of Atlanta**

Children's Healthcare of Atlanta (Children's) is a leading pediatric hospital systems in the US (Sangiorgio, 2005). Children's is a not-for-profit healthcare system with 430 licensed beds in two children's hospitals as well as several outpatient facilities. Children's has approximately 5,500 employees and access to 1,400 physicians, representing 31 pediatric specialties. They have 460,000 annual patient visits, seeing both patients from the Atlanta metropolitan area and providing tertiary care to children from all over the state of Georgia. While Children's two hospitals, Egleston and Scottish Rite, are part of the same system, they operate very differently: Egleston is an academic hospital and Scottish Rite is a non-academic private-practice hospital. However, both hospitals have the same management and serve the same urban community. This presents

a unique environment for research, as it is possible to examine two very different hospitals while controlling for management and geographic differences.

### **Children's EMR/CPOE Implementation**

In 2002, the leadership at Children's developed a vision for implementing clinical information systems to improve safety, quality and efficiency. The long-term vision includes a community pediatric health record for patients, including clinical documentation from all inpatient and outpatient encounters. As the first step in achieving this vision, Children's is implementing an inpatient EMR with related functions including CPOE. The technologies are currently being implemented in four stages:

- **Stage 1: Inpatient Pharmacy System (EpicRx)**

System that coordinates medication ordering, dispensing, administration, billing, and patient management. This system includes an embedded decision support system to provide alerts and guidance throughout the medication order life cycle. It also provides automated pharmacy communication and workflow.

- **Stage 2: Electronic Medication Administration Record (eMAR), admissions documentation, ancillary orders (Stage 2)**

Stage 2 provides the first set of EMR functions used extensively by the nursing and ancillary staff. The eMAR component of this stage integrates with EpicRx to communicate dosing schedules and facilitate clinician documentation of medication administration at the point of care. The admissions database function enables nurses to electronically document patient medical history, allergies, and other information when the patient is admitted. The ancillary orders functions enable nursing/administrative staff to enter ancillary orders and automate the coordination and management of orders by ancillary staff.

- **Stage 3: Nursing Documentation & non-clinical orders (RN Doc)**

During this stage, functions that enable nursing and ancillary staff to electronically document patient care activities will be implemented. For example, this includes flow sheets and nursing notes. During this stage, additional order types will be added to the existing orders functionality to support entry and coordination of non-clinical orders (e.g., social work).

- **Stage 4: Computerized Provider Order Entry System (CPOE)**

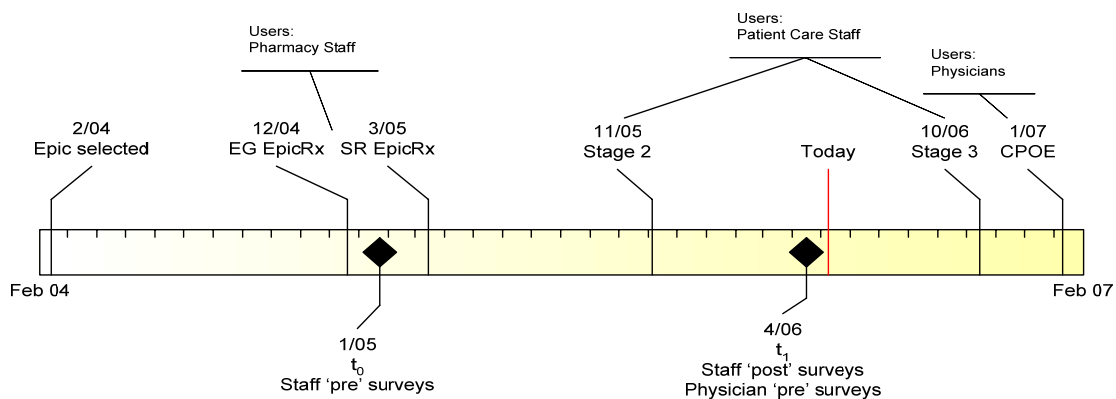
This stage will provide CPOE functions and represents the first major rollout to physicians. This stage includes decision support provided at the point of ordering (e.g., drug interaction and allergy checking), order sets for each clinical area, and automation of the order processing workflow. CPOE functions will be integrated with EpicRx and eMAR to provide complete automation of medication ordering, dispensing, and administration.

To ensure the success of their EMR/CPOE implementation, Children's underwent an extensive due diligence phase to learn from the EMR/CPOE experiences of other healthcare providers. Children's designed their implementation process to take advantage of best practices and lessons learned from these providers, as well as lessons learned from their previous experience implementing an EMR in the Emergency Room. Children's realized that in order to achieve their goals for the EMR implementation, it was critical to take a user-centered approach to implementation that would ensure that the system would be accepted and effectively used by the clinical staff. Therefore, their implementation approach incorporated: 1) methods and concepts from user-centered design to ensure that the system would meet user needs and the demands of the work context; and 2) from change management to ensure that clinical users were aware of and prepared for the change that using the system would have on their work.

The first step in the implementation process was to choose a vendor. Children's assembled a team of physicians and clinical, pharmacy, administrative, and IT staff who established the functional and technical criteria for the clinical system. Once the criteria were established, this team conducted an extensive search and evaluation of qualified EMR/CPOE vendors. This effort culminated with multi-day site visits by two vendors, after which the selection team chose Epic Systems Corporation (Epic) as the vendor. Epic develops integrated inpatient, ambulatory, and payor information systems for large healthcare organizations, academic medical centers, and children's healthcare settings. Because Epic's product line also includes ambulatory functions, it fit well with

Children's future vision of incorporating both ambulatory and inpatient encounters into an integrated patient record.

For the system implementation, Children's adopted a staged approach. Children's used this approach to manage risks associated with implementing EMR/CPOE. Using a staged approach made both practical and financial sense because it enabled Children's to manage the scope of work to be delivered and demonstrate incremental progress every 6-12 months. For example, Children's began by replacing key clinical functions that were part of their legacy system, SMS. These functions enabled them to build a foundation using the new technology while implementing functions the IT department was already familiar and comfortable with. It also enabled the team to gain some quick wins with users by replacing SMS functions that they were highly unsatisfied with. Children's implementation timeline including the target user group for each stage is provided in Figure 4. Note that this research focuses primarily on Stage 2, the first major stage used by clinical staff, and CPOE, the first major stage used by physicians. Information on the other stages is provided for historical context.



**Figure 4: Children's EMR implementation timeline**

Since each implementation stage addresses a subset of users, communications and training were tailored to the needs of the specific user group and functionality to ensure users knew what to expect and were able to develop the skills/knowledge they needed to successfully use the system at go-live. Using a staged approach also reduced the amount of change that users had to adopt during each stage by limiting the scope of the system functions to learn and the clinical processes that change as a result of the implementation. One downside of using this approach is that for the period between Stage 2 rollout and CPOE rollout, patients' medical records are divided, with some sections of the record residing in paper charts and other sections residing in the EMR. To reduce confusion related to this division of information, as various EMR functions go live the EMR is the only location where that information resides. Only sections not currently supported in the EMR reside in the paper chart.

Children's due diligence on EMR/CPOE implementation indicated that engaging clinicians (users) throughout the design and implementation process was critical to success. Consequently, they used methods from Change Management and UCD to ensure that they got clinical user input and developed user buy-in throughout the implementation process. Table 11 provides an overview of the methods they employed.

The implementation used Epic Systems' Design-Build-Validate (DBV)© methodology, which is based on user-centered design principles. The Children's implementation team began by identifying current state workflow. This was accomplished by shadowing users in the field and through interviews and user workgroups (focus groups). Once the current workflows were defined, the vendor came in and assembled the Epic tools needed to meet needs based on the current state workflows. Next, the Children's team compared the current state workflows and requirements to the Epic tools to identify gaps and make design decisions based on those gaps. Finally, the system was built based on these decisions. After the build, users reviewed the system as built and provided feedback on the system and workflow design. The outcomes from these reviews were design change requests and input to future state workflows to ensure users would accept the new system.

In the system implementation process, several key groups ensured that clinical user needs were adequately understood and addressed. These groups included the Clinical Informatics team, the Department Champions, workgroups, and Super Users. The Clinical Informatics team was an integral part of the implementation team composed of former clinicians all with 10+ years of experience working in the hospital. These clinicians had first hand knowledge of clinical work practices and the work context in the hospital. This team worked closely with representative users in each work area to understand current work processes, define system requirements, and design future state workflows. Clinical Informatics team members shadowed users in the field, interviewed users, and reviewed policies, procedures, and current documentation tools for each work area to collect information on work practices and system requirements. Clinical Informatics participated in design sessions to provide the clinical perspective on design decisions. Representatives from Clinical Informatics also conducted Q/A sessions at staff meetings to ensure that users were well informed about the system and implementation process.

Department Champions provided vital user feedback on the design and implementation. Department Champions are a group of user representatives, one from each unit on both campuses impacted by the EMR implementation. Champions for the units most impacted by the implementation meet monthly, while representatives from areas only lightly affected by the system met quarterly. At these meetings, the Clinical Informatics team updated the Champions on project activities and timelines, set expectations about the system and system use, obtained Champion input on design challenges/issues and any policy changes related to the system (e.g., when is medication documentation considered 'late'? ). Dept. Champions, in turn, communicated this information back to people on their units.

Workgroups for each work area were formed to iteratively provide input on work processes and requirements for that area. These workgroups, essentially focus groups, included a subset of the Dept. Champions and additional subject matter experts (clinicians). Lead by Clinical Informatics team members, these workgroups completed

deep workflow analysis on a specific component of the application and, after the system was built, validated the system design and future workflows.

Super Users also played a vital roll in the implementation. This subset of users from each unit completed extensive training on the system so that they could provide on-the-unit support for other users in their unit in the period following rollout. Super users completed training prior to the broader user population and provided feedback on both the system and training materials to iteratively improve both. During the first 7-10 days after go-live, Super Users were on the units providing support and working one-on-one with other users to help them become proficient with the system. During this time, Super Users did not have any patient care responsibilities so that they could focus on supporting the other staff and working with the implementation team to resolve any issues that arose.

Because Stage 2 affected critical patient care processes (e.g., medication administration), ensuring that users developed adequate system skills prior to rollout was crucial.

Therefore, training and other learning activities were instituted to help users develop these skills. To ensure the quality of the training materials, lead trainers were integrated into the implementation team to ensure they had broad and deep knowledge of the system. Trainers worked closely with Clinical Informatics as they developed training materials to make sure they would make sense to clinicians. Clinical Informatics also provided real-life scenarios to use as hands-on examples in training classes. Training materials were iteratively improved, first based on feedback from Clinical Informatics and then based on feedback from Super Users. Additionally, a clinician (either from Clinical Informatics or the Super Users) was present at each training class to answer clinical questions that arose during the class. Training was required for all users.

**Table 11. Children's use of Change Management and UCD methods**

<b>Methods/Tools Employed</b>	<b>Children's Use of Method/Tool</b>
<b>Change Management Tools</b>	
Define Vision & Goals/ROI	Executive committee established project goals as part of a strategic plan. Established goals included improvements in efficiency and patient safety.
Change management plan	No formal plan was completed, but informal change processes were put in place to ensure successful change.
Stakeholder analysis	The Chief Learning Officer (CLO), CIO, and physician medical directors of the implementation from each campus attended a monthly meeting about how to get clinical stakeholders (especially opinion leaders) involved and engaged in the adoption process. They focused on understanding what was happening in the clinical stakeholders' practice and connecting that to how Epic could help them. In addition, one of the physician sponsors conducted interviews with individual physicians to identify change management needs and plan to address those gaps. Feedback from monthly and quarterly Department Champions was also used to gauge clinical staff stakeholder opinions and needs.
Stakeholder engagement	To engage stakeholders, various efforts were made to get them involved in the change. Implementation team leaders engaged in frequent conversations with operations leaders and physician opinion leaders. Committees and a governance structure was established with key stakeholders involved to facilitate an ongoing dialog.
Sponsor roadmaps	Clinical sponsors (physicians & clinical operations leaders) had a portion of their time dedicated to the Epic project. Executive level sponsors were engaged throughout the process. For example, a monthly meeting was held with key stakeholders and sponsors at the operational level and quarterly meetings were held with the executive team. There was also a continuous 1-on-1 dialog with key sponsors.

**Table 11 (continued)**

<b>Methods/Tools Employed</b>	<b>Children's Use of Method/Tool</b>
Training plans	A full training needs analysis was conducted for each release. This needs analysis identified training needs by group for each stage. This included a review of job descriptions, input from Dept. Champions, a survey of managers to help map training to job codes. The goal was to deliver training 'just-in-time and just right'.
Communication plans	A communication plan including target audiences, messages, and methods of communicating was completed at the outset of the project and was continuously revised as needed based on feedback on communication effectiveness. Key audiences included users, supervisors/managers, operations directors, and executives. Methods employed included periodic face-to-face meetings, existing electronic and print newsletters, email, existing Intranet site, and overhead pages.
Create short term wins	System implementation was divided into stages that would be implemented every 6-12 months. The first stages were selected to provide quick wins in the eyes of users.
Transition plan/change timeline	A target timeline for all stages was established at beginning of the project and revised as needed at the onset of each stage. The initial timeline and subsequent revisions was communicated with key stakeholder groups.
Leadership/coaching skills training	The Clinical Informatics team and Dept. Champions completed 4 hours of change management training (i.e., 'Influential Leadership' training)
Change readiness assessment	Readiness for change was assessed through feedback from Dept. Champions and ongoing dialogs with other stakeholders as well as a user survey conducted 8-9 months prior to system rollout.

**Table 11 (continued)**

<b>Methods/Tools Employed</b>	<b>Children's Use of Method/Tool</b>
Resistance management plans	Informal resistance management plans were utilized. Based on stakeholder analysis the team took action to address resistance. Monthly meetings with CLO, CIO and clinical sponsors were used to identify barriers and/or where things were not moving and how to resolve them (e.g., through policy standardization, workflow changes). For example, early input from physicians indicated that many physicians felt uncomfortable with computers. Thus, basic computer skills training was offered to physicians and was very successful with them.
Manage personal transitions/coaching	Informal coaching was conducted, primarily by Dept. Champions, Clinical Informatics, and Super Users
Mentors	Dept. Champions and Super Users served as technology mentors who helped staff users learn how to use the new system.
Facilitative/participative sessions	During design, representative users participated in work groups that defined current work practices/requirements and provided input on system and future state workflow designs. Dept. Champions also provided input on decisions related to the system implementation.
Q&A Sessions	Q&A opportunities were provided at Dept. Champion sessions, Manager meetings, and other meetings with key stakeholder groups. Additional communication regarding common questions was provided at the department level.
Learning initiatives	Children's used a blended approach to learning that included both classroom teaching and learning in the work environment through use of the playground for practice, provision of tip sheets, and Super User support on the units. Prior to Epic training, a basic computer skills certification process was conducted. All future users were required to score 80% or better on the computer skills certification or take remedial training via CBT. Also, Epic training was required; a 'no training, no work' policy was instituted requiring people who did not complete training to go home once the system went live.

**Table 11 (continued)**

<b>Methods/Tools Employed</b>	<b>Children's Use of Method/Tool</b>
Training	Classroom training materials were rigorously developed in parallel with application design/development. The training leads on the project worked with the implementation team from the beginning of the project on system design and workflow mapping to ensure they had an in-depth knowledge of the system and work processes. As classes were conducted, each class had both a technical trainer and a clinical specialist there to ensure that clinical practice questions could be answered as they arose during training.
Measure & report outcomes	At the beginning of each stage, metrics related to project goals were identified and measures were taken as appropriate to quantify outcomes associated with each stage. For example, metrics addressed medical error rates, efficiency, and user acceptance.
Celebrations	Big milestones were celebrated with key groups as appropriate. For example, after Stage 2 go-live, project leaders held a party for the implementation team and Dept. Champions to acknowledge all of their hard work.
Recognition & rewards systems	The organization recognized and rewarded units who had 100% of employees pass computer proficiency skills test by posting 'pass' rates for each unit on the Intranet and rewarding units with ice cream parties when 100% pass rate was achieved. Dept. Champions and other key users involved in the implementation were recognized for their participation using the existing hospital recognition/rewards system.
Conduct after-action reviews	At the completion of Stage 2, sunset reviews were facilitated with the implementation team and Dept. Champions to identify lessons learned from Stage 2. Researchers from Emory also conducted interviews with managers prior to and following implementation of each stage to obtain perceptions and feedback on the implementation process. At the completion of each stage a 3-4 day work session with the vendor was also conducted.

**Table 11 (continued)**

<b>Methods/Tools Employed</b>	<b>Children's Use of Method/Tool</b>
<b>User-Centered Design Methods</b>	
Documentation & artifact review	Clinical Informatics reviewed all policies and procedures related to each clinical area and analyzed all current documentation tools (forms, etc.) during design.
Field studies/ observations	Clinical informatics shadowed clinicians and conducted field interviews to document the current state workflows and identify requirements during design. After implementation, Clinical Informatics observed users interacting with the system in the field to identify needs for tip sheets and training. During selection of computer carts, the three candidate carts were put on the units so that users could interact with them and provide feedback to the cart selection team. Also, trainers rounded on the units before and after rollout to observe users interacting with the system and provide on-site assistance/instruction. They also provided feedback on user interactions to the implementation team.
Focus Groups	Focus groups worked with Clinical Informatics to validate current state workflows and requirements for each clinical area. Future state workflow walkthroughs demonstrating the system were conducted to obtain iterative feedback on system and workflow design. Dept. Champion meetings also served as a focus group to provide feedback and suggestions on design decisions affecting many units.
Inspection-based evaluations	Heuristic Walkthrough evaluations of Stage 2 usability were conducted and feedback was provided to the implementation team. Where possible, identified issues were addressed with configuration changes or highlighted in the training.
Interviews	Clinical Informatics conducted interviews with subject matter experts to collect information on current state workflows and system requirements. Additionally, researchers from Emory interviewed managers prior to and following rollout to collect feedback on the implementation process.

**Table 11 (continued)**

<b>Methods/Tools Employed</b>	<b>Children's Use of Method/Tool</b>
Participatory design sessions	Representative users participated in workflow workgroups (focus groups) to provide input on requirements and future state workflows. The Clinical Informatics team members, all former clinicians with 10+ years experience in the hospital, were integral members of the implementation team, participating in all DBV sessions and other implementation activities.
Personas/user profiles	Job descriptions were reviewed to identify which people would be impacted by which parts of the system. These profiles were used to identify training and other needs.
Prototypes	System demos were reviewed and feedback on the design was obtained in DBV sessions. After training, users were provided a 'playground' version of the system in which they could practice and provide feedback to the team prior to rollout. Computer carts were demonstrated on the units prior to making a final selection on which carts to purchase.
Surveys & questionnaires	Surveys were conducted throughout the implementation lifecycle to collect input from representative users on a variety of topics. For example, surveys in the Dept. Champion meetings gathered feedback on policy/design decisions related to the implementation, IT readiness & acceptance surveys collected system perceptions from users at various stages of the implementation process, and post-training surveys collected feedback on user satisfaction with training.
Task analysis techniques	Flow charts depicting current state workflows were developed during the requirements/design stage. Based on these, future state workflows were developed and iteratively reviewed/revised.
Use cases/scenarios	Clinical Informatics developed system use scenarios for training and for use in the Heuristic Walkthrough evaluations.

Because many of Stage 2's users had not used computers at work before, ensuring that users had adequate basic computer skills prior to the training was important. Therefore, all users were required to take a Windows® basic skills test. Those who did not pass the test were required to complete computer-based training (CBT) on basic computer skills. An optional typing skills CBT was available to users as well.

To ensure that users continued building their skills with the system between the training class and rollout, a 'playground' version of the system was accessible to users on the units. Periodically, trainers assigned homework to encourage people to practice using the system. Additionally, for several weeks prior to the rollout trainers completed rounds on the units to do additional one-on-one training as needed with users.

Significant efforts were also employed to ease the transition to the new system during rollout. Centralized command centers at each campus served as a central location for communication, support, and issue identification/resolution. The support team held meetings with Super Users at the beginning and end of each shift to provide a forum for two-way communication about system use and issue identification/resolution. Each unit had one or more Super User on each shift to provide support to users. In addition, trainers and members of the support team conducted rounds on the units to observe how things were working in the field and to provide support as needed. A phone hotline also provided direct access to the Command Center for additional support. Users could also submit electronic feedback on the system or problems using the 'Feedback' button present on the toolbar.

### **Measures**

This research examines factors that influence user acceptance of EMR/CPOE systems to inform the development of implementation methods that ensure user acceptance of the technology. Because this research focuses on perceptions of the clinical personnel who use these systems, survey questions are used as to measure both the independent and dependent variables. Independent variables include perceptions regarding safety in the hospitals, level of design input, output quality, and user characteristics (e.g., staff

position, work area, computer experience). Safety perceptions are measured using a tool developed and validated for the Agency for Healthcare Research & Quality (AHRQ). Other independent variables are assessed using survey questions developed for this research based on previously validated tools, when available. The dependent variable, performance expectancy (PE), and an intermediate variable, effort expectancy (EE), are measured using two survey instruments (1 pre-implementation and 1 post-implementation) developed for this project based on existing survey tools in the IT acceptance and healthcare technology literature. The following sections provide details regarding each variable and how it is measured.

### **Independent Variables**

The proposed theoretical model presented in Figure 2 list the independent variables in the left column of the figure. A description of each variable is provided in Table 12. Because several of these variables only apply either prior to implementation (pre) or after implementation (post), Table 12 also identifies the time (pre, post, or both) that the independent variable applies. The sections following Table 12 provide the justification for including each variable in the theoretical model and details of how that variable is measured.

**Table 12. List of independent variables**

<b>Variable</b>	<b>Time</b>	<b>Description</b>
Culture of Safety: Teamwork Within Units (Unit Teamwork)	Pre, Post	Perceptions regarding the quality of teamwork in the individual's work area (e.g., people support one another, respect each other, help each other)
Culture of Safety: Staffing (Staffing)	Pre, Post	Perceptions regarding whether staffing in the individual's work area is appropriate (e.g, have enough staff, work longer hours than is best)
Culture of Safety: Teamwork Across Hospital Units (Hospital Teamwork)	Pre, Post	Perceptions regarding the quality of teamwork across different work areas (e.g., cooperate well, work together well)
Culture of Safety: Hospital Handoffs and Transitions (Transitions)	Pre, Post	Perceptions about the quality of care processes during shift changes and transitions between hospital work areas (e.g., exchange of information, things 'falling between the cracks')
Autonomy	Pre, Post	Perceptions about how use of the system affects the individual's autonomy on the job, including both their privacy and degree of control over their work.
Communication	Pre, Post	Perceptions about how use of the system affects the individual's communication with their coworkers and patients/patient families.
Social Influence (Patient)	Pre, Post	Perceptions of the degree to which use of the system will enhance/degrade their image with patients and their families.
Job-related Characteristics	Pre, Post	Characteristics of the individual's job: work area, staff position, number of hours worked per week, years of clinical experience, and years of experience in their current work area (for staff) or Children' (for physicians).
Compatibility	Pre, Post	Individual's perception of how well the system fits with their existing work values, needs, and experiences

**Table 12 (continued)**

<b>Variable</b>	<b>Time</b>	<b>Description</b>
Computer Experience	Pre, Post	Degree of experience/comfort with computer systems in general.
Perceived Need	Pre	Degree to which an individual perceives there is a need for the system related to avoiding medical errors and/or achieving process efficiency
Design Involvement	Pre	Degree to which an individual feels their needs have been represented and they have been informed during the design process.
Output Quality	Post	Perception of how well the system supports the tasks it is intended to support
System Reliability	Post	Perception of the degree to which the system is subject to frequent problems/crashes
System Expertise	Post	Individual's self-rated confidence in using the system
Support: Personnel	Post	An aspect of facilitating conditions, indicating the degree to which a person or group is available to assist the user with the system

### Culture of Safety Independent Variables

AHRQ-sponsored research has identified aspects of safety culture that are important for understanding and improving patient safety in hospitals (Sorra & Nieva, 2004). Based on this research these aspects of Culture of Safety include seven unit-level and three hospital-level aspects of safety:

#### *Unit level*

- Supervisor/Manager Expectations & Actions Promoting Safety
- Organizational Learning—Continuous Improvement
- Teamwork Within Units (Unit Teamwork)
- Communication Openness
- Feedback and Communication About Error

- Nonpunitive Response to Error
- Staffing

#### *Hospital level*

- Hospital Management Support for Patient Safety
- Teamwork Across Hospital Units (Hospital Teamwork)
- Hospital Handoffs and Transitions (Transitions)

In the context of this research, only a subset of the safety culture constructs have a direct conceptual relationship to the EMR/CPOE implementation: Unit Teamwork, Staffing, Hospital Teamwork, and Transitions. The EMR/CPOE implementation is likely to affect safety culture due to its impact on staff workload and communication about patient care activities (especially via documentation provided in the system). Therefore, there is a conceptual link between the implementation and these four safety constructs because they are significantly affected by staff workload and/or communication processes. Note that the two communication constructs are not expected to be directly affected because they measure attitudes toward openness and feedback about errors and patient safety events, not communication about patient care in general.

Clinical staff perceptions on patient safety in the hospital will be assessed using the Hospital Survey on Patient Safety (Sorra & Nieva, 2004). This survey, developed by Westat for AHRQ and the Quality Interaction Coordination Task Force (QuIC), measures twelve dimensions of safety culture. This survey is available on the AHRQ website (<http://www.ahrq.gov/QUAL/hospculture/>) as part of an AHRQ effort to develop a national repository on safety culture to enable benchmarking across hospitals. This instrument measures the seven unit-level and three hospital-level aspects of safety. In addition, it assesses several outcome variables: overall perceptions of safety, patient safety grade, frequency of event reporting, and number of events reported. While these outcomes are of importance to patient safety, they are of secondary importance in this study as they are less sensitive measures compared to the specific safety dimensions identified above. Therefore, the research presented here focuses on only those four aspects of safety culture. However survey items related to other constructs were included

in the surveys as part of a broader research initiative and ongoing Children's Quality Department projects. Results related to these initiatives are out of the scope of the research presented here. Copies of the surveys distributed to staff at  $t_0$  and  $t_1$  are included in *Appendix A*. The safety survey items are in sections A-H of both surveys.

At  $t_0$ , the patient safety survey was administered to patient care staff in its entirety. However, based on negative feedback from  $t_0$  respondents regarding the length of the survey, several questions were omitted during the  $t_1$  administration. Specifically, the following items were omitted:

- *All 3 items from the Hospital Management scale.* Since  $t_0$  scores were high on this construct and the EMR/CPOE implementation would only indirectly affect this construct, it was of limited importance in the context of this study.
- *One of four items from the Unit Teamwork scale.* Analysis of the  $t_0$  responses indicated that dropping item A11 from Unit Teamwork had little impact on the reliability of the scale ( $\alpha=0.806$  with 4 items,  $\alpha=0.804$  excluding A11).
- *One of four items from the Hospital Teamwork scale.* Analysis of the  $t_0$  responses indicated that dropping item F6 from Hospital Teamwork improved the reliability of this scale ( $\alpha=0.802$  with 4 items,  $\alpha=0.811$  excluding F6).

At  $t_0$ , the patient safety survey was also piloted with a set of physicians. Because the survey was developed and validated using a hospital nursing staff population, there was concern that the instrument as originally designed might not be appropriate for a physician population. Feedback from the pilot physician group confirmed these concerns and indicated that many of the questions did not apply to physicians and that the survey length would result in low response rates. Consequently, researchers worked with input from clinicians to eliminate and or adapt questions that did not apply to physicians. These revised safety survey questions were included in the  $t_1$  pre-CPOE implementation survey distributed to physicians. A copy of the complete  $t_1$  physician survey is included in *Appendix A*; Sections A-E contain safety survey items. Analyses to validate the factor structure of the survey items prior to use of the resulting safety scales in the PE and EE analyses presented in this research is provided in *Appendix B*. Note that this analysis

indicated that the Staffing construct was actually measured two distinct items: *staffing – physicians* and *staffing – staff*. Therefore, these two items are treated independently in the subsequent analyses.

### Other Independent Variables

In addition to the four Culture of Safety constructs discussed previously, a number of other factors may influence PE and/or EE. These items and how they will be measured are described in the following sections. The survey items used to assess each construct are provided in Table 13 for reference. A copy of the surveys is provided in *Appendix A*. The questions used to assess these variables are included in sections I & J of the staff surveys and section F & G in the physician survey.

#### *Autonomy*

Findings from studies of EMR/CPOE studies highlight the importance of keeping the clinician in control of the care process (Teich et al., 2000; Upperman, Staley, Friend, Benes et al., 2005). Additionally, one study reported that nurses were concerned that use of computers would lead to increased monitoring of care activities (McLane, 2005). Anecdotal evidence from Children's patient care staff confirmed this concern. Therefore these two aspects of clinician autonomy were included in the proposed model and questions to measure these factors were included in the survey instrument. Note that the question regarding concern about increased monitoring of care activities was omitted from the physician survey since feedback from Children's indicated this was not a concern for physicians and there was no evidence in the literature indicating this was a concern for physicians.

#### *Communication*

Because delivery of care requires coordination among a number of different care providers, communication between members of the care team and with the patient/patient family are crucial to delivery of quality care. Studies have demonstrated that implementation of EMR/CPOE changes communication patterns between clinicians (Ash, Berg, & Coiera, 2004). Additionally, there is evidence of concern about the affect

of these systems on interactions with patients (Dansky, Gamm, Vasey, & Barsukiewicz, 1999). Therefore, the impact of the system on communication with other clinicians and with patients/patient families is likely to affect users' perceptions of PE. Thus, survey items were developed to assess the participants' perceptions of how system use affects their communication with coworkers and patients and patient families.

### *Social Influence (Patients)*

Social influence is “the degree to which an individual perceives that important others believe he or she should use the new system (Venkatesh, Morris, Davis, & Davis, 2003, p. 451)”, which is closely tied to the Image construct in other work (Moore & Benbasat, 1991). MIS/HCI models of IT acceptance indicate that Social Influence affects PE prior to system implementation, but this influence diminishes as the user gains experience with the system (Venkatesh & Davis, 2000). However, in a hospital clinical environment, clinicians interact with a number of different ‘stakeholders’ who may have widely divergent perspectives on clinician’s use of EMR/CPOE (e.g., hospital administration, peers, other groups of clinicians (e.g., physicians vs. nurses), and patients/patient families). Therefore, assessments utilizing the general ‘important people’ concept provided in the MIS/HCI literature seemed inappropriate as it would not provide any insight into which group was driving this perception. However, in order to limit the length of the surveys to a reasonable size it was not possible to assess this dimension for all divergent stakeholder groups. Therefore, focusing on social influence of a highly important stakeholder group seemed prudent. Findings in the general EMR literature indicate the perceived affect of the system on the relationship with the patient is of concern to clinicians (e.g., Dansky, Gamm, Vasey, & Barsukiewicz, 1999). Therefore, the social influence related to the patient/patient family was selected for inclusion in the proposed research model. This construct is assessed using a question adapted from the Chismar and Wiley-Patton (2002) study that applied TAM to Pediatrician’s use of Internet applications.

### *Job-related Characteristics*

As discussed in the *Background* section, individuals with different job characteristics like staff position (e.g., physician vs. nurse) and work area (e.g., ICU vs. general care) have reported varying levels of satisfaction with EMR/CPOE. Therefore characteristics of the individual's job including work area, staff position, number of hours worked per week, and years of clinical experience are included in the model and assessed in each survey.

### *Compatibility*

In their development of an instrument to measure technology adoption, Moore & Benbasat (1991) identified compatibility as “the degree to which an innovation is perceived as being consistent with existing values, needs, and past experiences of potential adopters” (p.195). A number of EMR/CPOE implementations indicated many users were unhappy with the system because of the changes it imposed on their work practices (e.g., Aarts, Doorewaard, & Berg, 2004; e.g., Massaro, 1993a). Therefore, this concept warrants inclusion in the proposed model so that the relationship between compatibility with work practices and PE can be better understood.

However, Moore & Benbasat's result indicated that their compatibility scale was confounded with PE. Similarly, Venkatesh and colleagues (2003) conceptually included this concept as a contributor to 'Facilitating Conditions' in UTAUT, but their factor analysis resulted in omitting all of the Compatibility questions. (See the Background section *Performance Expectancy - Compatibility* for more details.) As such, including the 4-item Moore & Benbasat Compatibility scale seemed in appropriate. However, given the anecdotal evidence of a relationship between work compatibility and acceptance of EMR/CPOE, it was important to include some measure of compatibility as an independent variable. Therefore, the Moore & Benbasat's question related to the technology's fit with the way the user works is included to measure compatibility.

### *Computer Experience*

Computer experience represents an individual's prior experience with computing applications in general, as opposed to the specific system being examined. Intuitively, a

person's prior experience with computers would influence their perceptions about the new system, especially prior to any hands-on exposure to the system. However, the role that computer experience plays in affecting acceptance of and satisfaction with technology is unclear. Some studies indicate that computer experience affects pre-implementation attitude toward EMR (van der Meijden, Tange, Boiten, Troost, & Hasman, 2000) and post-implementation satisfaction with EMR/CPOE (Weiner et al., 1999). However others indicate that it does not significantly affect EMR/CPOE user satisfaction (Gardner & Lundsgaarde, 1994; Murff & Kannry, 2001). Additionally, results from the MIS/HCI literature indicate that computer experience affects attitude toward a system, but not PE. For completeness and due to the unclear role of computer experience in the context of EMR/CPOE acceptance and satisfaction, it is included as a variable in the conceptual model. Computer experience is measured by the individual's self-rated frequency of computer use or their self-rated comfort with computers.

#### *Perceived Need (Pre-only)*

Frequently, two primary reasons cited for implementing EMR/CPOE are to achieve reductions in medical errors and to achieve process efficiencies. Studies note the importance of making clinicians aware of these expected benefits to ensure their support for what is a significant change (e.g., Massaro, 1993a). Therefore, the degree to which an individual perceives there is a need for the system related to avoiding medical errors and/or achieving process efficiency may affect PE. Survey items are included to assess these perceptions.

#### *Design Involvement (Pre-only)*

Lessons learned from previous EMR/CPOE highlight the importance of clinician involvement throughout design and implementation (Massaro, 1993b; Poon et al., 2004; Sittig & Stead, 1994). Thus, prior to implementation, the degree to which an individual feels their needs have been represented and they have been informed during the design process is expected to influence their perceptions of PE. Since no existing scales for assessing this were identified in the literature, survey items on this topic were developed specifically for this study.

### *Output Quality (Post-only)*

Output quality refers to how well a system support the tasks it is intended to support (Venkatesh & Davis, 2000). In a study applying TAM2 to four different business applications, Venkatesh and Davis found that output quality interacted with job relevance to affect PE. Their results indicate that as an application was judged to be more relevant to an individual's job, output quality became more important. Because only one system (EMR/CPOE) is being examined in this study and it supports required clinical documentation and other tasks, job relevance is not relevant in the current study context, so only output quality is included in the theoretical model. The output quality survey items are adapted from existing surveys (Chismar & Wiley-Patton, 2002; Venkatesh & Davis, 2000), but extended to address both the availability and quality of information provided in the EMR/CPOE.

Because the pre-implementation surveys assessed user perceptions before training or any other interactions with the system, output quality is omitted from the pre-implementation surveys since users are unlikely to have a basis for answering these questions. However, future research utilizing the pre-implementation survey instrument to assess perceptions between training and rollout should include these questions.

### *System Reliability (Post-only)*

Even if a system is designed to perfectly support the user's work, if it is frequently unavailable due to problems or crashes, it will not adequately support the work. Therefore, the users' perception of the system's reliability can also be expected to influence PE and EE. A question on perceived system reliability is included to assess this factor.

### *System Expertise (Post-only)*

Experience with the system has been demonstrated to affect both PE and EE (Xia & Lee, 2000) Intuitively, this ability to effectively use the system may influence a user's perception of its usefulness (PE) and ease of use (EE). To account for this in the PE and

EE models, users' system expertise is assessed by using their self-rated confidence in using the system.

*Support: Personnel (Post-only)*

Support – personnel indicates the degree to which a person or group is available to assist users when they need help with the system. This is part the broader facilitating conditions construct, which incorporates aspects of both organizational and technical support for using the system. The UTAUT study indicated that the broader facilitating conditions had little effect on intention to use and system use, so the broader construct was not included in the model. However, because another study (Al-Gahtani & King, 1999) indicated that availability of technical support was a significant contributor to PE, it was important to examine this aspect of facilitating conditions. At Children's, front-line user support was provided by Super Users who worked on the unit with the users. Therefore a question was included about the degree to which this group could effectively assist users.

**Table 13. Survey items for non-culture of safety independent variables**

Concept	Question(s)
Autonomy – Privacy	I am concerned that the system can capture and track patient-care activities
Autonomy – Control	I believe that Epic will reduce the control I currently have over my work
Communication	I believe Epic will reduce my communication with my coworkers I believe Epic will reduce my communication with patients and their families Epic makes it easier for me to share knowledge/information with other users of the system*
Social Influence	I believe that using Epic will enhance my image with the patients and their families

**Table 13 (continued)**

<b>Concept</b>	<b>Question(s)</b>
Job-related Characteristics	<p>What is your primary work area at Children's?</p> <p>Typically, how many <u>hours per week</u> do you work at Children's?</p> <p>What is your staff position in this hospital?</p> <p>How long have you worked in your current hospital <u>work area</u>?</p> <p>How long have you worked in your current specialty or profession?</p>
Compatibility	I believe Epic will fit into my workflow
Computer Experience	<p>I use computers for personal or professional purposes (5-point scale from Frequently to Never)</p> <p>Have you previously used IT systems for work functions/processes?</p> <p>I feel comfortable using computers (5-point scale from Strongly Disagree to Strongly Agree)</p>
Design Involvement	<p>I feel that my needs have been represented in the Epic design process</p> <p>I feel comfortable with Epic because I have been informed/updated throughout the implementation process</p>
Perceived Need	<p>Most medical errors occur due to process failures in the current system</p> <p>I feel the current practices are efficient; therefore, I do not see the need to implement the system</p>
Output Quality	<p>Epic provides accurate, reliable information</p> <p>Epic provides more information for better clinical decision making</p> <p>Epic provides faster access to information for better clinical decision making</p>
System Reliability	Epic is subject to frequent system problems and crashes that could contribute to medical errors
System Expertise	I am a confident user of the Epic system
Support - Personnel	The Epic super users have the knowledge and expertise to assist service users

\* Only included in post-survey since this question only applies after the user has had exposure to the system (similar to Output Quality and System Reliability questions).

## Dependent Variables

This research focuses on two dependent variables: performance expectancy (PE) and effort expectancy (EE). PE is the primary outcome variable, while EE is an intermediate variable that is expected to both be affected by some dependent variables and to affect PE. As discussed in the *Background* section, PE is the degree to which a user believes that use of the system helps them improve their job performance. EE is the degree to which a system is perceived as easy to use.

Both of these constructs have been examined extensively in the MIS/HCI literature. However, as noted previously, evidence from the application of PE in healthcare indicates that this construct needs to be broadened to include items related to quality of patient care in order to present a more accurate assessment of PE in healthcare technology. In fact, in their validation of UTAUT, Venkatesh et al (2003) “...the measures for UTAUT should be viewed as preliminary and future research should be targeted at more fully developing and validating appropriate scales for each of the constructs with an emphasis on content validity and then revalidating the model. (p. 467)”. Therefore, this research endeavors to more fully develop and validate the PE and EE constructs for application to healthcare technologies like EMR/CPOE.

As discussed in the *Proposed Model* section, much of the past research on user perceptions of EMR/CPOE has focused on user satisfaction, of which EE is a component, as opposed to acceptance. However, studies examining technology acceptance in healthcare show that PE has a bigger effect on intention to use technology than EE (Chismar & Wiley-Patton, 2002; Hu, Chau, Sheng, & Kar Yan, 1999; Van Schaik, Bettany-Saltikov, & Warren, 2002), supporting MIS/HCI findings that PE is a better predictor of technology adoption than user satisfaction. Thus user satisfaction assessment scales employed in other EMR/CPOE studies (e.g., EUCS, QUIS) were inadequate for this study.

For this study PE and EE scales from MIS/HCI were adapted for application to healthcare technology acceptance. The few studies of healthcare technology acceptance (as opposed to user satisfaction) (Hu, Chau, Sheng, & Kar Yan, 1999; Van Schaik, Bettany-Saltikov, & Warren, 2002) highlight the need to adapt PE survey items to ensure their content validity for healthcare technologies. However, the EE scale needed little modification for application to these technologies. The PE and EE survey items included in this research are adapted from existing survey instruments from UTAUT and related models (Moore & Benbasat, 1991; Venkatesh, Morris, Davis, & Davis, 2003) and from instruments used to evaluate healthcare technologies including EMR/CPOE (Lee, Teich, Spurr, & Bates, 1996). Items used to assess PE in pre- and post-implementation surveys are presented in Table 14. Items used to assess EE are presented in Table 15. Note that because the pre-implementation surveys were being administered prior to training, and therefore prior to any personal exposure to the system, users would not have an adequate basis for answering several of the EE questions (e.g., ‘Epic is easy to use’). Therefore, these questions were omitted in the pre-implementation surveys. Note that the MIS/HCI studies that validated the EE scale were all administered after training (Venkatesh & Davis, 2000) or at some point after system rollout (Moore & Benbasat, 1991; Venkatesh, Morris, Davis, & Davis, 2003) when respondents had some degree of personal exposure to the technology.

**Table 14. Performance Expectancy Survey Items**

<b>Pre Question</b>	<b>Post Question</b>
Epic will allow me to accomplish my tasks more efficiently	I believe Epic has enabled me to accomplish my tasks more efficiently.
I believe Epic can assist me in improving the quality of care I deliver	I believe Epic assists me in improving the quality of healthcare I deliver.
I believe that Epic can help to reduce medical errors	I believe that Epic helps to reduce medical errors.
I believe Epic will make my current workload heavier	I believe Epic has made my workload heavier.
I believe usage of Epic will reduce my administrative workload and give me more time to spend with patients	I believe that using Epic has given me more time to spend with patients.
	Epic has enhanced my effectiveness on the job.*

\*This question was added in the post-implementation surveys in an effort to increase the robustness and internal validity of the scale.

**Table 15. Effort Expectancy Survey Items**

<b>Pre Question</b>	<b>Post Question</b>
It will be easy for me to learn to use Epic	The features of the Epic system were easy to learn.
	I find it easy to get Epic to do what I want it to do.
	Epic is user-friendly.
	Epic is easy to use.

### **Incremental improvements to survey instruments**

Based on the analysis of the staff pre-implementation survey responses and review of the pre-implementation survey by physicians for content validity, the pre-implementation survey was modified slightly prior to administration to the physicians at  $t_1$ . Survey length was of particular concern for this population so several questions were dropped:

- *1 item from Performance Expectancy*: “I believe Epic can assist me in improving the quality of care I deliver.” This was dropped because analysis of staff  $t_0$  data indicated that this item was the least diagnostic of the PE-scale items (i.e. had the least variability in answers). Also, Pearson Correlation of the 5-item PE scale to a 4-item scale excluding this question resulted in  $r=0.987$  ( $p<0.001$ ), indicating the two scales are almost perfectly correlated and internal consistency of the 4-item scale ( $\alpha=0.835$ ) was comparable to that of the 5-item scale ( $\alpha=0.876$ ).
- *Autonomy – Privacy*: “I am concerned that the system can capture and track patient-care activities.” This item was dropped after review of the survey with clinicians and survey of the literature indicated this was not a concern for physicians, as it was for staff.
- *Need – Errors*: “Most medical errors occur due to process failures in the current system” This item was removed based on feedback from the clinician review of the survey.

Two additional questions were added to further examine perceptions on the impact of the system on patient care outcomes. These items were:

- “Implementation of Epic will lead to improved patient satisfaction with their clinical experience”
- “Implementation of Epic will improve patient safety”

## Data Collection

The following sections describe the methods used to distribute and collect the surveys at each time period for this research. In addition, the populations surveyed at each time are described.

### Survey Distribution and Collection

To assess clinician perceptions about safety and the EMR/CPOE implementation, surveys were distributed and collected at two different time points. Survey participants included physicians, nurses, and other patient care staff and are described in detail in the next section. Three sets of surveys were distributed for this research. The timing, content, and population targeted for each survey was determined based on Children's Epic implementation timeline (Figure 4). The timing and target population for each survey data set is presented in Table 16.

**Table 16. Overview of survey data sets**

Survey Set	EMR Stage	EMR Users/ Target population	Timing	Survey Items Included
Staff-Pre	Stage 2	Nurses and other patient care staff	$t_0$ : 8-9 months <i>prior</i> to implementation	1. AHRQ Safety 2. IT Acceptance (Pre)
Staff-Post	Stage 2	Nurses and other patient care staff	$t_1$ : 5-6 months <i>after</i> implementation	1. AHRQ Safety Survey 2. IT Acceptance (Post)
Physicians-Pre	CPOE	Physicians	$t_1$ : 8-9 months <i>prior</i> to implementation	1. Adapted AHRQ Safety Survey 2. Revised IT Acceptance (Pre)

As Table 16 indicates, the surveys are designed to assess EMR/CPOE user perceptions prior to and following implementation of the first major stage to affect the given user group. Pre-implementation perceptions were assessed approximately 8-9 months prior to implementation, before any hands-on training or knowledge of the system. This time period prior to implementation was selected because UTAUT and other technology acceptance research (discussed previously) has shown that as users gain hands-on experience with the system, the factors that influence IT acceptance change. This research examines how these relationships change prior to system exposure versus after implementation. Also, soliciting user perceptions at this early stage provides valuable input to the implementation team regarding user expectations and concerns while the team still has time to make changes that can improve user acceptance after implementation.

Post-implementation perceptions were assessed 5-6 months after implementation. This timeframe was selected in order to give users time to become proficient with the system, but still be close enough in time to the go-live that users are able to recall how they worked prior to system implementation. The physician post-implementation surveys will be distributed 5-6 months after implementation of CPOE. Results from these surveys will be presented in future research. Note that for the staff surveys, the PE and EE assessments at  $t_1$  will be based on only a subset of the planned EMR functionality, specifically Stage 2 (eMAR and ancillary orders). As such, PE ratings may be limited due to the limited set of functionality currently in place. However, it is still important to assess PE at this intermediate stage to ensure that the intermediate stage does not hinder clinicians in their jobs during the interim. Also, it will enable comparisons to PE ratings after the full EMR implementation to see how they change as additional functions are rolled out.

This research focuses on two primary user groups: patient care staff (e.g., nurses, therapists) and physicians. Because Children's is implementing their EMR/CPOE in stages, pre- and post-implementation perceptions for patient care staff (staff), was coordinated around the implementation of Stage 2. Stage 2 represented the first set of

EMR functions that would require nurses, respiratory therapists, and other staff to enter documentation in the EMR as opposed to the paper chart. Therefore it represented a major shift in many work processes performed by these groups. In contrast, the first stage that significantly affects physicians will be CPOE. When CPOE goes live, physicians will enter all orders and complete patient documentation online in the system, which represents a major shift in their work processes.

For each survey, the data collection method was tailored to the target population and their work context at the time. The methods were selected in order to 1) ensure the data collected was a representative sample of the target population; and 2) achieved the best response rate possible for the population. The methods employed for each data collection effort are described in detail below.

#### Staff-Pre Surveys ( $t_0$ )

The staff-pre surveys targeted a diverse population of patient care staff, described in detail in the *Participants* section. One factor contributing to the selection of the survey distribution/collection method was this population's variability in terms of computer experience and use of computers at work. At this point in time ( $t_0$ ) many in this user population, especially nurses, were not using computers routinely at work. Consequently, there was a concern that using an electronic mechanism (e.g., website) to distribute and collect surveys would result in over-sampling users who use computers and omitting users who had little to no computer experience. Since the perceptions of users with less computer experience is especially important to the validity of these results, it was important to select a distribution mechanism that would encourage participation from this group. Therefore, paper-based surveys were used to collect these surveys.

In order to encourage participation in the survey, the study investigators asked the Department Champion group to distribute paper surveys by hand to the target population. The Department Champions, described previously, included representatives from all units affected by the EMR implementation at both campuses. Due to their existing relationships and visibility on the units, this group was in a good position both to

distribute surveys to the appropriate people and to remind them to complete the surveys as the survey deadline approached. The Department Champions were given signs to post on their hospital unit to remind participants to complete the surveys. They were also provided inter-office mail envelopes which participants could use to return the surveys. Department Champions were compensated for their time with a \$5 gift certificate. All surveys were anonymous in order to encourage candor, especially regarding safety perceptions. Responses were returned via inter-office mail to the study investigators.

#### Staff-Post Surveys ( $t_1$ )

The staff-post surveys targeted the same user population as the staff-pre surveys. However, this population's work context had changed at this point ( $t_1$ ). Now, these users were required to use computers in their daily work. Also, they had become familiar with completing online surveys, as prior to  $t_1$  this population completed online surveys related to the EMR training and a brief 1-month post-implementation survey. This made use of online survey distribution and collection more desirable for  $t_1$ . Thus, surveys were made available online through Zoomerang ([www.zoomerang.com](http://www.zoomerang.com)), a survey development/distribution website. The format of the questions online was comparable to the print format used previously. However, paper copies of the survey were also made available for users who preferred to complete the survey on paper.

Unit managers for the target units distributed the surveys via email. The researchers provided a draft email to unit managers including a link to the online survey and an attached print version for users who preferred to complete the questionnaire on paper. (The study investigators were copied on these emails to obtain accurate numbers for the number of users receiving the survey in order to calculate the response rate.) For consistency with the previous data collection method, the Department Champions were again utilized to encourage users to complete the surveys by the deadline and post signs about the surveys on their hospital unit. Department Champions were compensated for their time with a \$5 gift certificate. As with the previous surveys, these were anonymous. Paper copies were returned via interoffice mail and electronic responses were downloaded from the survey website.

### Physician-Pre Surveys (t<sub>1</sub>)

The physician group presented a challenge as many of the physicians affiliated with Children's are private practice physicians who spend little time in the hospital. However, a subset of these physicians spend a considerable time in the hospital and are responsible for a majority of the orders and patient care documentation in the hospitals. In order to ensure that the EMR/CPOE is accepted by this crucial group of active physicians, they were targeted specifically for this survey. Analysis of patient documentation activity indicated that 263 of the credentialed physicians at Children's were responsible for completing 98% of patient records. Therefore, this 'active' physician population was targeted for participation using a direct mailing. Physicians were mailed a paper copy of the survey and provided a postage-paid reply envelop to return their responses. Approximately one week before the survey deadline, an email reminder was sent to those physicians with an email address on file. This reminder email included an attached electronic copy of the survey for those who had lost the previously provided paper copy.

All responses were anonymous, although some respondents chose to send their responses via email using the electronic copy of the survey. For these responses, identifying information associated with the email was deleted in order to protect participant identities. Of the 263 surveys mailed out, 2 were returned as undeliverable.

### **Participants**

The participants in this research are clinical staff working in Children's hospitals (Egleston or Scottish Rite) who are (or will be) using the Epic EMR system. However, the target clinician users include very diverse groups. Specifically, Stages 2 and 3 provides functions used by nurses, therapists, and other patient care staff while CPOE provides functions for physicians. The work done by each of these groups differs as does their culture. The differences between these groups have resulted in physicians and nurses having different perceptions regarding CIS in general care environments (Lee, Teich, Spurr, & Bates, 1996; Weiner et al., 1999). Therefore, these groups warrant independent examination. This research examines perceptions of both patient care staff (staff) and physicians. The perceptions of staff are examined prior to and following

implementation of Stage 2 to test the proposed EMR/CPOE acceptance model. Physician perceptions prior to CPOE implementation are also examined to test the robustness of the model when applied to a different clinical user group. Note: Due to Children's implementation timelines, post-CPOE perceptions are not examined as part of the results presented here. However, examination of physician's post-implementation perceptions will be completed as future research.

### Patient Care Staff

Patient care staff (staff) are the primary users of the Stage 2 functions. These users include nurses, patient care technicians, ancillary staff, and unit secretaries. Staff work at one of Children's two hospitals, but rarely work at both. While some patient care staff are non-clinical (e.g., social work, child life), this survey only focused on clinical staff with direct patient contact. This population was selected because they are in the best position to directly impact quality of patient care in clinical process and have more direct knowledge of how use of the system could impact clinical processes. The same population was targeted for the pre and post-implementation surveys, however due to normal hospital employee turn-over the specific individuals targeted for the survey may have changed. For confidentiality reasons, no identifying information was collected on participants. However background information on respondents was collected to ensure that the populations for the pre and post-implementation surveys were similar.

### *Staff-pre surveys ( $t_0$ )*

For the  $t_0$  surveys, 1534 surveys were distributed to staff and 369 responses were received (24.1%). This is comparable to the response rate obtained in other studies of nursing perceptions (e.g., Hu, Chau, Sheng, & Kar Yan, 1999). Because the research examines user acceptance of EMR, it was important to ensure that the analysis focuses only on direct users of Stage 2. However, the Department Champion group used to distribute the surveys includes representatives from departments affected by future stages (e.g., Outpatient) or only secondarily by Epic (e.g., Emergency, which uses a different EMR system). Therefore, the responses were reviewed and responses from groups not

directly affected by Stage 2 were excluded from the analysis. Those excluded from the analysis were:

- Those with campus missing or invalid (n=4)
- Those from work area 'Outpatient' (n=5)
- Staff position missing (n=5) or other (n=8)
- Staff position PT/OT/ST (n=2)

In addition, 4 records were excluded due to a substantial amount of missing data (i.e., 80% or more IT acceptance questions left blank). As a result of these exclusions, 341 responses were included in the analysis (22.2% of the original population). A description of the respondents is provided in Table 17.

At  $t_1$ , surveys were distributed to 1331 staff members. 423 responses were received for a response rate of 31.8%. Similar to  $t_0$ , some responses from groups not directly affected by Stage 2 were received. Therefore, the responses from groups not directly affected were excluded from the analysis. Those excluded from the analysis were:

- Those with campus missing or invalid (n=7)
- Those from work area 'Outpatient' (n=20), Emergency (n=2)
- Staff position other (n=20)
- Staff position PT/OT/ST (n=9), Child Life (n=2), Social Work (n=2), Nutritionist (n=6)

2 records were excluded due to a substantial amount of missing data (i.e. 80% or more of IT acceptance questions left blank). As a result of these exclusions, 353 responses were included in the analysis (26.5% of the original population). A description of the respondents is provided in Table 17.

**Table 17. Staff population characteristics at t<sub>0</sub> and t<sub>1</sub>**

	Number (%*)	
	Staff t <sub>0</sub>	Staff t <sub>1</sub>
<b>Total Responses</b>	341 (100)	353 (100)
<b>Campus</b>		
Egleston (Academic)	162 (47.5)	167 (47.3)
Scottish Rite (Nonacademic)	179 (52.2)	186 (52.7)
<b>Staff Position</b>		
Admin/Management	4 (1.2)	15 (4.2)
Patient care tech/Technician	28 (8.2)	25 (7.0)
Nurse	245 (71.8)	268 (75.9)
Respiratory therapist	52 (15.2)	32 (9.1)
Unit secretary	12 (3.5)	13 (3.7)
<b>Work area</b>		
Clinical/ancillary support	7 (2.1)	26 (7.4)
Inpatient GCA/PCA	132 (38.7)	119 (33.7)
Inpatient ICU	165 (48.4)	137 (38.8)
Many units	12 (3.5)	20 (5.7)
Non-clinical support	5 (1.5)	10 (2.8)
Surgical services	11 (3.2)	32 (9.1)
Other/missing	9 (2.6)	9 (2.5)
<b>Yrs working in hospital work area</b>		
Less than 1 yr	59 (17.3)	55 (15.6)
1 to 5 yrs	176 (51.6)	156 (44.2)
6 to 10 yrs	53 (15.5)	66 (18.7)
11 to 15 yrs	26 (7.6)	40 (11.3)
16 to 20 yrs	14 (4.1)	22 (6.2)
21 years or more	9 (2.6)	10 (2.8)

**Table 17 (continued)**

	Number (%*)	
	Staff t <sub>0</sub>	Staff t <sub>1</sub>
<b>Yrs working in current profession</b>		
Less than 1 yr	33 (9.7)	20 (5.7)
1 to 5 yrs	115 (33.7)	85 (24.1)
6 to 10 yrs	70 (20.5)	73 (20.7)
11 to 15 yrs	37 (10.9)	55 (15.6)
16 to 20 yrs	28 (8.2)	45 (12.7)
21 years or more	57 (16.7)	74 (21.0)
<b>Hours worked per week</b>		
Less than 20	16 (4.7)	11 (3.1)
20 to 39	276 (80.9)	262 (74.2)
40 or more	48 (14.1)	79 (22.4)
<b>Use Computers</b>		
Frequently	222 (65.1)	267 (75.6)
Often	57 (16.7)	55 (15.6)
Sometimes	54 (15.8)	19 (5.4)
Rarely	7 (2.1)	8 (2.3)
Never	0	1 (0.3)
Missing	1 (0.3)	0

\* Percentages may not add up to 100% due to missing values and rounding.

Comparisons of the staff participants at each time indicated there was no difference in *Yrs working in hospital work area* ( $\chi^2 = 7.358$ ,  $p=0.195$ ). There were significantly more participants who used computers frequently and less who used computers sometimes at t<sub>1</sub> ( $\chi^2 = 22.824$ ,  $p<0.001$ ). This result was expected due to staff use of the EMR system at t<sub>1</sub>. The proportion of participants working less than 20 and 20-39 hours per week was the same at both time periods ( $\chi^2 < 1$ ,  $p>0.005$ ), but the proportion working 40 or more hours increased slightly from 14% to 22% ( $\chi^2 = 7.567$ ,  $p<0.01$ ). Similarly, the only difference in two populations on *Yrs working in current profession* was a slight decrease from t<sub>0</sub> to t<sub>1</sub>

in the proportion of people working 1 to 6 years ( $\chi^2=4.5$ ,  $p=0.034$ ) and slight increase for people working 16 to 20 years ( $\chi^2=3.959$ ,  $p=0.047$ ).

There were several other differences in the two populations. The  $t_1$  population included more staff working in Ancillary and Surgical Services ( $\chi^2 > 10$ ,  $p<0.01$ ). Since these work areas are a small portion of the overall population at both times, this difference is likely to have a minimal impact on overall study results. There was no significant difference in proportion of staff working in Inpatient GCA/PCA, Inpatient ICU, Many units, Non-clinical support, or Other ( $\chi^2 < 3$ ,  $p>0.05$ ).  $t_1$  had a greater proportion of participants who were administration/management ( $\chi^2=6.368$ ,  $p=0.012$ ) and smaller proportion of respiratory therapists ( $\chi^2=4.762$ ,  $p=0.029$ ). Again, since these positions are a small portion of the overall population at both times, this difference is not of concern. There was no difference in the proportion of Patient Care Technicians/Technicians, Nurses, or Unit Secretaries, ( $\chi^2<2$ ,  $p>0.05$ ).

To account for these differences work area, position, and computer experience were included as predictors in the regression analyses and subgroup analyses were completed when testing hypotheses related to changes in PE and EE.

### Physicians

The  $t_1$  physician pre-implementation surveys were distributed to the 263 most active physicians. Two surveys were undeliverable due to incorrect addresses. Of the remaining 261 surveys, 113 responses were received (43.3%). Because the research examines user acceptance of EMR, it was important to ensure that the analysis focuses only on direct users of the Epic inpatient CPOE functions (Stage 4). Some of the active physicians surveyed may primarily work in areas affected by future stages (e.g., Outpatient) or only secondarily by Epic (e.g., Emergency, which uses a different EMR system). Therefore, the responses were reviewed and responses from groups not directly affected by Stage 4 were excluded from the analysis. Those excluded from the analysis were:

- Those with campus missing ( $n=1$ )
- Those from work area 'Outpatient' ( $n=7$ ) or 'Emergency' ( $n=2$ )

As a result of these exclusions, 103 responses were included in the analysis (39.5% of the original population). A description of the respondents from each campus is provided in Table 18

**Table 18. Physician population characteristics at t<sub>1</sub>**

	<b>Number (%*)</b>
<b>Total Responses</b>	103 (100)
<b>Campus</b>	
Egleston (Academic)	50 (48.5)
Scottish Rite (Nonacademic)	53 (51.5)
<b>Specialty</b>	
Hospitalist	11 (10.7)
Intensivist	7 (6.8)
Anesthesiology	8 (7.8)
Cardiology	6 (5.8)
Neonatology	4 (3.9)
Oncology	6 (5.8)
Surgery	23 (22.3)
Other	33 (32.0)
Missing	5 (4.9)
<b>Work area</b>	
Clinical/ancillary support	1 (1.0)
Inpatient GCA/PCA	12 (11.7)
Inpatient ICU	17 (16.5)
Many units	31 (30.1)
Surgical services	35 (34.0)
Other/missing	7 (6.8)

**Table 18 (continued)**

	<b>Number (%*)</b>
<b>Total Responses</b>	103 (100)
<b>Yrs working in at Children's</b>	
Less than 1 yr	6 (5.8)
1 to 5 yrs	27 (26.2)
6 to 10 yrs	24 (23.3)
11 to 15 yrs	18 (17.5)
16 to 20 yrs	12 (11.7)
21 years or more	14 (13.6)
Missing	2 (1.9)
<b>Yrs working in current specialty</b>	
Less than 1 yr	4 (3.9)
1 to 5 yrs	13 (12.6)
6 to 10 yrs	26 (25.2)
11 to 15 yrs	14 (13.6)
16 to 20 yrs	19 (18.4)
21 years or more	25 (24.3)
Missing	2 (1.9)
<b>Hours worked per week</b>	
Less than 20	18 (17.5)
20 to 39	20 (19.4)
40 to 59	30 (29.1)
60 or more	32 (31.1)
Missing	3 (2.9)
<b>Feel comfortable with computers</b>	
Strongly agree	48 (46.6)
Agree	43 (41.7)
Neither	2 (1.9)
Disagree	5 (4.9)
Strongly disagree	2 (1.9)
Missing	3 (2.9)

\* Percentages may not add up to 100% due to missing values and rounding.

## Analysis Methods

A number of analysis methods will be employed to answer the identified research questions and test the proposed hypotheses. These methods are highlighted in Table 19. Details regarding the specific statistical tests applied to each hypothesis and support for their appropriateness are provided in the *Results* section.

**Table 19. Analysis methods**

	Hypothesis	Data Set	Analysis method
How do clinical staff perceptions of safety relate to aspects of EMR/CPOE acceptance?			
1.1	PE in EMR/CPOE will have two components: Impact on User Performance & Impact on Patient Care	Staff-Pre ( $t_0$ ); Staff-Post ( $t_1$ ); Physician-Pre ( $t_1$ )	Factor Analysis
1.2	Pre-implementation perceptions regarding patient safety will contribute to PE <sup>1</sup> & EE-ease of learning <sup>2</sup>	Staff-Pre ( $t_0$ ); Physician-Pre ( $t_1$ )	Correlations Linear Regression <sup>1</sup> Logistic Regression <sup>2</sup>
1.3	Post-implementation perceptions regarding patient safety will contribute to PE & EE	Staff-Post ( $t_1$ )	Correlations Linear Regression
1.4	Pre-implementation factors other than safety perceptions will contribute to PE <sup>1</sup> & EE-ease of learning <sup>2</sup>	Staff-Pre ( $t_0$ ); Physician-Pre ( $t_1$ )	Correlations Linear Regression <sup>1</sup> Logistic Regression <sup>2</sup>
1.5	Post-implementation factors other than safety perceptions will contribute to PE & EE	Staff-Post ( $t_1$ )	Correlations Linear Regression
How does the relationship between safety perceptions and aspects of EMR/CPOE acceptance change as users gain experience with the system?			
2.1	The size and, in some cases the direction, of the relationship between components of safety culture and components of acceptance will change between pre and post-implementation	Staff-Pre ( $t_0$ ); Staff-Post ( $t_1$ )	Comparison of correlations and regression models in 1.2 & 1.3

**Table 19 (continued)**

	<b>Hypothesis</b>	<b>Data Set</b>	<b>Analysis method</b>
How do perceptions related to EMR/CPOE acceptance change during the implementation life cycle when using a user-centered implementation approach?			
3.1	User perceptions of PE will improve from pre to post-implementation; Subgroups (e.g., work area, staff position) may have a moderating effect	Staff-Pre ( $t_0$ ); Staff-Post ( $t_1$ )	t-test (overall and by subgroup)
3.2	User perceptions of EE will improve from pre to post-implementation; Subgroups (e.g., work area, staff position) may have a moderating effect	Staff-Pre ( $t_0$ ); Staff-Post ( $t_1$ )	$\chi^2$ test (overall and by subgroup)
Does use of user-centered implementation (UCI) methods result user acceptance of EMR and CPOE?			
4.1	User perceptions of PE will be positive post-implementation; Subgroups (e.g., work area, staff position) may have a moderating effect	Staff-Post ( $t_1$ )	One sample t-test (overall and by subgroup)
4.2	User perceptions of EE will be positive post-implementation; Subgroups (e.g., work area, staff position) may have a moderating effect	Staff-Post ( $t_1$ )	One sample t-test (overall and by subgroup)
How can UCI be enhanced to improve future implementations of EMR/CPOE?			
5.1	Do UCI approaches need to be modified to ensure that user concerns about patient safety are addressed?	Results from 1.1-1.3, 2.1	Qualitative analysis
5.2	Based on the results in Q3 and Q4, are there particular subgroups of clinical staff that have special needs which UCI can be enhanced to address?	Results from 3.1-3.2, 4.1-4.2	Qualitative analysis

## RESULTS

The following sections present the results of the statistical analyses used to test the stated hypotheses. Each section describes the statistical test used, the justification for using that test, and the results of each test.

### **Factor Analysis of Measurement Scales**

For each survey data set, two factor analyses were completed in order to validate the measurement scales used in this research. The first factor analysis included all items that addressed outcomes resulting from use of the system (outcome items). This provided insight into the underlying factors that measure user perceptions of the outcomes that result from use of the system, including performance expectancy (PE). The second factor analysis included all items that addressed inputs related to the implementation process, organizational factors, or characteristics of the system (input items). This analysis provided insight into the underlying input factors that contribute to user acceptance. Identifying the underlying input and outcome factors is a prerequisite to analyzing the relationships among input and outcome factors.

A principal components analysis (PCA) examined the underlying factor structure. The PCA method is used to reduce the dimensionality of a set of correlated measures by determining the true dimensionality of the data and constructing new measures based on the true dimensionality (R. A. Johnson & Wichern, 1988). Therefore, each factor analysis consisted of the following steps:

1. Run PCA factor analysis
2. Determine the appropriate number of factors based on review of the Eigenvalues, scree plots, rotated factor loading, and content validity of resulting factors (Edwards, Sainfort, Jacko, & Kongnakorn, 2006)
3. Validate that resulting factors explain an adequate amount of the total variance
4. Validate that resulting constructs have adequate internal consistency using Cronbach's  $\alpha$ , a measure of scale reliability.  $\alpha > 0.7$  is generally considered acceptable in human factors and social sciences research.

Table 20 (Staff-pre) and Table 21 (Staff-post) present the results from the outcomes factor analyses, which accounted for 71.5% and 78.3% of the total variance, respectively. Table 22 (Staff-pre) and Table 23 (Staff-post) present the results from the inputs factor analyses, which accounted for 86.8% and 80.6% of the total variance, respectively. The results of these analyses are discussed in detail in the following sections. Following these sections, the results from the physician outcomes and inputs factor analyses are presented to provide further supporting evidence for the factor structure observed in the Staff-pre surveys.

**Table 20. Outcome item factor loadings - staff pre-implementation (t<sub>0</sub>)**

		<b>Factor Loadings</b>		
<b>Survey Item</b>		<b>1</b>	<b>2</b>	<b>3</b>
<b>Performance Expectancy</b> ( $\alpha=0.876$ )	Epic will allow me to accomplish my tasks more efficiently	<b>0.807</b>	-0.187	-0.235
	I believe Epic can assist me in improving the quality of care I deliver	<b>0.841</b>	-0.113	-0.109
	I believe that Epic can help to reduce medical errors	<b>0.787</b>	-0.056	-0.102
	I believe usage of Epic will reduce my administrative workload and give me more time to spend with patients	<b>0.764</b>	-0.135	-0.193
	I believe that using Epic will enhance my image with the patients and their families	<b>0.777</b>	-0.114	0.004
I believe Epic will make my current workload heavier		-0.517	0.197	0.592
<b>Communication</b> ( $\alpha=0.640$ )	I believe Epic will reduce my communication with my coworkers	-0.102	<b>0.830</b>	0.234
	I believe Epic will reduce my communication with patients and their families	-0.182	<b>0.868</b>	0.046
<b>Control</b>	I believe that Epic will reduce the control I currently have over my work	-0.073	0.151	<b>0.920</b>

**71.5% of total variance explained by 3 factors.**

**Table 21. Outcome item factor loadings - staff post-implementation (t<sub>1</sub>)**

		Factor loadings			
Survey items		1	2	3	4
<b>Performance Expectancy</b> ( $\alpha=0.920$ )	Epic has enhanced my effectiveness on the job.*	<b>0.831</b>	-0.067	-0.132	0.131
	I believe Epic has enabled me to accomplish my tasks more efficiently.	<b>0.853</b>	-0.139	-0.188	0.183
	I believe Epic assists me in improving the quality of healthcare I deliver.	<b>0.821</b>	-0.098	-0.187	0.160
	I believe that Epic helps to reduce medical errors.	<b>0.754</b>	-0.023	-0.188	0.315
	I believe that using Epic has given me more time to spend with patients.	<b>0.783</b>	-0.027	-0.126	0.151
	I believe that using Epic has enhanced my image with the patients and their families.	<b>0.836</b>	-0.018	0.177	0.058
I believe Epic has made my workload heavier.		-0.660	0.218	0.478	-0.056
<b>Communication</b> ( $\alpha=0.757$ )	I believe Epic has reduced my communication with my coworkers.	0.026	<b>0.889</b>	0.174	0.001
	I believe Epic has reduced my communication with patients and their families.	-0.189	<b>0.873</b>	0.125	-0.055
Using Epic has reduced the control I have over my work.		-0.163	0.265	<b>0.892</b>	-0.063
The Epic system makes it easier for me to share knowledge/information with other users of the system.*		0.343	-0.043	-0.059	<b>0.925</b>

**78.3% of total variance explained by 4 items**

\*Questions not included in pre-implementation survey

**Table 22. Input items factor loadings – staff pre-implementation (t<sub>0</sub>)**

Survey items		Factor loadings				
		1	2	3	4	5
It will be easy for me to learn to use Epic		0.171	0.175	<b>0.933</b>	-0.071	0.047
Design Involvement ( $\alpha=0.667$ )	I feel that my needs have been represented in the Epic design process*	<b>0.918</b>	0.082	0.023	-0.012	0.076
	I feel comfortable with Epic because I have been informed/updated throughout the implementation process*	<b>0.684</b>	0.159	0.408	-0.038	0.044
I feel the current practices are efficient; therefore, I do not see the need to implement the system*		-0.034	<b>-0.911</b>	-0.168	0.047	-0.131
I believe Epic will fit into my workflow		0.532	0.670	0.092	0.014	0.045
I am concerned that the system can capture and track patient-care activities		-0.025	-0.032	-0.067	<b>0.995</b>	0.053
Most medical errors occur due to process failures in the current system*		0.088	0.129	0.047	0.054	<b>0.984</b>

**86.8% of total variance explained by 5 factors**

\* Questions not included in post-implementation survey

**Table 23. Input item factor loadings - staff post-implementation (t<sub>1</sub>)**

		Factor loadings				
Survey Items		1	2	3	4	5
<b>Effort Expect.</b> ( $\alpha=0.829$ )	Epic is easy to use.*	<b>0.864</b>	0.215	0.111	-0.045	-0.025
	The features of the Epic system were easy to learn.	<b>0.807</b>	0.009	0.124	-0.180	-0.094
	Epic is user-friendly.*	<b>0.679</b>	0.447	0.136	-0.045	0.095
	I find it easy to get Epic to do what I want it to do.*	<b>0.629</b>	0.487	0.006	-0.158	0.050
<b>Support for Decisions</b> ( $\alpha=0.814$ )	I believe Epic fits in well with the way I like to work.	0.451	<b>0.711</b>	0.059	0.005	-0.015
	Epic provides faster access to information for better clinical decision making.*	0.089	<b>0.887</b>	0.078	-0.084	0.006
	Epic provides more information for better clinical decision making.*	0.188	<b>0.770</b>	0.292	-0.110	-0.041
Epic provides accurate, reliable information.*		0.187	0.232	<b>0.937</b>	-0.073	-0.000
I am concerned that the system can capture and track patient-care activities.		-0.026	-0.015	-0.002	0.005	<b>0.994</b>
Epic is subject to frequent system problems and crashes that could contribute to medical errors.*		-0.191	-0.126	-0.072	<b>0.964</b>	0.005

**80.6% of total variance explained by 5 factors**

\* Questions not included in pre-implementation survey

## **Outcome factors - Staff**

Comparing the  $t_0$  and  $t_1$  outcome factor analyses results reveals similar results at the two time periods. This provides strong supporting evidence for the validity of the results as the factors remain consistent over time. Specifically, three factors were consistent at  $t_0$  and  $t_1$ : 1) Performance Expectancy (PE), 2) Communication, and 3) Control. At  $t_1$ , a fourth factor, support for decision processes, which was not part of the  $t_0$  survey, was also observed. Note that the item 'I believe Epic will make my current workload heavier' weighed approximately evenly on the same two different factors (PE and Control) in both the  $t_0$  and  $t_1$  results. This item was excluded from both factors, as the content of this item indicates it is an independent factor that may be influenced by both PE and Control.

### Performance Expectancy

The PE factor included 5 items at  $t_0$  and these same 5 items were included in PE at  $t_1$ . An additional item included on in the  $t_1$  surveys (effectiveness on the job) also contributed to PE at  $t_1$ . A review of the items indicates that both individual job outcomes (e.g. efficiency, quality) and items related to impact on patient care (e.g., medical errors, time with patients) weighed approximately equally on PE. This result contradicts hypothesis 1.1, which hypothesized that PE would consist of two sub-components, one related to individual performance and one on patients/patient care. It is also interesting to note that the Social Influence item (re: enhancing image with patients and their families) was part of the PE factor instead of a separate factor as originally anticipated.

The PE items in the factor reported good consistency in both the pre-implementation surveys ( $\alpha=0.876$ ) and the post-implementation surveys ( $\alpha=0.920$ ). Therefore, a PE scale was calculated for use in subsequent analyses. The PE scale was calculated by averaging responses for the items in the scale (5-items at  $t_0$ , 6-items at  $t_1$ ). Note: It is likely that the higher  $\alpha$  achieved in the  $t_1$  surveys is a result of the addition of the 6<sup>th</sup> survey item on job effectiveness. Therefore this item should be included in future uses of the pre-implementation surveys.

### Communication

The two survey items that assessed use of the system's impact on communication contributed to the second factor, providing evidence of a 'communication' outcome factor. This result was observed at both  $t_0$  and  $t_1$ . However, reliability analysis of these items provided mixed results. At  $t_0$ ,  $\alpha$  was only 0.640, lower than is typically acceptable in human subjects research. At  $t_1$ , however,  $\alpha$  was at the acceptable level of 0.757. (Note: this construct was also observed in the physician pre-implementation surveys ( $\alpha = 0.681$ ), presented in the following section.) For the purposes of this research, these two items were combined into a single scale, but future research needs to further examine and develop the Communication scale. The Communication scale was calculated by averaging the responses on the two Communication items.

### Others

Two additional outcome survey items were identified as independent factors. At both  $t_0$  and  $t_1$ , the item regarding reduced control over work was weighted as a separate factor. (Note: Again, the same result was also observed in the physician pre-implementation surveys.) Additionally, the survey item added at  $t_1$  on the ease of sharing knowledge with others weighed as an independent factor as well. Therefore, in all subsequent analyses these two items are treated as independent variables.

### **Input factors - Staff**

Based on the knowledge base on IT acceptance and EMR/CPOE acceptance and satisfaction, the factors contributing to PE and other outcomes prior to implementation were anticipated to differ from those post-implementation. Therefore, while the input survey items at  $t_0$  and  $t_1$  had some overlap, there were many differences, therefore the pre- and post-implementation input factor analyses are examined separately in the following sections.

### Pre-implementation

Most of the input items in the pre-implementation ( $t_0$ ) survey weighed in as independent factors in the factor analysis results. This was anticipated as the goal of the research was

to examine a broad range of potential influences on PE as opposed to creating scales to assess a narrow range of input factors. However, the two items on involvement/input into the design process contributed to the one factor. The internal consistency was relatively low ( $\alpha=0.667$ ), so these items were treated independently in the subsequent analyses.

### Post-implementation

In the post-implementation surveys, a number of items related to specific aspects of the system were added. Recall that these items were excluded from the pre-implementation surveys because they were administered prior to training when the users had no personal exposure to the system on which to judge these items. The analysis identified two factors related to these items: effort expectancy (EE) and support for decision processes (SDP). These factors are discussed in detail below. Three additional items also weighted as independent factors. Consistent with  $t_0$ , the item on concern about tracking patient-care activities was an independent factor at  $t_1$ . In addition, the item on accurate, reliable information and the item on system reliability (i.e., problems and crashes) were identified as independent factors.

#### *Effort Expectancy*

As anticipated based on the MIS/HCI literature, the four survey items related to ease of use all loaded on the EE factor. These four items also demonstrated good reliability ( $\alpha=0.829$ ), therefore they were combined into the EE scale for the subsequent analyses. The EE score was calculated by averaging the user's response on the four EE items.

#### *Support for Decision Processes*

Three items related to support for clinical decision making processes contributed to a second input factor. These items addressed speed of access to and amount of information for clinical decision making and the degree to which the system fits with the way the user likes to work. This 3-item factor demonstrated good reliability ( $\alpha=0.814$ ). Therefore, these items were combined into the support for decision processes (SDP) scale for subsequent analyses by averaging the individual scores on these three items.

### **Validation of factors – Physician pre-implementation factor analysis**

In order to further validate the factors identified in the staff pre-implementation surveys, factor analyses of outcome and input items from the physician pre-implementation responses was conducted independently. Recall that the pre-implementation survey was refined based on the  $t_0$  staff results, so the two new survey items were included in the outcomes factor analysis.

The initial outcomes factor analysis hinted at the existence of two PE constructs instead of the one observed in the staff  $t_0$  and  $t_1$  results. However, the factor structure on these was not clear as many of the PE-related items weighed moderately on both of these constructs. Results indicated that two items, the workload item from the original pre-implementation survey and the new patient outcome item on patient satisfaction with care were weighing on multiple factors. Recall that in the staff factor analyses, the workload item was dropped from PE because similar confounding was observed at both  $t_0$  and  $t_1$ . Similar to the workload item, review of the content of the patient satisfaction item indicate that it is independent, but is likely affected by PE and other outcome factors. The relationship that both these independent factors had with the other factors might be confounding the factor structure of the other items. Thus, these two items were excluded from the factor analysis. (Note: for completeness, the initial factor analyses that included the workload and patient satisfaction items is provided in Appendix C.)

The final outcomes factor analysis, presented in Table 24, had much clearer factor loadings and confirmed that for physicians, PE consists of two factors: one factor related to job performance (PE-job) and second related to patient safety (PE-safety). Internal consistency of scales for both PE factors was good ( $\alpha > 0.80$ ), therefore both of these scales were used for subsequent analyses. The PE scales were calculated by averaging responses for the items in each scale (4-items for PE-job, 2-items for PE-safety).

While the structure of PE differed for physicians compared to staff, analyses of both data sets indicated that communication and autonomy-control were independent of the PE factors and each other.

**Table 24. Outcome item factor loadings – physician pre-implementation (t<sub>1</sub>)**

		Factor loadings			
Survey items		1	2	3	4
<b>PE - job</b> ( $\alpha=0.880$ )	I believe that using Epic will enhance my image with the patients and their families	<b>0.700</b>	0.318	0.010	-0.075
	Using Epic will enhance my effectiveness on the job*	<b>0.714</b>	0.321	-0.084	0.458
	Using Epic will enable me to accomplish my tasks more efficiently.	<b>0.837</b>	0.179	-0.115	0.350
	I believe using Epic will give me more time to spend with patients	<b>0.869</b>	0.144	-0.050	0.182
<b>PE - safety</b> ( $\alpha=0.817$ )	Implementation of Epic will improve patient safety*	0.401	<b>0.821</b>	-0.114	0.051
	I believe that Epic can help to reduce medical errors	0.171	<b>0.904</b>	0.039	0.130
I believe that Epic will reduce the control I currently have over my work		-0.257	-0.099	0.168	<b>-0.895</b>
<b>Communication</b> ( $\alpha=0.681$ )	I believe Epic will reduce my communication with staff and colleagues	0.128	-0.001	<b>0.866</b>	-0.191
	I believe Epic will reduce my communication with patients and their families	-0.251	-0.047	<b>0.857</b>	-0.005

**81.5% of total variance explained by 4 factors**

\* Question not included in staff pre-implementation survey

The results of the input items factor analysis are presented in Table 25. Similar to the results observed in the staff pre-implementation surveys, all of these items appear to be independent. Recall that while the staff results hinted at the existence of a design input construct, but one item also weighed substantially on another factor and internal consistency was not high. Consequently, the design involvement items were treated independently for subsequent analyses. The results observed for physicians were similar, so these items are treated independently in the physician analyses as well.

**Table 25. Input item factor loadings – physician pre-implementation (t<sub>1</sub>)**

	Survey items	Factor loadings			
		1	2	3	4
Design Input ( $\alpha=0.820$ )	I feel that my needs have been accommodated in the Epic design process	<b>0.660</b>	<b>0.638</b>	-0.132	0.088
	I feel comfortable with Epic because I have been informed/updated throughout the implementation process	<b>0.934</b>	0.200	-0.072	0.196
	I feel the current practices are efficient; therefore, I do not see the need to implement the system	-0.088	-0.241	<b>0.955</b>	-0.141
	It will be easy for me to learn to use Epic	0.179	0.163	-0.141	<b>0.958</b>
	I believe Epic will fit well with the way I like to work	0.240	<b>0.863</b>	-0.310	0.210

**95.2% of total variance explained by 4 factors**

## Data distribution

Prior to completing the remaining analysis, the characteristics of the data in this study must be considered as characteristics of the data determine which statistical methods can be employed to test the research hypotheses. This research utilizes three types of data: categorical, interval (discrete), and interval (continuous). The data type of each variable is presented in Table 26. Many of the variables are discrete interval data because the survey questions were asked using Likert-scale ratings (1=strongly disagree to 5=strongly agree) or ordered categories (e.g., increasing ranges of years worked in the hospital).

**Table 26. Variable data types**

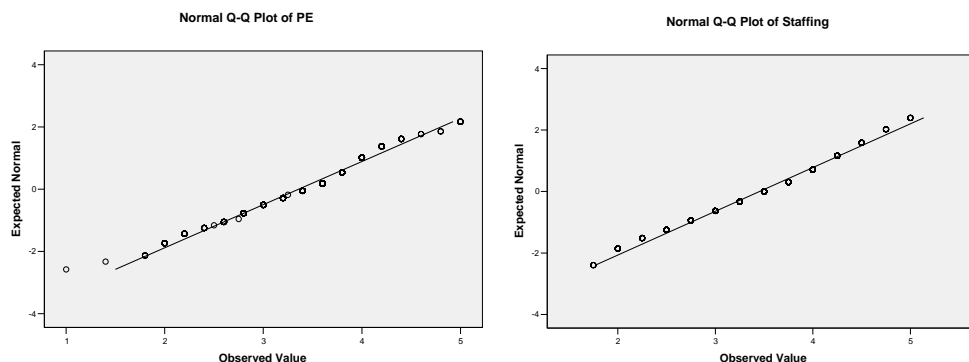
<b>Categorical</b>	<b>Interval (Discrete)</b>	<b>Interval (Continuous)</b>
Campus	Autonomy – Privacy	Communication scale
Staff position	Autonomy – Control	Effort Expectancy scale
Work area	Compatibility*	Performance Expectancy scale
Work shift**	Design – Represented*	Safety - Hospital Teamwork
	Design – Informed*	Safety - Handoffs & Transitions
	Hours Worked per Week	Safety - Staffing
	Perceived Need – Errors*	Safety - Unit Teamwork
	Perceived Need – Efficiency*	Support for Decision Processes scale
	Output Quality – Accuracy**	
	Support – Personnel**	
	Communication – Sharing Info**	
	System Reliability**	
	System Expertise**	
	Years worked at Children's	
	Years worked in specialty	
	Computer Experience	

\*Only applies to pre-implementation

\*\*Only applied to post-implementation

In order to inform selection of the appropriate statistical analysis methods for the subsequent sections, the data distribution of interval (discrete or continuous) variables was examined to determine if they closely approximate a normal distribution. Parametric tests for correlation (e.g., Pearson), group comparisons (e.g., t-test), and predictive modeling (e.g., linear regression) are based on the assumption that the outcome variables closely approximate the normal distribution. Parametric statistical test have more power and, thus, are more desirable. If the normality assumption is not met, nonparametric tests, which are assumption free, must be used.

Most of the outcome variables in the subsequent analyses are continuous (e.g., PE, EE). For continuous variables, the normality assumption was tested by examining Q-Q plots. If the Q-Q plot resembles a straight line, then the data distribution is approximately normally distributed (Wu & Hamada, 2000). In the interested of space, Q-Q plots for all variable are not presented here. However, representative example Q-Q plots are provided in Figure 5.



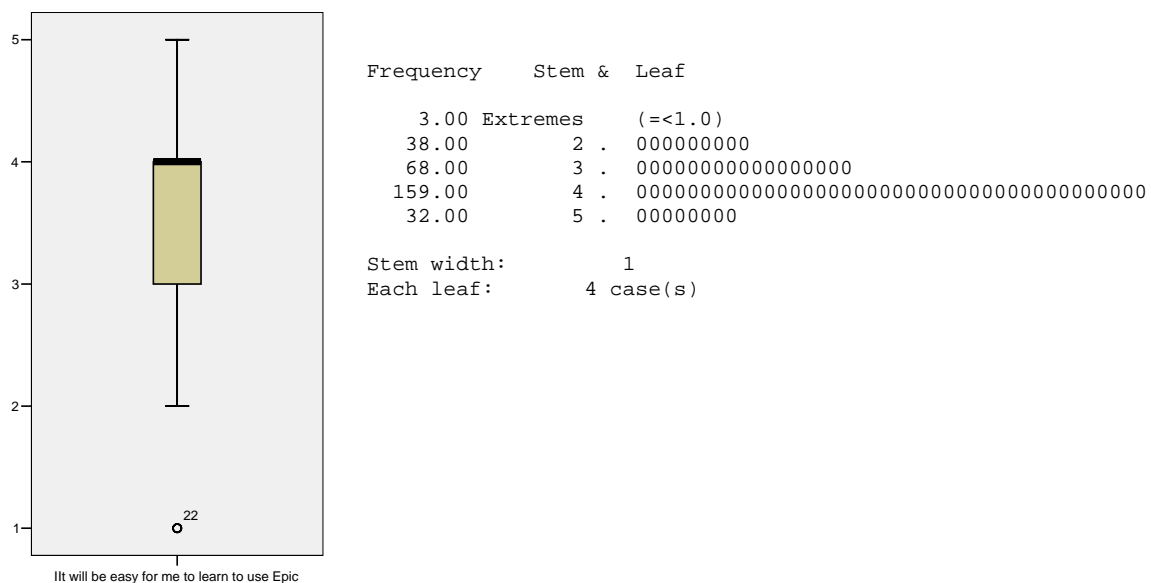
**Figure 5. Representative Q-Q plots - PE (left) and Staffing (right)**

Review of the Q-Q plots for the continuous outcomes, indicated that all of the following variables are approximately normally distributed. Therefore, it is appropriate to use parametric tests for these variables:

- Effort Expectancy scale
- Performance Expectancy scale
- Safety - Handoffs & Transitions
- Safety - Hospital Teamwork

- Safety - Staffing
- Safety - Unit Teamwork
- Support for Decision Processes scale

Only one discrete variable served as an outcome variable in the following analyses. This was the EE item on ease of learning. For discrete variables, Q-Q plots can sometime be misleading. Therefore, histograms and boxplots of the data were also examined to see if the data resembled the expected patterns for normal data (Edwards, Sainfort, Jacko, & Kongnakorn, 2006). The plots for this item at  $t_0$  (see Figure 6) indicate that this item is not normally distributed. Similarly, this item was not normally distributed at  $t_1$ , therefore analyses using this item (e.g., correlation, regression modeling) use statistical tests appropriate for nonparametric data.



**Figure 6. Example Boxplot & histogram of  $t_0$  EE - ease of learning**

### **Correlations between IT factors and Safety Culture**

Correlations between aspects of safety culture of safety and IT factors are examined in order to test hypotheses 1.2 and 1.3, which hypothesize that PE and EE will be correlated with aspects of safety culture. For staff-pre surveys ( $t_0$ ), PE and the safety culture scales were normally distributed, so the Pearson correlation coefficient examined correlations among these variables. However, since *EE – ease of learning* requires nonparametric tests, Spearman's rho was used to examine correlations with this variable. For staff-post ( $t_1$ ) surveys, PE, EE, SDP and the safety culture scales are all approximately normally distributed, so the Pearson coefficient is used to test for significant correlations. Correlations for all three data sets (staff-pre, staff-post, and physician-pre) are presented below.

**Table 27. Correlation (r) for staff pre-implementation (t<sub>0</sub>)**

	PE	EE - learning†	Unit Team.	Staffing	Hospital Team.	Transitions
PE	1.00					
EE-learning†	<b>0.23**</b>	1.00				
Unit Teamwork	<b>0.14*</b>	0.07	1.00			
Staffing	<b>0.21**</b>	<b>0.15**</b>	<b>0.36**</b>	1.00		
Hospital Teamwork	<b>0.29**</b>	0.09	<b>0.40**</b>	<b>0.38**</b>	1.00	
Transitions	<b>0.25**</b>	0.09	<b>0.30**</b>	<b>0.32**</b>	<b>0.60**</b>	1.00

\*\*Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

†Because this item is not normally distributed, the Spearman's rho correlation coefficient was used instead of the Pearson correlation reported for other variables.

**Table 28. Correlation (r) for staff post-implementation (t<sub>1</sub>)**

	PE	EE	SDP	Unit Team.	Staffing	Hospital Team.	Transitions
PE	1.00						
EE	<b>0.66**</b>	1.00					
SDP	<b>0.86**</b>	<b>0.61**</b>	1.00				
Unit Teamwork	0.08	<b>0.13*</b>	<b>0.11*</b>	1.00			
Staffing	<b>0.19**</b>	<b>0.19**</b>	<b>0.15**</b>	<b>0.31**</b>	1.00		
Hospital Teamwork	<b>0.30**</b>	<b>0.25**</b>	<b>0.26**</b>	<b>0.21**</b>	<b>0.31**</b>	1.00	
Transitions	<b>0.22**</b>	<b>0.27**</b>	<b>0.19**</b>	<b>0.30**</b>	<b>0.31**</b>	<b>0.57**</b>	1.00

\*\*Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

**Table 29. Correlation (r) for physician pre-implementation (t<sub>1</sub>)**

	PE-job	PE-safety	EE-learning†	Unit Team.	Staffing - MD†	Staffing - Staff†	Hospital Team.	Transitions
<b>PE</b>	1.00							
<b>PE-safety</b>	<b>0.55**</b>	1.00						
<b>EE†</b>	<b>0.36**</b>	0.14	1.00					
<b>Unit Teamwork</b>	<b>0.23*</b>	0.15	0.19	1.00				
<b>Staffing - MD†</b>	-0.084	-0.03	-0.02	-0.13	1.00			
<b>Staffing - Staff†</b>	<b>0.21*</b>	0.02	<b>0.34**</b>	<b>0.50**</b>	<b>-0.20*</b>	1.00		
<b>Hospital Teamwork</b>	<b>0.23*</b>	0.00	0.12	<b>0.46**</b>	-0.15	<b>0.22*</b>	1.00	
<b>Transitions</b>	0.031	<b>-0.25*</b>	0.09	<b>0.22*</b>	<b>-0.21*</b>	<b>0.29**</b>	<b>0.59**</b>	1.00

\*\*Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

† Because this item is not normally distributed, the Spearman's rho correlation coefficient was used instead of the Pearson correlation reported for other variables.

### **Regression models on Performance Expectancy**

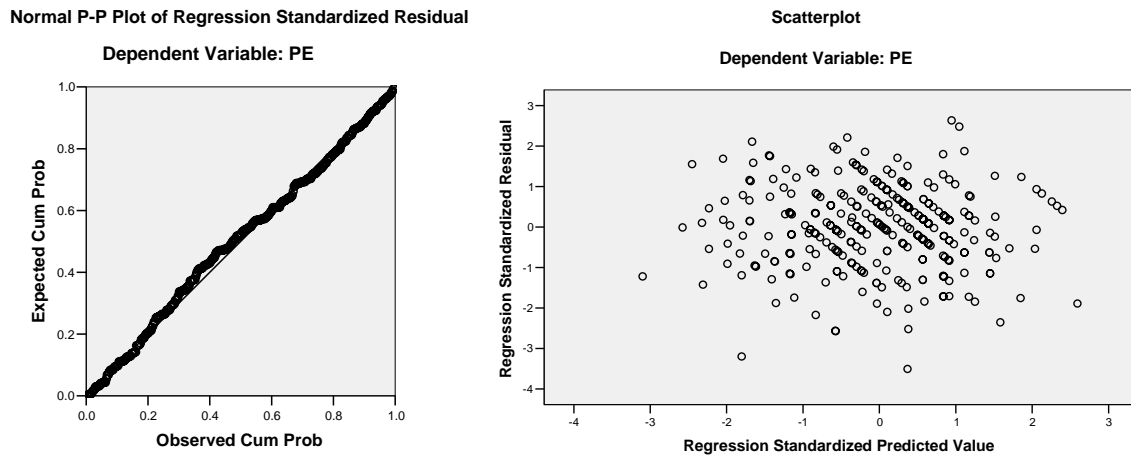
One of the objectives of this research is to identify factors that influence user perceptions of PE. Because PE is a continuous variable that is approximately normally distributed, linear regression models were constructed to accomplish this (Neter, Kutner, Nachtsheim, & Wasserman, 1996). Separate models are presented for staff pre- ( $t_0$ ) and post-implementation ( $t_1$ ) survey responses to test the hypothesis that the factors that contribute to PE change during the systems implementation lifecycle. The resulting models are presented in Table 30 and Table 31, respectively. Models of the two PE factors for physician pre-implementation were also constructed to examine the robustness of the staff PE pre-implementation model. These models are presented in Table 32 and Table 33.

**Table 30. Staff pre-implementation (t<sub>0</sub>) linear regression model on PE**

	Unstandardized Coefficients		Std. Coeff.			Correlations		Collinearity Statistics	
	B	Std. Error	B	t	Sig.	Partial	Part	Tolerance	VIF
(Constant)	1.552	0.193		8.048	0.000				
Compatibility	0.364	0.037	0.427	9.969	0.000	0.517	0.328	0.591	1.693
Perceived Need – Errors	0.163	0.027	0.205	5.936	0.000	0.339	0.195	0.908	1.101
Perceived Need – Efficiency*	0.205	0.032	0.246	6.365	0.000	0.360	0.210	0.725	1.380
Design Involvement – Needs represented	0.169	0.032	0.206	5.366	0.000	0.309	0.177	0.739	1.354
Time in Profession: more than 20 yrs	-0.168	0.067	-0.085	-2.521	0.012	-0.151	-0.083	0.950	1.053
Work area: GCA/PCA	0.121	0.050	0.082	2.407	0.017	0.144	0.079	0.942	1.062
Position: Resp. Therapist	-0.149	0.068	-0.076	-2.202	0.029	-0.132	-0.72	0.917	1.090

\* This item was negatively worded, so it was reverse coded for the analysis.

The staff  $t_0$  model (Table 30) significantly predicted PE ( $F=92.956$ ,  $p<0.001$ ) and presented in  $r^2=0.705$  and  $\text{adj-}r^2=0.698$ . This indicates that the model is a good fit for the data. Examination of the residual plots (Figure 7) indicates that the residuals are normally and randomly distributed, meeting the assumptions of the linear regression model. In addition examination of the Tolerance and VIF statistics indicates that there is no problem with multicollinearity (i.e., Tolerance  $> 0.2$  and VIF  $< 10$  (Field, 2000)).

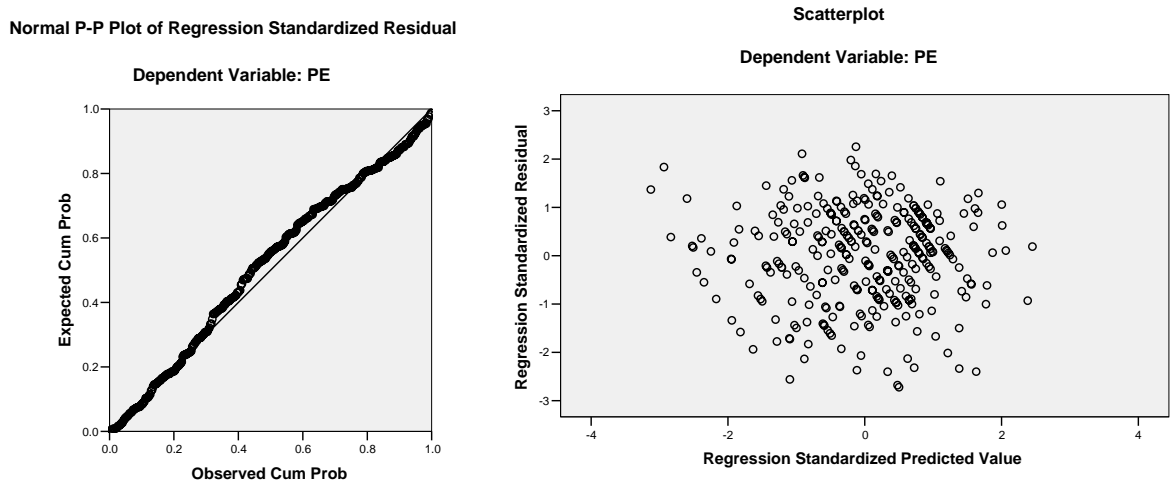


**Figure 7. Residual plots for staff  $t_0$  PE regression**

**Table 31. Staff post-implementation (t<sub>1</sub>) linear regression model on PE**

	Unstandardized Coefficients		Std. Coeff.			Correlations		Collinearity Statistics	
	B	Std. Error	B	t	Sig.	Partial	Part	Tolerance	VIF
(Constant)	-0.057	0.172		-0.331	0.741				
SDP	0.657	0.036	0.663	18.060	0.000	0.731	0.486	0.537	1.863
EE	0.165	0.046	0.138	3.578	0.000	0.207	0.096	0.484	2.065
Work area: ICU	-0.121	0.049	-0.069	-2.468	0.014	-0.145	-0.066	0.938	1.066
Comm. – Facilitate Sharing Info	0.080	0.032	0.079	2.485	0.014	0.146	0.067	0.712	1.405
Support: Personnel	0.068	0.031	0.068	2.185	0.030	0.128	0.059	0.736	1.358
Position: Unit Sect.	0.368	0.136	0.077	2.715	0.007	0.159	0.073	0.895	1.117
40 or more hrs worked per week	-0.143	0.059	-0.069	-2.438	0.015	-0.143	-0.066	0.914	1.094
Yrs worked in current work area	-0.046	0.021	-0.062	-2.208	0.028	-0.130	-0.059	0.907	1.103

The staff  $t_1$  model (Table 31) significantly predicted PE ( $F=137.049$ ,  $p<0.001$ ) and presented in  $r^2=0.794$  and  $\text{adj-}r^2=0.788$ . This indicates that the model is a good fit for the data. Examination of the residual plots (Figure 8) indicates that the residuals are normally and randomly distributed, meeting the assumptions of the linear regression model. In addition examination of the Tolerance and VIF statistics indicates that there is no problem with multicollinearity.



**Figure 8. Residual plots for staff  $t_1$  PE regression**

Factor analysis of the physician pre-implementation surveys indicated that PE consists of two factors for physicians, one on job performance (PE-job) and the other on patient safety (PE-safety). Therefore, linear regression models on both PE-job and PE-safety are presented in Table 32 and Table 33, respectively. The model in Table 32 significantly predicts PE-job ( $F=89.475$ ,  $p<0.001$ ) and presented in  $r^2=0.773$  and  $\text{adj-}r^2=0.764$ . This indicates that the model is a good fit for the data. The model in Table 33 significantly predicts PE-safety ( $F=18.867$ ,  $p<0.001$ ) and presented in  $r^2=0.417$  and  $\text{adj-}r^2=0.395$ . This indicates that the model is a good fit for the data.

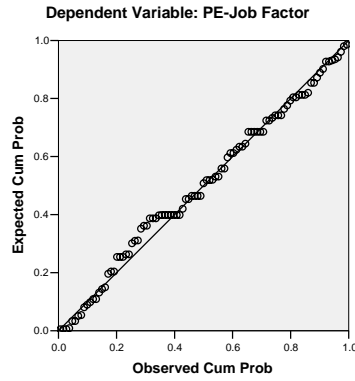
**Table 32. Physician pre-implementation (t<sub>1</sub>) linear regression model on PE-job**

	Unstandardized Coefficients		Std. Coeff.			Correlations		Collinearity Statistics	
	B	Std. Error	B	t	Sig.	Partial	Part	Tolerance	VIF
(Constant)	0.319	0.167		1.911	0.060				
Compatibility	0.561	0.063	0.651	8.892	<0.001	0.707	0.477	0.536	1.864
Design – Needs represented	0.262	0.065	0.295	4.013	<0.001	0.412	0.215	0.533	1.877
Time in Prof: 16 to 20 years	-0.237	0.115	-0.111	-2.061	0.043	-0.226	-0.111	0.991	1.009

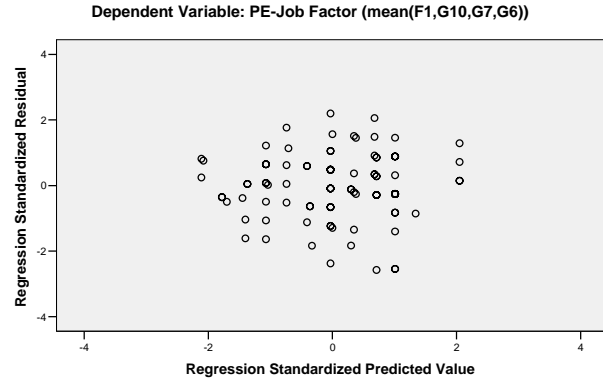
**Table 33. Physician pre-implementation (t<sub>1</sub>) linear regression model on PE-safety**

	Unstandardized Coefficients		Std. Coeff.			Correlations		Collinearity Statistics	
	B	Std. Error	B	t	Sig.	Partial	Part	Tolerance	VIF
(Constant)	2.894	0.345		8.178	0.000				
Design – Needs represented	0.339	0.098	0.406	3.460	0.001	0.363	0.297	0.535	1.868
Safety – Transitions	-0.271	0.088	-0.266	-3.092	0.003	-0.329	-0.266	0.997	1.003
Compatibility	0.189	0.095	0.234	1.993	0.050	0.219	0.171	0.535	1.868

Normal P-P Plot of Regression Standardized Residual

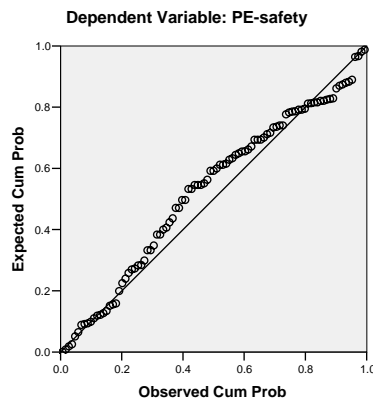


Scatterplot

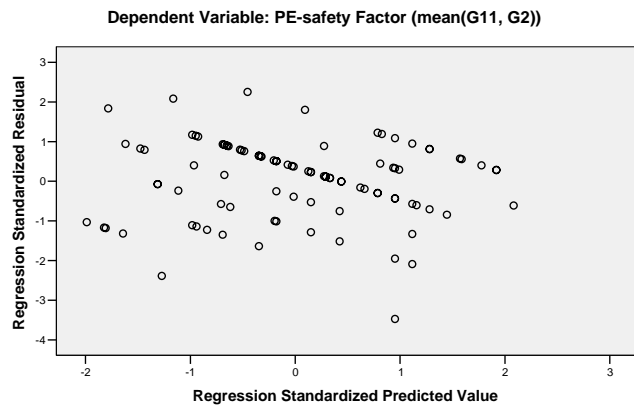


**Figure 9. Residual plots for model on physician PE-job**

Normal P-P Plot of Regression Standardized Residual



Scatterplot



**Figure 10. Residual plots for model on physician PE-safety**

Examination of the residual plots for both the PE-job and PE-safety models (Figure 9 and Figure 10) indicated that residuals are normally and randomly distributed, meeting the assumptions of the linear regression model. In addition examination of the Tolerance and VIF statistics indicates that there is no problem with multicollinearity in either model.

### **Regression models on Effort Expectancy**

Recall that in the pre-implementation surveys only asked one EE question, *EE – ease of learning (EE - learning)*. Because *EE- learning* is discrete and not normally distributed, logistic regression was used to develop the pre-implementation model of EE (Field, 2000). The logistic regression modeled whether the participant agreed (responded favorably) that the system would be easy to learn (value = *agree* or *strongly agree*) or did not (value = *neutral*, *disagree*, or *strongly disagree*). At post-implementation, all four EE items were asked and the EE-scale constructed. Because the EE scale is normally distributed, linear regression (Neter, Kutner, Nachtsheim, & Wasserman, 1996) was used to model EE for post-implementation. The pre- and post-implementation models of EE are presented below.

#### **Pre-implementation model of EE –learning**

Logistic regression models for *EE –learning* were constructed for both the staff and physicians data sets using the Backwards – Likelihood Ratio method. The staff ( $t_0$ ) model, presented Table 34, significantly predicted whether the participant would have a favorable perception of *EE – learning* ( $\chi^2=72.390$ ,  $p<0.001$ ). The model correctly classified participants as either favorable or not in 75.6% of cases. To further test the fit of the model, an ROC curve was constructed and the area under the ROC curve was 0.721, significantly greater than 0.50 ( $p<0.001$ ). These two factors indicated that the model is a good fit for the data.

**Table 34. Staff (t<sub>0</sub>) logistic regression on EE - learning**

Predictor	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-4.682	0.850	30.345	1	<0.001	0.077
Work Area: Inpatient ICU	0.781	0.306	6.528	1	0.011	2.184
Autonomy – Privacy: Not Concerned	0.909	0.329	7.610	1	0.006	2.481
Design involvement – Informed	0.711	0.164	18.888	1	<0.001	2.035
Need – Efficiency*	0.354	0.176	4.036	1	0.045	1.424
Computer Use: Often or Frequently	0.850	0.391	4.735	1	0.030	2.339
Difficult to schedule time for training: Disagreed or Strongly Disagreed	0.938	0.317	8.743	1	0.003	2.554

\*This item was negatively worded, so it was reverse coded for the analysis

**Table 35. Physician (t<sub>1</sub>) logistic regression on EE - learning**

Predictor	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-4.079	1.447	7.949	1	0.005	0.017
Design Involvement – Informed (Agree or Strongly Agree)	2.328	0.811	8.230	1	0.004	10.253
Hrs per Week: < 20	-3.037	1.201	6.397	1	0.011	0.048
Hrs per Week: > 60	-1.766	0.814	4.708	1	0.030	0.171
Comfortable w/ comp.: Strongly Agree	2.333	0.841	7.704	1	0.006	10.313
Safety: Staffing - Staff	1.441	0.430	11.255	1	0.001	4.226

The physician (t<sub>1</sub>) model, presented Table 35, significantly predicted whether the participant would have a favorable perception of EE – learning ( $\chi^2=53.665$ ,  $p<0.001$ ). The model correctly classified participants as either favorable or not in 88.5% of cases. To further test the fit of the model, an ROC curve was constructed and the area under the ROC curve was 0.87, significantly greater than 0.50 ( $p<0.001$ ). These two factors indicated that the model is a good fit for the data.

## Post-implementation model of EE

The staff-post ( $t_1$ ) model on EE (Table 36) significantly predicted EE ( $F=33.109$ ,  $p<0.001$ ) and presented in  $r^2=0.481$  and  $\text{adj-}r^2=0.466$ . This indicates that the model is a good fit for the data. Examination of the residual plots (Figure 8) indicates that the residuals are normally and randomly distributed, meeting the assumptions of the linear regression model. In addition examination of the Tolerance and VIF statistics indicates that there is no problem with multicollinearity. Residual plots from the regression model (Figure 11) indicate that the assumptions of linear regression are met (i.e., error terms are randomly and approximately normally distributed).

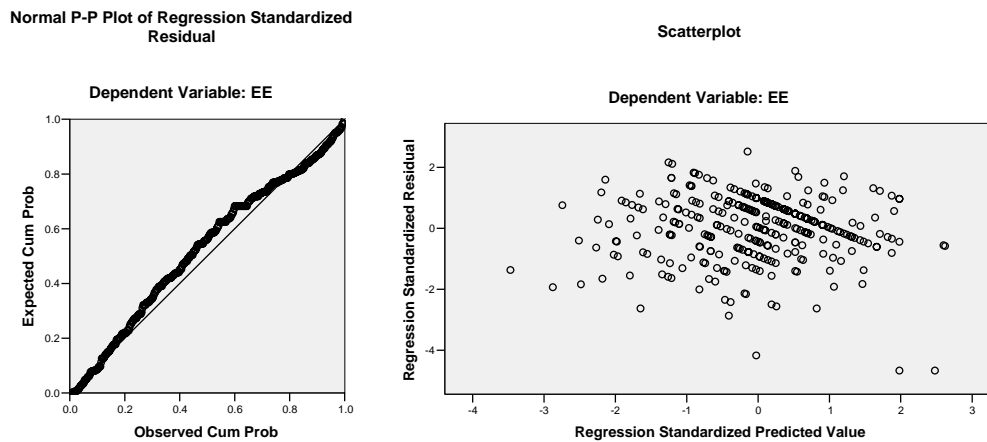


Figure 11. Residual plots for staff  $t_1$  EE regression

**Table 36. Staff post-implementation (t<sub>1</sub>) linear regression model on EE**

	Unstandardized Coefficients		Std. Coeff.			Correlations		Collinearity Statistics	
	B	Std. Error	B	t	Sig.	Partial	Part	Tolerance	VIF
(Constant)	1.789	0.290		6.171	0.000				
Support: Personnel	0.194	0.042	0.231	4.601	0.000	0.262	0.196	0.721	1.387
System expertise	0.207	0.043	0.230	4.798	0.000	0.273	0.204	0.791	1.264
Output quality: accurate, reliable information	0.199	0.047	0.195	4.270	0.000	0.245	0.182	0.868	1.152
System reliability*	0.138	0.033	0.186	4.170	0.000	0.239	0.178	0.915	1.092
Position: Resp. Therapist	-0.287	0.112	-0.114	-2.557	0.011	-0.150	-0.109	0.917	1.091
Yrs worked in current work area	-0.084	0.027	-0.134	-3.042	0.003	-0.177	-0.130	0.931	1.074
Position: Unit Sect	0.577	0.177	0.143	3.251	0.001	0.189	0.139	0.932	1.073
40 or more hrs worked per week	-0.210	0.077	-0.120	-2.713	0.007	-0.158	-0.116	0.922	1.085

\* This item was negatively worded, so it was reverse coded for the analysis

### **Examination of Pre- and Post-Implementation Perceptions**

The following analyses examine user perceptions of PE and EE to better understand the effectiveness of the UCI methodology employed during the implementation of Children's EMR/CPOE system. Specifically, first the change in PE and *EE – learning* from pre-implementation to post-implementation are examined. Next, post-implementation perceptions of PE and EE are examined to determine whether or not they are favorable.

#### **How do PE and EE perceptions change from $t_0$ to $t_1$ ?**

Pre-implementation perceptions of PE and EE were assessed 8-9 months prior to EMR implementation before users had any hands-on personal experience with the system. Therefore it is of interest to determine how those perceptions changed after implementation, when users had several months of real-world experience using the system. Because PE is a continuous and approximately normally distributed, independent t-tests (Sheskin, 1997) were conducted to test whether or not PE perceptions changed from  $t_0$  to  $t_1$  for all respondents and for subgroups of respondents based on job characteristics. These results are presented in Table 37. In each t-test, Levene's statistics indicated whether or not the assumption of equal variances was met. If the Levene's statistic was significant ( $p < 0.05$ ), the t-statistic with equal variances not assumed was used for the test, otherwise the t-statistic with equal variances assumed was used. To further illustrate these differences, graphs comparing  $t_0$  and  $t_1$  PE ratings for several subgroups are provided in Figures 12-14. In the interest of brevity, only graphs for subgroups with notable difference are included.

Note that each test examines a specific group independently. Consequently, it is not appropriate to make an adjustment to account for multiple simultaneous tests. These adjustments, like the a Bonferroni method (Wu & Hamada, 2000) are only used when multiple hypotheses are being tested simultaneously (e.g., the means of the groups are equal). Also, Bonferroni is not recommended for use when large numbers of test are being conducted since it inflates the changes of a Type II error. As such an  $\alpha$ -value of

0.05 is used to in the following tests, noting that each test result should be examined independently.

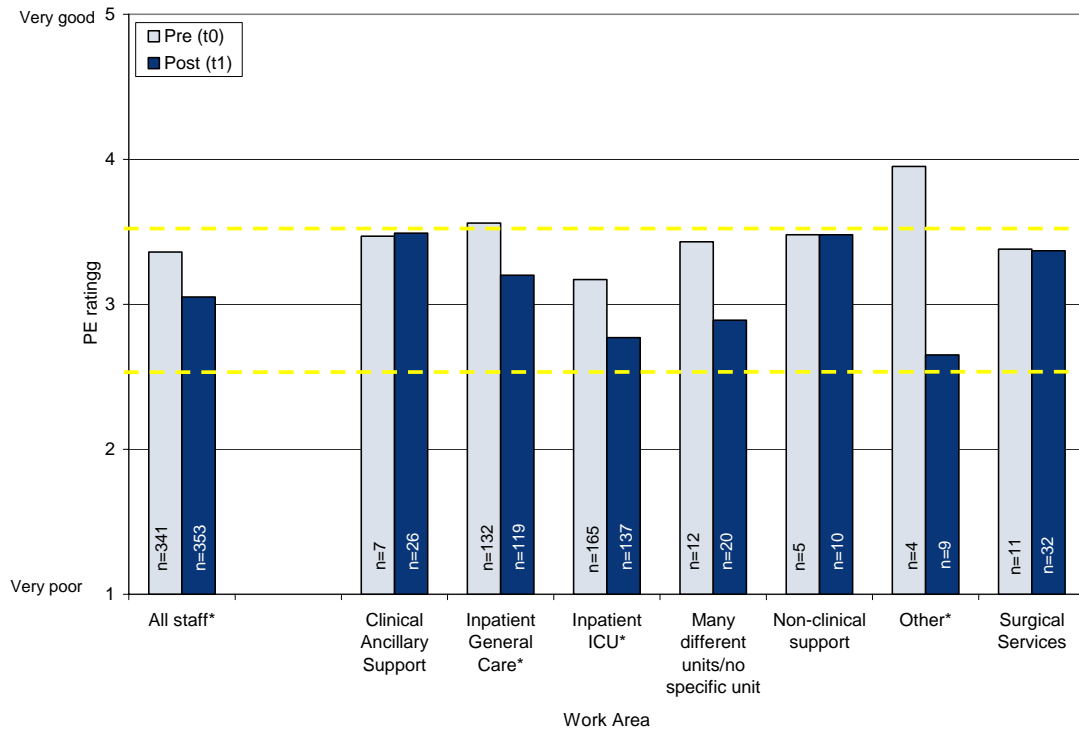
**Table 37. Independent-sample t-test comparing  $t_0$  to  $t_1$  PE ratings**

<b>Group</b>	<b>N (<math>t_0</math>)</b>	<b>N (<math>t_1</math>)</b>	<b>Mean Diff. (<math>t_1 - t_0</math>)*</b>	<b>T</b>	<b>p</b>
All participants	341	353	<b>-0.312</b>	-5.235	<b>&lt;0.001</b>
<i>Campus</i>					
Egleston (Academic)	162	167	<b>-0.370</b>	-4.328	<b>&lt;0.001</b>
Scottish Rite (Non-academic)	179	186	<b>-0.260</b>	-3.118	<b>0.002</b>
<i>Work area groups</i>					
Clinical Ancillary Support	7	26	0.021	0.095	0.925
Inpatient General Care (GCA/PCA)	132	119	<b>-0.363</b>	-3.861	<b>&lt;0.001</b>
Inpatient ICU	165	137	<b>-0.396</b>	-4.238	<b>&lt;0.001</b>
Many different units/no specific unit	12	20	-0.543	-1.797	0.082
Non-clinical support	5	10	0.003	0.009	0.993
Other	4	9	<b>-1.302</b>	-2.331	<b>0.040</b>
Surgical Services	11	32	-0.008	-0.035	0.972
<i>Staff position groups</i>					
Administration/Management	4	15	<b>-0.939</b>	-2.279	<b>0.036</b>
Patient Care Technician	28	25	-0.073	-0.406	0.687
Registered Nurse, LVN, or LPN	245	268	<b>-0.382</b>	-5.741	<b>&lt;0.001</b>
Respiratory Therapist	52	32	<b>-0.428</b>	-2.303	<b>0.024</b>
Unit Secretary	12	13	<b>0.472</b>	2.221	<b>0.036</b>
<i>Years worked in current work area</i>					
Less than 1 year	59	55	-0.187	-1.459	0.147
1 to 5 years	176	156	<b>-0.232</b>	-2.683	<b>0.008</b>
6 to 10 years	53	66	<b>-0.407</b>	-2.703	<b>0.008</b>
11 to 15 years	26	40	<b>-0.569</b>	-3.038	<b>0.003</b>
16 to 20 years	14	22	-0.376	-1.580	0.123
21 or more years	9	10	0.072	0.177	0.862

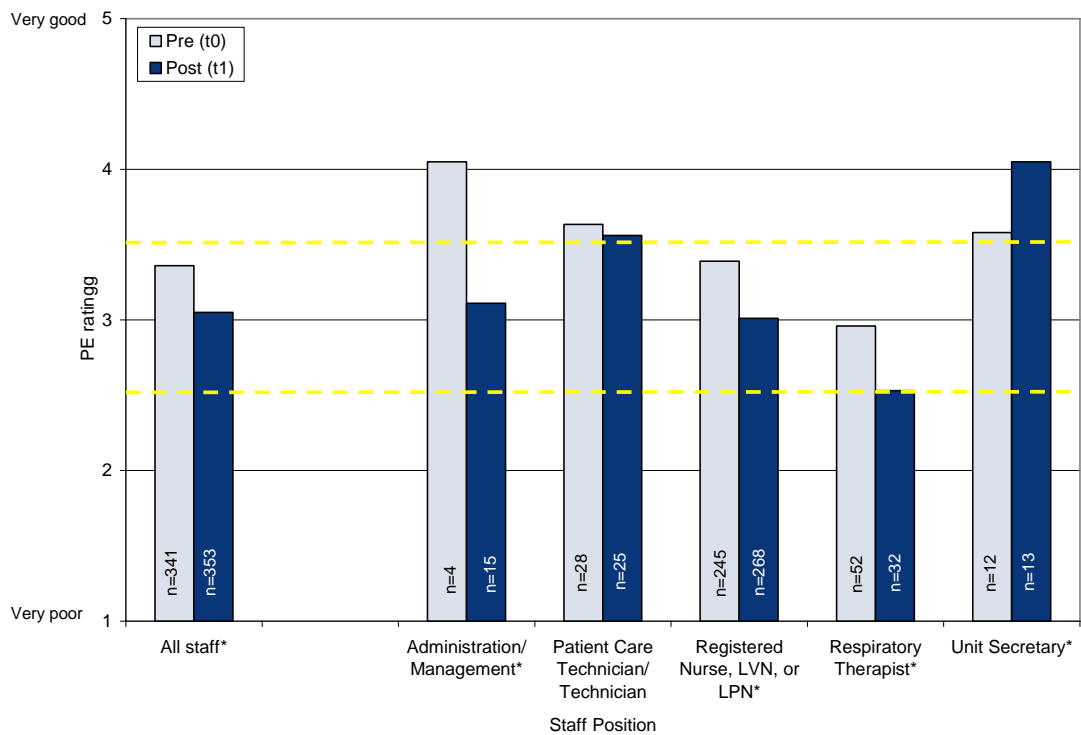
**Table 37 (continued)**

<b>Group</b>	<b>N (t<sub>0</sub>)</b>	<b>N (t<sub>1</sub>)</b>	<b>Mean Diff. (t<sub>1</sub> – t<sub>0</sub>)*</b>	<b>T</b>	<b>P</b>
<i>Years in current specialty/profession</i>					
Less than 1 year	33	20	<b>-0.622</b>	-2.954	<b>0.005</b>
1 to 5 years	115	85	<b>-0.248</b>	-2.341	<b>0.020</b>
6 to 10 years	70	73	-0.054	-0.438	0.662
11 to 15 years	37	55	<b>-0.392</b>	-2.210	<b>0.030</b>
16 to 20 years	28	45	<b>-0.659</b>	-3.206	<b>0.002</b>
21 or more years	57	74	-0.222	-1.655	0.100
<i>Hours worked per week at Children's</i>					
Less than 20 hours	16	11	0.308	1.077	0.292
20 to 39 hours	276	262	<b>-0.298</b>	-4.475	<b>&lt;0.001</b>
40 or more hours	48	79	<b>-0.440</b>	-3.067	<b>0.003</b>
<i>Use computers (frequency)</i>					
Frequently	222	267	<b>-0.386</b>	-5.537	<b>&lt;0.001</b>
Often	57	55	-0.219	-1.453	0.149
Sometimes	54	19	<b>-0.408</b>	-2.175	<b>0.033</b>
Rarely	7	8	0.748	1.328	0.207

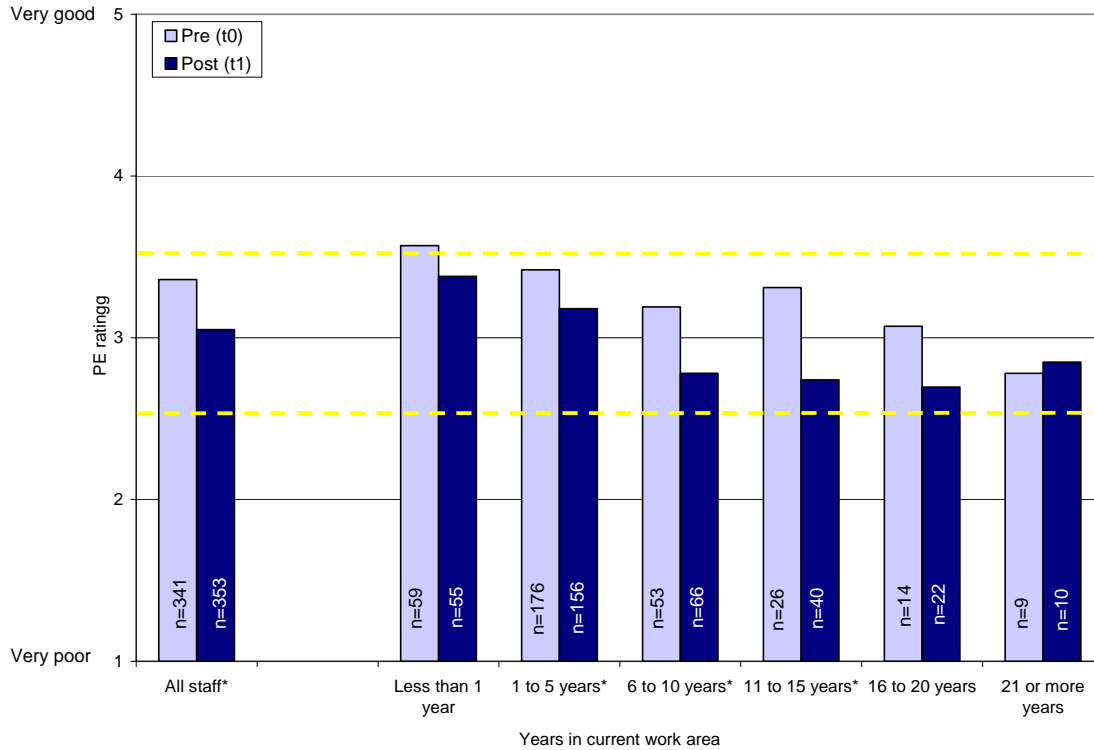
\* Because mean difference is calculated as Mean<sub>t1</sub>-Mean<sub>t0</sub>, negative values indicate a decline in favorableness of perceptions while a positive number indicates an improvement.



**Figure 12. Comparison of  $t_0$  to  $t_1$  PE ratings by work area**



**Figure 13. Comparison of  $t_0$  to  $t_1$  PE ratings by staff position**



**Figure 14. Comparison of  $t_0$  to  $t_1$  PE ratings by years in current work area**

Since at  $t_0$ , only one question in the EE scale was asked (i.e. *EE - Learning*),  $t_0$  and  $t_1$  responses on this question were compared for differences. Responses for this question are discrete numbers (1-5) and are not normally distributed. Therefore, the Chi-squared ( $\chi^2$ ) test (Sheskin, 1997) was used to test changes from  $t_0$  to  $t_1$  for ease of learning. The test compared the percentage of participants responding favorably (agree or strongly agree) versus those that did not (neutral, disagree, strongly disagree). Note that the  $\chi^2$  assumes that the expected count for each group (cell in the contingency table) is at least 5. Therefore, for groups with a small number of participants (e.g.,  $n < 10$  at both time periods) it was not possible to complete this test. These groups are identified in the results table as 'N/A'. To further illustrate these changes, graphs comparing the percentage of participants responding favorably at  $t_0$  and  $t_1$  for several subgroups are provided in Figures 15-17. In the interest of brevity, only graphs for subgroups with notable difference are included.

**Table 38. Independent-sample t-test comparing t<sub>0</sub> to t<sub>1</sub> Ease of learning rating**

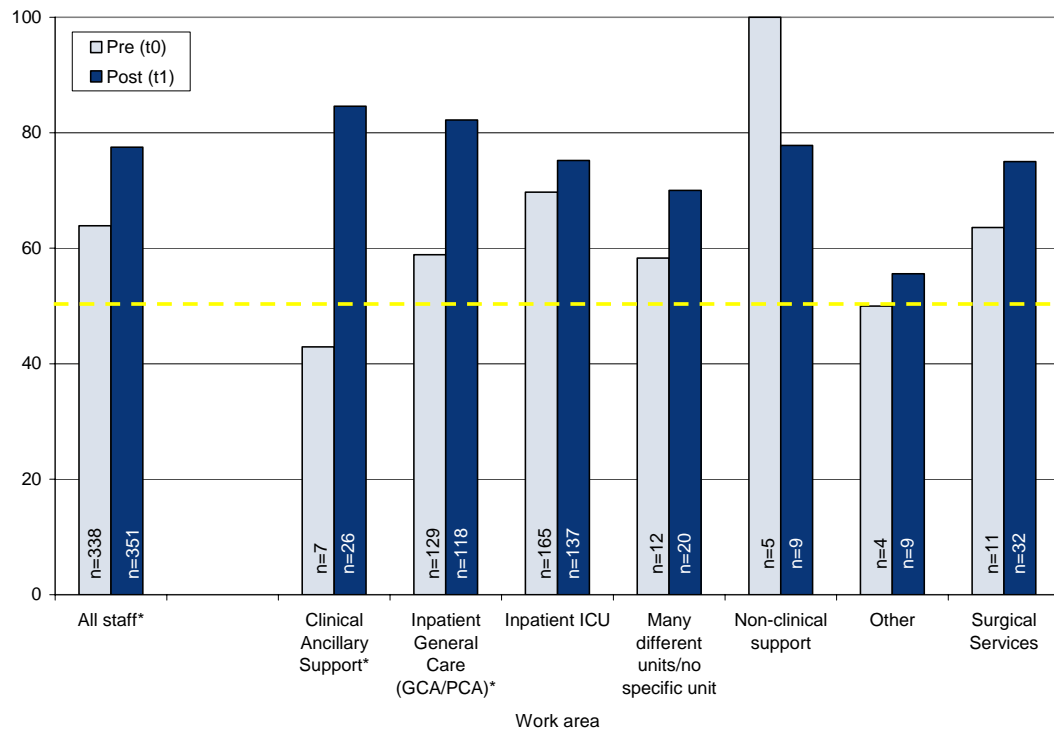
Group	% Favorable Responses		$\chi^2$	P
	t <sub>0</sub>	t <sub>1</sub>		
All participants	63.9	<b>77.5</b>	15.385	<b>&lt;0.001</b>
<i>Campus</i>				
Egleston (Academic)	61.6	<b>77.1</b>	9.179	<b>0.002</b>
Scottish Rite (Non-academic)	65.9	<b>77.8</b>	6.405	<b>0.011</b>
<i>Work area groups</i>				
Clinical Ancillary Support*	42.9	<b>84.6</b>	5.236	<b>0.022</b>
Inpatient General Care (GCA/PCA)	58.9	<b>82.2</b>	15.929	<b>&lt;0.001</b>
Inpatient ICU	69.7	75.2	1.122	0.290
Many different units/no specific unit*	58.3	70.0	0.453	0.501
Non-clinical support*	100.0	77.8	N/A**	
Other	50.0	55.6	N/A**	
Surgical Services*	63.6	75.0	0.525	0.469
<i>Staff position groups</i>				
Administration/Management	50.0	92.9	N/A**	
Patient Care Technician/Technician	75.0	76.0	0.007	0.933
Registered Nurse, LVN, or LPN	64.5	<b>79.0</b>	13.385	<b>&lt;0.001</b>
Respiratory Therapist	50.0	50.0	0.000	1.000
Unit Secretary*	91.7	100.0	1.128	0.288
<i>Years worked in current work area</i>				
Less than 1 year	69.0	<b>90.9</b>	8.385	<b>0.004</b>
1 to 5 years	65.5	<b>81.9</b>	11.278	<b>0.001</b>
6 to 10 years	60.4	68.2	0.784	0.376
11 to 15 years	65.4	69.2	0.106	0.745
16 to 20 years	35.7	63.6	2.676	0.102
21 or more years*	55.6	60.0	0.038	0.845

**Table 38 (continued)**

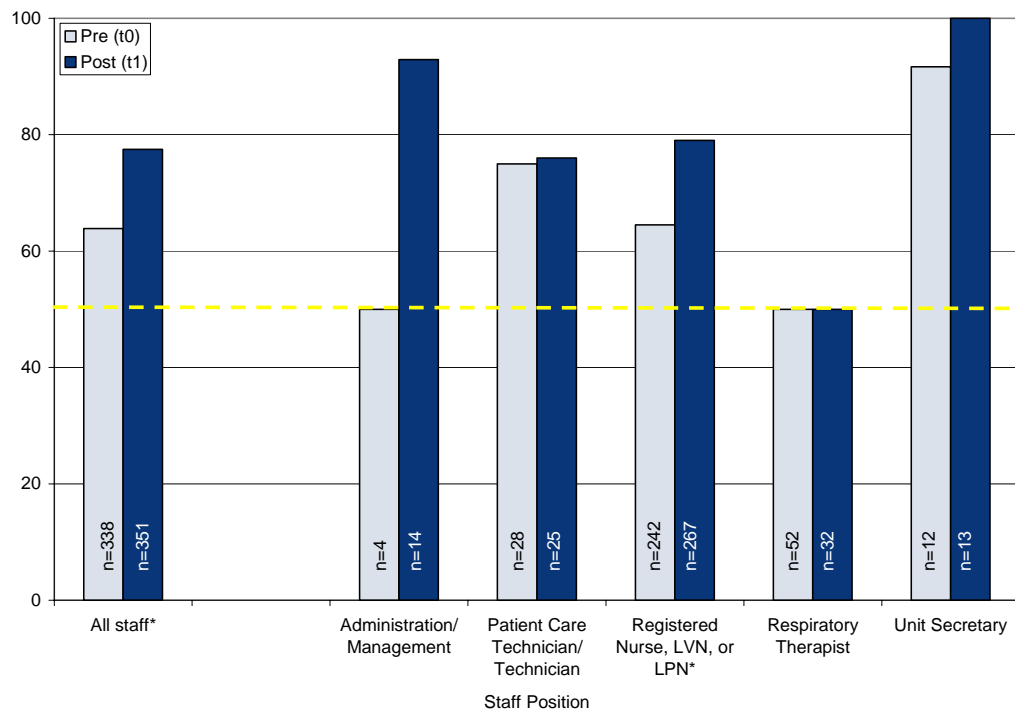
Group	% Favorable Responses		$\chi^2$	P
	t <sub>0</sub>	t <sub>1</sub>		
<i>Years in current specialty/profession</i>				
Less than 1 year*	71.9	<b>100</b>	6.802	<b>0.009</b>
1 to 5 years	72.8	<b>87.1</b>	5.940	<b>0.015</b>
6 to 10 years	62.9	<b>80.3</b>	5.266	<b>0.022</b>
11 to 15 years	59.5	<b>78.2</b>	3.739	<b>0.053</b>
16 to 20 years	59.3	71.1	1.067	0.302
21 or more years	47.4	60.8	2.350	0.125
<i>Hours worked per week at Children's</i>				
Less than 20 hours*	62.5	72.7	0.307	0.580
20 to 39 hours	65.2	<b>77.8</b>	10.324	<b>0.001</b>
40 or more hours	58.3	<b>76.9</b>	4.875	<b>0.027</b>
<i>Use computers (frequency)</i>				
Frequently	72.9	<b>81.2</b>	4.816	<b>0.028</b>
Often	53.6	<b>72.2</b>	4.090	<b>0.043</b>
Sometimes	42.6	36.8	0.192	0.661
Rarely	33.3	75.0	N/A**	

\* Expected count for 1 of 4 cells is less than 5, a mild violation of the Chi-squared test assumptions.

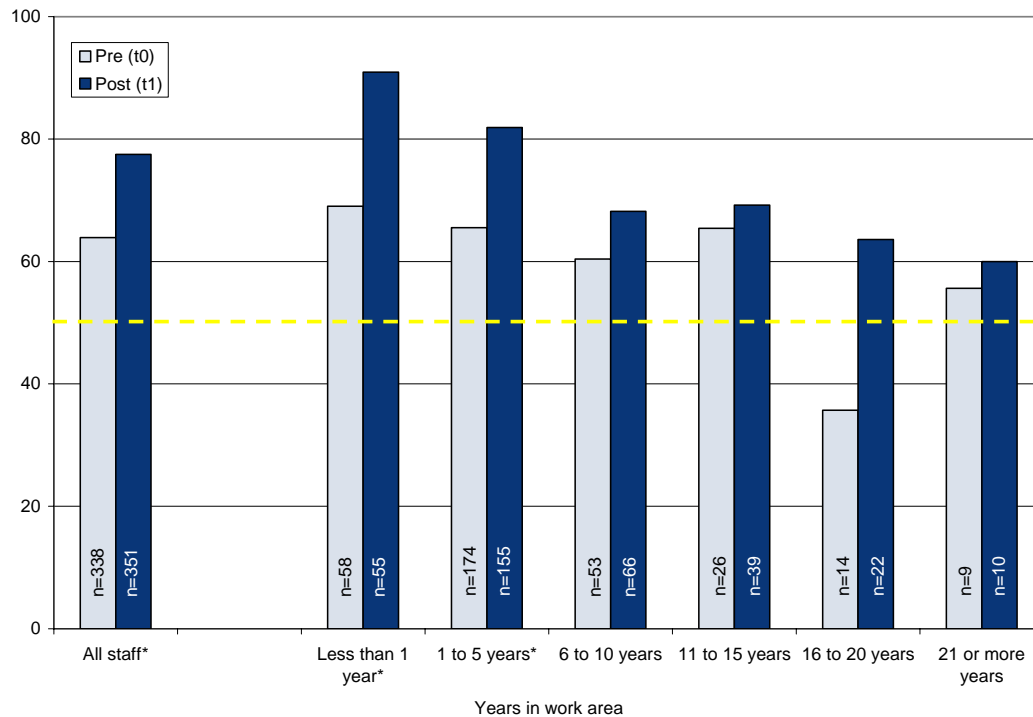
\*\* Expected count for 3 or more of 4 cells less than 5, a severe violation of the Chi-squared test assumptions.



**Figure 15. Percentage of responses by work area rating EE-learning favorably**



**Figure 16. Percentage of responses by staff position rating EE-learning favorably**



**Figure 17. Percentage of responses by years in work area rating EE-learning favorably**

### **Are post-implementation perceptions of PE and EE favorable?**

Children’s EMR implementation incorporated UCI methods from both user-centered design and change management. Therefore, it is of interest to determine whether user perceptions of the EMR were positive, neutral, or negative after the system was in use. Both PE and EE are continuous variables where 3 represents neutral perceptions and values greater than 3 represent favorable perceptions. Hence, a one-sample t-test tested whether or not the mean value for PE and EE was significantly greater than 3. This test was completed for all participants. In addition, this test was completed for subgroups of participants based on various job characteristics to determine if any particular groups had favorable or unfavorable perceptions. The t-test results for PE are presented in Table 39 and those for EE are presented in Table 40. Note that groups in which perceptions were significantly greater than 3 (favorable), the mean is displayed in bold, while perceptions significantly less than 3 (not favorable), the mean is displayed in bold italics. Recall that figures 12-14 provide graphs of PE ratings for selected subgroups to illustrate these

differences. In addition figures 18-20 provide graphs of EE ratings at  $t_1$  to illustrate subgroup differences on this measure of acceptance.

**Table 39. One-sample t-test results for post-implementation ( $t_1$ ) PE**

Group	N	Mean	Std. Dev	t	p
All participants	353	3.048	0.850	1.050	0.295
<i>Campus</i>					
Egleston (Academic)	167	3.00	0.870	0.012	0.991
Scottish Rite (Non-academic)	186	3.09	0.832	1.466	0.144
<i>Work area groups</i>					
Clinical Ancillary Support	26	<b>3.49</b>	0.515	4.823	<b>&lt;0.001</b>
Inpatient General Care (GCA/PCA)	119	<b>3.20</b>	0.836	2.629	<b>0.010</b>
Inpatient ICU	137	<b>2.77*</b>	0.866	-3.088	<b>0.002</b>
Many different units/no specific unit	20	2.89	0.763	-0.645	0.527
Non-clinical support	10	3.48	0.687	2.225	0.053
Other	9	2.65	0.966	-1.092	0.306
Surgical Services	32	<b>3.37</b>	0.695	3.043	<b>0.005</b>
<i>Staff position groups</i>					
Administration/Management	15	3.11	0.731	0.589	0.565
Patient Care Technician/Technician	25	<b>3.56</b>	0.649	4.312	<b>&lt;0.001</b>
Registered Nurse, LVN, or LPN	268	3.01	0.815	0.177	0.859
Respiratory Therapist	32	<b>2.53*</b>	0.952	-2.771	<b>0.009</b>
Unit Secretary	13	<b>4.05</b>	0.473	8.009	<b>&lt;0.001</b>
<i>Years worked in current work area</i>					
Less than 1 year	55	<b>3.38</b>	0.676	4.153	<b>&lt;0.001</b>
1 to 5 years	156	<b>3.18</b>	0.848	2.710	<b>0.007</b>
6 to 10 years	66	<b>2.78*</b>	0.883	-2.006	<b>0.049</b>
11 to 15 years	40	<b>2.74*</b>	0.785	-2.080	<b>0.044</b>
16 to 20 years	22	2.70	0.715	-1.997	0.059
21 or more years	10	2.85	1.137	-0.417	0.686

**Table 39 (continued)**

<b>Group</b>	<b>N</b>	<b>Mean</b>	<b>Std. Dev</b>	<b>t</b>	<b>P</b>
<i>Years in current specialty/profession</i>					
Less than 1 year	20	3.03	0.733	0.193	0.849
1 to 5 years	85	<b>3.18</b>	0.788	2.156	<b>0.034</b>
6 to 10 years	73	3.19	0.820	1.960	0.054
11 to 15 years	55	3.12	0.999	0.859	0.394
16 to 20 years	45	2.85	0.907	-1.074	0.289
21 or more years	74	<b>2.82*</b>	0.779	-2.029	<b>0.046</b>
<i>Hours worked per week at Children's</i>					
Less than 20 hours	11	<b>3.63</b>	0.627	3.349	<b>0.007</b>
20 to 39 hours	262	3.07	0.814	1.311	0.191
40 or more hours	79	2.92	0.955	-0.761	0.449
<i>Use computers (frequency)</i>					
Frequently	267	3.05	0.838	0.938	0.349
Often	55	3.03	0.856	0.221	0.826
Sometimes	19	2.85	0.813	-0.800	0.434
Rarely	8	3.46	1.125	1.163	0.283

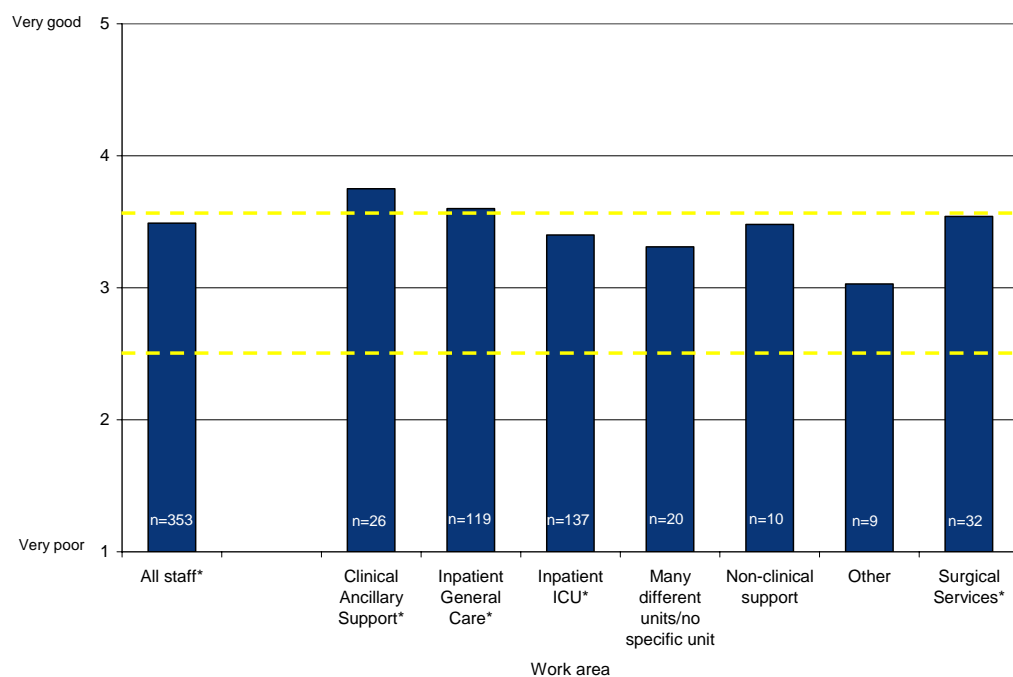
\* These groups are significantly less than 3, indicating perceptions of PE are not favorable.

**Table 40. One-sample t-test results for post-implementation (t<sub>1</sub>) EE**

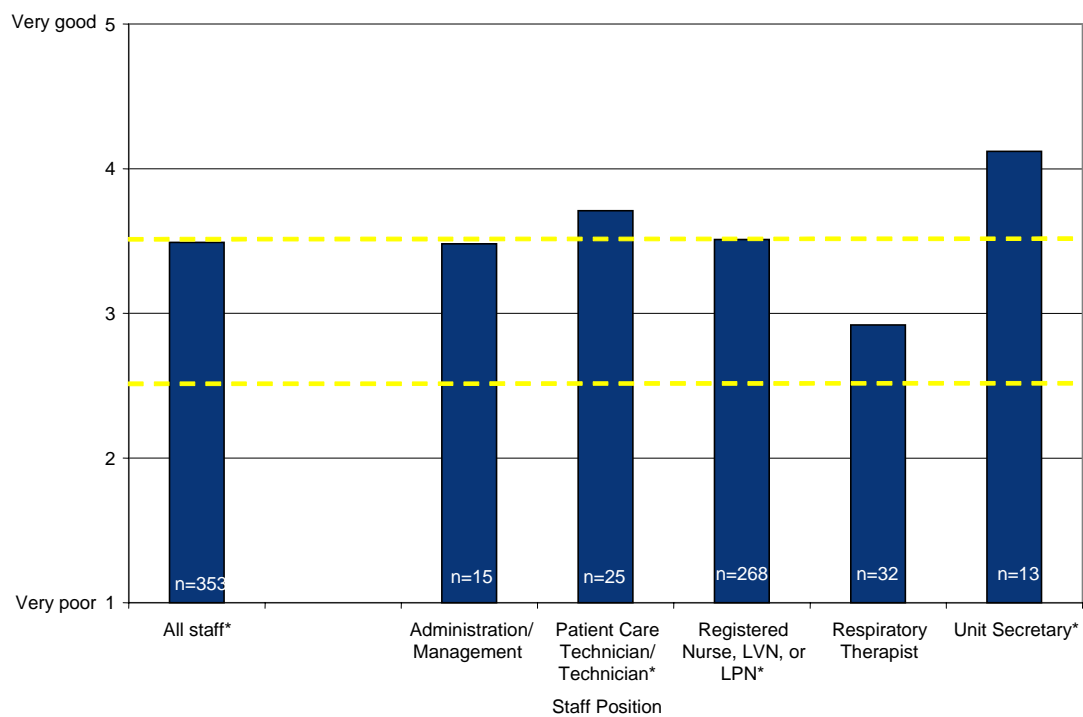
<b>Group</b>	<b>N</b>	<b>Mean</b>	<b>Std. Dev</b>	<b>t</b>	<b>p</b>
All participants	353	<b>3.49</b>	0.738	12.572	<b>&lt;0.001</b>
<i>Campus</i>					
Egleston (Academic)	167	<b>3.39</b>	0.776	6.419	<b>&lt;0.001</b>
Scottish Rite (Non-academic)	186	<b>3.59</b>	0.690	11.687	<b>&lt;0.001</b>
<i>Work area groups</i>					
Clinical Ancillary Support	26	<b>3.75</b>	0.448	8.509	<b>&lt;0.001</b>
Inpatient General Care (GCA/PCA)	119	<b>3.60</b>	0.757	8.644	<b>&lt;0.001</b>
Inpatient ICU	137	<b>3.40</b>	0.722	6.512	<b>&lt;0.001</b>
Many different units/no specific unit	20	3.31	0.993	1.407	0.175
Non-clinical support	10	3.48	0.795	1.891	0.091
Other	9	3.03	0.879	0.095	0.927
Surgical Services	32	<b>3.54</b>	0.585	5.187	<b>&lt;0.001</b>
<i>Staff position groups</i>					
Administration/Management	15	<b>3.48</b>	0.630	2.971	<b>0.010</b>
Patient Care Technician/Technician	25	<b>3.71</b>	0.553	6.421	<b>&lt;0.001</b>
Registered Nurse, LVN, or LPN	268	<b>3.51</b>	0.693	12.091	<b>&lt;0.001</b>
Respiratory Therapist	32	2.92	0.958	-0.446	0.659
Unit Secretary	13	<b>4.12</b>	0.666	6.036	<b>&lt;0.001</b>
<i>Years worked in current work area</i>					
Less than 1 year	55	<b>3.75</b>	0.542	10.258	<b>&lt;0.001</b>
1 to 5 years	156	<b>3.58</b>	0.749	9.744	<b>&lt;0.001</b>
6 to 10 years	66	<b>3.32</b>	0.782	3.370	<b>0.001</b>
11 to 15 years	40	<b>3.30</b>	0.610	3.151	<b>0.003</b>
16 to 20 years	22	3.24	0.758	1.477	0.155
21 or more years	10	3.28	0.924	0.941	0.371

**Table 40 (continued)**

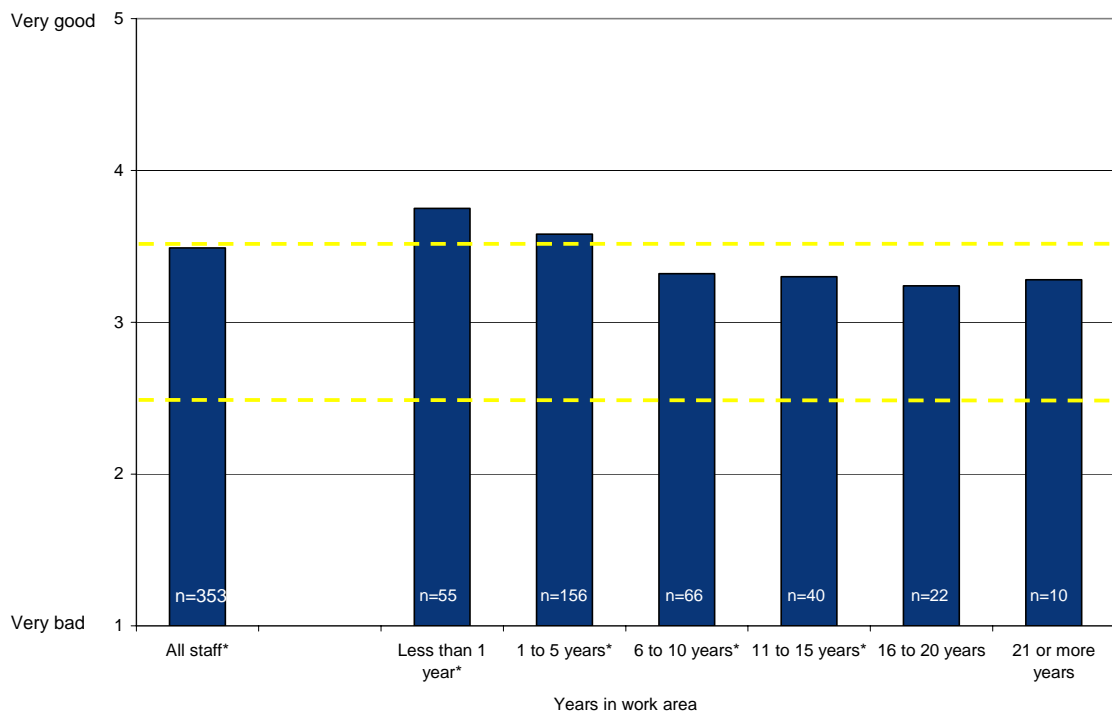
<b>Group</b>	<b>N</b>	<b>Mean</b>	<b>Std. Dev</b>	<b>t</b>	<b>p</b>
<i>Years in current specialty/profession</i>					
Less than 1 year	20	<b>3.64</b>	0.503	5.667	<b>&lt;0.001</b>
1 to 5 years	85	<b>3.64</b>	0.746	7.851	<b>&lt;0.001</b>
6 to 10 years	73	<b>3.58</b>	0.679	7.357	<b>&lt;0.001</b>
11 to 15 years	55	<b>3.59</b>	0.725	6.076	<b>&lt;0.001</b>
16 to 20 years	45	3.24	0.836	1.917	0.62
21 or more years	74	<b>3.28</b>	0.719	3.300	<b>0.001</b>
<i>Hours worked per week at Children's</i>					
Less than 20 hours	11	<b>3.77</b>	0.778	3.293	<b>0.008</b>
20 to 39 hours	262	<b>3.54</b>	0.694	12.569	<b>&lt;0.001</b>
40 or more hours	79	<b>3.30</b>	0.839	3.148	<b>0.002</b>
<i>Use computers (frequency)</i>					
Frequently	267	<b>3.52</b>	0.738	11.589	<b>&lt;0.001</b>
Often	55	<b>3.41</b>	0.732	4.113	<b>&lt;0.001</b>
Sometimes	19	3.13	0.647	0.886	0.387
Rarely	8	<b>3.75</b>	0.791	2.683	<b>0.031</b>



**Figure 18. EE ratings by work area**



**Figure 19. EE ratings by staff position**



**Figure 20. EE ratings by years in work area**

## DISCUSSION

### Factor structure of IT acceptance and related constructs

#### Performance Expectancy

As described in the *Results* section, factor analyses of the outcome survey items for staff at both  $t_0$  and  $t_1$  indicated that Performance Expectancy (PE) consisted of one factor ( $\text{Mean}_{t_0}=3.36$ ,  $\text{SD}_{t_0}=0.72$ ;  $\text{Mean}_{t_1}=3.05$ ,  $\text{SD}_{t_1}=0.85$ ). This single factor combined items that addressed individual job performance, impact on patient care, and social influence - patients (i.e., impact on image with patient/patient family). However, similar analysis of physician pre-implementation responses identified two distinct PE factors: one combining items on individual job performance (including time spent with patients and social influence – patients), and a second that combines items on patient safety (i.e., Epic will improve patient safety, help reduce medical errors).

On average, physicians rated PE-safety ( $\text{Mean}=3.78$ ,  $\text{SD}=0.81$ ) higher than PE-job ( $\text{Mean}=2.83$ ,  $\text{SD}=0.88$ ). Based on this, it may be that the significant publicity that EMR/CPOE has received in the medical literature regarding its potential to improve patient safety has contributed to the presence of two independent factors instead of the one factor observed for staff. The numerous articles demonstrating the potential of EMR/CPOE systems to improve patient safety (e.g., Bates et al., 1998; Bates et al., 1999; King, Paice, Rangrej, Forestell, & Swartz, 2003; Potts, Barr, Gregory, Wright, & Patel, 2004; Upperman, Staley, Friend, Neches et al., 2005) appear to have resulted in higher physician expectations regarding the impact EMR/CPOE on patient safety. Similarly, some highly publicized CPOE implementations have reported disruptions to physician workflows and increased physician time on order entry (Aarts, Doorewaard, & Berg, 2004; Bates, Boyle, & Teich, 1994; e.g., Massaro, 1993a; Tierney, Miller, Overhage, & McDonald, 1993; Weiner et al., 1999), which may have contributed to lower ratings of PE-job for physicians. This dichotomy in expected outcomes of EMR/CPOE from the physician perspective is a likely contributor to the dual nature of PE for physicians.

In contrast, the fact that PE is one factor for staff indicates that staff perceptions of the impact on personal job performance and the impact on safety are very tightly linked. Considering the literature on EMR/CPOE from the nurses' perspective provides some insight into the source of this tight integration. In this literature, results reported neutral to positive impact on time and other aspects of care processes for nursing staff (Lærum, Karlsen, & Faxvaag, 2004; e.g., Massaro, 1993a; Walker & Prophet, 1997; Weiner et al., 1999). The fact that reported results on the impact of EMR/CPOE on patient safety and nursing performance are more consistent may account for PE being one factor instead of two for this group. Another potential contributor to this finding may be that nurses are taking a narrower view in assessing impact on patient safety, considering only the impact on their patient care tasks (e.g., medication administration, patient monitoring, etc.) where the physicians may be considering a broader view that encompasses the impact on the entire care team (physicians, nurses, pharmacist, etc.). However, further research into the source of the observed differences between physicians and staff is needed to determine if this is the case.

One other observation of note is that for physicians and staff (at both time points), *Social influence – patient* was part of the PE/PE-job factor, rather than a separate factor, as expected based on the MIS/HCI literature. In the MIS literature, *Social influence – image* was a distinct factor with a moderate to low effect on PE (Venkatesh & Davis, 2000). This is very different from being an integral part of the PE construct. However, recall that *Social influence – patient* assessed the degree to which the participant thought using the system would enhance their image with patients/patient families. In contrast, the *Social influence - image* items used in the MIS literature assess image with 'people in my organization'. It is likely that the observed difference in results is due to the specification of patients and patient families. Due to the nature of clinical care, the importance of the clinician-patient relationship likely makes a clinicians' image with patients an integral aspect of their perceptions of their job performance.

## **Effort Expectancy**

Staff post-implementation results indicated that the 4-item EE scale from the MIS/HCI literature on IT acceptance is appropriate for use in evaluating EMR/CPOE systems. The factor analysis indicated these 4 items all loaded on the same factor. Also, the 4-item EE scale demonstrated good internal consistency. Therefore use of this scale in examining user acceptance of EMR/CPOE systems is recommended. Recall that three of the four items in the scale were omitted from the pre-implementation surveys because they occurred before users had any exposure to the system. This was done because prior to exposure, users did not have an adequate basis for answering items related to the interface and interactions with the system. However, the EE scale is appropriate for use in pre-implementation assessments that occur after some exposure to the system (e.g., after training, after system walkthroughs, etc.). For example, Van Schaik et al. (2002) used a similar scale to assess clinician perceptions of a prototype postural assessment system to obtain user feedback after a prototype demonstration.

## **Support for Decision Processes**

An unanticipated construct was identified in the staff post-implementation factor analysis of input survey items. This construct, *Support for decision processes (SDP)*, consists of the compatibility item (i.e., ‘fits with the way I like to work’) and two output quality items that address the system’s provision of faster access to and access to more information for clinical decision making. This item demonstrated good internal reliability ( $\alpha=0.829$ ) and was a significant predictor of PE. Based on SDP’s demonstrated relationship with PE (discussed in the section on *Factors that influence IT acceptance*), future research needs to further examine this construct and its role in acceptance of healthcare information technology.

## **Other Constructs**

The factor analyses performed identified other constructs of interest in examining acceptance of EMR/CPOE. One such factor was *Communication*. This outcome construct was observed in all three survey data sets (staff-pre, staff-post, and physician-pre). This factor addressed the impact of the system on communication with coworkers and

patients. While the internal consistency ratings were only moderate (ranging from 0.640 to 0.757), the fact that it showed up consistently indicates further investigation into the communication construct may be of interest. Also, other research has indicated that changes to communication and coordination processes due to EMR/CPOE implementation can create new opportunities for patient care problems (e.g., lack of awareness of events, loss of feedback (Ash, Berg, & Coiera, 2004; Dykstra, 2002)). Therefore research into developing means for measuring, and subsequently managing, changes in communication is warranted.

Both the staff and physician analyses also provide evidence of a *design involvement* construct prior to implementation. The design involvement construct observed in these results had low-to-moderate internal consistency. However, future research on this factor is warranted since the UCD and Change Management literature emphasize the importance of user participation in successful technology/change adoption. EMR/CPOE best practices and lessons learned have also highlighted the importance of user involvement during implementation (Ahmad et al., 2002; Ash, Fournier, Stavri, & Dykstra, 2003; Poon et al., 2004; Sittig & Stead, 1994; Upperman, Staley, Friend, Benes et al., 2005). In this study the two design involvement items significantly influenced pre-implementation PE for both staff and physicians, providing further evidence of the importance of this construct in understanding EMR/CPOE acceptance. Thus, future research should examine additional survey items to inform the development of a scale to better assess the degree of design involvement.

### **Relationship between IT acceptance and safety culture**

Correlations between aspects of safety culture and IT acceptance factors (PE and EE) were examined to develop a better understanding of how aspects of EMR/CPOE acceptance relate to perceptions of safety in the hospital in which the technology is being implemented. Because EMR/CPOE systems are usually implemented to achieve improvements in patient safety and quality of care, it was expected that current perceptions would contribute to the perceived need for, and consequently, expected benefit from implementing EMR/CPOE.

## Performance Expectancy

Review of the reported correlations indicates that for staff, PE was moderately correlated with safety perceptions regarding *Staffing* and *Hospital teamwork* ( $r$ : 0.19-0.30). The strength of these relationships was very similar at  $t_0$  and  $t_1$ . For physicians prior to implementation, the *PE-job* factor was also moderately correlated with *Staffing (staff)*, and *Hospital teamwork* ( $r$ : 0.21-0.23). However, the correlation of these items with *PE-safety* was not significant. (Note: In the staff surveys, the staffing construct measured staff staffing levels, not physician staffing.) The relationship with staffing may be related to staff perceptions about having enough bandwidth to learn and effectively integrate use of the system into their care processes. Additionally, one study of physicians and nurses indicated that CPOE users most often sought help from their peers (Lee, Teich, Spurr, & Bates, 1996). Thus this relationship to staffing may also reflect an expectation that units where staff have the bandwidth to help each other learn to use the system will be more likely to benefit from use of the system. The relationship between *Hospital teamwork*, which encompasses questions related to coordination between units, may reflect an underlying belief that achieving benefits from EMR (in terms of PE) will require good coordination between hospital units.

*Unit teamwork* was also correlated with PE for staff at  $t_0$  ( $r=0.14$ ) and *PE-job* for physicians ( $r=0.23$ ), but this relationship was no longer significant for staff at  $t_1$ . It is unclear why this relationship went away after implementation. However, this result is similar to observed TAM2 results regarding the diminishing influence of *Subjective Norm* (aka, Social Influence) on PE (Venkatesh & Davis, 2000). For the mandatory systems examined in the TAM2 study, *Subjective Norm*, an indicator of the degree to which ‘important others’ think they should use the system, had a moderate influence prior to implementation, but the strength of this relationship diminished considerably by 3-months after implementation (to the point of insignificance for one of two systems studied). In the pediatric hospitals studied here, EMR use was mandatory. It may be that the observed relationship with *Unit teamwork* may be a function of the *Subjective Norm* phenomenon: on units with good teamwork, others’ expectations related to use EMR/CPOE may be influencing the user expectations of PE prior to implementation, but

after implementation PE assessments are based on the individual's own interactions with the system instead of other's opinions. Another possible reason for this result may be that prior to implementation, participants working on units with good teamwork felt they could rely on others in the unit to help them learn the system and more quickly achieve benefits from its use. 5-6 months after implementation, the time of the  $t_1$  surveys, the staff surveyed may have moved through most of the learning curve and be judging PE solely on their interactions with the system. Future research will examine whether or not this diminishing relationship over time is also observed for physicians.

Opposite correlations were observed for physicians versus staff for *Transitions*. For physicians, *PE-safety* was moderately negatively correlated ( $r=-0.253$ ) with *Transitions*. For staff, a moderate positive relationship between PE and *Transitions* was observed at both  $t_0$  ( $r=0.25$ ) and  $t_1$  ( $r=0.22$ ). This indicates that physicians who thought transitions were currently problematic (low score on *Transitions*) had higher ratings of *PE-safety*. Thus it appears that the perceived safety need (i.e. poor transitions) results in higher expectations of system positively impacting patient safety. It is interesting to note that the staff pre-implementation model on PE, discussed in the following section, indicates that staff who felt that errors occurred due to problems in the current ( $t_0$ ) system also rated PE higher. This further supports the theory that the perceived patient safety needs contribute to PE. Thus, the positive relationship between PE and *Transitions* for staff at  $t_0$  and  $t_1$  is puzzling. Staff who had more negative perceptions about hospital transitions also had lower ratings of PE. It may be that staff who see transitions as problematic feel that the additional burden of using the system or the changes to communication patterns and information sharing processes will not help alleviate existing problems or, worse, will further contribute to problems with transitions. Further research into these seeming conflicting results is needed.

### **Effort Expectancy**

Prior to implementation ( $t_0$ ), *EE-learning* was only correlated with perceptions about staff staffing levels (i.e., *Staffing* in the staff surveys, *Staffing – staff* in the physician surveys). The strength of this relationship was low for staff ( $r=0.15$ ) and moderate for physicians

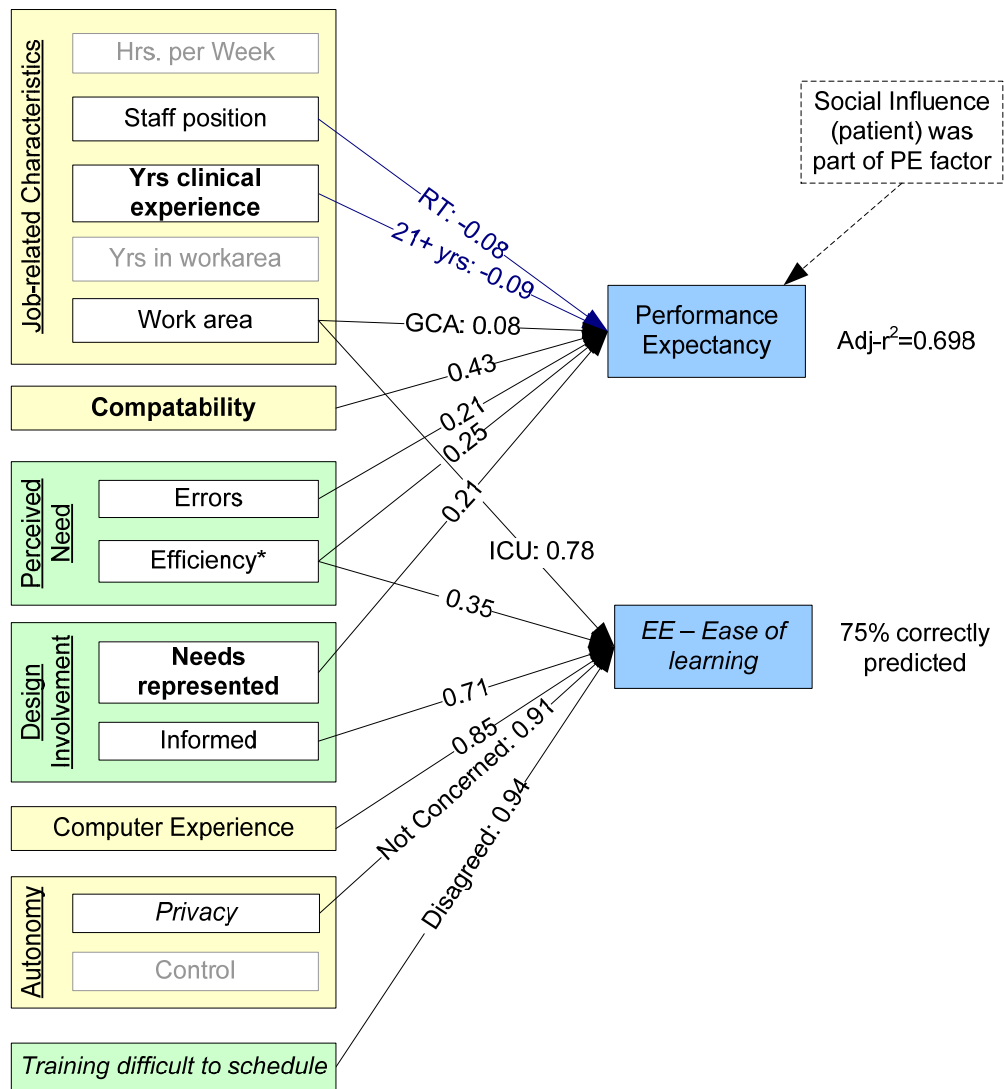
( $r=0.34$ ). Interestingly, *EE-learning* was not correlated with physician perceptions about physician staffing. For staff at  $t_1$ , *Staffing* was also correlated with EE ( $r=0.19$ ).

Contributors to the pre-implementation relationship between ease of learning and staff staffing levels could include: 1) nursing staff may feel that staffing levels need to provide them enough bandwidth to learn the system, and 2) both nursing staff and physicians may anticipate that other nursing staff on the unit will help them become proficient with the system once it goes live. Lee et al.'s (1996) observation that clinician CPOE users most often sought help from their peers provides some support for this theory. The observed relationship between staffing and EE (which included ease of learning) after implementation for staff provides further evidence for this theory, since perceptions about ease of use (i.e., EE) tended to increase as perceptions about staffing levels improved. Note that the directionality of the relationship between staffing and EE cannot be assumed without further research. Specifically, do those who find the system easy to use spend less time on system-based tasks and, based on their own workload, feel staffing levels are appropriate? Or are those who feel staffing levels are better getting more support from fellow staff members in learning the system, and thus, find it easier to use?

After implementation, EE for staff was also correlated to *Hospital teamwork*, and *Transition* ( $r: 0.25-0.27$ ). This is similar to the results observed for PE. Again, the relationship with *Hospital teamwork* implies that improved coordination across hospital units also improves perceived ease of use of the EMR. Similarly, in hospital areas where transitions are less problematic using the system is easier. In both of these instances the cause and effect are not clear – is ease of use of the system facilitating transitions and hospital teamwork or is the lack of problems related to transitions and hospital teamwork contributing to the perception that the system is easy to use? One potential area for future research would be to examine how well use of the EMR facilitates resolving problems related to handoffs and transitions and cross-unit coordination. This would provide further insight into the nature of the relationship that PE and EE have with these two aspects of patient safety.

### **Factors that influence IT Acceptance**

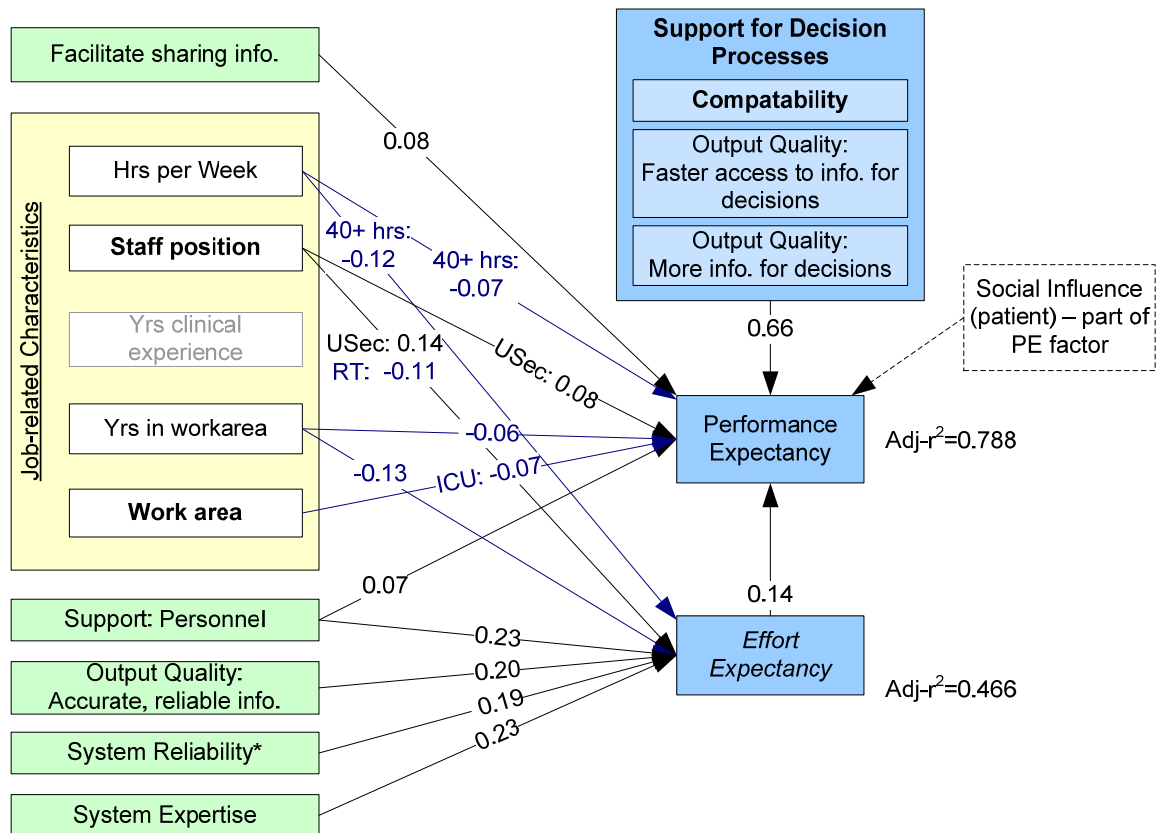
This research examined factors that influence clinician acceptance of EMR/CPOE systems during their implementation in a pediatric hospital system. Potential influencers of acceptance examined included patient safety perceptions, systems implementation factors, system characteristics, and user characteristics. Statistical models identified the factors that demonstrated the strongest relationship with PE and EE, two aspects of IT acceptance. A summary of these findings is presented in Figures 12-14 below. The subsequent sections discuss these findings and their implications for future implementations of EMR/CPOE.



**Figure 21. Model of PE & EE - learning for staff prior to implementation (t<sub>0</sub>)**

Note: The Standardized Beta coefficients from the linear regression model on PE is noted on the lines between each predictor and PE. The Beta coefficient from the logistic regression is noted on the lines to EE – ease of learning. Blue lines and text indicate negative relationships.

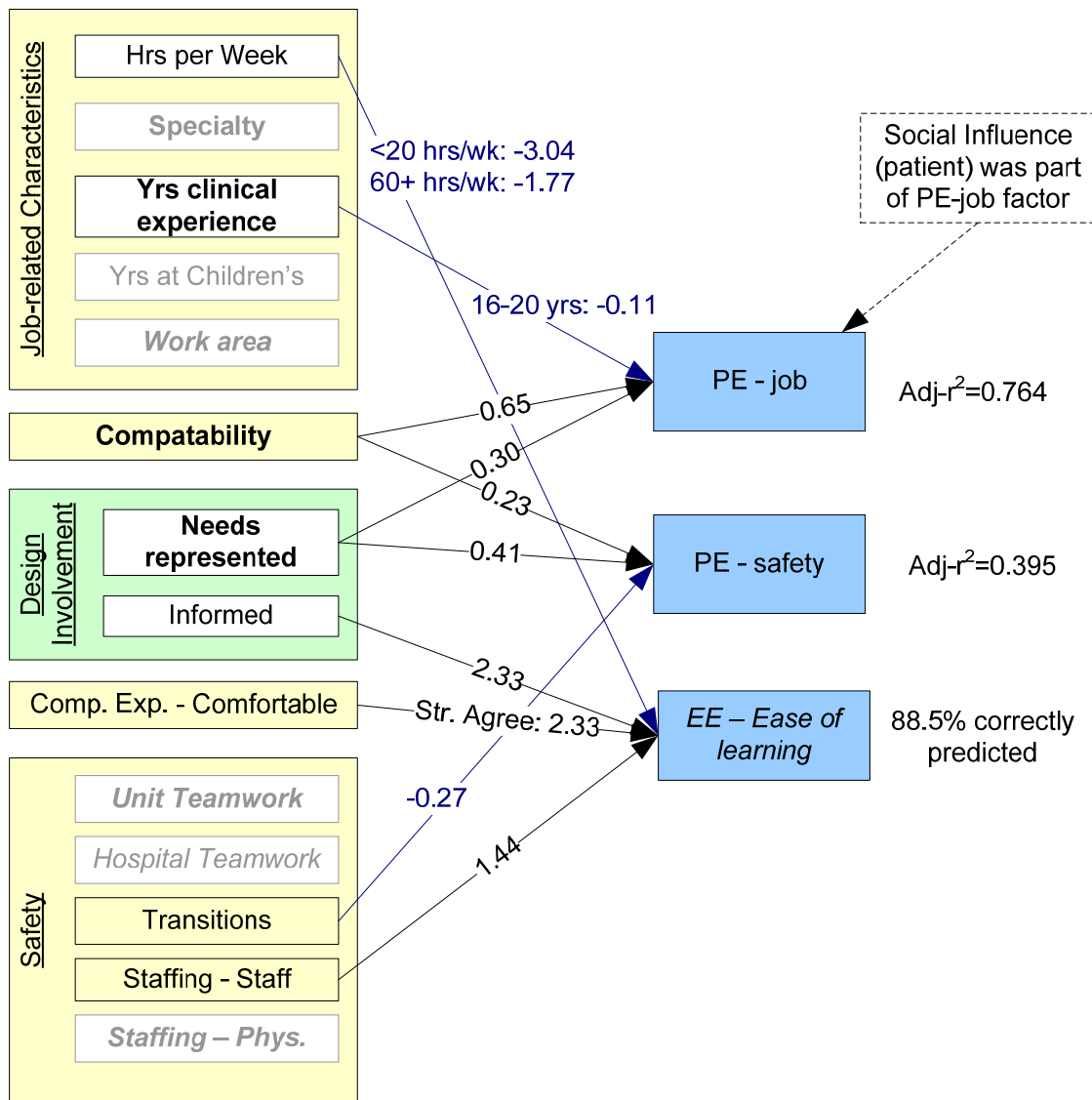
\*Negatively worded item reverse coded for analysis.



**Figure 22. Model of PE & EE - learning for staff after to implementation (t<sub>1</sub>)**

Note: The Standardized Beta coefficients from the linear regression model on PE is noted on the lines between each predictor and PE. The Beta coefficient from the logistic regression is noted on the lines to EE – ease of learning. Blue lines and text indicate negative relationships.

\*Negatively worded item reverse coded for analysis



**Figure 23. Model of PE & EE - learning for physicians prior to implementation**

Note: The Standardized Beta coefficients from the linear regression model on PE is noted on the lines between each predictor and PE. The Beta coefficient from the logistic regression is noted on the lines to EE – ease of learning. Blue lines and text indicate negative relationships.

## Factors that influence Performance Expectancy

The three models of PE identified several factors that significantly predict PE ratings. The results, presented previously, indicate that all models were a good fit, accounting for over 75% of the variability in the staff PE and physicians *PE-job* ratings. The model for physician *PE-safety* accounted for approximately 40% of the variability in those ratings. While this is low compared with the other two models, this is quite acceptable for survey data. The additional variability in the *PE-safety* ratings may be a result of variability among physicians in the amount and content of information they have been exposed to on the potential safety benefits of EMR/CPOE, either through the medical literature or from peers at other patient care settings (e.g., hospitals, clinics). However, the degree of fit of the three models indicates that the systems implementation, job-related, and safety factors identified in the models have a significant influence on PE.

### Systems implementation factors

Consider first the staff and physician models of PE prior to EMR/CPOE implementation (Figure 21 and Figure 23, respectively). Despite the fact that PE was a single construct for staff and two distinct constructs (*PE-job* and *PE-safety*) for physicians, the two models have interesting similarities. *Compatibility* and *Design Involvement – Needs Represented (Needs Represented)* were significant predictors of PE for staff and both *PE-job* and *PE-safety* for physicians. Examining the Std. Beta Coefficients ( $\beta_{\text{std}}$ ) in these models indicates that *Compatibility*, the degree to which use of the system fits with the way the user likes to work, was the factor with the strongest influence on staff PE ( $\beta_{\text{std}}$  0.43 vs.  $\leq |0.25|$  for other predictors). Similarly, *Compatibility* had the strongest influence on physician *PE-job* ( $\beta_{\text{std}}$  0.65 vs.  $\leq |0.30|$ ). Further evidence of the importance of *Compatibility* is provided in the model of staff PE after implementation. Specifically, *Support for Decision Processes (SDP)*, a scale which encompasses *Compatibility*, is the strongest predictor of post-implementation PE ( $\beta_{\text{std}}=0.66$  vs.  $\leq |0.14|$  for other predictors).

The strong influence of *Compatibility* in predicting PE, the perceived benefit or performance improvement associated with using the system, echoes findings reported

from previous EMR/CPOE systems. For example, the comparison of the Cordero (2004) and Han (2005) studies presented in the *EMR & CPOE in Pediatrics* section highlights the importance of compatibility. In the Cordero study where the CPOE system was designed to be compatible with urgent care processes in the ICU achieved positive patient care outcomes (e.g., improved survival rates, improved medication turn-around times). In the Han study, using the CPOE system was incompatible with urgent care processes for ICU transport patients, resulting in delays in providing care (e.g., medications) and ultimately increasing mortality. Addressing workflow concerns has proven to be a factor critical to EMR/CPOE success both in studies of failed or painful implementations (e.g., Aarts, Doorewaard, & Berg, 2004; Ali et al., 2005; Massaro, 1993b) and successful ones (e.g., Ahmad et al., 2002; Potts, Barr, Gregory, Wright, & Patel, 2004; Upperman, Staley, Friend, Benes et al., 2005). The importance of compatibility emphasizes the need to use UCI methods such as task analysis to develop a solid understanding of users' current work practices and apply that knowledge to design technology that compliments and/or improves those work practices. In those instances where significant changes to work practices are warranted, it is important to apply UCI change management methods to ensure that users understand the need to change work practices, as evidenced by the moderate effect of *Perceived Need – Efficiency* in the staff PE model.

The presence of *Needs Represented* in the pre-implementation PE models is also supported by evidence in the EMR/CPOE literature. In the regression results, *Needs Represented* had a moderate influence on staff PE ( $\beta_{\text{std}}=0.21$ ) and on physician *PE-job* ( $\beta_{\text{std}}=0.30$ ), but demonstrated the strongest influence on physician *PE-safety* ( $\beta_{\text{std}}=0.41$ ). In the review of EMR/CPOE best practices presented previously, empowering and involving users in the implementation was cited as important to success in 7 different studies, the most of any best practice except one – addressing workflow concerns was cited in 8 studies. For example, consider the CPOE implementation at Brigham & Women's Hospital. This implementation achieved good satisfaction ratings from physicians and nurses and cited 'substantial physician involvement and leadership in application development (p. 52)' as a key success factor (Lee, Teich, Spurr, & Bates, 1996). Brigham & Woman's also reported achieving patient care benefits from their

CPOE implementation including a reduction in errors (Bates et al., 1998) and improved prescribing practices (Teich et al., 1999). Similarly, the Ohio State University Health System, which achieved reductions in turn-around time for key orders (e.g., medications, radiology procedures, and lab results) cited involvement of clinicians (e.g., physicians, residents, and nurses) as a key success factor (Mekhjian et al., 2002). The body of research on UCD, reviewed previously, demonstrates that better understanding of user needs (including user, task, and context-driven needs) through user involvement and representation during design leads to the design of more effective systems.

It is also interesting to consider the finding that, for physicians, *Needs Represented* had the strongest influence on *PE-safety*, compared to a moderate influence on *PE-job*. Results from Brigham & Women's Hospital provide insight into a reason for this finding. This study examined the impact of CPOE on prescribing practices in the hospital (Teich et al., 2000). Researchers found that CPOE was most effective (i.e., guidelines/alerts were acted on) when the system recommended practices that were widely accepted by physicians and were *not* viewed as changes to care plans. They emphasize that 'it is critical that the physician, not the computer, make the final decision on all orders... the intent is not to have the system think for the physician, but rather for it to handle certain rote functions, so that the physician can focus on overall diagnostic and treatment plans and on communicating effectively with patients. (p.13)'. Consequently, they conclude in order for CPOE to increase the impact of guidelines and recommendations, the rules and guidelines must be developed by a 'respected clinical body using a strong evidence base' and the supporting evidence for the guidelines and rules must be effectively communicated to the ordering physicians. These findings and conclusions indicate that representing physician's needs, especially related to patient care practices, are, indeed, important to physician acceptance and utilization of CPOE. Thus, physician understanding and acceptance of predefined order sets, guidelines, and alerts prior to implementation is important to their acceptance of the EMR/CPOE as it influences the impact they think the system will have on patient care, and especially patient safety.

After implementation, when users have had hands-on experience with the system, characteristics of the system and the system rollout were expected to influence PE perceptions. The staff post-implementation model of PE confirmed that this is the case. As mentioned previously, the strongest predictor of PE ( $\beta_{\text{std}}=0.66$ ) was *Support for Decision Processes (SDP)*, which includes *Compatibility* along with the availability of more information and faster access to information for clinical decision making. Similar to this finding, the ability of the system to facilitate sharing information with other users also had a positive effect on PE ( $\beta_{\text{std}}=0.08$ ). These two demonstrated relationships indicate that staff feel that the EMR systems' ability to provide quick access to the *right* information by the *right* person in a manner that *fits with* clinical care process is crucial in order to deliver a substantial improvement to their job performance.

EE, the system's ease of use, also had a significant positive effect ( $\beta_{\text{std}}=0.14$ ) on PE. This result is both logical and consistent with results in studies of IT acceptance in non-healthcare domains (Venkatesh & Davis, 2000). Studies of user satisfaction with EMR/CPOE have also found that aspects of EE (e.g., system response time, number of screens/clicks, information display, etc.) contribute to user satisfaction with EMR/CPOE (e.g., Lee, Teich, Spurr, & Bates, 1996; Murff & Kannry, 2001; Weiner et al., 1999).

The relationship between PE and *Support – personnel* is also an important finding. This aspect of support, the ability of support personnel on the units (i.e., super users) to help users, had a significant positive effect ( $\beta_{\text{std}}= 0.07$ ) on PE. The EMR/CPOE literature provides anecdotal evidence of the need to have super users who provide on-the-unit support to help users learn and effectively use these systems (Ammenwerth, Mansmann, Iller, & Eichstadter, 2003; Lee, Teich, Spurr, & Bates, 1996; Upperman, Staley, Friend, Benes et al., 2005). The results of this study regarding the influence of super user support on PE and EE (discussed in the later) provide quantitative evidence of how important super user support is to fostering acceptance of EMR/CPOE systems.

### Job-related factors

In addition to the role that the above factors related to the system implementation have on PE, several user job characteristics also significantly influenced PE for both staff and physicians. While the influence of these variables is weak compared to the previously discussed factors ( $|\beta_{\text{std}}| \leq 0.11$ ), they are interesting, nonetheless. These differences based on work area and role are not surprising since other studies of EMR/CPOE have identified similar user population-based differences. These results were reviewed previously in the *Background* section on *Post-implementation acceptance and satisfaction with EMR/CPOE*. In this study, prior to implementation respiratory therapists tended to rate PE slightly lower while staff working in Inpatient GCA had slightly higher ratings. After implementation, job-related differences continued to influence staff PE. Unit secretaries rated PE higher and respiratory therapist lower compared to other staff. These differences make sense when details regarding Children's EMR implementation are taken into account. These role-based differences and the contextual factors that contributed to them are discussed in more detail in the following sections.

These combined results emphasize that in healthcare different units/roles have different needs and implementation plans need to ensure that each area has people 'at the table' during design and testing to ensure needs are represented in the system. This is the only way to ensure that each unit's specific needs are met *at go-live*, instead of requiring system changes after the system is in place. This concept in the context of the results observed in this study for respiratory therapists is discussed further in the *Putting it into Practice* section.

The staff and physician models of PE provide evidence that duration of clinical experience also influences IT acceptance. Prior to implementation, physicians with 16 to 20 years of clinical experience rated *PE-job* lower compared to other physicians. Staff with 21+ years of clinical experience also rated pre-implementation PE lower than other patient care staff. Similarly, after implementation as the number of years working in their current work area increased, ratings of PE decreased slightly. In order to determine if this was related to more experience clinicians having less desire to be involved in design,

correlations between the design involvement factors and clinical experience were examined. For physicians, there was no correlation between the two design involvement factors and either years of clinical experience or years working at Children's. For staff, there was a low correlation between time in current profession and both *Design Involvement – Needs represented* ( $r=-0.127$ ,  $p=0.21$ ) and *Design Involvement – Informed* ( $r=-0.189$ ,  $p=0.001$ ). Thus, hesitation on their part to get engaged in the design process or use of methods that were less effective at engaging this group may have contributed to their more conservative assessments of PE. Other factors may also be contributing to this influence of clinical experience. For example, it may be that more seasoned staff feel that they are already quite effective on the job, leaving less room for the system to improve their personal performance. Alternately, the lower PE ratings for more experienced clinicians could be related to burnout. Further research is needed to determine the underlying causes of this finding.

While most studies of EMR/CPOE did not explicitly examine duration of clinical experience, a few studies did examine age. In most circumstances, age and duration of clinical experience are highly correlated. (The exception to this would be someone who began their clinical career later in life, thus they would fall into a higher (older) age group, but lower experience group.) One study found that age affected nurses' pre-implementation attitudes toward and EMR (Dillon, Blankenship, & Crews, 2005). Nurses in their thirties had more positive attitudes toward the system than nurses in their forties and fifties. This is similar to the results observed in this study, as nurses with more clinical experience (21+ years) had lower PE ratings.

Staff participants working 40 or more hours a week also rated PE slightly lower. This result may be related to clinician burnout or to a perception that use of the system adds to (or at least fails to alleviate) an already high workload. For example, feedback from staff after the Epic implementation consistently indicates that logging into the system takes 'too long'. Nurses who work more than 40 hours per week must login to the system more often during a week in order to document medication administration, etc. The combination of more logins and a long login time may be reducing their perceptions of

the benefits of using the system. It is also possible that higher workloads could have limited their ability to be involved in design. Examination of correlations between the two design involvement factors and Hours worked per week indicated they were not significantly correlated, indicating this is unlikely to be the case.

The work area, role, and other job and experience-related differences observed in the current study and past studies of EMR/CPOE demonstrate that different sub-populations of users in the hospital have different needs. While which subpopulation is different seems to vary from study to study, their repeated presence demonstrates that variability in user needs and clinical practices is prevalent in many healthcare environments. Therefore, EMR/CPOE implementation methods need to emphasize understanding and designing to meet these special needs and not take a one-size-fits-all approach. Accomplishing this is discussed in the *Putting it into Practice* section.

#### Patient safety factors

One interesting difference between the staff and physician models of PE is the influence that perceptions of safety have on PE. In the staff model, the four aspects of safety are notably absent from both the pre- and post-implementation models. However, in the physician model, perceptions regarding *Transitions* had a moderate negative influence ( $\beta_{\text{std}}=-0.27$ ) on *PE-safety*. In other words, physicians who had more negative perceptions on how safe transitions and hand-offs in the hospital currently are had more positive perceptions on the impact EMR/CPOE would have on patient safety. The absence of the safety constructs from the staff surveys, however, does not mean that current perceptions about safety did not contribute to PE for staff. In fact, in the staff pre-implementation model, *Perceived Need – Errors*, had a moderate influence ( $\beta_{\text{std}}=0.21$ ) on PE. This indicates that as staff who had poorer current perceptions about errors (i.e., most error occur due to process failures in the current system) rated PE higher. (Recall that for staff, PE encompassed both aspects of job performance and patient safety.) Thus the findings for both physicians and staff indicate that people who have poorer current perceptions of certain aspects of patient safety expect performance improvements after EMR/CPOE implementation. Thus, one way to improve user acceptance of these systems is to

emphasize expected patient safety improvements when communicating with users prior to implementation, and be sure to deliver on those expected patient safety benefits. It is interesting to note, however, that the four safety constructs were not significant predictors of post-implementation PE for staff.

It is interesting to consider why two different predictors provided evidence of the influence current safety perceptions have on pre-implementation PE. The staff surveys included both the four safety scales and the *Perceived Need – Errors* item. In contrast, the physician surveys exclude the *Perceived Need – Errors* item in order to reduce the length of the survey and, consequently, ensure an adequate response rate. The presence of *Perceived Need – Errors* item instead of one or more of the safety scales in the staff model that included all of these factors may indicate that this single indicator of the perceived safety-related need for the system is a better predictor compared to the safety scales. Future research is needed to examine this.

#### Change in factors that influence PE over time

The pre- and post-implementation models demonstrate that the factors that influence PE change over time. This is consistent with results from research on acceptance of technology in other industries (Venkatesh & Davis, 2000). While compatibility with work practices was important both prior to and following implementation, other factors influencing PE differed. Prior to implementation, users who perceived a greater need for the system and felt that their needs were represented in the design process had higher expectations of impact the system would have on their job performance. After implementation, PE ratings were driven primarily by characteristics of the system. These characteristics included how well the system supported clinical decision making and facilitated sharing information and the system's ease of use (EE). One aspect of the rollout process, the support provided by super users, also had a positive impact on PE after implementation.

## **Factors that influence Effort Expectancy**

Prior to implementation factors that influence ease of learning, an aspect of EE, were examined. Both the staff and physician logistic regression models on expected ease of learning (EE- learning) predicted whether or not a participant expected the system to be easy to learn with more than 75% accuracy. The staff linear regression model of EE after implementation was also a good fit to the data, accounting for close to 47% of the variability in EE ratings. Thus the factors identified in each of these models have a significant influence on expected ease of learning and/or EE.

### Pre-implementation EE- learning

Logistic Regression models identified factors that significantly increased or decreased the odds that a participant responded that the system would be easy to learn (either agree or strongly agree). An intuitive result observed for both staff and physicians was the influence of computer experience. Physicians who strongly agreed they were comfortable with computers were 10 times more likely to respond that the system would be easy to learn; staff that used computers often or frequently were more than twice as likely. This is consistent with findings from a Dutch general care hospital which reported that physicians and staff who had less computer experience expected it to take longer to learn to use an EMR (van der Meijden, Tange, Boiten, Troost, & Hasman, 2000).

An aspect of design involvement, feeling informed (*Informed*), was also a significant predictor of ease of learning for both staff and physicians prior to implementation. For staff, a unit increase in the *Informed* rating doubled the odds that person would report that they felt the system would be easy to learn. Physicians who agreed or strongly agreed they were informed during design were more than 10 times as likely. This finding is consistent with EMR/CPOE best practices, reviewed previously, which emphasize the importance of clinician involvement in design.

Similar to the results observed for PE, job-related characteristics were significant predictors of *EE-learning* for both physicians and staff. However, the characteristics that were significant differed. For staff, participants working in the Inpatient ICU were more

than twice as likely feel the system would be easy to learn. Children's ICU nurses were already used to using technology (e.g., monitors, ventilators) in patient care, which may account for why they were more likely to think learning to use the EMR system would be easy. For physicians those who worked less than 20 hours or more than 40 hours per week at Children's were dramatically less likely to expect the system to be easy to learn. Physicians who spend less time in the hospital may be worried that their less frequent use of the system will make it more difficult to learn. Conversely, those working more than 40 hours a week may be worried that adding the workload of learning the system to their existing workload will make the system difficult to learn.

The presence of these job-related characteristics again emphasizes the special needs of particular groups within the hospital. In this case, these special needs relate to concerns about learning to effectively use the system. Implementation teams need to identify and account for these differences in training and rollout support plans. For example, given the concerns about ease of learning for groups of physicians based on the number hours they work per week, special training and/or learning initiatives could be developed to target each group.

Concern about difficulty scheduling training influenced staff perceptions of ease of learning. Staff who did not think it would be difficult to schedule training were 2 ½ times as likely to expect the system to be easy to learn. Note that while concern about scheduling training was not significant in the physician model, a qualitative review of the data indicated that 7 out of 11 physicians who strongly agreed that it would be difficult to schedule time for training also did not expect the system to be easy to learn. The relationship between concern about scheduling training and expected ease of learning emphasizes the importance of providing training classes of reasonable length in easily accessible locations and a variety of times in order to make it easier for users to attend training and, thus, make learning the system easier.

In addition to the above factors, *Perceived need – efficiency* affected expected ease of learning for staff. Participants who disagreed that existing processes were efficient were

40% more likely to expect the system to be easy to learn compared to someone who responded neutrally to this question. This could be a result of users with a lower perceived need from an efficiency standpoint having a general more negative view of the system because they see less need for it or it could be that they are concerned that learning the system would slow them down. Future research is needed to determine the cause of this result.

Staff who disagreed or strongly disagreed that they were concerned about the system tracking patient care information (*Autonomy – privacy*) were almost 2 ½ times more likely to feel the system would be easy to learn. Note that directionality in this case cannot be assumed. It may be that staff who are concerned that the system will be hard to learn are worried about the system tracking mistakes as they learn to use the system. Note that 70% of staff in one adult inpatient environment believed that implementation of EMR would lead to increased monitoring by administrators and external agencies (McLane, 2005).

For physicians, their ratings of one aspect of patient safety, *Staffing –staff*, also influenced expected ease of learning. Physicians who agreed (rating=4) that there was enough staff to handle the workload were more than 4 times as likely to expect the system to be easy to learn compared to physicians who rated staffing neutral (rating = 3). Based on this result it may be that physicians are counting on the nurses and/or other staff to help them learn to use the system.

#### Post-implementation EE

After implementation, the full EE scale was examined to identify factors that influenced staff perceptions about the system's usability. The strongest influence ( $\beta_{\text{std}} = 0.231$ ) on EE was *Support – personnel*, the ability of super users to support users. This demonstrates that the super users played an important role in helping other staff learn to effectively use the system. In addition, *System expertise*, a user's self-rated comfort with the system, was also a significant predictor of EE. However, directionality of this relationship is less clear – those who find the system easy to use are more likely to rate

themselves as comfortable using the system and visa versa. (Note: In light of the questionable directionality of this relationship, a regression model of EE excluding *System expertise* was created as well. The model was basically the same and the adj-r<sup>2</sup> was 0.431, only a .035 reduction in the amount of variability accounted for in the model.)

Two system characteristics also predicted EE ratings: 1) accuracy and reliability of information ( $\beta_{\text{std}} = 0.195$ ), and 2) system reliability ( $\beta_{\text{std}} = 0.186$ ). Staff who rated the accuracy and reliability of information provided by the system higher also rated the system as easier to use. This is logical since inaccurate information leads to additional work to find the correct information and correct the problem. Intuitively, system reliability PE; those who felt the system was subject to frequent problems and crashes were less likely to find the system easy to use. The presence of both of these factors in the EE model highlight the need for implementation teams to conduct extensive testing prior to go live, not just for safety reasons, but also to improve usability of the system for clinical users.

Similar to the pre-implementation results, job-related characteristics influenced EE after implementation. Consistent with the PE and *EE-learning* models, the size of their effect was smaller ( $\beta_{\text{std}} < |0.15|$ ) compared the effect of other factors in the model. Of the clinical staff, respiratory therapists rated the system as more difficult to use, while unit secretaries rated the system easier to use. This is consistent with the PE results discussed previously. Also similar to the PE results, as the number of years a person worked in their current work area increased their ratings of EE decreased slightly. Staff who worked 40 or more hours per week also rated EE slightly lower. As discussed in the PE section, this may be a result of long login times multiplied by more logins for this staff group. This is discussed further in the section on *Putting it into Practice*.

It is interesting to note that while computer experience was significant in the pre-implementation models of *EE-learning*, it did *not* influence EE for staff after implementation. This is consistent with findings in the MIS literature which found that

after implementation, spreadsheet users' level of computer experience did not affect their ratings of ease of use (Al-Gahtani & King, 1999).

### **Use of UCI methods and EMR/CPOE acceptance**

Children's employed an implementation approach based on UCI methods and principles. Thus, it was expected that good levels of user acceptance of the EMR/CPOE would be achieved. The observed results indicated that while the methods employed achieved favorable changes in and post-implementation ratings of EE, PE ratings were generally neutral. The following sections discuss these results and their implications for improving user acceptance in future EMR/CPOE implementations both in pediatric and other hospital environments.

### **Changes in PE and EE perceptions from $t_0$ to $t_1$**

User perceptions of PE and EE were assessed 8-9 months prior to and 5-6 months after EMR implementation. To examine the effectiveness of the UCI-based methodology employed to implement the system, changes in staff perceptions of PE and EE-learning from pre- ( $t_0$ ) to post-implementation ( $t_1$ ) were examined. The before/after comparisons in Table 37 indicate that overall perceptions of PE declined between  $t_0$  and  $t_1$  ( $p < 0.001$ ). Subgroup analyses indicated that this finding was consistent across campuses and 17 other subgroups including Inpatient GCA/PCA, Inpatient ICU, nurses, and others. For most subgroups where PE declined, the decline was moderate (the mean decreased by less than 0.5). However, five groups demonstrated a larger decline:

- Work area group – Other: 1.302<sup>1</sup>
- Staff position – Administration/management: 0.939<sup>1</sup>
- Yrs worked in current work area – 11 to 15 years: 0.569
- Yrs in current profession – Less than 1 year: 0.622

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<sup>1</sup> The sample size for Work area group – Other and Staff Position – Administration/Management are very low ( $n \leq 5$  at  $t_0$ ) which may partially account for the magnitude of the observed differences.

- Yrs in current profession – 16 to 20 years: 0.659

Thirteen subgroups did not demonstrate a significant change in PE. These included clinical ancillary support, non-clinical support, surgical services, and patient care technicians/technicians. Only Unit Secretaries demonstrate a significant improvement in PE scores.

While the PE results do not appear to support the conclusion that the UCI methods were successful at improving EMR acceptance, the results for *EE - learning* tell a different story. Here, in fact, almost the opposite effect is observed. Overall, the percentage of all participants who indicated that the system would be/was easy to learn significantly increased from 63.9% to 77.5% ( $p < 0.001$ ). In fact there was an improvement (increase) between  $t_0$  and  $t_1$  for all groups except three, and that improvement was significant for 15 subgroups. The three groups that did not demonstrate an improvement were:

- Non-clinical support (100% to 77.8%, note: sample size too small to run  $\chi^2$  tests)
- Respiratory therapists (No change - 50% at  $t_0$  and 50% at  $t_1$ ,  $p = 1.000$ )
- Frequency of Comp Use – Sometimes (Decline not significant - 43%  $t_0$  to 37%  $t_1$ )

The reason that PE declined or stayed neutral while *EE-learning* improved for most groups may be a function of the stage of the EMR implementation at which post-implementation perceptions were assessed. Post-implementation surveys were completed after Stage 2, an intermediate stage which includes only eMAR and ancillary orders functions. Pre-implementation assessments of PE were likely based on expectations of the entire EMR/CPOE system, while post-implementation PE is based only on a subset of the functionality (those functions that are currently ‘live’). Naturally, the impact of a subset of functions would be lower than those for the fully functional system.

Additionally, because only a subset of EMR functions are available in the system at  $t_1$ , staff had to use the paper chart for some functions and the EMR for others. These dual locations for patient information may also be contributing to the decline in PE. Note that once the full EMR functionality is implemented, paper charts will not be used which will simplify work practices and is anticipated to improve PE.

In conclusion, the observed results indicate that Children's implementation approach enabled them to exceed user expectations about ease of learning. However, the intermediate stage of the implementation prevented them from achieving similar results for PE. However, post-implementation PE ratings remained neutral or positive for most user subgroups, as discussed in the following section.

### **Favorableness of PE and EE perceptions after implementation**

Because of the implementation approach employed by Children's, it was anticipated that they would achieve favorable user acceptance of the EMR after implementation, despite being at an intermediate stage in the EMR implementation. To test this, staff ratings of PE and EE after implementation were examined to determine if the ratings were, on average, favorable. Favorable ratings are ratings greater than 3, since all of the items used to construct these scales were scored on a scale from 1 to 5 where 3 was neutral and values greater than 3 were favorable. Similar to the results reported for the change from  $t_0$  to  $t_1$ , the results for PE and EE differed, with assessments of EE being the most favorable.

Overall assessments of PE were neutral (mean = 3.048). Subgroup analyses revealed that most groups maintained this neutral assessment, with mean PE ratings that were neither significantly greater than or less than 3. However, 9 subgroups had favorable assessments of post-implementation PE (i.e., mean PE significantly greater than 3):

- Work areas:
  - ❖ Clinical ancillary support (mean = 3.49)
  - ❖ Inpatient General Care (mean = 3.20)
  - ❖ Surgical services (mean = 3.37)
- Staff position:
  - ❖ Patient care technician/technician (mean = 3.56)
  - ❖ Unit secretary (mean = 4.05)
- Yrs worked in current work area:
  - ❖ Less than 1 year (mean = 3.38)
  - ❖ 1 to 5 years (mean = 3.18)

- Yrs worked in current specialty:
  - ❖ 1 to 5 years (mean = 3.18)
- Hrs worked per week:
  - ❖ Less than 20 hours (mean = 3.63)

Five sub groups reported PE ratings that were unfavorable on average (i.e., significantly less than 3):

- Inpatient ICU (mean = 2.77)
- Respiratory therapists (mean = 2.53)
- Yrs worked in current work area:
  - ❖ 6 to 10 years (mean = 2.78)
  - ❖ 11 to 15 years (mean = 2.74)
- Yrs worked in current profession – 21 or more yrs (mean = 2.82)

Note that the lowest average PE rating was 2.53 (respiratory therapists). The fact that the lowest average PE is less than .5 below neutral (3) indicates that these perceptions are only moderately unfavorable, tending toward neutral.

In contrast to the fairly neutral ratings of PE, EE ratings after implementation were generally favorable, as evidenced by the overall average rating of 3.49, significantly greater than 3 ( $p < 0.001$ ). Subgroup analyses provided additional evidence of favorable EE perceptions. The average EE rating was favorable (greater than 3) for 32 of 33 subgroups examined and this difference was significant for 25 of these groups. Only respiratory therapists had a mean EE rating of less than 3 (2.92), but this was not significantly less than 3, indicating a neutral rating.

The observed results regarding the favorable ratings of EE and relatively neutral ratings of PE are consistent with changes in PE and EE ratings prior to and following implementation. The UCI-based implementation approach employed by Children's resulted in positive perceptions of system ease of use (EE). However, this ease of use did not consistently translate to favorable ratings of the systems' impact on individual job

performance. As discussed previously, the neutral ratings of PE may partially be due to the fact that only a subset of EMR functions was available in the system at  $t_1$ . Because of the limited functionality available at this intermediate stage in the EMR implementation, staff are required to use the paper chart for some nursing documentation tasks (e.g., flow sheets, nursing notes) and the electronic chart for other tasks (e.g., admissions questions, medication administration documentation). Managing these dual locations for patient information may be contributing to predominantly neutral, rather than positive, PE ratings since this limits the ability of the system to contribute to gains in personal efficiency and effectiveness.

Another potential contributor to the observed PE results may be the time required to login to the system. Feedback from the Department Champions and responses from open-ended questions in the post-implementation surveys indicated that many users felt it took too long to log into the system. Investigations by the Clinical Informatics team confirmed that it often took more than 10 seconds to login and in some cases, up to a minute or more. Why is this important in regards to the observed PE results? Consider that staff in Inpatient GCA had favorable PE ratings while Inpatient ICU staff had unfavorable ratings. Compared to Inpatient GCA patients, Inpatient ICU patients typically are given substantially more medications during the day. Thus, nurses in the ICU have to login more frequently to document administered medications. Thus ICU nurses incur more time spent waiting during logins, an inefficient use of their time. This time inefficiency may be contributing to their lower PE ratings since efficiency and effectiveness are part of PE.

The difference in PE ratings between staff with less versus more experience in their work area is also of interest. Staff working in their work area for less than one year had favorable PE ratings while those working in their work area longer or with more than 16 years of clinical experience tended to have less favorable ratings. Further research is needed to determine the reason for this difference. However, one possible explanation is that more experienced staff feel they are already achieving high job performance and,

thus, the system can make only limited contributions to improving their already high performance levels.

The work area and staff position differences in PE are similar to results from studies of EMR/CPOE user satisfaction and acceptance (e.g., Lærum, Karlsen, & Faxvaag, 2004; Lee, Teich, Spurr, & Bates, 1996). In most of these, the researchers linked these reported differences to differences in the degree of task-technology fit within each area. The implications of these work area and staff position differences and the role that task-technology fit plays in these differences is discussed in more detail in the following section.

### **Putting it into practice: applying UCI to improve EMR/CPOE acceptance**

The results from this study provide further evidence of the need to apply UCI methods to improve clinician acceptance of EMR/CPOE systems. The UCI methods employed at Children's helped them implement a system the users found easy to use and had neutral PE ratings, despite being at an intermediate stage in the EMR/CPOE implementation. Others have also highlighted the need to and benefits from addressing human factors and organizational considerations in CPOE (Abrams & Carr, 2005; Scanlon, 2004) and healthcare technologies in general (C. M. Johnson, Johnson, & Zhang, 2005; Karsh, 2004; Lorenzi, Riley, Blyth, Southon, & Dixon, 1997).

However, results from the technology industry in general indicate user-centered methods for technology implementation are underutilized in practice (Mao, Vredenburg, Smith, & Carey, 2005; Seffah & Metzker, 2004). One reason for this is that applying UCI is not easy. When users are involved in design, they will tell developers things they really do not want to hear. They will bring to light problems that are difficult to solve and identify new needs and requirements. Some of these problems and needs may be organizational or policy related and thus will require a policy decision instead of a technical solutions (Massaro, 1993a). However, it is better to identify and address these potential roadblocks early using UCI methods instead of after implementation when things go wrong. Using the UCI approach is worth the effort because it:

- Saves the cost and hassle of post-implementation rework
- Minimizes patient safety risks, especially during initial rollout period by avoiding major problems
- Builds goodwill between clinical users and IT staff by building relationships and communication channels

In addition to these benefits, the prominent roll that *Compatibility* and both aspects of design involvement (*Represented* and *Informed*) play in the PE and EE models emphasize the need for using UCI methods. Given the need for, benefits and challenges of using UCI, hospitals implementing EMR/CPOE system need help putting these methods into practice. The UCI framework presented here is one tool to help put UCI into practice. This section provides additional insight based on the results from this study that can help other hospitals use UCI to ensure acceptance of EMR/CPOE systems.

The results of this study demonstrate that the technology's compatibility with the work and work context is central to achieving performance benefits from using the system and that user involvement in design is critical to ensuring that work practices and needs are thoroughly understood so the system can be designed to fit with them. As the UCI framework presented previously indicates, compatibility and design involvement go hand in hand. In fact, the body of research on user-centered design methods, reviewed in the UCI section, has demonstrated that better understanding of user needs (including user, task, and context-driven needs) through user involvement and representation during design leads to the design of more effective systems. For example, methods that involve user participation like field studies and focus groups can be used to collect information about users and work practices to inform task analyses that accurately reflect users' current work practices. This knowledge can then be applied to design technology that compliments those work practices. Change management methods are applied to inform users about the changes the new technology will create and help them develop the skills they need to integrate the new technology with the way they work.

The result of this study on EMR/CPOE acceptance in two pediatric hospitals and experiences from other EMR/CPOE implementations provide valuable lessons learned about how to apply UCI to EMR/CPOE implementation. These lessons, discussed in detail in the following sections, are:

- Understand and address varying needs of clinical users, especially work area and clinical position differences driven by special patient care needs associated with the given work area and/or patient care tasks for which that role is responsible
- Ensuring compatibility does not mean work practices should not change; informed decisions based on patient care needs should determine which processes should and should not change, and the transition to new processes needs to be actively managed
- Address clinicians' patient safety concerns by actively engaging them in the design process
- Learn from seasoned clinicians; their experience may make them more skeptical about changes, but applying their knowledge and concerns to system and process design can both improve the quality of the design and foster clinician support for the implementation
- Facilitate learning to use the system effectively; provide accessible training and other learning methods to help users develop the skills they need to maximize their benefit from using the system
- Super users are super; they provide front-line, clinically-based support from a familiar face, making it easier for users to learn and achieve benefits from using the system
- Testing is crucial, not just for safety reasons; testing for system accuracy, reliability, and task-technology fit helps improve ease of use and user acceptance
- Set appropriate expectations about intermediate stages in a phased implementation; use change management methods to communicate about temporary inconveniences and when/how future stages will address them

#### Understand and address differences in needs

The work area and role-based differences observed in the current study and past studies of EMR/CPOE demonstrate that different sub-populations of the users in the hospital have different needs. While which subpopulation is different seems to vary from study to

study, their repeated presence demonstrates that variability in user needs and clinical practices is prevalent in most healthcare environments. Therefore, the EMR/CPOE implementation methodology needs to emphasize understanding and designing to meet these special needs and not take a one-size-fits-all approach.

In most past studies of EMR/CPOE user satisfaction where unit or specialty or position-based differences have been observed, the researchers linked the reported differences to differences in the degree of task-technology fit within the less satisfied group. Consider as an example Brigham & Women's Hospital. After CPOE implementation, it took physicians twice as long to enter orders (Bates, Boyle, & Teich, 1994). Medical house officers recovered some of this time through reduced time required for administrative tasks. However, this was not the case for surgeons, whose time to enter orders increased to 73 minutes a day. Surgeons dissatisfaction with this state of affairs was reflected with lower user satisfaction (Lee, Teich, Spurr, & Bates, 1996). Since these studies, the hospital has put in place measures to reduce time requirements for surgery users, but the interim period during between rollout of the system and implementation of these fixes increased the workload for surgeons.

Similarly, when a Norwegian adult-care hospital implemented EMR/HIS, medical secretaries, nurses and physicians differed in their use of and satisfaction with the system (Lærum, Karlsen, & Faxvaag, 2004). Secretaries used the system more often and were more satisfied with the system compared to nurses and physicians. The researchers identified several task-technology fit factors that contributed to these differences:

- Secretaries' work was stationary and they used an assigned computer. Nurses and physicians work is mobile and they had to use shared computers, which were not always available.
- Secretaries' tasks were generally smaller in scope and had smaller and more easily defined range of information types when compared to nurse and physician tasks. This made them more suitable to the computer-based environment

- Results indicated that scanned documents (e.g., old medical records) were problematic. Nurses and physician tasks require considerable use of these scanned documents while secretaries used little content from scanned documents.

In a more chilling example, consider results reported from Children's Hospital of Pittsburgh. While their CPOE implementation achieved overall reductions in the hospital's harmful ADE rate (Upperman, Staley, Friend, Neches et al., 2005), mortality increased for a certain class of patients, CCU inter-facility transport patients (Han et al., 2005). The increased mortality for this population was attributed to delays in care resulting from lack of fit between technology and patient care needs in this work area. Specifically, the length of time required for physicians to enter and nurses to verify medication orders resulted both in delays in starting patients on critical medications and took clinicians away from the bedside at a critical time in patient care. Thus, while longer time to enter orders was acceptable on general care units, the time-critical nature of these patient's condition meant this was not acceptable for physicians in the CCU as it could, and did, have fatal consequences for some of their patients.

As in these three studies, unit and role-based outcome differences observed at Children's in this study can also be linked back to the fit between the work and the technology. Consider the difference in results observed in this study for unit secretaries (secretaries) as opposed to respiratory therapists (RTs). Secretaries had the highest overall PE and EE ratings after implementation and RTs the lowest. These ratings are consistent with the different impact the system implementation had on these groups. For secretaries, their work practices changed very little. The primary change was that the old, difficult to use system (SMS) was replaced with an easier to use system with a graphical interface (Epic). There were several new types of orders that they had to enter, but their core processes stayed the same and they were highly accepting of the new system.

In contrast, implementation of the EMR resulted in substantial changes for the RTs. Prior to implementation respiratory orders were managed manually, not in a computer system. This enabled and fostered substantial variability in work practices both across campuses

and across units within each campus. Transferring to the electronic system required a certain degree of standardization, thus RTs had to change some of their established work practices. Prior to implementation, RTs wrote down details of treatments on paper and a business person keyed in all of the charges. Once the system went live, charges were automatically generated when the order was submitted. However, this created one big change for RTs and one big problem. The change was the chart structure for respiratory orders had to be changed to accommodate automatically generating charges, which created an additional learning burden on the users since they had to learn a new chart structure in addition to the new system and work processes.

The problem automatic charging created was related to patient care requirements. If an RT went to give a patient a scheduled breathing treatment and clinical care guidelines indicated the patient did not need it (i.e., their breathing was good), the treatment was cancelled. However, since charges had already been generated in the system, this now required someone to go in and back out the charges. Prior to implementation, charges were only entered after the treatment was given, so backing out charges was never necessary. This problem created difficulties as the RT had to coordinate with the secretaries or the patient's nurse to have them back out the charges or back out the charges themselves, creating an additional workload burden on the RTs. This difficulty was reflected in their lower PE and EE scores.

These examples demonstrate that in healthcare different units and roles have different needs and implementation plans need to ensure that each area has people 'at the table' during design and testing to ensure needs are represented in the system design. While there were some RTs involved in design at Children's, post-implementation feedback from the implementation team indicates that they did not have RTs from enough different area represented, thus they did not uncover many process differences and special needs until after implementation. While the implementation team took great pains to resolve as many of these issues as possible, this retrofitting took time and some issues cannot be addressed until future phases. Making changes to address issues identified after go-live is more difficult and costly than identifying and addressing them prior to go-live. Thus it is

important to have all units and roles adequately represented during design to ensure that each group's specific needs are met *at go-live*, instead of requiring changes once the system is in place. It is especially important to identify groups that have highly variable processes, like the RT's at Children's, and ensure that this group has a diverse set of users involved in the implementation to ensure that this variability is adequately understood and addressed by the implementation team.

These role and unit-based differences combined with the important influence of compatibility on PE also highlight the need for systems to be designed so that they are adaptable to the needs of different groups. Specifically, EMR vendors need to examine these differences and design their systems to be adaptable not just at the global level, but also for specific user groups as well. This will give local implementation teams greater flexibility in designing the system and work processes to meet different groups' needs.

#### Ensuring compatibility does not mean work practice should not change

The observed results of this study and the above section highlight the importance of designing the system to be compatible with work practices and to meet the special needs of different units. However, this does not mean that work practices should not change. In some cases, the current work practices may be inefficient or unable to support taking full advantage of the new technology. In these cases, work redesign methods should be applied to develop proposed workflows that better take advantage of the new technology while not placing undue additional burden on the user.

Understanding the current work practices is the first step in determining what should change and what should remain the same in the new work practice design. For example, use UCI methods to gather information from representative users regarding what current work practices are and use task analysis methods to synthesize this information. Pay special attention to differences in work practices across units/roles. When these differences are identified, uncover the reason for this variability. Is there a valid (e.g., patient care-driven) reason that creates a need to support the variability? For example, is the time-critical nature of this unit's patients the reason they use a different process? If

so, the system needs to provide the flexibility to support this unit's special process needs. However, if the only reasons for having different practices are 'we've always done it this way' and/or 'I like to do it my way', this is a sign that standardizing on a best practice is probably warranted. Using a consistent process will simplify system development and initial and on-going training. Also, identifying and adopting a best practice will have the added benefit of improving quality across the organization as a whole.

Children's recent RT experience provides examples of both cases. Much of the process variability from unit to unit was a result of different RT work styles and preferences. Thus, working with representatives from various units to standardize many of these processes would have simplified system requirements and made training RTs to use the system easier. So in this case, redesigning processes was probably warranted. However, some variability in the RT order process is necessary and the system must be flexible enough to easily handle it. For example, an RT should skip a scheduled treatment when patient care practices indicate that is what is best for the patient. Thus the system needs to be designed to effectively handle these cases since they happen relatively frequently and are necessary to provide the best care possible to the patient. The system should have been designed to avoid the extra steps needed to back-out charges for skipped therapies. While vendor constraints prevented avoiding this completely, automated routines and other steps should (and in some cases were) put into place to streamline this process and reduce the time and effort burden on users. When such new steps are required, it is important to clarify who is responsible for completing new steps and define communication and coordination processes to simplify completing them. For example, designing the system so that when RTs cancel an order they can send an automated alert to the appropriate person (e.g., an accounting clerk) to back out the charges would streamline coordination for this step.

In those instances where significant work redesign is warranted to achieve operational goals or is necessitated due to system constraints, it is important to apply change management methods to ensure that users understand the need to change work practices (as evidenced by the moderate effect of *Perceived Need – Efficiency* in the staff PE

model). Specifically, the team needs to communicate with users to help them understand the need for the process change and training and learning initiatives need to teach users both the new work processes and new technology in an integrated manner. Note that the implementation of CPOE in the Ohio State University Health System demonstrates that even when workflow changes are required (e.g., due to standardization), successful IT adoption can be achieved when clinicians are actively involved in the work redesign effort and strong a focus is placed on understanding and meeting clinical process needs (Ahmad et al., 2002).

#### Address patient safety

The results presented in this study indicate that for both physicians and staff, those who have poorer current perceptions of certain aspects of patient safety have higher pre-implementation expectations of the benefit of EMR/CPOE (PE for staff, PE-safety for physicians). Thus, one way to foster pre-implementation acceptance is to emphasize expected patient safety improvements. Then, the implementation approach needs to ensure that these expected (and communicated) patient safety improvements are achieved. One important way to ensure that patient safety benefits are achieved is by ensuring that clinical users' needs are represented during the design process.

*Design Involvement – Needs represented* had a significant influence both on staff pre-implementation PE (which incorporates items on safety) and on physician PE-safety. These front line clinicians are intimately familiar with care processes and the care needs of their patients and requirements based on these needs and processes need to be accounted for in the system design. The best way to accomplish this is to involve users in the design. This way, the implementation team benefits from the clinicians' knowledge and experience and the clinicians' gain confidence that the system is going to meet their patients' care needs. Before they accept an EMR/CPOE system, physicians and other clinicians want to be sure that the system fosters use of best practices for the care of their patients. As discussed previously, a study of the impact of CPOE on physician prescribing practices indicated that CPOE guidelines/alerts were acted on most often when the system recommended practices that were widely accepted by physicians and

were *not* viewed as changes to care plans (Teich et al., 2000). They emphasize that it is important that physicians remain in control of patient care while using the system to automate ‘rote’ functions. The best way to determine which functions should be automated and which care guidelines/rules will have the best effect on patient care is to talk to the clinicians. Engaging them in this manner ensures that design decisions will promote better patient care and helps foster clinician confidence that the system will improve patient safety.

#### Learn from seasoned clinicians

For both physicians and staff, clinical experience affected pre-implementation PE and, for staff, post-implementation PE and EE. These results indicated that more seasoned clinicians (i.e., more years of clinical experience or more years in their current work area) were less positive about PE and EE. In other words, they are tougher critics when it comes to the system. This is likely due to their years of clinical experience and iterative improvement of their own work practices through the years to ensure that they are as effective as possible. As senior personnel, they are often in a position to be opinion leaders who can either foster support for or build substantial roadblocks to implementation. Therefore, it is especially important to engage these users during design.

Engaging experienced clinicians is difficult. Because of their array of clinical experiences, they can come up with exception cases and problematic use case scenarios. This can, and often does, drive designers crazy because it often translates to new system requirements. But engaging experienced clinicians is worth the effort because:

- Integrating their year of experience about what works and what does not into both the system and work process design enables other users (especially less experienced users) to adopt best practices, thus improving the overall performance of the organization
- Actively engaging them in the design process fosters a sense of system ownership in these potentially ‘tough critics’, so they become an advocate of the system instead of a detractor

### Facilitate learning to use the system effectively

In order to achieve the expected benefits of using the EMR/CPOE for both the individual and the organization, clinicians need to develop the skills and knowledge necessary to effectively use the system. Thus, training and other learning activities are crucial to success. The pre-implementation *EE-learning* results indicate that certain user groups were more concerned about ease of learning. This reflects the special needs of particular groups when it comes to learning the system. Implementation teams need to identify and account for these differences when developing training and rollout support plans. For example, at Children's, physicians who work more than 60 or less than 20 hours per week are more concerned about how easy it will be to learn to use the system. Thus, as training plans for CPOE are developed, special training and/or learning initiatives need to be developed to target these groups.

In this study, staff concerns about scheduling training also affected pre-implementation feelings about how easy the system would be to learn. This highlights the need to provide training classes of reasonable length in easily accessible locations and a variety of times in order to make it easier for users to attend training and, thus, make learning the system easier. When more extensive training is needed, breaking the training up into multiple shorter classes or using computer-based (any time, any where) training for portions of the training may also make finding time to attend training sessions easier for users. For example, Children's provided computer-based training on basic computer skills so that staff with little computer experience could complete that training at their convenience prior to attending the Epic training class. Also, training classes were offered at three different locations during days and evenings six days a week for eight weeks to make it easier for staff to find time to attend the training.

### Super users are super!

The results for both PE and EE demonstrate the important role that super users play in both helping users learn the system and maximize their benefits from using the system. In fact, after implementation *Support – personnel*, the ability of super users to support users, was the strongest single influence on EE ratings. Several factors contribute to their

effectiveness including: 1) they on the unit with the users, readily available when a 'help' situation arises; 2) many have both clinical and system expertise; 3) they are a familiar face, making it easier to ask them for help; and 4) they can work with users one-on-one to provide customized support and training.

Other successful EMR/CPOE implementations have also used super users to provide front line support (Cordero, Kuehn, Kumar, & Mekhjian, 2004; Upperman, Staley, Friend, Benes et al., 2005). One study also cited having fewer super users on the unit as a factor contributing to lower acceptance of a nursing system on one unit compared to three other units in the same hospital (Ammenwerth, Mansmann, Iller, & Eichstadter, 2003). In one Norwegian hospital, many physicians and other clinical users did not attend the mandatory EMR training sessions (Lærum, Karlsen, & Faxvaag, 2004). Thus, for the first month they used a network of super users on the units and medical secretaries trained as ambulant trainers to teach physicians and nurses the system on the units.

At Children's super users staffed at go-live were not assigned any patient care responsibilities in the first 7-10 days after rollout. This enabled them to focus 100% on providing one-on-one support to users and communicating between the implementation team and users as issues arose and were resolved. In addition to providing support at go-live, super users also completed training first and provided feedback on how to improve the training courses and tip sheets for other users. They also assisted trainers in one or more regular user training class, providing clinical expertise to answer user questions during class. This repeated training reinforced what they learned in the super user class and helped prepare them to answer user questions and facilitate user learning during rollout.

#### Testing, testing, testing

EMR/CPOE implementers are aware of the safety critical nature of these systems, thus rigorous testing should occur prior to rollout. However, this testing is not just important from a patient safety perspective. The post-implementation model of EE indicates that accuracy and reliability of information and system reliability also help make the system

easier to use. Thus testing the system for accuracy and reliability and resolving identified issues prior to rollout helps make the system more usable *and* safer.

However, tests for accuracy and reliability are not the only components of a comprehensive test plan. Recall that support for decision processes (including compatibility) is a key determinant of system effectiveness from the user's perspective (PE). Therefore testing during the systems lifecycle should address task-technology fit as well. For example, use prototypes and walk-throughs at several points in the design stage to get user feedback on task-technology fit and proposed changes to work practices. Identifying and addressing big issues at these early stages is much less painful and expensive than uncovering them at the end of development or, worse, after rollout. In later stages of design and during development, actual user testing with high fidelity prototypes (or portions of the in-development system) can also provide early feedback on both accuracy and task-technology fit. Additionally, including formal user acceptance testing (UAT) during the testing stage at the end of development is often useful. Having users test the system helps to identify bugs/problems that the implementation team might miss and serves as great change management tool – positive user feedback can be formally or informally communicated to other users to build support for and excitement about the system.

#### Set appropriate expectations for intermediate stages

As the results presented here indicate, when a staged implementation is used, the intermediate stages do not achieve the full system benefits being communicated to the user community. Prior to implementation of these stages, make users aware of what the benefits and limitations of the intermediate stage will be. It is important to set accurate expectations with users, especially regarding any temporary pain points associated with the intermediate stage. For example, in the Children's implementation staff were informed that during the interim period paper charts would be used for some documentation tasks while the electronic chart would be used for others. However, they were also informed that this was temporary until the next stages go live, which was scheduled to be within 12-18 months. To simplify work processes during this

intermediate stage, each type of documentation only resided in one place – either the paper chart (e.g., flow sheets) or the electronic chart (e.g., MAR). Results from this study indicate that user PE ratings declined moderately from  $t_0$  (when they were likely thinking about the whole system) to  $t_1$  (when they were thinking about the intermediate stage that was currently live). However, the PE ratings remained neutral or positive for most user groups and user support for and engagement in the implementation project has remained high. Actively managing expectations about the interim period has helped maintain project momentum and user support.

Important points to communicate about these temporary inconveniences are: What implication do they have on care processes? How long will they affect users? What is being done to limit any negative impact? Communicating this information is important from a change management perspective as it can prevent new barriers to adoption of future stages from developing. Emphasizing the temporary nature of pain points and the system stages whose implementation will relieve them helps create positive energy around future implementations as opposed to negative energy. The goal of these change management activities is to make sure that instead of users saying “Things are bad now, I bet the next stage will make it even worse” the users are saying “I can’t wait for the next stage to go live so that this will be easier”.

### **Results summary: guidelines by discipline**

The following guidelines are provided to further facilitate putting the results of this research into practice. Three sets of guidelines are provided targeting each of the primary disciplines to which this research contributes: healthcare information technology, human-computer interaction & user-centered design, and change management.

#### **Healthcare information technology guidelines**

- Use the UCI framework as a guide for integrating user-centered design methods and change management into the system development lifecycle, especially related to determining how and when to get clinicians involvement in the implementation.

- Include a change management resource on the implementation team so that they are fully aware of project happenings and so they can manage communications and other change management activities during the course of the HIT implementation.
- Engage a variety of clinicians in the implementation to ensure that work area, staff position and specialty-specifics needs and current process differences are identified and addressed. Also be sure to engage more experienced clinicians so the HIT project can learn from and take advantage of their experiences.
- Project plans should provide time and resources for examining and documenting current work practices/processes and defining new work processes that take advantage of the HIT.
- In defining work processes related to the technology,
  - Design new work processes to be compatible with patient care needs and the way that clinicians work.
  - In instances where current practices are highly variable, standardize on best practices unless patient care needs dictate that variability should be supported
- Use user-centered design methods from the UCI framework to involve users in early prototype reviews and in system testing to obtain feedback on potential design problems and other issues so that they can be resolved prior to rollout.
- Budget and plan to meet user training and support needs. Well trained and accessible super users on the unit are an especially valuable for training and support.

### **Human-computer interaction & user-centered design**

- Ensure that change management efforts are integrated into the design lifecycle and plans and execution. This can be accomplished by completing a UCI plan and integrating a change management lead on to the implementation team.
- Applying user-centered design methods is challenging in HIT due to high variability among processes and unit/role needs. Therefore, project plans need to incorporate methods for engaging a large, diverse set of users.
- Design evaluations need to emphasize patient safety concerns in addition to usability concerns. In some cases, there may be a trade off between usability principles (e.g., efficiency) and patient safety (e.g., extra verifications).

- Due to the importance of compatibility to clinician acceptance of HIT, it is important for user feedback methods that involve walkthroughs and demonstration to integrate both the technical system/interface and the new work processes. This ensures that the users develop a more comprehensive understanding of the impact of the HIT on their clinical work so that they can provide more informed feedback to the implementation team.

### **Change management**

- Ensure that change management efforts are coordinated with user-centered design activities in order to leverage design activities as change management opportunities.
- Because being informed throughout design helps foster clinician IT acceptance,
  - Use a variety of mechanisms to communicate important information with various user groups.
  - Revise communication plans as new situations arise during the implementation.
  - Use communication to set appropriate expectation about the implementation process, the system (i.e., what it will and *will not* do), and process and policy changes related to the system.
  - Provide opportunities for two-way communication between the user community and the implementation team in order to build more collaborative (and less adversarial) relationships between the two communities.
- Identifying barriers to HIT adoption and acceptance early in the implementation life cycle is crucial in order to provide the implementation team time to address barriers that affect system or work process design.

### **Results summary: answering the proposed research questions**

The results discussed in the previous sections provide support to answer the research questions posed at the beginning of this study. The results are summarized below in the context of each research questions and supporting evidence (or lack thereof) for each experimental hypothesis is reviewed.

1. How do clinical staff perceptions of safety relate to aspects of EMR/CPOE acceptance?

*H1.1 Due to the dual priorities in healthcare (quality of care and operational effectiveness), Performance Expectancy will consist of two sub-components: one related to the impact of the technology on patients/patient care, and one on user's individual performance.*

The results provide support for this hypothesis in the physician cohort, but not in the patient care staff population. The factor analysis for physicians prior to implementation resulted in two PE factors: impact on individual job performance (PE-job) and impact on patient safety (PE-safety). Conversely, for staff items related to these two areas contributed to only one factor. It is likely that this difference is related to the dichotomous impact of EMR/CPOE from the physician perspective (e.g., improved safety vs. likely increase in time to enter orders) and more consistent impact of EMR/CPOE from the nursing perspective (e.g., improved safety and neutral to positive effect on personal efficiency).

*H1.2 Prior to implementation, staff perceptions regarding aspects of culture of safety in the hospital will contribute to Performance Expectancy and expected ease of learning, an aspect of EE.*

The results provided only partial support for this hypothesis. Correlations demonstrated low to moderate relationship between PE and all four safety aspects prior to implementation for both staff and physicians. *EE- learning* was only significantly correlated with *Staffing - staff* for both staff and physicians. Despite these significant correlations, the linear and logistic regression models of PE and *EE- learning* prior to implementation indicated that factors other than safety perceptions are the primary influences on user perceptions of PE and EE. For staff, none of the safety factors were significant predictors of either PE or *EE- learning*. For physicians, only *Transitions* was significant in the *PE-safety* model and only *Staffing – staff* was a significant predictor of *EE- learning*. In both of these models, one or more other predictors had a stronger influence than the safety factor on expected ease of learning. None of the safety factors was significant in the *PE-job* model.

*H1.3 After implementation, staff perceptions regarding aspects of culture of safety in the hospital will contribute to Performance Expectancy and Effort Expectancy.*

The results provided only partial support for this hypothesis. Despite these significant moderate correlations, the linear regression models of PE and EE did not identify any of these aspects of safety as significant predictors. Thus, while both post-implementation perceptions regarding patient safety are related to PE and EE, factors other than safety culture are driving user perceptions of PE and EE for staff.

*H1.4 Prior to implementation job/ user and systems implementation factors in addition to culture of safety will contribute to Performance Expectancy and expected ease of learning, an aspect of EE.*

Evidence supporting this hypothesis was observed for both staff and physicians. While there were similarities in the models, several factors differed in the models. The following job/user and systems implementation factors were significant predictors in each model:

Staff PE model:

- ❖ *Job/user:* staff position (Respiratory Therapist); years of clinical experience (21+ years); and work area (Inpatient GCA)
- ❖ *Systems implementation:* compatibility; perceived need (both errors and efficiency); and design involvement – needs represented

Physician PE-job model:

- ❖ *Job/user:* Years of clinical experience (16-20years)
- ❖ *Systems implementation:* compatibility; and design involvement – needs represented

Physician PE-safety model:

- ❖ *Job/user:* N/A
- ❖ *Systems implementation:* compatibility; design involvement – needs represented

Staff EE-ease of learning model:

- ❖ *Job/user:* work area (Inpatient ICU); computer experience
- ❖ *Systems implementation:* perceived need – efficiency; design involvement – informed; autonomy – privacy; and difficulty scheduling training

Physician EE-ease of learning model:

- ❖ *Job/user*: hrs per week (<20 and more than 60); computer experience
- ❖ *Systems implementation*: design involvement – informed

The influence of *compatibility* and *design involvement – needs represented* was consistent across all three PE models (staff and physician PE-job and PE-safety). Also, *years of clinical experience* was present in both the staff model of PE and the physician PE-job model. While the experience group that was a significant predictor differed between staff and physicians, both represented highly experienced clinicians (21+ years for staff and 16-20 years for physicians). Ease of learning, *computer experience* and *design involvement - informed* demonstrated positive influences in both the staff and physicians models.

It is also interesting to note that *design involvement* affected both PE and EE, though different aspects of *design involvement* influenced each (*needs represented* for PE and *informed* for EE). For staff, *perceived need – efficiency* also influenced both PE and EE.

*H1.5 After to implementation, job, user, and systems implementation factors in addition to culture of safety will contribute to Performance Expectancy and Effort Expectancy.*

Evidence supporting this hypothesis was observed. Recall that post-implementation perceptions only examined staff. The following job/user and systems implementation factors were significant predictors in each model:

PE model:

- ❖ *Job/user*: hrs per week (40 or more); staff position (Unit Secretary); years worked in current work area; and work area (Inpatient ICU)
- ❖ *Systems implementation*: support for decision processes; EE; communication - facilitate sharing info.; support - personnel

EE model:

- ❖ *Job/user*: hrs per week (40 or more); staff position (Unit Secretary, Respiratory Therapist); years worked in current work area; and system expertise

- ❖ *Systems implementation*: support – personnel; output quality – accurate, reliable information; and system reliability

Several factors influenced both PE and EE of staff after implementation. These factors were *support – personnel*, *years worked in current work area*, *staff position (Unit Secretary)*, and *hours per week (40 or more)*.

2. How does the relationship between safety perceptions and perceptions contributing to EMR/CPOE acceptance change as users gain experience with the system?

*H2.1 The size and, in some cases, the direction of the relationship between components of safety culture and Performance and Effort Expectancy will differ after users gain hands-on experience with the system.*

Partial support was provided for this hypothesis. Examining the results of the correlations that PE and EE have with the four aspects of safety, several changes were indeed observed. The correlation that PE demonstrated with staffing, hospital teamwork, and transitions remained steady from  $t_0$  to  $t_1$ , but the significant correlation between PE and unit teamwork at  $t_0$  diminished to the point of insignificance at  $t_1$ . For EE, the correlation with staffing remained similar from  $t_0$  to  $t_1$ . The relationship between EE and the remaining three safety factors changed. Prior to implementation, there was no correlation with unit teamwork, hospital teamwork, or transitions; but after implementation these items demonstrated low-to-moderate correlations with EE.

While the correlation results provide support for this hypothesis, the results of the regression models present conflicting evidence. Both prior to and after implementation, none of the four aspects of patient safety were present in the staff models for PE or EE. This result fails to support this hypothesis, as the effect in the regression models remained the same (no effect) at  $t_0$  and  $t_1$ .

Thus, the relationship that PE and EE have with the four aspects of safety change over time, but they were consistently low enough at both times that they were not significant predictors of either variable at either time. Note that these results may differ for physicians once implementation of CPOE is complete. Staffing (staff) and transitions were significant in the physician models EE-ease of learning and PE-

safety, respectively. Future research will examine whether these influences continue after implementation as well.

3. How do perceptions related to EMR/CPOE acceptance change during the implementation life cycle when using a user-centered implementation approach?

*H3.1 User perceptions of Performance Expectancy will improve between  $t_0$  and  $t_1$ .*

These results fail to support this hypothesis for all groups except unit secretaries. Unit secretaries reported a significant increase in PE from  $t_0$  to  $t_1$ . 13 subgroups reported no significant change in PE and 19 subgroups reported a significant decline in PE. Anecdotal evidence from sunset reviews and discussions with implementation team members indicates this result may be due to one or both of the following factors: 1) post-implementation surveys were conducted after an intermediate system rollout which required users to use both the paper chart and EMR for clinical tasks, thus diminishing the positive impact on PE during the interim period until the full EMR is implemented; and 2) lengthy login times and other login difficulties limited the impact of the system on efficiency.

*H3.2 User perceptions of expected ease of learning, an aspect of EE, will improve between  $t_0$  and  $t_1$ .*

In contrast, the observed results provide substantial support for this hypothesis. User perceptions of *EE-learning* improved from pre to post-implementation overall ( $p < 0.001$ ). Additionally, 15 of 33 subgroups demonstrated a significant improvement in ease of learning from  $t_0$  to  $t_1$ . 15 of the remaining 18 subgroups also demonstrated an improvement, although this change was not significant. None of the subgroups demonstrated a significant decline in expected ease of learning.

4. Does use of user-centered implementation (UCI) methods result user acceptance of EMR and CPOE?

*H4.1 User perceptions of Performance Expectancy will be positive (average greater than 3 on a 1 to 5 scale) after implementation ( $t_1$ )*

Mixed results related to this hypothesis were reported. Results indicated that perceptions of PE were neutral following implementation for staff overall and for 25 of 39 subgroups examined. 9 subgroups reported favorable perceptions of PE (significantly  $> 3$  ( $p < 0.05$ ) on a scale from 1 to 5 where 3 is neutral and 5 is highly favorable). Most of these were moderately favorable (3.18-3.56), while one group, unit secretaries, was more favorable (4.05 on a scale of 5). This evidence provides support for this hypothesis. However, 5 subgroups reported perceptions that were unfavorable (significantly  $> 3$ ,  $p < 0.05$ ). Note that all of these groups were only moderately unfavorable, with no group averaging below 2.5.

*H4.2 User perception of Effort Expectancy will be positive (average greater than 3 on a 1 to 5 scale) after implementation ( $t_1$ )*

Results provided substantial evidence for this hypothesis. Overall staff ratings of EE after implementation were 3.49, significantly greater than 3 ( $p < 0.01$ ) on a scale from 1 (very poor) to 5 (very good) where 3 is neutral. Similarly, average EE ratings for 31 of 39 subgroups were also favorable (significantly  $> 3$ ,  $p < 0.05$ ; range: 3.28-4.12). The remaining subgroups had neutral average EE ratings (2.92 – 3.48).

5. Based on the staff perceptions observed here, how can UCI be enhanced to improve future implementations of EMR/CPOE and, potentially, other large scale clinical information systems implementations?

*a) Based on the results in Q1 and Q2, do UCI approaches need to be modified to ensure that user concerns about patient safety are adequately addressed?*

The results of this study indicate that the following steps can help ensure that patient safety concerns are addressed:

- i) Make sure that staffing levels are adequate, especially during rollout and the transition period immediately following rollout. Also consider scheduling rollout during a time period that usually has lower census levels and/or consider temporarily suspending elective surgeries during the transition period. All of these factors reduce the patient care workload during the transition period, giving clinicians the bandwidth to learn to use the system effectively.

- ii) Involve clinicians from various roles and specialties in design to ensure that patient safety concerns are identified and addressed prior to rollout. Clinician involvement is especially important when defining automated rules and guidelines related to patient care.
- iii) Through focus groups and/or in individual interviews with staff, walk through future processes for key handoffs and transitions (e.g., shift change, patient transfer between units, etc.) using a prototype or storyboard. Use these walkthroughs to ensure that system use facilitates effective transitions or, at a minimum, does not introduce new opportunities for things to ‘fall through the cracks’.

*b) Based on the results in Q3 and Q4, are there particular subgroups of clinical staff that have special needs which UCI can be enhanced to address?*

Each work area (unit) and position potentially has special needs. UCI methods need to apply a macro/micro approach to ensure that both global (cross-unit/cross-specialty) and local (specific unit or specialty) needs are adequately met. At the macro level, ‘global’ user groups need to be engaged in decisions related to big picture/issues that affect multiple groups (e.g., login process, time-out requirements, etc.). Micro level work groups should examine work practices and needs in detail for a given group. Using this macro/micro approach enables the implementation team to use the ‘global’ groups and processes to negotiate standardization across groups when appropriate while micro level activities ensure that non-negotiable requirements for each area are understood and addressed. For example, in the ICU time-critical patient needs mean long order entry times and other factors that delay getting medications and other treatments to patients are non-negotiable. However, whether the default time for daily med doses is 8 am or 9 am is probably negotiable across units.

## CONCLUSIONS

Designing EMR/CPOE systems that are usable within the clinical work context is important because it enables clinicians to focus time and energy on the patient, rather than on using the system. However, accomplishing this in practice is difficult given the complexity of these systems and the dynamic clinical care processes they must support. The present research endeavored to provide EMR/CPOE implementers knowledge and tools to accomplish this in practice by extending the knowledge base on technology acceptance and system implementation methods employed to achieve high-levels of user acceptance. This research reviewed best practices from user-centered design, change management, and past EMR/CPOE implementations to develop a framework for user-centered implementation. Next, factors that contribute to clinician acceptance over time of EMR/CPOE technologies were studied in a pediatric hospital system as it implemented EMR with CPOE. These findings on clinician acceptance were then applied to provide further guidance on how to apply UCI methods to improve clinician acceptance of EMR/CPOE systems.

This research made contributions to the body of knowledge in three fields: healthcare information technology (HIT), human-computer interaction/user-centered design, and change management. The contributions to each field are summarized below. Note that cross-disciplinary contributions are listed under each field to which they apply and are highlighted with an asterisk (\*).

### **Healthcare information technology**

- The study findings indicate that the EMR/CPOE's compatibility with work processes and clinician involvement in design involvement are crucial to ensuring acceptance of the technology. This finding provides quantitative evidence supporting implementation best practices noted in other EMR/CPOE studies. This finding also emphasizes the importance of applying user-centered methods to implement EMR/CPOE systems.
- Lessons learned and guidelines for applying UCI to implementation of HIT were developed based on study findings and previous research.\*

- From a methodological standpoint, a healthcare technology-adapted performance expectancy scale was tested and validated and an effort expectancy scale from the MIS/HCI literature was pilot tested and validated for application to EMR/CPOE. In addition to these scales, the current study identified the need for scales that address the level of user design involvement, degree of system support for clinical decision making, and the system's impact on communication.\*

### **Human-computer interaction & user-centered design**

- The UTAUT model of technology acceptance was extended and applied to acceptance of EMR/CPOE. The results demonstrate that in addition to factors previously identified in the technology acceptance literature, patient safety considerations play a significant role in acceptance of EMR/CPOE systems by clinicians. This study integrated this patient safety aspect into the acceptance model and identified those factors that contribute to EMR/CPOE acceptance in pediatric hospitals both prior to and following implementation.
- This research presented a framework for user-centered implementation (UCI) which combines methods and best practices from user-centered design and change management and links them to the systems implementation lifecycle. Evidence from previous EMR/CPOE studies and the present research emphasizes the need to apply UCI methods and principles when implementing EMR/CPOE systems. This framework was supplemented with additional practical advice on applying UCI based on the EMR/CPOE acceptance results observed in the present study.\*
- Guidelines targeted toward user-centered design practitioners for applying UCI were presented.
- From a methodological standpoint, a healthcare technology-adapted performance expectancy scale was tested and validated and an effort expectancy scale from the MIS/HCI literature was pilot tested and validated for application to EMR/CPOE.\*

## **Change management**

- This research presented a framework for user-centered implementation (UCI) which combines methods and best practices from user-centered design and change management and links them to the systems implementation lifecycle.\*
- Guidelines targeted toward change management practitioners for applying UCI were presented.

While the findings presented here are in the context of pediatric inpatient hospitals, based on their consistency with findings from general care hospitals it is expected that many of the findings on clinician acceptance of EMR/CPOE will translate to other clinical environments as well. However future research needs to explore this. The UCI framework developed for this research, however, is based on methods whose effectiveness in practice has been demonstrated in a number of industries and systems, including this pediatric EMR/CPOE implementation. Therefore, the UCI framework for systems implementation can be applied to a broader array of system implementation projects, not just EMR/CPOE.

## **Areas for future research**

There are a number of areas for future research that can build on results from this study. Areas of particular interest are described below.

### **Similarities and differences between staff and physicians**

After implementation of CPOE at Children's, similar research on changes in PE and EE-learning over time should be examined to determine if changes observed for staff are also observed for physicians. Specifically, this research should examine changes to correlations with safety factors, differences between pre- and post-implementation models of PE, and changes in PE and *EE-learning* ratings before and after implementation. In addition, levels of PE and EE after implementation should be examined to determine whether or not they are favorable. These results should be compared to the staff results presented here to identify similarities and differences.

### **Further examine the effectiveness of using UCI methods in healthcare**

While the UCI framework has solid foundation in the UCD and change management literature, further validation of their effectiveness in the implementation of healthcare technology is needed. First, because the results presented here represent acceptance of technology at an intermediate stage of implementation, staff acceptance needs to be examined again once the full implementation is complete. Also, to further improve the accuracy of the models developed here, completing a follow up study that employed a paired sample design would be useful. This would enable before-and-after comparison of participants' responses which would reduce the variability in the model and enable explicitly examining the relationship between pre-implementation factors (e.g., design involvement) and post-implementation acceptance. In addition, future studies should examine the effectiveness of applying the UCI framework to implementation of EMR/CPOE in other healthcare organizations (e.g., adult care hospitals, outpatient clinics, etc.) and for other technologies (e.g., patient decision support systems, clinical decision support systems, etc.).

### **Measuring EMR/CPOE acceptance and factors that influence acceptance**

The factor analyses in the present research indicate that the structure of performance expectancy differs between physicians and staff. For staff, PE is one construct that encompasses both personal job performance and patient safety. For physicians two distinct constructs, one addressing personal job performance and the other patient safety, were observed. Future research needs to investigate the reason for this observed difference and determine if it persists in the contest of other healthcare technologies.

The factor analyses also provided evidence of the existence of three additional constructs that affect user acceptance and potentially other outcomes related to implementation of EMR/CPOE. These constructs are: 1) design involvement, 2) communication, and 3) support for decision processes/compatibility. Future research needs to further develop scales to measure these constructs and further examine their relationship to EMR/CPOE implementation outcomes like user acceptance.

### **The relationship between Performance Expectancy and aspects of safety**

The regression models on PE indicated that for physicians and staff an increase in the perceived need for CPOE related to improving patient safety increases pre-implementation PE. Contrary to these findings, however, staff demonstrated a positive relationship between PE and *Transitions*. In other words, staff who tended to think hospital transitions and handoffs were problematic (which would imply a need to alleviate these problems) also had lower ratings of PE. Further research needs to examine the cause of these seemingly conflicting results. Additionally, future research could examine how well use of the EMR facilitates resolving problems related to handoffs and transitions and cross-unit coordination. This would provide further insight into the nature of the relationship that PE has with both *Transitions* and *Hospital Teamwork*.

### **Examine causes of the observed influence of clinical experience**

The difference in PE ratings between staff with less versus more experience in their work area is also of interest. Staff working their work area for 5 or less years had favorable PE ratings while those with 6 to 15 years in their work area or with more than 20 years of clinical experience had unfavorable ratings. Further research is needed to determine the reasons for this observed difference.

### **Examine workflow issues for different groups**

This study and past EMR/CPOE difference have highlighted the variability in work processes for specific work areas and/or roles. It would be useful to conduct an ethnographic study that examines these differences and the underlying sources of these differences. Better understanding the sources of these differences could be applied to:

1. Help implementation teams determine what variability in work processes needs to be supported and what can potentially be changed (standardized)
2. When variability is warranted, this knowledge would help implementation teams design technology and work processes to better support required variability
3. When standardization and work process redesign is warranted, this knowledge would help teams target change management methods to facilitate adoption of the change.

### **Develop a model for predicting acceptance based on system implementation factors**

The models presented in this research and the previously identified directions for future research could contribute to the development of a model for predicting clinician acceptance of healthcare technology. Specifically, this model could use characteristics of the system implementation (e.g., design involvement), the user population (e.g., computer experience, clinical experience), and the work processes (e.g., degree of variability, fit with use of proposed technology) to predict how well the new technology will be accepted. By using this predictive model, implementation teams could make mid-project course corrections to improve the likelihood that the technology will be accepted by clinical users.

## APPENDIX A. SURVEYS

### t<sub>0</sub> Staff Pre-implementation Survey

#### Instructions

Sections A through K ask for your opinions about patient safety issues, medical errors, event reporting, and the upcoming launch of EpicRx, eMAR, and CPOE at Children's. This voluntary survey will take about 20 minutes to complete. If you do not wish to respond to an item, you may leave it blank. However, please respond to as many items as possible to ensure that the survey results can be used to improve the Epic implementation. Please respond to each item in the survey. As you answer the questions, please keep in mind the following:

- **There are no right or wrong answers.**
- **Don't think too long about each question – your first instinct is best.**
- **Some of the questions may seem wordy or repetitive – they are asked this way for specific reasons.**
- **If you don't understand a question, please don't answer it.**
- **Please, give your own responses and don't discuss the questions with others before you answer them.**

- *An “event” is defined as any type of error, mistake, incident, accident, or deviation, regardless of whether or not it results in patient harm.*
- *“Patient safety” is defined as the avoidance and prevention of patient injuries or adverse events resulting from the processes of health care delivery.*

**After completing the survey**, please use the envelope provided to return the survey via internal mail to:

Georgia Tech EPIC Research Team  
c/o Sherry Bloomer  
1677 Tullie Cr.  
Atlanta, GA 30329

**SECTION A: Your Work Area**

In this survey, think of your work area as the unit, department, or clinical area of the hospital where you spend most of your work time or provide most of your clinical services.

**Which campus is your primary campus at Children's? Mark ONE answer by filling in the circle.**

- ☐ a. Egleston                      ☐ c. Office Park                      ☐ e. Immediate Care  
☐ b. Scottish Rite                      ☐ d. Rehab Centers                      ☐ f. Other

**What is your primary work area at Children's? Mark ONE answer by filling in the circle.**

- ☐ a. Many different hospital units/No specific unit  
☐ b. Clinical Ancillary/Support (e.g., lab, rad, OT/PT)                      ☐ e. Inpatient GCA/PCA                      ☐ i. Surgical Services  
☐ c. Emergency                      ☐ f. Non-clinical support                      ☐ j. Other, please specify:  
☐ d. Inpatient ICU                      ☐ g. Outpatient                      ☐ h. Pharmacy
- 

**Please indicate your agreement or disagreement with the following statements about your work area. Mark your answer by filling in the circle.**

Think about your work area	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. People support one another in this unit .....	①	②	③	④	⑤
2. We have enough staff to handle the workload.....	①	②	③	④	⑤
3. When a lot of work needs to be done quickly, we work together as a team to get the work done.....	①	②	③	④	⑤
4. In this unit, people treat each other with respect .....	①	②	③	④	⑤
5. Staff in this unit work longer hours than is best for patient care .....	①	②	③	④	⑤
6. We are actively doing things to improve patient safety.....	①	②	③	④	⑤
7. We use more agency/temporary staff than is best for patient care..	①	②	③	④	⑤
8. Staff feel like their mistakes are held against them.....	①	②	③	④	⑤
9. Mistakes have led to positive changes here .....	①	②	③	④	⑤
10. It is just by chance that more serious mistakes don't happen around here .....	①	②	③	④	⑤
11. When one area in this unit gets really busy, others help out .....	①	②	③	④	⑤
12. When an event is reported, it feels like the person is being written up, not the problem .....	①	②	③	④	⑤
13. After we make changes to improve patient safety, we evaluate their effectiveness .....	①	②	③	④	⑤
14. We work in "crisis mode" trying to do too much, too quickly.....	①	②	③	④	⑤
15. Patient safety is never sacrificed to get more work done.....	①	②	③	④	⑤
16. Staff worry that mistakes they make are kept in their personnel file.....	①	②	③	④	⑤

**SECTION B: Your Supervisor/Manager**

Please indicate your agreement or disagreement with the following statements about your immediate supervisor/manager or person to whom you directly report. Mark your answer by filling in the circle.

	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. My supervisor/manager says a good word when he/she sees a job done according to established patient safety procedures .....	①	②	③	④	⑤
2. My supervisor/manager seriously considers staff suggestions for improving patient safety .....	①	②	③	④	⑤
3. Whenever pressure builds up, my supervisor/manager wants us to work faster, even if it means taking shortcuts .....	①	②	③	④	⑤
4. My supervisor/manager overlooks patient safety problems that happen over and over .....	①	②	③	④	⑤

**SECTION C: Communications**

How often do the following things happen in your work area? Mark your answer by filling in the circle.

Think about your hospital work area	Never ▼	Rarely ▼	Some- times ▼	Most of the time ▼	Always ▼
1. We are given feedback about changes put into place based on event reports .....	①	②	③	④	⑤
2. Staff will freely speak up if they see something that may negatively affect patient care .....	①	②	③	④	⑤
3. We are informed about errors that happen in this unit.....	①	②	③	④	⑤
4. Staff feel free to question the decisions or actions of those with more authority .....	①	②	③	④	⑤
5. In this unit, we discuss ways to prevent errors from happening again .....	①	②	③	④	⑤
6. Staff are afraid to ask questions when something does not seem right .....	①	②	③	④	⑤

**SECTION D: Frequency of Events Reported**

In your hospital work area, when the following mistakes happen, how often are they reported?

Mark your answer by filling in the circle.

	Never ▼	Rarely ▼	Some- times ▼	Most of the time ▼	Always ▼
1. When a mistake is made, but is <u>caught and corrected before affecting the patient</u> , how often is this reported? .....	①	②	③	④	⑤
2. When a mistake is made, but has <u>no potential to harm the patient</u> , how often is this reported? .....	①	②	③	④	⑤
3. When a mistake is made that <u>could harm the patient</u> , but does not, how often is this reported? .....	①	②	③	④	⑤

**SECTION E: Patient Safety Grade**

Please give your work area in this hospital an overall grade on patient safety. Mark ONE answer.

- ☐ **A** Excellent     
 ☐ **B** Very Good     
 ☐ **C** Acceptable     
 ☐ **D** Poor     
 ☐ **E** Failing

**SECTION F: Your Hospital**

Please indicate your agreement or disagreement with the following statements about your hospital. Mark your answer by filling in the circle.

	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
<b>Think about Children's Healthcare of Atlanta:</b>					
1. Hospital management provides a work climate that promotes patient safety.....	①	②	③	④	⑤
2. Hospital units do not coordinate well with each other.....	①	②	③	④	⑤
3. Things “fall between the cracks” when transferring patients from one unit to another .....	①	②	③	④	⑤
4. There is good cooperation among hospital units that need to work together .....	①	②	③	④	⑤
5. Important patient care information is often lost during shift changes.....	①	②	③	④	⑤
6. It is often unpleasant to work with staff from other hospital units....	①	②	③	④	⑤
7. Problems often occur in the exchange of information across hospital units .....	①	②	③	④	⑤
8. The actions of hospital management show that patient safety is a top priority .....	①	②	③	④	⑤
9. Hospital management seems interested in patient safety only after an adverse event happens .....	①	②	③	④	⑤
10. Hospital units work well together to provide the best care for patients.....	①	②	③	④	⑤
11. Shift changes are problematic for patients in this hospital.....	①	②	③	④	⑤

**SECTION G: Number of Events Reported**

In the past 12 months, how many event reports have you filled out and submitted? Mark ONE answer.

- |   |   |
|---|---|
| <input type="radio"/> a. No event reports     | <input type="radio"/> d. 6 to 10 event reports    |
| <input type="radio"/> b. 1 to 2 event reports | <input type="radio"/> e. 11 to 20 event reports   |
| <input type="radio"/> c. 3 to 5 event reports | <input type="radio"/> f. 21 event reports or more |

**SECTION H: Your Comments**

Please feel free to write any comments about patient safety, error, or event reporting in your hospital.

**SECTION I: Epic EMR Readiness**

Currently, plans are underway to implement Epic in your work area to provide pharmacy functionality (EpicRx), electronic medication administration records (eMAR), and/or computerized provider order entry (CPOE). Please indicate your agreement or disagreement with the following statements about the system implementation. When answering these questions, please think about the component(s) of the system that you will be using most often. (E.g., EpicRx for pharmacists.) Please mark your responses based on these components. Mark your answer by filling in the circle.

Think about your hospital work area/unit...	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. I believe people who learn to use the system will be more valuable to the organization. ....	①	②	③	④	⑤
2. I am concerned that the system can capture and track patient-care activities. ....	①	②	③	④	⑤
3. I believe that using Epic will enhance my image with the patients and their families. ....	①	②	③	④	⑤
4. I feel that my needs have been represented in the Epic design process. ....	①	②	③	④	⑤
5. I feel comfortable with Epic because I have been informed/updated throughout the implementation process. ....	①	②	③	④	⑤
6. In general, implementation of Epic will be beneficial (even if it is not particularly beneficial to me).....	①	②	③	④	⑤

**For the following question, please write in your answer.**

7. What type of training/support would enable you to learn to use the new technology (EpicRx, eMAR, CPOE) more easily/faster?

8. What do you expect the organization to do help you learn and use the new technology (EpicRx, eMAR, CPOE)?

**SECTION J: Epic EMR Impact**

The implementation of EpicRx, eMAR, and CPOE will change work practices in this hospital. Please indicate your agreement or disagreement with the following statements about implementation issues related to the system. When answering these questions, please think about the component(s) of the system that you will be using most often. (E.g., EpicRx for pharmacists.) Please mark your responses based on these components. Mark your answer by filling in the circle.

	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. I believe Epic can assist me in improving the quality of care I deliver. ....	①	②	③	④	⑤
2. Most medical errors occur due to process failures in the current system. ....	①	②	③	④	⑤
3. I believe that Epic can help to reduce medical errors.....	①	②	③	④	⑤
4. I believe that Epic will reduce the control I currently have over my work. ....	①	②	③	④	⑤
5. I believe Epic will make my current workload heavier .....	①	②	③	④	⑤
6. I believe Epic will fit into my workflow.....	①	②	③	④	⑤
7. I believe usage of Epic will reduce my administrative workload and give me more time to spend with patients.....	①	②	③	④	⑤
8. I feel the current practices are efficient; therefore, I do not see the need to implement the system.....	①	②	③	④	⑤
9. Epic will allow me to accomplish my tasks more efficiently...	①	②	③	④	⑤
10. I believe Epic will reduce my communication with my coworkers .....	①	②	③	④	⑤
11. I believe Epic will reduce my communication with patients and their families. ....	①	②	③	④	⑤
12. It will be easy for me to learn to use Epic. ....	①	②	③	④	⑤
13. It will be difficult to schedule time to complete Epic training..	①	②	③	④	⑤
14. If the resources are available, I will spend additional time to become familiar with Epic.....	①	②	③	④	⑤

**For the following question, please write in your answer.**

15. In your opinion, what will the *advantages* of using the new technology (EpicRx, eMAR, CPOE) be?

16. In your opinion, what will the *disadvantages* of using the new technology (EpicRx, eMAR, CPOE) be?

17. How do you think that the new technology (EpicRx, eMAR, CPOE) will influence your normal workflow?

**SECTION K: Background Information**

**This background information will help us better understand and apply the survey results. Mark ONE answer for each question by filling in the circle.**

1. How long have you worked at Children's Healthcare of Atlanta?  

<input type="radio"/> a. Less than 1 year	<input type="radio"/> d. 11 to 15 years
<input type="radio"/> b. 1 to 5 years	<input type="radio"/> e. 16 to 20 years
<input type="radio"/> c. 6 to 10 years	<input type="radio"/> f. 21 years or more
2. How long have you worked in your current hospital work area?  

<input type="radio"/> a. Less than 1 year	<input type="radio"/> d. 11 to 15 years
<input type="radio"/> b. 1 to 5 years	<input type="radio"/> e. 16 to 20 years
<input type="radio"/> c. 6 to 10 years	<input type="radio"/> f. 21 years or more
3. Typically, how many hours per week do you work at Children's Healthcare of Atlanta?  

<input type="radio"/> a. Less than 20 hours per week
<input type="radio"/> b. 20 to 39 hours per week
<input type="radio"/> c. 40 hours per week or more
4. What is your staff position in this hospital? Mark ONE answer that best describes your staff position.  

<input type="radio"/> a. Registered Nurse	<input type="radio"/> j. Respiratory Therapist
<input type="radio"/> b. Physician Assistant/Nurse Practitioner	<input type="radio"/> k. Physical, Occupational, or Speech Therapist
<input type="radio"/> c. LVN/LPN	<input type="radio"/> l. Technician (e.g., EKG, Lab, Radiology)
<input type="radio"/> d. Patient Care Technician / Nurse Tech	<input type="radio"/> m. Administration/Management
<input type="radio"/> e. Attending/Staff Physician	<input type="radio"/> n. Social work
<input type="radio"/> f. Resident Physician/Physician in Training	<input type="radio"/> o. Child life
<input type="radio"/> g. Pharmacist	<input type="radio"/> p. Other, please specify: _____
<input type="radio"/> h. Nutritionist	
<input type="radio"/> i. Unit Secretary	
5. In your position, do you typically have direct interaction or contact with patients?  

<input type="radio"/> a. YES, I typically have direct interaction or contact with patients.
<input type="radio"/> b. NO, I typically do NOT have direct interaction or contact with patients.
6. How long have you worked in your current specialty or profession?  

<input type="radio"/> a. Less than 1 year	<input type="radio"/> d. 11 to 15 years
<input type="radio"/> b. 1 to 5 years	<input type="radio"/> e. 16 to 20 years
<input type="radio"/> c. 6 to 10 years	<input type="radio"/> f. 21 years or more
7. I use computers for personal or professional purposes  

<input type="radio"/> a. Frequently	<input type="radio"/> d. Rarely
<input type="radio"/> b. Often	<input type="radio"/> e. Never
<input type="radio"/> c. Sometimes	
8. Have you previously used IT systems for other work functions/processes?  

<input type="radio"/> a. Yes, extensively
<input type="radio"/> b. Yes, occasionally
<input type="radio"/> c. No

**THANK YOU FOR COMPLETING THIS SURVEY.**

## **t<sub>1</sub> Staff Post-implementation Survey**

### **Instructions**

This survey asks for your opinions about patient safety issues, medical errors, event reporting, and use of Epic eMAR and orders functions at Children's. This voluntary survey will take about 20-25 minutes to complete. If you do not wish to respond to an item, you may leave it blank. However, please respond to as many items as possible to ensure that the survey results can be used to improve the Epic implementation. Please respond to each item in the survey. As you answer the questions, please keep in mind the following:

- **There are no right or wrong answers.**
- **Don't think too long about each question – your first instinct is best.**
- **Some of the questions may seem wordy or repetitive – they are asked this way for specific reasons.**
- **If you don't understand a question, please don't answer it.**
- **Please, give your own responses and don't discuss the questions with others before you answer them.**

- *An “event” is defined as any type of error, mistake, incident, accident, or deviation, regardless of whether or not it results in patient harm.*
- *“Patient safety” is defined as the avoidance and prevention of patient injuries or adverse events resulting from the processes of health care delivery.*

### SECTION A: Your Work Area

**In this survey, think of your work area as the unit, department, or clinical area of the hospital where you spend most of your work time or provide most of your clinical services.**

**Which campus is your primary campus at Children's? Mark ONE answer by filling in the circle.**

- |  |  |   |
|--|--|---|
| <input type="radio"/> a. Egleston      | <input type="radio"/> c. Office Park   | <input type="radio"/> e. Immediate Care |
| <input type="radio"/> b. Scottish Rite | <input type="radio"/> d. Rehab Centers | <input type="radio"/> f. Other          |

**What is your primary work area at Children's? Mark ONE answer by filling in the circle.**

- |  |   |   |
|--|---|---|
| <input type="radio"/> a. Many different hospital units/No specific unit        |   |   |
| <input type="radio"/> b. Clinical Ancillary/Support<br>(e.g., lab, rad, OT/PT) | <input type="radio"/> e. Inpatient GCA/PCA    | <input type="radio"/> i. Surgical Services      |
| <input type="radio"/> c. Emergency   | <input type="radio"/> f. Non-clinical support | <input type="radio"/> j. Other, please specify: |
| <input type="radio"/> d. Inpatient ICU   | <input type="radio"/> g. Outpatient           |   |
|  | <input type="radio"/> h. Pharmacy             |   |

**Please indicate your agreement or disagreement with the following statements about your work area. Mark your answer by filling in the circle.**

Think about your work area	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. People support one another in this unit .....	①	②	③	④	⑤
2. We have enough staff to handle the workload.....	①	②	③	④	⑤
3. When a lot of work needs to be done quickly, we work together as a team to get the work done.....	①	②	③	④	⑤
4. In this unit, people treat each other with respect .....	①	②	③	④	⑤
5. Staff in this unit work longer hours than is best for patient care ...	①	②	③	④	⑤
6. We are actively doing things to improve patient safety.....	①	②	③	④	⑤
7. We use more agency/temporary staff than is best for patient care .....	①	②	③	④	⑤
8. Staff feel like their mistakes are held against them.....	①	②	③	④	⑤
9. Mistakes have led to positive changes here .....	①	②	③	④	⑤
10. It is just by chance that more serious mistakes don't happen around here.....	①	②	③	④	⑤
11. When an event is reported, it feels like the person is being written up, not the problem .....	①	②	③	④	⑤
12. After we make changes to improve patient safety, we evaluate their effectiveness .....	①	②	③	④	⑤
13. We work in "crisis mode" trying to do too much, too quickly.....	①	②	③	④	⑤
14. Patient safety is never sacrificed to get more work done.....	①	②	③	④	⑤
15. Staff worry that mistakes they make are kept in their personnel file.....	①	②	③	④	⑤

**SECTION B: Your Supervisor/Manager**

Please indicate your agreement or disagreement with the following statements about your immediate supervisor/manager or person to whom you directly report. Mark your answer by filling in the circle.

	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. My supervisor/manager says a good word when he/she sees a job done according to established patient safety procedures .....	①	②	③	④	⑤
2. My supervisor/manager seriously considers staff suggestions for improving patient safety .....	①	②	③	④	⑤
3. Whenever pressure builds up, my supervisor/manager wants us to work faster, even if it means taking shortcuts .....	①	②	③	④	⑤

**SECTION C: Communications**

How often do the following things happen in your work area? Mark your answer by filling in the circle.

Think about your hospital work area	Never ▼	Rarely ▼	Some- times ▼	Most of the time ▼	Always ▼
1. We are given feedback about changes put into place based on event reports .....	①	②	③	④	⑤
2. Staff will freely speak up if they see something that may negatively affect patient care .....	①	②	③	④	⑤
3. We are informed about errors that happen in this unit .....	①	②	③	④	⑤
4. Staff feel free to question the decisions or actions of those with more authority .....	①	②	③	④	⑤
5. In this unit, we discuss ways to prevent errors from happening again .....	①	②	③	④	⑤
6. Staff are afraid to ask questions when something does not seem right .....	①	②	③	④	⑤

**SECTION D: Frequency of Events Reported**

In your hospital work area, when the following mistakes happen, how often are they reported?

Mark your answer by filling in the circle.

	Never ▼	Rarely ▼	Some- times ▼	Most of the time ▼	Always ▼
1. When a mistake is made, but is <u>caught and corrected before affecting the patient</u> , how often is this reported? .....	①	②	③	④	⑤
2. When a mistake is made, but has <u>no potential to harm the patient</u> , how often is this reported? .....	①	②	③	④	⑤
3. When a mistake is made that <u>could harm the patient</u> , but does not, how often is this reported? .....	①	②	③	④	⑤

**SECTION E: Patient Safety Grade**

Please give your work area in this hospital an overall grade on patient safety. Mark ONE answer.

- ☐ **A**      ☐ **B**      ☐ **C**      ☐ **D**      ☐ **E**  
 Excellent      Very Good      Acceptable      Poor      Failing

**SECTION F: Your Hospital**

Please indicate your agreement or disagreement with the following statements about your hospital. Mark your answer by filling in the circle.

	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
Think about Children's Healthcare of Atlanta:					
1. Hospital units do not coordinate well with each other .....	①	②	③	④	⑤
2. Things "fall between the cracks" when transferring patients from one unit to another .....	①	②	③	④	⑤
3. There is good cooperation among hospital units that need to work together .....	①	②	③	④	⑤
4. Important patient care information is often lost during shift changes .....	①	②	③	④	⑤
5. Problems often occur in the exchange of information across hospital units .....	①	②	③	④	⑤
6. Hospital units work well together to provide the best care for patients .....	①	②	③	④	⑤
7. Shift changes are problematic for patients in this hospital.....	①	②	③	④	⑤

**SECTION G: Number of Events Reported**

In the past 12 months, how many event reports have you filled out and submitted? Mark ONE answer.

- |   |   |
|---|---|
| <input type="radio"/> a. No event reports     | <input type="radio"/> d. 6 to 10 event reports    |
| <input type="radio"/> b. 1 to 2 event reports | <input type="radio"/> e. 11 to 20 event reports   |
| <input type="radio"/> c. 3 to 5 event reports | <input type="radio"/> f. 21 event reports or more |

**SECTION H: Your Comments**

Please feel free to write any comments about patient safety, error, or event reporting in your hospital.

**SECTION I: Epic EMR Satisfaction**

Several months ago Epic was implemented in your work area to provide order entry, electronic medication administration records (eMAR), or other clinical documentation functions. Please indicate your agreement or disagreement with the following statements about the system implementation. When answering these questions, please think about the component(s) of the system that you use most often (e.g., eMAR, orders). Please mark your responses based on these components. Mark your answer by filling in the circle.

		Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
Think about your hospital work area/unit...		▼	▼	▼	▼	▼
18.	Epic provides accurate, reliable information.....	①	②	③	④	⑤
19.	Epic is user-friendly. ....	①	②	③	④	⑤
20.	Epic has enhanced my effectiveness on the job... ..	①	②	③	④	⑤
21.	I am a confident user of the Epic system .....	①	②	③	④	⑤
22.	The Epic super users have the knowledge and expertise to assist service users .....	①	②	③	④	⑤
23.	I am concerned that the system can capture and track patient-care activities.....	①	②	③	④	⑤
24.	I believe that using Epic has enhanced my image with the patients and their families.....	①	②	③	④	⑤
25.	I find it easy to get Epic to do what I want it to do. ....	①	②	③	④	⑤
26.	The features of the Epic system were easy to learn .....	①	②	③	④	⑤
27.	It was difficult to schedule time to go to Epic training.....	①	②	③	④	⑤
28.	Epic is easy to use.....	①	②	③	④	⑤

For the following question, select the phrase that best fills in the blank.

12. After becoming proficient with Epic, I feel that Epic has \_\_\_\_\_ the time I spend on clinical documentation & order processing

Reduced  
a lot  
▼  
①

Reduced  
a little  
▼  
②

Not  
changed  
▼  
③

Increased  
a little  
▼  
④

Increased  
a lot  
▼  
⑤

N/A  
I do not feel proficient  
with Epic yet  
⑥

For the following questions, please write in your answer.

13. What further training/support do you need for continued learning about how to use Epic?

14. What would have made the implementation of Epic smoother?

**SECTION J: Epic EMR Impact**

The implementation of EpicRx, eMAR, and other Epic components has changed work practices in this hospital. Please indicate your agreement or disagreement with the following statements related to how the system has impacted your work. When answering these questions, please think about the component(s) of the system that you will be using most often (e.g., eMAR, orders). Please mark your responses based on these components. Mark your answer by filling in the circle.

	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. I believe Epic assists me in improving the quality of healthcare I deliver.....	①	②	③	④	⑤
2. I believe that Epic helps to reduce medical errors .....	①	②	③	④	⑤
3. Epic provides more information for better clinical decision making.....	①	②	③	④	⑤
4. Epic provides faster access to information for better clinical decision making .....	①	②	③	④	⑤
5. I believe Epic has enabled me to accomplish my tasks more efficiently .....	①	②	③	④	⑤
6. I believe Epic has made my workload heavier.....	①	②	③	④	⑤
7. Using Epic has reduced the control I have over my work .....	①	②	③	④	⑤
8. Epic is subject to frequent system problems and crashes that could contribute to medical errors. ....	①	②	③	④	⑤
9. I believe Epic fits in well with the way I like to work .....	①	②	③	④	⑤
10. I believe that using Epic has given me more time to spend with patients .....	①	②	③	④	⑤
11. I believe Epic has reduced my communication with my coworkers.....	①	②	③	④	⑤
12. I believe Epic has reduced my communication with patients and their families .....	①	②	③	④	⑤
13. The Epic system makes it easier for me to share knowledge/information with other users of the system .....	①	②	③	④	⑤

**For the following question, please write in your answer.**

14. In your opinion, what are the biggest advantages of using Epic?

15. In your opinion, what are the biggest disadvantages of using Epic?

16. In general, how has Epic changed your workflow (i.e. the way you do your work)?

**SECTION K: Background Information**

**This background information will help us better understand and apply the survey results. Mark ONE answer for each question by filling in the circle.**

1. How long have you worked at Children's Healthcare of Atlanta?  

<input type="radio"/> a. Less than 1 year	<input type="radio"/> d. 11 to 15 years
<input type="radio"/> b. 1 to 5 years	<input type="radio"/> e. 16 to 20 years
<input type="radio"/> c. 6 to 10 years	<input type="radio"/> f. 21 years or more
2. How long have you worked in your current hospital work area?  

<input type="radio"/> a. Less than 1 year	<input type="radio"/> d. 11 to 15 years
<input type="radio"/> b. 1 to 5 years	<input type="radio"/> e. 16 to 20 years
<input type="radio"/> c. 6 to 10 years	<input type="radio"/> f. 21 years or more
3. Typically, how many hours per week do you work at Children's Healthcare of Atlanta?  

<input type="radio"/> a. Less than 20 hours per week	<input type="radio"/> d. 40 to 49 hours per week
<input type="radio"/> b. 20 to 29 hours per week	<input type="radio"/> e. 50 to 59 hours per week
<input type="radio"/> c. 30 to 39 hours per week	<input type="radio"/> f. 60 hours per week or more
4. What shift do you primarily work?  

<input type="radio"/> a. Days	<input type="radio"/> d. Weekend days
<input type="radio"/> b. Nights	<input type="radio"/> e. Weekend nights
<input type="radio"/> c. Evenings	<input type="radio"/> f. Rotate
5. What is your staff position in this hospital? Mark ONE answer that best describes your staff position.  

<input type="radio"/> a. Registered Nurse, LVN, or LPN	<input type="radio"/> h. Technician (e.g., EKG, Lab, Radiology)
<input type="radio"/> b. Physician Assistant/Nurse Practitioner	<input type="radio"/> i. Unit Secretary
<input type="radio"/> c. Patient Care Technician / Nurse Tech	<input type="radio"/> j. Administration/Management
<input type="radio"/> d. Pharmacist	<input type="radio"/> k. Social work
<input type="radio"/> e. Nutritionist	<input type="radio"/> l. Child life
<input type="radio"/> f. Respiratory Therapist	<input type="radio"/> m. Other, please specify: _____
<input type="radio"/> g. Physical, Occupational, or Speech Therapist	
6. In your position, do you typically have direct interaction or contact with patients?  

<input type="radio"/> a. YES, I typically have direct interaction or contact with patients.
<input type="radio"/> b. NO, I typically do NOT have direct interaction or contact with patients.
7. How long have you worked in your current specialty or profession?  

<input type="radio"/> a. Less than 1 year	<input type="radio"/> d. 11 to 15 years
<input type="radio"/> b. 1 to 5 years	<input type="radio"/> e. 16 to 20 years
<input type="radio"/> c. 6 to 10 years	<input type="radio"/> f. 21 years or more
8. How often do you use computers for personal or professional purposes?  

<input type="radio"/> a. Frequently	<input type="radio"/> d. Rarely
<input type="radio"/> b. Often	<input type="radio"/> e. Never
<input type="radio"/> c. Sometimes	
9. Prior to Epic Stage 2 go-live (Nov. 2, 2005) did you previously use IT systems for other work functions/processes?  

<input type="radio"/> a. Yes, extensively
<input type="radio"/> b. Yes, occasionally
<input type="radio"/> c. No

**THANK YOU FOR COMPLETING THIS SURVEY.**

## t<sub>1</sub> Physician Pre Survey

### Instructions

This survey asks for your opinions about patient safety issues, medical errors, event reporting, and the upcoming launch of electronic clinical documentation and CPOE at Children's. This voluntary survey will take about 20 minutes to complete. If you do not wish to respond to an item, you may leave it blank. However, please respond to as many items as possible to ensure that the survey results can be used to improve the Epic implementation. Please respond to each item in the survey. As you answer the questions, please keep in mind the following:

- **There are no right or wrong answers.**
- **Don't think too long about each question – your first instinct is best.**
- **Some of the questions may seem wordy or repetitive – they are asked this way for specific reasons.**
- **If you don't understand a question, please don't answer it.**
- **Please, give your own responses and don't discuss the questions with others before you answer them.**

- *“Patient safety” is defined as the avoidance and prevention of patient injuries or adverse events resulting from the processes of health care delivery.*

**After completing the survey**, please use the envelope provided to return the survey to:

Georgia Tech EPIC Research Team  
Quality Department  
1677 Tullie Cr.  
Atlanta, GA 30329

**SECTION A: Your Work Area**

In this survey, think of your work area as the unit, department, or clinical area of the hospital where you spend most of your work time or provide most of your clinical services.

Which campus is your primary campus at Children's? Mark ONE answer by filling in the circle.

- ☐ a. Egleston                      ☐ c. Office Park                      ☐ e. Immediate Care  
☐ b. Scottish Rite                      ☐ d. Rehab Centers                      ☐ f. Other

What is your primary work area at Children's? Mark ONE answer by filling in the circle.

- ☐ a. Many different hospital units/No specific unit  
☐ b. Clinical Ancillary/Support (e.g., lab, rad)                      ☐ d. Inpatient ICU                      ☐ g. Surgical Services  
☐ c. Emergency                      ☐ e. Inpatient GCA/PCA                      ☐ h. Other, please specify: \_\_\_\_\_

Please indicate your agreement or disagreement with the following statements about your work area. Mark your answer by filling in the circle.

Think about your work area	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. Nurses treat physicians with respect .....	①	②	③	④	⑤
2. Children's has enough staff to handle the workload .....	①	②	③	④	⑤
3. Physicians treat nurses with respect.....	①	②	③	④	⑤
4. Physicians work longer than is best for patient care .....	①	②	③	④	⑤
5. Children's is actively doing things to improve patient safety .....	①	②	③	④	⑤
6. When one area in this unit gets really busy, others help out ...	①	②	③	④	⑤
7. Physicians are interested in improving patient safety.....	①	②	③	④	⑤

**SECTION B: Communications**

How often do the following things happen in your work area? Mark your answer by filling in the circle.

Think about your hospital work area	Never ▼	Rarely ▼	Some- times ▼	Most of the time ▼	Always ▼
1. Physicians will freely speak up if they see something that may negatively affect patient care .....	①	②	③	④	⑤
2. Nurses will freely speak up if they see something that may negatively affect patient care .....	①	②	③	④	⑤
3. Physicians feel free to question the decisions or actions of consulting physicians .....	①	②	③	④	⑤
4. Nurses feel free to question the decisions or actions of physicians .....	①	②	③	④	⑤
5. Physicians rarely question actions or decisions of consulting physicians .....	①	②	③	④	⑤
6. Physicians often discuss ways to prevent errors from happening again.....	①	②	③	④	⑤

**SECTION C: Patient Safety Grade**

Please give your work area in this hospital an overall grade on patient safety. Mark ONE answer.

- |                       |                       |                       |                       |                       |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| <b>A</b>              | <b>B</b>              | <b>C</b>              | <b>D</b>              | <b>E</b>              |
| Excellent             | Very Good             | Acceptable            | Poor                  | Failing               |

**SECTION D: Your Hospital**

Please indicate your agreement or disagreement with the following statements about your hospital. Mark your answer by filling in the circle.

		Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
		▼	▼	▼	▼	▼
<b>Think about Children's Healthcare of Atlanta:</b>						
1.	Hospital management provides a work climate that promotes patient safety.....	①	②	③	④	⑤
2.	Hospital units do not coordinate well with each other.....	①	②	③	④	⑤
3.	Things “fall between the cracks” when transferring patients from one unit to another .....	①	②	③	④	⑤
4.	There is good cooperation among hospital units that need to work together .....	①	②	③	④	⑤
5.	Important patient care information is often lost during shift changes.....	①	②	③	④	⑤
6.	Physicians frequently do not pass on important information to on-call colleagues .....	①	②	③	④	⑤
7.	The actions of hospital management show that patient safety is a top priority .....	①	②	③	④	⑤
8.	Hospital units work well together to provide the best care for patients .....	①	②	③	④	⑤

**SECTION E: Your Comments**

Please feel free to write any comments about patient safety, error, or event reporting in your hospital.

**SECTION F: Epic EMR Perceptions**

Currently, plans are underway to implement Epic to provide clinical documentation and/or computerized provider order entry (CPOE). Please indicate your agreement or disagreement with the following statements about the system implementation. When answering these questions, please think about the component(s) of the system that you will be using most often. Please mark your responses based on these components. Mark your answer by filling in the circle.

Think about your hospital work area/unit...	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
7. I believe that using Epic will enhance my image with the patients and their families. ....	①	②	③	④	⑤
8. I feel that my needs have been accommodated in the Epic design process. ....	①	②	③	④	⑤
9. I feel comfortable with Epic because I have been informed/updated throughout the implementation process. ....	①	②	③	④	⑤
10. I feel the current practices are efficient; therefore, I do not see the need to implement the system	①	②	③	④	⑤
11. It will be difficult to schedule time to complete Epic training .....	①	②	③	④	⑤
12. It will be easy for me to learn to use Epic .....	①	②	③	④	⑤
13. If the resources are available, I will spend additional time to become familiar with Epic .....	①	②	③	④	⑤

**For the following question, please write in your answer.**

8. What type of training/support would enable you to learn to use the new technology (clinical documentation, CPOE) more easily/faster?

**SECTION G: Epic EMR Impact**

The implementation of electronic clinical documentation and CPOE will change work practices in this hospital. Please indicate your agreement or disagreement with the following statements about implementation issues related to the system. When answering these questions, please think about the component(s) of the system that you will be using most often. Please mark your responses based on these components. Mark your answer by filling in the circle.

	Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼
1. Implementation of Epic will lead to improved patient satisfaction with their clinical experience .....	①	②	③	④	⑤
2. I believe that Epic can help to reduce medical errors .....	①	②	③	④	⑤
3. I believe that Epic will reduce the control I currently have over my work.....	①	②	③	④	⑤
4. I believe Epic will make my current workload heavier.....	①	②	③	④	⑤
5. I believe Epic will fit well with the way I like to work.....	①	②	③	④	⑤
6. I believe using Epic will give me more time to spend with patients.....	①	②	③	④	⑤
7. Using Epic will enable me to accomplish my tasks more efficiently. ....	①	②	③	④	⑤
8. I believe Epic will reduce my communication with staff and colleagues.....	①	②	③	④	⑤
9. I believe Epic will reduce my communication with patients and their families .....	①	②	③	④	⑤
10. Using Epic will enhance my effectiveness on the job .....	①	②	③	④	⑤
11. Implementation of Epic will improve patient safety .....	①	②	③	④	⑤

For the following question, please write in your answer.

13. In your opinion, what will the *advantages* of using electronic clinical documentation and/or CPOE be?

14. In your opinion, what will the *disadvantages* of using electronic clinical documentation and/or CPOE be?

15. How do you think that using electronic clinical documentation and/or CPOE will influence your normal workflow?

#### **SECTION H: Background Information**

**This background information will help us better understand and apply the survey results. Mark ONE answer for each question by filling in the circle.**

1. How long have you worked at Children's Healthcare of Atlanta?  

<input type="radio"/> a. Less than 1 year	<input type="radio"/> d. 11 to 15 years
<input type="radio"/> b. 1 to 5 years	<input type="radio"/> e. 16 to 20 years
<input type="radio"/> c. 6 to 10 years	<input type="radio"/> f. 21 years or more
  
2. Typically, how many hours per week do you work at Children's Healthcare of Atlanta?  

<input type="radio"/> a. Less than 20 hours per week	<input type="radio"/> d. 40 to 49 hours per week
<input type="radio"/> b. 20 to 29 hours per week	<input type="radio"/> e. 50 to 59 hours per week
<input type="radio"/> c. 30 to 39 hours per week	<input type="radio"/> f. 60 hours per week or more
  
3. What is your staff position in this hospital? Mark ONE answer that best describes your staff position.  

<input type="radio"/> a. Attending/Staff Physician	<input type="radio"/> d. Administration/Management
<input type="radio"/> b. Physician Assistant/Nurse Practitioner	<input type="radio"/> e. Other, please specify: _____
<input type="radio"/> c. Resident Physician/Physician in Training	
  
4. What is your medical specialty? Mark ONE answer that best describes your medical specialty.  

<input type="radio"/> a. Hospitalist	<input type="radio"/> g. Oncology
<input type="radio"/> b. Intensivist	<input type="radio"/> h. Radiology
<input type="radio"/> c. Anesthesiology	<input type="radio"/> i. Surgery
<input type="radio"/> d. Cardiology	<input type="radio"/> j. Other, please specify: _____
<input type="radio"/> e. Emergency	
<input type="radio"/> f. Neonatology	
  
5. How long have you worked in your current specialty or profession?  

<input type="radio"/> a. Less than 1 year	<input type="radio"/> d. 11 to 15 years
<input type="radio"/> b. 1 to 5 years	<input type="radio"/> e. 16 to 20 years
<input type="radio"/> c. 6 to 10 years	<input type="radio"/> f. 21 years or more
  
6. In your position, do you typically have direct interaction or contact with patients?  

<input type="radio"/> a. YES, I typically have direct interaction or contact with patients.
<input type="radio"/> b. NO, I typically do NOT have direct interaction or contact with patients.
  
7. I feel comfortable using computers  

<b>Strongly Disagree</b>	<b>Disagree</b>	<b>Neither</b>	<b>Agree</b>	<b>Strongly Agree</b>
▼	▼	▼	▼	▼
①	②	③	④	⑤
  
8. Have you previously used IT systems for other work functions/processes?  

<input type="radio"/> a. Yes, extensively
<input type="radio"/> b. Yes, occasionally
<input type="radio"/> c. No

**THANK YOU FOR COMPLETING THIS SURVEY.**

## **APPENDIX B. VALIDATION OF SAFETY CONSTRUCTS IN PHYSICIAN SAFETY SURVEY**

Because the AHRQ Survey on Patient Safety was developed and validated using a hospital nursing staff population, there was concern that the instrument as originally designed might not be appropriate for a physician population. Feedback from the pilot physician group confirmed these concerns and indicated that many of the questions did not apply to physicians and that the survey length would result in low response rates. Consequently, researchers worked with input from clinicians to eliminate and or adapt questions that did not apply to physicians. The final set of questions was presented previously in Appendix A. Prior to using any of the safety scales in the proposed analyses on PE and EE, the validity of the 4 scales of interest in the research was tested. (Note: all negatively worded items were reversed prior to this analysis.)

The internal validity of these scales (using Cronbach's  $\alpha$ ) was:

- Staffing  $\alpha=0.351$
- Unit Teamwork  $\alpha=0.508$
- Hospital Teamwork  $\alpha=0.798$
- Handoffs & Transitions  $\alpha=0.627$

Because of the low  $\alpha$ 's reported, a PCA factor analysis using Varimax rotation was conducted to provide further insight into the underlying factor structure (see Table 41). Based on these results, it was clear that the two items in the staffing construct, one regarding physician staffing and the other having enough patient care staff, were distinct items instead of a single construct. Logically, this makes sense because the level and adequacy of staffing for these two personnel groups are affected by different factors and are unlikely to vary consistently. Thus, these two items were treated as separate independent variables in the subsequent analyses on PE and EE. Note that based on the  $\alpha$  values, content review, and factor analysis of the remaining three constructs, these three constructs were left as is for the purposes of this research. However, the  $\alpha$  values and

factor analysis results indicates that further research needs to further examine and refine these factors, especially the Unit Teamwork factor, to improve its internal consistency.

**Table 41. Factor analysis of revised physician patient safety survey items**

		Component			
		1	2	3	4
Staffing	Survey Item				
Staffing	Physician's work longer than is best for patient care*	0.052	0.105	-0.037	0.812
	Children's has enough staff to handle the workload	0.092	0.749	0.165	0.241
Unit Teamwork	Nursed treat physicians with respect	0.184	0.799	-0.162	0.148
	Physician's treat nurses with respect	0.095	0.751	0.163	-0.185
	When one area of this unit gets really busy, other help out	0.585	0.330	0.111	-0.353
Hospital Teamwork	Hospital units do not coordinate well with each other*	0.769	0.052	0.235	0.190
	There is good cooperation among hospital units that need to work together	0.811	0.233	0.053	0.078
	Hospital units work well together to provide the best care for patients	0.843	0.092	-0.008	-0.040
	Things "fall between the cracks" when transferring patients from one unit to another	0.669	-0.027	0.289	0.444
Transitions	Important patient care information is often lost during shift changes*	0.341	0.207	0.579	0.455
	Physicians frequently do not pass on important information to on-call colleagues*	0.110	0.048	0.891	-0.100

\*Negatively worded items were reversed prior to this analysis.

## **APPENDIX C. PHYSICIAN PRE-IMPLEMENTATION FACTOR**

### **ANALYSES RESULTS**

This appendix presents the preliminary factor analysis results for outcome items from the physician pre-implementation surveys. The final results are presented in the *Results* section. The initial analysis, including all output items did not produce a clear factor structure. Analysis of the staff surveys at  $t_0$  and  $t_1$  indicated that the workload question was independent, but highly correlated to other factors. The physician responses demonstrated similar results (presented below) for this item, so it was omitted from further analysis in order to facilitate obtaining a clearer factor structure for the other items.

**Table 42. Preliminary physician outcomes factor analysis (1)**

Survey Item	Component			
	1	2	3	4
I believe that using Epic will enhance my image with the patients and their families	0.389	0.552	0.123	-0.258
Using Epic will enhance my effectiveness on the job	0.631	0.475	-0.059	-0.408
Using Epic will enable me to accomplish my tasks more efficiently.	0.823	0.349	-0.082	-0.227
I believe using Epic will give me more time to spend with patients	0.887	0.316	-0.015	-0.011
I believe that Epic can help to reduce medical errors	0.079	0.864	-0.036	0.036
I believe Epic will make my current workload heavier	-0.786	-0.021	0.253	0.317
Implementation of Epic will improve patient safety	0.218	0.874	-0.125	-0.064
Implementation of Epic will lead to improved patient satisfaction with their clinical experience	0.408	0.683	0.080	-0.343
I believe that Epic will reduce the control I currently have over my work	-0.309	-0.136	0.185	0.843
I believe Epic will reduce my communication with staff and colleagues	0.090	0.043	0.862	0.256
I believe Epic will reduce my communication with patients and their families	-0.314	-0.092	0.835	-0.074

The subsequent factor analysis, presented below, demonstrated a much clearer factor structure. However, one of the new questions related to patient outcomes (i.e., improved patient satisfaction) was also weighing equally on two different constructs. This combined with the content of the item indicated that it, like the workload item, was a separate but highly related construct. Therefore, it was removed to see if this would further clarify the factor structure of the remaining items. This was the case and the resulting final factor analysis is presented in the *Results* section. Note that the final results presented the same factor structure as the results below, but the factor loadings more distinct.

**Table 43. Preliminary physician outcomes factor analysis (2)**

Survey item	Component			
	1	2	3	4
I believe that using Epic will enhance my image with the patients and their families	0.591	0.435	0.062	0.054
Using Epic will enhance my effectiveness on the job	0.710	0.352	-0.091	0.424
Using Epic will enable me to accomplish my tasks more efficiently.	0.856	0.206	-0.134	0.266
I believe using Epic will give me more time to spend with patients	0.900	0.170	-0.075	0.065
I believe that Epic can help to reduce medical errors	0.146	0.875	0.005	0.069
Implementation of Epic will improve patient safety	0.336	0.845	-0.119	0.059
Implementation of Epic will lead to improved patient satisfaction with their clinical experience	0.570	0.582	0.052	0.267
I believe that Epic will reduce the control I currently have over my work	-0.292	-0.105	0.167	-0.895
I believe Epic will reduce my communication with staff and colleagues	0.139	0.005	0.854	-0.239
I believe Epic will reduce my communication with patients and their families	-0.269	-0.054	0.864	0.043

## 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. *J Am Med Inform Assoc*, 11(3), 207-216.
- Abrams, H., & Carr, D. (2005). The human factor: unexpected benefits of a CPOE and electronic medication management implementation at the University Health Network. *Healthcare Quarterly*, 8 Spec No, 94-98.
- Adams, W. G., Mann, A. M., & Bauchner, H. (2003). Use of an electronic medical record improves the quality of urban pediatric primary care. *Pediatrics*, 111(3), 626-632.
- Ahmad, A., Teater, P., Bentley, T. D., Kuehn, L., Kumar, R. R., Thomas, A., et al. (2002). Key Attributes of a Successful Physician Order Entry System Implementation in a Multi-hospital Environment. *J Am Med Inform Assoc.*, 9(1), 16-24.
- Al-Gahtani, S. S., & King, M. (1999). Attitudes, satisfaction and usage: factors contributing to each in the acceptance of information technology. *Behaviour and Information Technology*, 18(4), 277-297.
- Ali, N. A., Mekhjian, H. S., Kuehn, P. L. R. N. M. S., Bentley, T. D., Kumar, R. P., Ferketich, A. K., et al. (2005). Specificity of computerized physician order entry has a significant effect on the efficiency of workflow for critically ill patients. *Critical Care Medicine*, 33(1), 110-114.
- Ammenwerth, E., Mansmann, U., Iller, C., & Eichstadter, R. (2003). Factors affecting and affected by user acceptance of computer-based nursing documentation: results of a two-year study. *J Am Med Inform Assoc*, 10(1), 69-84.
- Anton, J., Petouhoff, N. L., & Schwartz, L. M. (2003). *Integrating people with process and technology* (3rd ed.). Santa Maria, CA: The Anton Press.
- Ash, J. S., Berg, M., & Coiera, E. (2004). Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. *J Am Med Inform Assoc*, 11(2), 104-112.

- Ash, J. S., Fournier, L., Stavri, P. Z., & Dykstra, R. (2003). *Principles for a successful computerized physician order entry implementation*. Paper presented at the AMIA Annual Symposium.
- Ash, J. S., Gorman, P., Seshadri, V., & Hersh, W. R. (2004). Computerized physician order entry in U.S. hospitals: results of a 2002 survey. *J Am Med Inform Assoc*, 11(2), 95-99.
- Ash, J. S., Sittig, D. F., Seshadri, V., Dykstra, R. H., Carpenter, J. D., & Stavri, P. Z. (2005). Adding insight: A qualitative cross-site study of physician order entry. *International Journal of Medical Informatics*, 74(7/8), 623-628.
- Bainbridge, C. (1996). *Designing for Change*. Chichester: John Wiley & Sons.
- Bates, D. W., Boyle, D. L., & Teich, J. M. (1994). *Impact of computerized physician order entry on physician time*. Paper presented at the Annual Symp Comput Appl Med Care.
- Bates, D. W., Leape, L. L., Cullen, D. J., Laird, N., Petersen, L. A., Teich, J. M., et al. (1998). Effect of Computerized Physician Order Entry and a Team Intervention on Prevention of Serious Medication Errors. [Article]. *JAMA*, 280(15), (1311-1316).
- Bates, D. W., Teich, J. M., Lee, J., Seger, D., Kuperman, G. J., Ma'Luf, N., et al. (1999). The Impact of Computerized Physician Order Entry on Medication Error Prevention. *J Am Med Inform Assoc*, 6(4), 313-321.
- Berger, R. G., & Kichak, J. P. (2004). Computerized physician order entry: helpful or harmful? *J Am Med Inform Assoc*, 11(2), 100-103.
- Brill, P. L., & Worth, R. (1997). *The Four Levers of Corporate Change*. New York: American Management Association.
- Cameron, E., & Green, M. (2004). *Making sense of change management*. London: Kogan Page.
- Carroll, J. M. (1996). Encountering Others: Reciprocal Openings in Participatory Design and User-Centered Design. *Human-Computer Interaction*, 11(3), 285.

- Chang, P., Hsu, Y.-S., Tzeng, Y.-M., Sang, Y.-Y., Hou, I.-C., & Kao, W.-F. (2004). The Development of Intelligent, Triage-Based, Mass-Gathering Emergency Medical Service PDA Support Systems. *Journal of Nursing Research*, 12(3), 227-235.
- Change Management. (2006). Retrieved May 12, 2006, from [http://en.wikipedia.org/wiki/Change\\_management](http://en.wikipedia.org/wiki/Change_management)
- Cheng, C. H., Goldstein, M. K., Geller, E., & Levitt, R. E. (2003). *The Effects of CPOE on ICU workflow: an observational study*. Paper presented at the AMIA Annual Symposium.
- Chin, J. P., Diehl, V. A., & Norman, K. L. (1988). *Development of an instrument measuring user satisfaction of the human-computer interface* Paper presented at the SIGCHI conference on Human factors in computing systems, Washington DC.
- Chismar, W. G., & Wiley-Patton, S. (2002). *Test of the technology acceptance model for the internet in pediatrics*. Paper presented at the AMIA Annual Symposium.
- Chrusciel, D., & Field, D. W. (2003). From Critical Success Factors into criteria for performance excellence - an organizational change strategy. *Journal of Industrial Technology*, 19(4), 2-11.
- Committee on Data Standards for Patient Safety. (2003). *Key capabilities of an electronic health record system*. Washington DC: Institute of Medicine.
- Connor, P. E., & Lake, L. K. (1994). *Managing Organizational Change*. Westport, Conn: Praeger.
- Cordero, L., Kuehn, L., Kumar, R. R., & Mekhjian, H. S. (2004). Impact of Computerized Physician Order Entry on Clinical Practice in a Newborn Intensive Care Unit. *Journal of Perinatology*, 24(2), 88-93.
- Dansky, K. H., Gamm, L. D., Vasey, J. J., & Barsukiewicz, C. K. (1999). Electronic medical records: are physicians ready? *J Healthc Manag*, 44(6), 440-454; discussion 454-445.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319.

- Dillon, T. W., Blankenship, R., & Crews, T., Jr. (2005). Nursing attitudes and images of electronic patient record systems. *Comput Inform Nurs*, 23(3), 139-145.
- Dix, A., Finlay, J., Abowd, G., & Beale, R. (1998). *Human-Computer Interaction* (2nd ed.): Prentice Hall.
- Doll, W. J., & Torkzadeh, G. (1988). The measurement of end-user computing satisfaction. *MIS Quarterly*, 12(2), 259-276.
- Doll, W. J., Xia, W., & Torkzadeh, G. (1994). A confirmatory factor analysis of the end-user computing satisfaction. *MIS Quarterly*, 18(4), 453.
- Dykstra, R. (2002, November 9-13). *Computerized Physician Order Entry and Communication: Reciprocal Impacts*. Paper presented at the AMIA Annual Symposium, San Antonio, TX.
- Edwards, P. J., Sainfort, F., Jacko, J. A., & Kongnakorn, T. (2006). Methods of Evaluating Outcomes. In G. Salvendy (Ed.), *Handbook of Human Factors & Ergonomics* (pp. 1150-1187). New York: John Wiley & Sons.
- Field, A. (2000). *Discovering Statistics Using SPSS for Windows*. London: Sage Publications.
- Fortescue, E. B., Kaushal, R., Landrigan, C., McKenna, K. J., Clapp, M. D., Federico, F., et al. (2003). Prioritizing strategies for preventing medication errors and adverse drug events in pediatric inpatients. *Pediatrics*, 111(4 Pt 1), 722-729.
- Gamm, L. D., Barsukiewicz, C. K., Dansky, K. H., Vasey, J. J., Bisordi, J. E., & Thompson, P. C. (1998). *Pre- and post-control model research on end-users' satisfaction with an electronic medical record: preliminary results*. Paper presented at the AMIA Annual Symposium.
- Gardner, R. M., & Lundsgaarde, H. P. (1994). Evaluation of user acceptance of a clinical expert system. *J Am Med Inform Assoc*, 1(6), 428-438.
- Gulliksen, J., Lantz, A., & Boivie, I. (1999). *User centered design in practice - problems and possibilities* (No. TRITA-NA-D9813, CID-40). Stockholm: Centre for User Oriented IT Design, Royal Institute of Technology.

- Haddad, C. J. (2002). *Managing technological change : a strategic partnership approach*. Thousand Oaks, Calif.: Sage Publications.
- Han, Y. Y., Carcillo, J. A., Venkataraman, S. T., Clark, R. S. B., Watson, R. S., Nguyen, T. C., et al. (2005). Unexpected Increased Mortality After Implementation of a Commercially Sold Computerized Physician Order Entry System. *Pediatrics*, 116(6), 1506-1512.
- Hiatt, J. M., & Creasey, T. J. (2003). *Change Management*. Loveland, CO: Prosci Learning Center Publications.
- Holmes, A. (2001). *Failsafe IS project delivery*. Aldershot, England ; Burlington, VT: Gower.
- Hu, P. J., Chau, P. Y. K., Sheng, O. R. L., & Kar Yan, T. (1999). Examining the Technology Acceptance Model Using Physician Acceptance of Telemedicine Technology. *Journal of Management Information Systems*, 16(2), 91-112.
- Johnson, C. M., Johnson, T. R., & Zhang, J. (2005). A user-centered framework for redesigning health care interfaces. *Journal of Biomedical Informatics*, 38(1), 75-87.
- Johnson, R. A., & Wichern, D. W. (1988). *Applied Multivariate Statistical Analysis* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.
- Jones, R. A., Jimmieson, N. L., & Griffiths, A. (2005). The Impact of Organizational Culture and Reshaping Capabilities on Change Implementation Success: The Mediating Role of Readiness for Change. *Journal of Management Studies*, 42(2), 361-386.
- Karat, J., & Karat, C. M. (2003). The evolution of user-centered focus in the human-computer interaction field. *IBM Systems Journal*, 42(4), 532-541.
- Karsh, B. T. (2004). Beyond usability: designing effective technology implementation systems to promote patient safety. *Qual Saf Health Care*, 13(5), 388-394.
- Kaushal, R., Barker, K. N., & Bates, D. W. (2001). How can information technology improve patient safety and reduce medication errors in children's health care? *Archives of Pediatrics and Adolescent Medicine*, 155, 1002-1007.

- Kaushal, R., Bates, D. W., Landrigan, C., McKenna, K. J., Clapp, M. D., Federico, F., et al. (2001). Medication Errors and Adverse Drug Events in Pediatric Inpatients. *JAMA*, 285(16), 2114-2120.
- Kaushal, R., Shojania, K. G., & Bates, D. W. (2003). Effects of Computerized Physician Order Entry and Clinical Decision Support Systems on Medication Safety: A Systematic Review. *Archives of Internal Medicine* 163(12), 1409-1416.
- Kawamoto, K., Houlihan, C. A., Balas, E. A., & Lobach, D. F. (2005). Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *British Medical Journal*, 330, 765-772.
- Kimball, R. (1998). *The data warehouse lifecycle toolkit : expert methods for designing, developing, and deploying data warehouses*. New York: Wiley Computer Pub.
- King, W. J., Paice, N., Rangrej, J., Forestell, G. J., & Swartz, R. (2003). The Effect of Computerized Physician Order Entry on Medication Errors and Adverse Drug Events in Pediatric Inpatients. *Pediatrics*, 112(3), 506-509.
- Kirkpatrick, D. L. (1985). *How to Manage Change Effectively*. San Francisco: Jossey-Bass Publishers.
- Koppel, R., Metlay, J. P., Cohen, A., Abaluck, B., Localio, A. R., Kimmel, S. E., et al. (2005). Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors. *JAMA*, 293(10), 1197-1203.
- Kotter, J. P., & Cohen, D. S. (2002). *The Heart of Change*. Boston, Mass: Harvard Business School Press.
- Kuperman, G. J., & Gibson, R. F. (2003). Computer Physician Order Entry: Benefits, Costs, and Issues. *Annals of Internal Medicine*, 139(1), 31.
- 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, T. H., & 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 Med Inform Decis Mak*, 4, 18.

- Lee, F., Teich, J. M., Spurr, C. D., & Bates, D. W. (1996). Implementation of physician order entry: user satisfaction and self-reported usage patterns. *J Am Med Inform Assoc*, 3(1), 42-55.
- Leonard, V. K., Moloney, K. P., & Jacko, J. A. (2006). User-centered design of information technology. In W. S. Marras & W. Karwowski (Eds.), *The Occupational Ergonomics Handbook* (2nd ed., pp. 7.1-7.40). Boca Raton, FL: CRC Press, LLC.
- Lesar, T. S., Briceland, L., & Stein, D. S. (1997). Factors related to errors in medication prescribing. *Jama*, 277(4), 312-317.
- Lorenzi, N. M., Riley, R. T., Blyth, A. J. C., Southon, G., & Dixon, B. J. (1997). Antecedents of the People and Organizational Aspects of Medical Informatics: Review of the Literature. *J Am Med Inform Assoc*, 4(2), 79-93.
- Mahmood, M. A., Burm, J. M., Gemoets, L. A., & Jacquez, C. (2000). Variables affecting information technology end-user satisfaction: a meta-analysis of the empirical literature. *International Journal of Human-Computer Studies*, 52(4), 751-771.
- Mao, J.-Y., Vredenburg, K., Smith, P. W., & Carey, T. (2005). The state of user-centered design practice. *Communications of the ACM*, 48(3), 105-109.
- Massaro, T. A. (1993a). Introducing physician order entry at a major academic medical center: I. Impact on organizational culture and behavior. *Academic Medicine*, 68(1), 20-25.
- Massaro, T. A. (1993b). Introducing physician order entry at a major academic medical center: II. Impact on medical education. *Acad Med*, 68(1), 25-30.
- McConnell, S. (1996). *Rapid development: taming wild software schedules*. Redmond, WA: Microsoft Press.
- McLane, S. (2005). Designing an EMR planning process based on staff attitudes toward and opinions about computers in healthcare. *Comput Inform Nurs*, 23(2), 85-92.
- Mekhjjan, H. S., Kumar, R. R., Kuehn, L., Bentley, T. D., Teater, P., Thomas, A., et al. (2002). Immediate benefits realized following implementation of physician order

- entry at an academic medical center. *Journal of the American Medical Informatics Association*, 9(5), 529-539.
- Merriam-Webster. (2006). Merriam-Webster Online Dictionary. Retrieved May 12, 2006, from <http://www.webster.com/dictionary/change>
- Mikulich, V. J., Liu, Y.-C., Steinfeldt, J., & Schriger, D. L. (2001). Implementation of clinical guidelines through an electronic medical record: physician usage, satisfaction and assessment. *Int J Med Inform*, 63(3), 169-178.
- Moore, G. C., & Benbasat, I. (1991). Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation. *Information Systems Research*, 2(3), 192.
- Murff, H. J., & Kannry, J. (2001). Physician Satisfaction with Two Order Entry Systems. *J Am Med Inform Assoc*, 8(5), 499-511.
- Myers, T. F., Venable, H. H., & Hansen, J. A. (1998). Computer-enhanced neonatology practice evolution in an academic medical center. NICU Clinical Effectiveness Task Force. *J Perinatol*, 18(6 Pt 2 Su), S38-44.
- NACHRI. (2001). *All children need children's hospitals*. Alexandria, VA: National Association of Children's Hospitals and Related Institutions.
- NACHRI. (2006). Facts & Trends. Retrieved April 6, 2006, from <http://www.childrenshospitals.net/>
- Neter, J., Kutner, M. H., Nachtsheim, C. J., & Wasserman, W. (1996). *Applied Linear Statistical Models* (4th ed.). Boston, Mass.: WCB McGraw-Hill.
- Norman, D. A. (1986). Cognitive Engineering. In D. A. Norman & S. W. Draper (Eds.), *User Centered Design - New Perspectives on Human-Computer Interaction* (pp. 31-61). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Norman, D. A. (1990). *The design of everyday things* (1st Doubleday/Currency ed.). New York: Doubleday.
- Noyes, J., & Baber, C. (1999). *User-centered Design of Systems*. London: Springer.

- O'Connell, R. T., Cho, C., Shah, N., Brown, K., & Shiffman, R. N. (2004). Take note(s): differential EHR satisfaction with two implementations under one roof. *J Am Med Inform Assoc*, 11(1), 43-49.
- Oren, E., Shaffer, E. R., & Guglielmo, B. J. (2003). Impact of emerging technologies on medication errors and adverse drug events. *American Journal of Health-System Pharmacy*, 60(14), 1447.
- Patterson, R. (2002). Physician satisfaction with order entry systems. *J Am Med Inform Assoc*, 9(3), 308-309; author reply 309.
- Poissant, L., Pereira, J., Tamblyn, R., & Kawasumi, Y. (2005). The Impact of Electronic Health Records on Time Efficiency of Physicians and Nurses: A Systematic Review. *J Am Med Inform Assoc*, 12(5), 505-516.
- Poon, E. G., Blumenthal, D., Jaggi, T., Honour, M. M., Bates, D. W., & Kaushal, R. (2004). Overcoming Barriers To Adopting And Implementing Computerized Physician Order Entry Systems In U.S. Hospitals. *Health Affairs*, 23(4), 184-190.
- Potts, A. L., Barr, F. E., Gregory, D. F., Wright, L., & Patel, N. R. (2004). Computerized Physician Order Entry and Medication Errors in a Pediatric Critical Care Unit. *Pediatrics*, 113(1), 59-63.
- Rocha, B. H., Christenson, J. C., Evans, R. S., & Gardner, R. M. (2001). Clinicians' response to computerized detection of infections. *J Am Med Inform Assoc*, 8(2), 117-125.
- Rothschild, J. (2004). Computerized physician order entry in the critical care and general inpatient setting: a narrative review. *J Crit Care*, 19(4), 271-278.
- Saathoff, A. (2005). Human factors considerations relevant to CPOE implementations. *J Healthc Inf Manag*, 19(3), 71-78.
- Sangiorgio, M. P. (2005). 2005's 10 Best Children's Hospitals [Electronic Version]. *Child Magazine*. Retrieved May 3, 2006.
- Scanlon, M. (2004). Computer physician order entry and the real world: we're only humans. *Jt Comm J Qual Saf*, 30(6), 342-346.

- Schiff, G. D., & Rucker, T. D. (1998). Computerized Prescribing: Building the Electronic Infrastructure for Better Medication Usage. *JAMA*, 279(13), 1024-1029.
- Seffah, A., & Metzker, E. (2004). The obstacles and myths of usability and software engineering. *Communications of the ACM*, 47(12), 71-76.
- Senge, P. (1999). *The Dance of Change*. New York: Doubleday.
- Sheskin, D. J. (1997). *Handbook of Parametric and Nonparametric Statistical Procedures*. Boca Raton, FL: CRC Press.
- Shu, K., Boyle, D., Spurr, C. D., Horsky, J., Heiman, H., O'Connor, P., et al. (2001). Comparison of time spent writing orders on paper with computerized physician order entry. *Medinfo*, 10(Pt 2), 1207-1211.
- Sittig, D. F., Krall, M., Kaalaas-Sittig, J., & Ash, J. S. (2005). Emotional Aspects of Computer-based Provider Order Entry: A Qualitative Study. *J Am Med Inform Assoc*, 12(5), 561-567.
- Sittig, D. F., Kuperman, G. J., & Fiskio, J. (1999). *Evaluating physician satisfaction regarding user interactions with an electronic medical record system*. Paper presented at the AMIA Annual Symposium.
- Sittig, D. F., & Stead, W. W. (1994). Computer-based physician order entry: the state of the art. *J Am Med Inform Assoc*, 1(2), 108-123.
- Snyder, R., Weston, M. J., Fields, W., Rizos, A., & Tedeschi, C. (2005). Computerized provider order entry system field research: The impact of contextual factors on study implementation. *Int J Med Inform*.
- Sorra, J., & Nieva, V. (2004). *Pilot study: reliability and validity of the hospital survey on patient safety*. Westat.
- Stablein, D., Welebob, E., Johnson, E., Metzger, J., Burgess, R., & Classen, D. C. (2003). Understanding hospital readiness for computerized physician order entry. *Jt Comm J Qual Saf*, 29(7), 336-344.

- Staggers, N., & Kobus, D. (2000). Comparing response time, errors, and satisfaction between text-based and graphical user interfaces during nursing order tasks. *J Am Med Inform Assoc*, 7(2), 164-176.
- Teich, J. M., Glaser, J. P., Beckley, R. F., Aranow, M., Bates, D. W., Kuperman, G. J., et al. (1999). The Brigham integrated computing system (BICS): advanced clinical systems in an academic hospital environment. *Int J Med Inform*, 54(3), 197-208.
- Teich, J. M., Merchia, P. R., Schmiz, J. L., Kuperman, G. J., Spurr, C. D., & Bates, D. W. (2000). Effects of Computerized Physician Order Entry on Prescribing Practices. *Archives of Internal Medicine*, 160(18), 2741.
- Tierney, W. M., Miller, M. E., Overhage, J. M., & McDonald, C. J. (1993). Physician Inpatient Order Writing On Microcomputer Workstations: Effects on Resource Utilization. *JAMA*, 269(3), 379-383.
- Torkzadeh, G., & Doll, W. J. (1991). Test-Retest Reliability of the End-User Computing Satisfaction Instrument. *Decision Sciences*, 22(1), 26.
- Upperman, J. S., Staley, P., Friend, K., Benes, J., Dailey, J., Neches, W., et al. (2005). The introduction of computerized physician order entry and change management in a tertiary pediatric hospital. *Pediatrics*, 116(5), e634-642.
- Upperman, J. S., Staley, P., Friend, K., Neches, W., Kazimer, D., Benes, J., et al. (2005). The impact of hospitalwide computerized physician order entry on medical errors in a pediatric hospital. *Journal of Pediatric Surgery*, 40, 57-59.
- UsabilityNet. (2006). Tools & Methods. Retrieved May 20, 2006, 2006, from [www.usabilitynet.org](http://www.usabilitynet.org)
- van der Meijden, M. J., Tange, H., Troost, J., & Hasman, A. (2001). Development and implementation of an EPR: how to encourage the user. *Int J Med Inform*, 64(2-3), 173-185.
- van der Meijden, M. J., Tange, H. J., Boiten, J., Troost, J., & Hasman, A. (2000). The user in the design process of an EPR. *Stud Health Technol Inform*, 77, 224-228.

- van der Meijden, M. J., Tange, H. J., Troost, J., & Hasman, A. (2003). Determinants of success of inpatient clinical information systems: a literature review. *J Am Med Inform Assoc*, 10(3), 235-243.
- Van Schaik, P., Bettany-Saltikov, J. A., & Warren, J. G. (2002). Clinical acceptance of a low-cost portable system for postural assessment. *Behaviour & Information Technology*, 21(1), 47-57.
- Venkatesh, V., & Davis, F. D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Management Science*, 46(2), 186.
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: toward a unified view. *MIS Quarterly*, 27(3), 425-478.
- Vredenburg, K. (2003). Building ease of use into the IBM user experience. *IBM Systems Journal*, 42(4), 517-531.
- Vredenburg, K., Isensee, S., & Righi, C. (2002). *User-Centered Design: An Integrated Approach*. Upper Saddle River, NJ: PTR Prentice Hall.
- Vredeuhurg, K., Seidman, D. I., & Ritsko, J. J. (2003). Preface. *IBM Systems Journal*, 42(4), 515-516.
- Waitman, L. R., Pearson, D., Hargrove, F. R., Wright, L., Webb, T. A., Miller, R. A., et al. (2003). *Enhancing Computerized Provider Order Entry (CPOE) for neonatal intensive care*. Paper presented at the AMIA Annual Symposium.
- Walker, K. P., & Prophet, C. M. (1997). Nursing documentation in the computer-based patient record. *Stud Health Technol Inform*, 46, 313-317.
- Weed, L. L. (1997). New connections between medical knowledge and patient care. *BMJ*, 315(7102), 231-235.
- Weiner, M., Gress, T., Thiemann, D. R., Jenckes, M., Reel, S. L., Mandell, S. F., et al. (1999). Contrasting Views of Physicians and Nurses about an Inpatient Computer-based Provider Order-entry System. *J Am Med Inform Assoc.*, 6(3), 234-244.

- Weir, C. R., Crockett, R., Gohlinghorst, S., & McCarthy, C. (2000). *Does user satisfaction relate to adoption behavior?: an exploratory analysis using CPRS implementation*. Paper presented at the AMIA Annual Symposium.
- Williams, L. S. (1992). Microchips versus stethoscopes: Calgary hospital, MDs face off over controversial computer system. *Cmaj*, 147(10), 1534-1540, 1543-1534, 1547.
- Wilson, J. P., Bulatao, P. T., & Rascati, K. L. (2000). Satisfaction with a computerized practitioner order-entry system at two military health care facilities. *Am J Health Syst Pharm*, 57(23), 2188-2195.
- Wu, C. F. J., & Hamada, M. (2000). *Experiments: Planning, Analysis, and Parameter Design Optimization*. New York, NY: John Wiley & Sons, Inc.
- Xia, W., & Lee, G. (2000). *The influence of persuasion, training and experience on user perceptions and acceptance of IT innovation*. Paper presented at the 21st International Conference on Information Systems, Brisbane, Queensland.
- Zhang, P., Carey, J., Te'eni, D., & Tremaine, M. (2005). Integrating human-computer interaction development into the systems development lifecycle: a methodology. *Communications of AIS*, 15, 512-543.