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Western Michigan University The Center for Health information Technology Advancement

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The Third International Conference on Health Information Technology Advancement

Kalamazoo, Michigan, October 30-31, 2015

Conference Chair

Bernard Han, Ph.D., HIT Pro Department of Business Information Systems Haworth College of Business Western Michigan University Kalamazoo, MI 49008

Transactions Editor

Dr. Huei Lee, Professor Department of Computer Information Systems Eastern Michigan University Ypsilanti, MI 48197

Volume 3, No. 1

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CONFERENCE CHAIR

Bernard Han, Ph.D., HIT Pro Department of Business Information Systems Haworth College of Business Western Michigan University Western Michigan University (269) 387-5428, bernard.han@wmich.edu

CONFERENCE TRANSACTIONS EDITOR

Dr. Huei Lee Professor of Computer Information Systems Eastern Michigan University Huei.Lee@emich.edu

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TABLE OF CONTENTS

| I. Message from the Conference Chair Bernard Han | 5 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| II. Message from the Transactions Editor Huei Lee | 6 |
| III. Referred Papers | |
| A. HIT Adoption - Barriers and Success Factors | |
| EEMI - An Electronic Health Record for Pediatricians: Adoption Barriers, Services and Use in | |
| Juan C. Lavariega, Roberto Garza, Lorena G. Gómez, Víctor J. Lara-Díaz, and Manuel J. Silva-Cavazos | 7 |
| Realizing the Value of EHR Systems: Critical Success Factors Elizabeth A. Regan and Jumee Wang | 20 |
| Understanding User Resistance to Information Technology in Healthcare: The Nature and Role of Perceived Threats | |
| Madison Ngafeeson | 37 |
| Does Unlearning Impact Interaction of EHR End-Users? Julee Hafner and Cherie Noteboom | 50 |
| B. HIT for Healthcare Practice and Research | |
| A Case Study Perspective toward Data-driven Process Improvement for Balanced Perioperative Workflow Jim Ryan, Barbara Doster, Sandra Daily, and Carmen Lewis | 63 |
| Examining the Performance of Older and Younger Adults When Interacting with a Mobile Solution Supporting Levels of Dexterity | |
| Ayidh Alqahtani, Abdulwhab Alsalmah, and Ahmad Alaiad | 82 |
| Forecasting the Potential for Emergency Department Overcrowding Jeff Skinner and Raymond J. Higbea | 93 |
| Can Psychology Research Inform Health Information Data Collection? A. Michelle Wright | 101 |
| C. Emerging HIT Applications | |
| Smart Home Healthcare Settings: A Qualitative Study of the Domain Boundary Ahmad Alaiad, Dorsa Ziaei, and Muhammad Al-Ayyad | 108 |
| Exploring Cloud Computing Implementation Issues in Healthcare Industry Sadaf Ashtari, Ali Eydgahi, and Huei Lee | 122 |

| Patient Handoffs: A Review of Current Status in the USA Farzad Rafi Razi | 130 |
|----------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Socio-economic Dimension of Indoor Radon Gas in West Michigan - A Public Health Discourse and Merit to Use HIT in Shaping Health Behavior | |
| Azizur R. Molla | 137 |

D. HIT Education and Research

| First Generation College Students and Mobile Device Acceptance in Nursing Education DeAnna Gapp and Tsu-Yin Wu | 146 |
|-------------------------------------------------------------------------------------------------------------------------------------|-----|
| The Expert Survey-Based Global Ranking of Management- and Clinical-Centered Health Informatics and IT Journals | |
| Michael S. Dohan, Alexander Serenko, and Joseph Tan | 151 |
| Revisiting an Integrated Health Informatics and Technology Curriculum Model Bernard T. Han, Tracy L. Johnson, and Kenneth D. Bob | 162 |
| E. A List of Reviewers | 171 |

Message from Conference Chair

Bernard Han, Ph.D. HIT Pro, Haworth College of Business, WMU

It has been a wonderful journey for the *Center for Health Information Technology Advancement* (CHITA) at WMU to hold this biennial event since 2011. Similar to our success in ICHITA-2011 and ICHITA-2013, this year, with a theme of "Transforming Healthcare through Information Technology," we have accepted fourteen quality research papers, authored by thirty-two scholars, spread across multiple disciplines including nursing, health administration, psychology, management, and health information technology. Compared to the work published in 2011 and 2013, research contents and findings from this year are much richer and more prolific than before. In a quick summary, these fourteen papers are classified into four groups. A brief highlight is given below for each of these three categories.

A) HIT Adoption, Barriers, and Success Factors. Four papers fall into this category. Lavariega, Garza, Gómez, Lara-Díaz, and Silva-Cavazos explored a pilot EHR system designed for pediatricians to investigate its impacts on the quality for pediatric care in terms of medication prescription and error reduction along with user acceptance and resistance to this new electronic medical application. Regan and Wang examined ten critical success factors (CSF) and their implications on the success or failure in realizing the expected value from the investment of EHR as reported in existing literature. The third paper, authored by Ngafeeson, applies the *psychological reactance theory* to explain both the nature and relationship of *perceived threats* and *user resistance to IT* within the arena of healthcare applications. Lastly, Hafner and Noteboom investigate the influences of unlearning "old competencies" of end-users (e.g., physicians) toward the acceptance of "updated" EHR.

B) HIT Applications for Healthcare Practice. Three research papers and one short position paper confine their study to the use of HIT in healthcare practice. Ryan, Doster, Daily, and Lewis conducted an extensive study on how a data-driven approach with continuous process improvement has been used to balance the perioperative processes in streamlining the patient workflow for better performance. Alqahtani, Alsalmah, and Alaiad studied the performance differences between older and younger adults when interacting with a mobile game that is designed for senior healthcare. Skinner and Higbea employed Dixon Forecasting Model, along with the Bed Ratio and the National Emergency Department Overcrowding Scale (NEDOCS), to develop a forecasting tool to predict a within two-hour traffic to the emergency department. The last paper by Wright, a psychologist, provided an insightful suggestions on possible ways, from both users' and EHR's perspectives, to streamline health data collection.

C) Emerging HIT Applications. Four papers are accepted in this area. The first paper, authored by Alaiad, Ziaei, and Al-Ayyad, used a thematic approach to investigating the smart home setting with respect to the interaction among four major components - person, tasks, technologies, and environments. Ashtari, Eydgahi, and Lee studied the key issues of using cloud computing technology in healthcare practice. In specific, a research framework, composed of technological, organizational, environmental and human factors, is proposed and will be implemented for data collection and analysis. Razi provided a timely report on how patient handoff process can be improved by using an electronic device with a shared server hosted by a service provider that provides multi-site multi-unit patient care. Finally, the fourth paper, by Molla, studied the radon and its health risks for residents with limited knowledge in discerning Radon, and proposed how HIT can be used as an effective tool to shape people's behavior in mitigating Radon's effects on human health.

Having a collection of quality papers can never happen without quality reviewers. Finally, sincere thanks must be directed to all paper reviewers (see Page 162). Without your tireless and professional critiques, it is impossible to have this volume of publication – *Transactions of ICHITA-2015*.

Message from the Transactions Editor

Huei Lee, Ph.D. Professor, Eastern Michigan University

It is my pleasure to present the *Transactions of the International Conference on Health Information Technology Advancement,* which is related to the ICHTA-2015 held in the Western Michigan University, Kalamazoo, Michigan on October 30-31, 2015. I would like to express my appreciation to Bernard Han, Program Chair of the Conference, for his outstanding leadership. Through his help, the editorial process became easier and smoother.

This was the third year to publish the Transactions. Since the last time, new information technologies have emerged as essential tools for healthcare systems. These technologies includes mobile computing, cloud computing. Attending an academic/professional conference allows us to gain updated knowledge in both theories and practices. The purpose of this conference is not only to discuss the information systems of health care applications, but also to discuss academic curriculum trends and critical issues related to health care information systems. This year we received more submissions than we had expected. This volume contains about fourteen refereed papers in three categories, developed by more than thirty authors and co-authors. These papers have been gone through a rigorous double-blind review process. The Transactions publishes hard copy and online edition. The best papers will be considered for publication in the coming issues of *International Journal of Healthcare Information Systems and Informatics*. Secondly, I want to thank the authors, presenters, and reviewers for their persistent hard work for these papers/reviews for the Transactions of the ICHITA-2015 conference. I know that it was a lot of hard work, but it was well worth. I also would like to mention that Western Michigan University has established its own school of medicine.

Finally, I would like to thank everyone again for their participation in the ICHITA-2015. It has been an honor and a privilege to serve as the transactions editor. Without your help and support, the Transactions would not have been possible. In addition, the committee will greatly appreciate it if you can provide them with ideas and issues so that they can improve the quality of the Transactions in the future. We wish you enjoy the conference in Western Michigan University and look forward to seeing you again in future ICHITA conferences.

EEMI - An Electronic Health Record for Pediatricians: Adoption Barriers, Services and Use in MEXICO

Juan C. Lavariega, Roberto Garza, Lorena G. Gómez, Víctor J. Lara-Díaz, Manuel J. Silva-Cavazos Tecnológico de Monterrey Av. E. Garza Sada 2501, Monterrey NL, México Telephone Number: +52 (81) 83581400 ext. 5250 lavariega@itesm.mx, roberto.garza7@gmail.com, lgomez@itesm.mx, vj.laradiaz@gmail.com, manuel@silvacavazos.com

Abstract: The use of paper health records and handwritten prescriptions are prone to preset errors of misunderstanding instructions or interpretations that derive in affecting patients' health. Electronic Health Records (EHR) systems are useful tools that among other functions can assists physicians' tasks such as finding recommended medicines (and their contraindications) and dosage for a given diagnosis, filling prescriptions and support data sharing with other systems. By using an EHR many errors can be avoided. This paper presents EEMI (Expediente Electrónico Médico Infantil), a Children EHR focused on assisting pediatricians in their daily office practice. EEMI functionality keeps the relationships among diagnosis, treatment, and medications. EEMI also calculates dosages and automatically creates prescriptions which can be personalized by the physician. The system also validates patient allergies to avoid prescription of any pharmaceutical with alerts. EEMI was developed based on the experience of pediatricians in the Monterrey metropolitan area. This paper also presents the current use of EHRs in Mexico, the Mexican Norm (NOM-024-SSA3-2010), standards for the development of electronic medical records and its relationships with other standards for data exchange and data representation in the health area. This system is currently in production. It uses novel technologies such as cloud computing and software services.

INTRODUCTION

Mexico, like other developing countries, holds a social debt for its citizens with respect to the provision of health services. In particular one of the most vulnerable groups is the infant population. Even though the global child mortality rate (considering children under five years old) has been declining from 90 to 48 deaths per 1000 live births between 1990 to 2012 (World Health Organization, 2013), there is still work to be done. In urban parts of Mexico, the infant mortality rate is 16.2 deaths per 1000 live births, but the number in rural areas is even higher, where children present symptoms of malnutrition, untracked growth and untracked immunizations. However, more than a half of child deaths in general (rural and urban areas) are due to diseases that are preventable and treatable through simple and affordable interventions. Some of the most deadly childhood diseases like measles, polio, diphtheria, tetanus, pertussis and pneumonia have immunizations available that can protect children from illness and eventually, death (World Health Organization, 2013).

Electronic Health Records (EHRs) systems with key functionality for pediatricians can help reduce these problems (malnutrition, untracked growth and untracked immunizations) by recording a child's information, generating immunization schedules and comparing child growth with recommended world charts (Bulletin of the World Health Organization, 2007). EHRs assist pediatricians, who, as many other medical professionals, have a heavy work load and a priority for up to date knowledge. Pediatricians manage the physical, behavioral and mental health of children from birth up to age 21. They are trained to diagnose and treat a broad range of childhood illness, ranging from minor health problems to serious diseases. Unfortunately, pediatricians just like any human being, are susceptible to make mistakes, can feel tired and/or be distracted, and then write incorrect dosages, misspell a medication name or simply write an illegible prescription.

The National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP) defined a medication error as "any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer (NCCMERP). According to the American Society of Health-System, Pharmacists prescription errors are any incorrect drug selection, dose, dosage form, quantity, concentration, rate of administration, instructions of use, and any illegible prescriptions that

lead to errors (ASHP Guidelines, 1993). The dose selection errors represent more than 50% of all prescribing faults, but other possible errors could be due to inaccuracy in writing, poor legibility of handwriting, use of abbreviations or incomplete writing of a prescription because all of these errors can lead to misinterpretation by pharmacists and patients (Velo & Minuz, 2009).

In a study conducted at a Mexican university (Zavaleta-Bustos, et al, 2008), a sample of 370 prescriptions were randomly selected for analysis. The results indicated that 214 prescriptions (58%) of the sample had at least one error. The most common errors were incorrect indication, patient allergy to a medication, incorrect dosification, unjustified medications and duplicity of medications. Many of these errors were produced during the act of writing out a prescription.

Pediatricians, when confronted with an adult-oriented EHR, complain about not having specific functions for child medical care. The pediatricians' software requirements for EHRs are: immunization management, growth tracking, and medication dosing. Without these functions in an EHR, pediatricians are not capable to provide with quality care (Spooner, et al., 2007).

An EHR system that fully supports pediatric practice must allow the recording of multiple immunizations and be able to analyze immunization data to determine the age when each vaccine should be administered. In addition, the system must provide graphic information of a child's body measurements (weight, height, head circumference, body mass index) over time, as pediatricians make judgments based on these measurements. Another requirement is the method for calculating drug dosages; the system must be able to calculate doses based on weight or age depending of the medication (Spooner, et al., 2007). Based on these needs, EHR should be adopted as a helpful tool for physicians. However, in developed countries existing EHRs are expensive, difficult to use, developed from the hospital administration point of view, or do not meet physician's needs. As a consequence, unless there is a clear benefit (economical or better job status) for using EHR, physicians do not use EHRs and usually see these systems as a waste of time.

This papers presents EEMI (abbreviated by its name in Spanish, Expediente Electrónico Médico Infantil or Child Electronic Health Record) a system for the administration of medical records planned for pediatric medical practice. EEMI was designed and tested with the active participation of experienced pediatricians working at one of the top hospitals in the metropolitan area of Monterrey, Mexico. The objective of EEMI is to help pediatricians to minimize the possibility of errors, optimize consultation time (spend more time with patient, rather than filling forms) and keep track of patients' information.

The rest of this paper is organized as follows. Section 2 presents the use of EHR in context, including the barriers that this type of systems face during its adoption or rejection by medical professionals; a brief discussion of standards and international norms for EHRs; and a comparison of current EHRs including EEMI. Section 3, formally presents EEMI through the description of its functionality. Section 4 describes the technology used inEEMI. Finally, Section 5 discusses current status and future work.

BACKGROUND AND RELATED WORK

This section includes a description of the adoption barriers that EHRs face with the physician community; describes the standards and regulations currently available for EHR's; and concludes with a brief description of the main EHRs used in the US and in Mexico.

Adoption Barriers

According to some studies (Humpage, 2010; NCCMERP; Spooner, et al., 2007; Velo & Minuz, 2009), and our own experience (Ruiz, 2011) the use of EHRs, increases productivity by 20%, reduces waiting time up to 60% and saves 80% of paper work cost. Additionally, EHRs have other benefits such as: increasing security on patient sensitive data; providing easy and fast access to patient information; decreasing negative medical events (overmedication, incorrect treatment, etc.); and decreasing cost by unnecessary or repetitive treatments or laboratory tests. Despite their benefits, EHRs have not been fully adopted due to factors such as change resistance, cost, lack of incentives and complex customization (Humpage, 2010; Spooner, et al., 2007; Ruiz, 2011).

Diverse technology and adoption speed. There is no clear measure of how successful is the use of EHR, because doctors, patients and hospitals are using diverse technologies, and some of them are not using any at all. Some EHR systems run on standalone machines, others use mobile devices and internet services.

Resistance to change is the main barrier for adoption, particularly by physicians. Arguments given by physicians include system cost, job overload and concerns about information security and privacy. Physicians which use EHR, do because they have been instructed by their superiors or see a benefit, for example an economic bonus or a job promotion.

Cost is another barrier for adoption of EHRs. Most of electronic health record systems are implemented in large medical centers with complex functionality; from administrative activities management (insurance processing, billing, patient's registration, etc.) to health information management (patient medical history, lab analysis, surgery schedules, etc.). Therefore the cost of EHR increases and only large medical centers can afford to have electronic health records. It is difficult to quantify the benefits that physicians find in their practice when using EHR. It is hard to evaluate the increase in productivity, cost reduction, and the return of investment (ROI).

Incentives wrongly aligned. Cost savings by using an EHR may not have a direct impact in the physician income, but in the patient cost or in the health insurance company earnings. For example, an EHR can alert when a medicine is prescribed to an allergic person, then the patient or his/her insurance company can save money with the avoidance of the need for further anti-allergy-related treatment.

Personalization and work flow. Successful systems are customizable to different types of users (physicians in this case) but such a customization may be complex and time consuming. Additionally, physicians have a personal style to do their job and they see EHR as an unwelcome change in the way they work, affecting their productivity.

During the design and development of EEMI, pediatricians worked directly with the development team in order to correctly map their needs into EEMI functionality, minimize resistance to change and technology adoption. Deployment of EEMI was done in increments; physicians had a functional version of the system, on every release. Also workflow templates were generated for a less complex customization and a successful implementation.

Health Standards and the Mexican Norm

EHRs are nowadays subject to regulations with respect to how they represent, store and share information with other systems. A brief description of the Mexican norm for electronic health systems and international health information standards follows.

The Mexican Norms (**Norma Official Mexicana** NOM-024-SSA3-2010 and NOM-024-SSA3-2012) (Secretaría de Salud, 2011) are the standards that sets the objectives and functional requirements that an electronic health record must have in order to guarantee the interoperability, confidentiality, security, and information catalogs. Among its specification the Mexican Norm states that electronic health records have to demonstrate that a minimal set of data is generated. The Mexican Norm requires the use of international standards for disease classification (ICD), interoperability (HL7) and medical images format (DICOM). Systems that are regulated by the norm include those used in outpatient consultation, inpatient care, emergency care, pharmacy, laboratories, surgery, and imagining.

The **International Classification of Diseases (ICD)** [37] is the standard diagnostic tool for epidemiology, health management and clinical purposes. This includes the analysis of the general health situation of population groups. It is used to monitor the incidence and prevalence of diseases and other health problems, proving a picture of the general health situation of countries and populations. The ICD is published by the World Health Organization. The Mexican Norm requires that EHR use a disease catalog such as the ICD.

Logical Observation Identifiers Names and Codes (LOINC) [29] is the standard for identifying medical laboratory observations. LOINC includes categories for chemistry, hematology, and microbiology, among others in

its laboratory section. The clinical observations section includes vital signs, electrocardiograms and echocardiograms among other categories.

Digital Imaging and Communications in Medicine (DICOM) [17] is the standard for medical images. DCOM defines how to handle, store, print and transmit information in medical imaging. It includes a file format definition and a network communications protocol. This standard is implemented in almost all devices used in radiology, cardiology, and ultrasound. The standard is also being applied to ophthalmology and odontology. The Mexican norm, mentions DICOM as the standard to be used for medical images by EHRs.

Health Level Seven (HL7) [24] is a set of standards for the transference of clinical and administrative data between different health software applications including EHRs. HL7 refers to the focus of the standards in the application layer (or layer 7) in the Open System Interconnection (OSI) model. There are two versions: HL7 Version 2 and HL7 Version 3 from which Version 2 is the most widely used in health related systems. Communication between applications as defined in HL7 is through well-formed text documents. Mexican Norm requires data exchange between health systems to follow the HL7 standard.

EHR systems comparison

In the US, the adoption of EHR has increased in the last years, in part due to government incentives, maturity of the EHRs, and better acceptance by medical professionals. EHR enterprises have perceived the market growth and therefore they have developed a great variety of products, as shown in Table 1 (EPIC; Cerner; Allscripts; drchrono Inc.; Entrada; Smart EMR; eClinicalWorks; PracticeFusion Inc.; Athenahealth Inc.; iCare).

In Mexico, after the release of the Mexican Norm for Electronic Health Records in 2010(Secretaria de Salud 2011; NOM 2010), new EHR's have been developed. The majority of these EHR implementations are in public health system hospitals and some in private medical centers. Public institutions such as IMSS (Social Security Institute for Mexico), ISSSTE (Social Security Institute for State Workers), PEMEX Hospitals (Mexican National Oil Company), Secretaría de Marina (Mexican Navy) and the private ABC Hospital have their in-site developed EHR. There are few commercial systems such as eMedix, Med2k, and, Alert. None of the reviewed systems for Mexico has a patient version or portal. Table 2 shows the characteristics of EHR in Mexico (ISSSTE, 2010; Estado de Colima; Secretaría de Marina; Yacamán, 2010; Ortega V, 2014; eMedix; Med2k; *Alert Online*).

| EHR | Deployment | Focus on | e-prescribing | Standards | Comments |
|-----------------|-------------|-----------|--------------------------------------------------------------------------------------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| EPIC | On Premise | Hospital | Prescription creation | HL7 | Leader in the Gartner 2013 Magic quadrant for Enterprise EHR systems. |
| Cerner | Web, Mobile | Patient | NA | NA | Leader in the Gartner 2013 Magic quadrant forEnterprise EHRsystems. Personal Health Record. Shows metrics in a graph. |
| AllScripts | Web | Hospital | Pharmacy link | NA | Visionary in the Gartner 2013 Magic quadrant for Enterprise EHRsystems. |
| DrChrono | Web, Mobile | Physician | Prescription creation, Pharmacy link | ICD-9 | Patients can access their demographic information, manage appointments, query lab results, send and receive messages to physicians, pre-fill forms in advance. Shows metrics in a graph. |
| SmartEMR | Web | Physician | Prescription creation, link to Surescripts (largest e- prescribing network) | NA | Patient can review their medical history, receive appointment reminders, fill information in advance, request appointments, review lab results, request medicine refills and communicate with physicians. Shows metrics in a graph. |
| eClinicalWorks | Web, Mobile | Hospital | Prescription creation, Pharmacy link | ICD-9 | Patients can manage appointments, query their medical record, access lab results, request medicine refills and access educational information. |
| Practice Fusion | Web, Mobile | Physician | Prescription creation, Pharmacy link | ICD-9 | Patients can manage appointments, query lab results, consult prescriptions, consult immunization schedule and send messages to physician. Shows metrics in a graph. |
| Athena Health | Web, Mobile | Physician | NA | ICD-9 | Patients can manage appointments, receive appointment reminders, and consult lab results. Shows metrics in a graph. |

Table 1. EHRs in the USA

| EHR | Deployment | Focus on | e-prescribing | Standards | Comments |
|--------------|-----------------|-----------|-------------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------|
| IMSS | On Premise | Hospital | Prescription creation | NA | This system is only used for patients who are affiliated with IMSS. |
| ISSSTEMed | On Premise | Hospital | Prescription creation | NA | Interaction with pharmacy system and lab test, this system is only used for patients who are affiliated with ISSSTE. |
| SAECCOL | On Premise | Hospital | NA | ICD-9, ICD- 10 | This system is used by public hospitals in the state of Colima. |
| SICOHOSP | On Premise | Hospital | Prescription creation | ICD-10 | System used by Mexican Navy. Interaction with lab test system |
| Hospital ABC | On Premise | Hospital | NA | NA | System only used for patients in hospital. |
| PEMEX | On Premise | Hospital | ICD-10 | ICD-10 | This system is only used to keep health records of PEMEX workers. |
| eMedix | Web | Physician | NA | ICD-9, ICD- 10 | Available for any physician. Monthly fee. Image storage |
| Alert | On Premise, Web | Hospital | Prescription creation | HL7 | Software as a Service. Installed in 13 countries including Mexico. |
| Med2K | On Premise | Physician | Physician writes prescription | ICD-10 | Available to any physician. Installation Maintenance and license costs. Image storage, video and voice. |
| EEMI | Web | Physician | Prescription creation | ICD-10 | Available to any physician. Software as a service. Monthly fee. Automatic creation of immunization schedule. |

Table 2. EHRs in Mexico

The information summarized in Table 1 and Table 2 helped us to define and design the functionality on EEMI. One of the key factors we found in the analysis was the need to keep a record of immunizations, create prescriptions automatically but in an editable by physicians format and of course the imperative to follow the Mexican Norms (Secretaría de Salud, 2010, 2011) as well as international standards. In the following sections, a detailed discussion on EEMI is presented.

EEMI SYSTEM DESCRIPTION

EEMI is an electronic health record system based on the practice experience of pediatricians in Monterrey, Mexico. The system follows the Mexican norms in its functionality and data exchange. Figure 1 represents a contextual

overview of the services provided by EEMI. Users of the Child Electronic Health Record, presented in this paper, are physicians and their office assistants. The following paragraphs describe EEMI services.



Figure 1. EEMI Contextual Overview

Appointment Administration.

This module allows to creates and manage appointments. This service resolves date conflicts with national holidays and personal physician calendar. The physician can manage his/her own calendar to mark his/her vacations or define days out of the office.

Visits management.

This module includes access to previous diagnosis, known treatments and related medications to facilitate and speed up the physician diagnostic. The system is able to automatically generate a prescription based on the diagnostic and calculate the medication dosage. The automatically generated prescription can be edited by the physician according to his/her consideration.

Medical record management.

This module allows the management of information such as measurements, medical history, family, documents, laboratory results, immunizations, appointments, and visits history. New information can be added or current information can be updated.

Diagnosis.

This module allows the specification of visit diagnosis based on the International Classification of Diseases (World Health Organization). The system has a section for the diagnosis, treatments, medications formulary and brand names. This information is presented in form of lists that are related with each other and whenever a physician selects a diagnosis the system will display the possible treatments for that diagnosis, when a physician selects a treatment the system will display the possible medications for that treatment and the same goes for the medications and brand names.

Every time a physician selects a diagnosis the system will learn the relationships between diagnosis, treatment, medication and brand names and also the information for each one of them. This eliminates the need for the physician to type the same information every time for the same diagnosis. However, the possibility of modifying the selected treatment is kept always open, since there are no fixed combinations of diagnostic-treatment-medication-brand name.

Each physician can create, modify and save his/her own catalogs of diagnosis, treatments, medications and brand names and the information could be used by another physician but could also be modified in case of an error, or a different treatment preference, choice of medication or a different brand name. The creation of this medical collaboration will reduce the errors in diagnosis.

Additionally, the system identifies frequent diagnosis in the last "n" days and every time a physician selects one of them, the system will suggest a full diagnosis, set of diagnosis-treatment-medication and brand name based on the most recently used. This suggestion makes faster the process of consulting a patient and is also helpful because many diseases have different prevalence depending on the season of the year and have a tendency to appear as clusters.

Every time a medication is added to the prescription, the system validates that the medication doesn't have an incompatibility with other medications in the same prescription. EEMI also validates medication against patient's known allergies.

Prescriptions and dose calculation

Once the diagnosis is selected, the system creates the prescription based on the information of every treatment and medication; it calculates the dose and generates a text for each medication that contains the presentation, dose, administration route, dispensing time and duration of treatment. The physician can print the prescription and give the patient a legible prescription that will not cause any misinterpretation. The dose calculation for every medication can be calculated by bodyweight or patient's age.

Immunization schedule

The immunization schedule is automatically programmed based on the recommendations by the Mexican Ministry of Health (SSA). The doctor can personalize this schedule adding new immunizations not considered by the SSA. The system records the immunization and the age range of application. The recommended immunization date will be used for calculating the estimated date of application for a child and will create an appointment for that date. When a child is born and visits the pediatrician for the first time, the physician's assistant uses the system to schedule a full calendar of immunizations and appointments. This automation helps to keep track of the child's immunizations and allows the assistant and the physician to remind the family for future visits. EEMI sends automatic e-mail remainders to parents or tutors of child's immunizations appointments.

Growth graphs

The system displays the child's anthropometric measurements (weight, height, head circumference, body mass index) in a percentile chart, so the physician can assess the growth over time, but is also able to compare with population statistical data, because the system also displays the percentile distribution of all population values.

With EEMI, the pediatrician can view, print or save in various graphic formats data of weight for age, height for age, weight for height, head circumference for age, and body mass index for age.

In a weight for age graph the pediatrician can easily identify when a child presents overweight or malnutrition by just comparing the child weight and check if the value is outside the normal values. Figure 2 shows an example of a low weight for age graph, where the blue dots are the child's weight and the color lines are the normal values.



Figure 2 Growth Graph (weight vs age)

EEMI Benefits

The following are the benefits of EEMI adoption according to observations by the initial testing group. Most of the benefits are not directly quantifiable in monetary terms, but qualitative in terms of a better interaction between physicians and patients.

Tax Deductible Cost. In its current implementation as a software a service (SaaS), EEMI is tax deductible by the Mexican fiscal legislation. Therefore, there is no a direct economic cost to the physicians that are using EEMI. Other EHR that were developed as standalone desktop applications are not considered services by the fiscal law, and the investment and other monetary cost are covered by the adopters.

Optimization of Visit Time. During the visit, physicians spend more time talking with patients and understanding his/hers needs that looking for past visits records or writing down prescriptions and indications.

Elimination of prescription errors. One key functionality of EEMI is the automatic (and editable) creation of prescriptions. This feature reduces common errors that physicians may do while handwriting or even typing prescription. It also allows to reduce or even eliminate medication incompatibility errors by looking for contra-indications for medicines in the prescription.

Patient data consistency and privacy. Other key benefit mentioned by adopters of EEMI is the consistency in the information that is included in the prescriptions, such as medicines, dosage and particular indications. By having all this information at hand from visit to visit allows physicians a better understanding of the patients' progress.

Elimination of paper storage. The use of EEMI has permitted to reduce or eliminate the physical space required for storage of paper records.

EEMI Adoption and Barriers

EEMI has been evaluated by a group of physicians during its testing period. Even though, the acceptance of EEMI has been generally good, there are still some adoption barriers among the medical community. The most prevalent are:

Change resistance. As in any professional group, there is a group of physicians that is not willing to accept an EHR of any kind, and keeps attached to the traditional way to do a consult.

Use customization. One aspect for a good acceptance of an EHR according to the evaluation group has been the customization of the systems to the physician practice. EEMI has been successfully adapted to the way pediatricians work, however it is possible that other physicians find EEMI workflow inadequate to their practice.

Information transfer. Another key element for delay in the adoption of EEMI has been the burden of the initial transfer of patient information from one legacy systems to EEMI. Without this feature, physicians face the dilemma of capturing (typing) again all their patients records or to keep the legacy systems for old time patients and record the new patients in EEMI,

EEMI TECHNOLOGY DESCRIPTION.

EEMI is built based on the N-Tier Architecture, specifically 3-Tier Architecture. It's a client-server architecture where the logic, view and data are in different tiers. The data tier can contain one or more databases, the business tier contains all the logic of the project and the presentation tier contains the user interface. Currently EEMI is being implemented on a Service Oriented Architecture (SOA) that provides a loosely coupled approach that allows interoperability, maintenance and updates (Schuldt, 2009). The use of Web Services allows data sharing between applications. A study showed that physicians have an urgent requirement to access the electronic health record systems with personal devices such as tablets or smartphones; therefore, a Service Oriented Architecture is suggested in the study ((6). 624-628, 2009). With this architecture we can develop native applications for diverse operating systems (iOS and Android) that cover the mobile devices alternatives in the market. This is possible by only developing the presentation tier and using the Web services.

The Figure 3 shows the architecture of the system, which is composed of three tiers. The presentation tier contains all the interfaces that presents data to the end users and allows the data manipulation. The business logic tier contains all the web services that will obtain and modify the database. The data tier is responsible for the database management. This separation of tiers improves scalability, reusability, flexibility, and maintainability, because we have loosely coupled and highly cohesive methods in each tier that are easy to change or reuse. Is important that the system has these attributes because we want to extend this system to other medical areas like gynecology.



Figure 3. SOA for EEMI

EEMI is implemented in.NET Framework 4.5. The presentation tier was developed in ASP.NET, the business logic tier in Windows Communication Foundation (WCF) and for the data tier we use SQL Server 2012. The system is running in a cloud computing platform, Microsoft Azure.

CURRENT STATUS AND FUTURE WORK

At the time of writing this paper, EEMI has been in the acceptance testing phase with a pilot in a group of pediatricians in Monterrey, Mexico. We will review the results and observations of this phase for include improvements in the production version. The production version was completed by the end of August 2015.

As future work, EEMI will be integrated with the project for Monitoring and Assisting Maternity-Infant Care in rural areas (MAMICare) (Lavariega, Córdova, Gomez-Martinez, & Ávila, 2013). The MAMICare project monitors pregnant women to detect anomalies and prevent maternity and infant deaths. The EEMI system will continue with the monitoring of the child by keeping track of the growth and immunizations of the child.

New electronic devices are being reviewed. These devices send information via Bluetooth to automatically register the measurements in the system. One key idea is to incorporate these devices in the process of taking measurements to eliminate the possibility of human errors in typing data manually.

As a web application, EEMI can be accessed from any tablet or smartphone, however, the user interface may not look exactly the same in all devices. One objective in the short terms is to develop native iOS and Android applications of this electronic medical record, a decision has to be made upon including only the most important requirements for these new applications or include everything that is available in the current system.

CONCLUSION

In general, EEMI enhances the process of a pediatric medical consultation due to the automation of several common activities. It also reduces the possibility of error that could be incurred at any time the physician types repetitive diagnosis. Due to the automated functions, the physician can focus on giving a better medical care. As a consequence of fewer typing errors, patient information is more accurate and a sense of security can be established between physician and patients.

EEMI is a useful tool for keeping track of the child's growth and creating an immunization schedule for each child. The graphs will help the pediatrician to make decisions based on the weight, height, head circumference, and body mass index of a child.

With the use of a Service Oriented Architecture the system is scalable, reusable, flexible, and maintainable. This architecture makes it easier to make changes in the system, and reuse code because of the highly cohesive and loosely coupled methods. We can create native applications for iOS and Android by just developing the presentation tier and use the Web Services that are already developed in the business logic tier.

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Realizing the Value of EHR Systems: Critical Success Factors

Elizabeth A. Regan, Ph.D. University of South Carolina Department of Integrated Information Technology earegan@mailbox.sc.edu 803-777-2286 Jumee Wang, MPH, PhD candidate University of South Carolina Arnold School of Public Health wang389@email.sc.edu 803-777-1627

Abstract: Now that a majority of hospitals and primary care physicians have made the transition to electronic health record (EHR) systems, realizing value from this investment has become a major issue. The issue raises two key questions: Why do so many EHR implementations continue to fall short of achieving intended healthcare outcome goals? What differentiates those that succeed from those that fall short? This article builds on prior research using a systems framework to analyze the EHR implementation process. It focuses on ten common themes (CSFs) that appear to differentiate institutions which achieve positive healthcare outcomes from those that do not. Results are highly relevant for healthcare institutions now seeking to focus on realizing the value of their EHR systems.

INTRODUCTION

Now that a majority of hospitals and primary care physicians have made the transition to electronic health record (EHR) systems, realizing the full value from this investment has become a major issue. A recent College of Healthcare Information Management Executives (CHIME) survey indicates that optimization of EHRs will be a top priority in the next year for over 70 percent of respondents (Leventhal, 2015). This is hardly surprising since health IT implementation projects frequently fall short of achieving their potential. In fact this result is true of IT implementations across all industries; research indicates that half or more of IT projects continue to fall short of target goals (Aguirre, 2014). The key question for EHR implementation is what differentiates initiatives that succeed from those that fall short? This article builds on the authors' earlier research examining organizational EHR implementation from a systems framework to identify factors that differentiate institutions that achieve positive outcomes from those that report little to no impact and sometimes negative results. The primary aim is to identify what healthcare organizations that achieve the best results share in common that may account for their success in 'meaningfully using' health IT to improve care delivery.

A publicly subsidized demonstration project that implemented comprehensive, point-of-care, clinician-centric health IT systems in 20 New York city-area nursing homes illustrates the problem. The research findings reported considerable variation in outcomes:

"Despite the fact that each home implemented the same software and hardware via the same vendor, there have been variations observed both by early research findings and by the 1199 Training Fund coordinators about how the adoption of HIT has affected, and has been used by, homes. Examples of these differences range from how homes responded to bugs in the HIT system, to whether the technology was fundamentally perceived as a means of improving clinical indicators, financial outcomes, employee efficiency, or the entire culture of a home and perceived time savings. Variation was also reported in use of available health IT data. The quality improvement possibilities inherent in these capabilities are very rich, but not all homes have engaged in these types of analyses and customizations, and those that did, pursued different strategies." (Klinger & White, 2010)

Although there is a growing consensus that health information technology and exchange play foundational roles in addressing cost, quality, and access challenges of the United States healthcare system, prescriptions for how to get there successfully vary widely. Frequent failure to achieve intended healthcare outcomes is evident in the growing attention being placed on EHR "optimization" and "realizing the value of health IT." Despite well-established methodologies and recommendations for managing health IT implementation initiatives, the same lessons continue being learned through trial and error by clinicians, health IT specialists, and healthcare systems of every ilk. The

cost is significant in dollars and results, with some experts reporting failure to achieve intended results 50 percent or more of the time (Keshavjee, 2006; Leviss, 2010; Goroll, Simon, Tripathi, Ascenzo, & Bates, 2009). Studies assessing the impact of EHRs tend to focus on technical factors, overlooking the possibility, as systems theory would suggest, that lack of results may be attributable to people, process, and other dynamics of the healthcare setting rather than the technology itself.

Systems theory provides a framework for viewing health IT implementation holistically as opposed to reductionisticly. It recognizes the extremely complex dynamics of the healthcare environment. The objective is not just to look at individual factors, but to also look at the complex interaction of people, process, and technology to gain better insight into differences in outcomes.

Our initial study findings (Regan & Wang, 2015) identified ten context, process, and technology variables that appear to differentiate institutions which have been most successful in achieving *meaningful use* (i.e., optimizing or achieving the value of EHRs). In order to further validate and clarify previous findings, this second phase of the study compared additional examples of EHR implementation and related research on the systemic nature of innovation and change. Results are highly relevant for healthcare institutions now seeking to focus on realizing the value of their EHR systems. The intent is to move beyond basic questions of whether health IT creates value to focus more on understanding *how* the technology can be "meaningfully" used to transform care delivery to achieve the primary aim of increasing patient access and improving quality of patient care at reduced costs (Jones, 2014, p.52).

BACKGROUND / LITERATURE REVIEW

As the momentum for transitioning to electronic health records accelerates, the national focus has shifted from buying and using the technology to sharing information across the continuum of care and transforming the United States health care system. Many observers believe that national momentum for healthcare change has reached the "tipping point," in the terminology of Malcolm Gladwell. However, the challenges of realizing value from investments in transitioning to EHR systems on a national basis remain daunting. Buy-in among healthcare professionals continues to be problematic (Khoja, 2013; Coplan, 2013; Heisey-Grove, 2014).

To further validate and clarify previous findings, the second phase of research has focused on identifying additional multifunctional health IT interventions published since 2012. Research reports and case studies, both success stories and failures, evaluated in the first phase of this project, identified a wide range of variables believed to impact outcomes. These variables, which relate to people and process as well as technology, are presented in the form of incentives, barriers, lessons learned, implementation guidelines, and others. Lau et al. (2012) identified over 100 factors in their review of 43 selected studies. Table 1 and 2 provide two representative frameworks showing the many variables associated with successful implementations of EHR systems. Table 1 is based Karim Keshavjee et al.'s (2006) systematic review of EHR implementation frameworks. They concluded that existing EHR implementation frameworks did not explain all elements experienced by implementers and have not helped to make EHR implementation any more successful. Table 1 summarizes their overarching framework that integrates multiple conceptual frameworks with the goal of explaining factors that lead to successful EHR implementation. Table 2 is based on the work of Dr. Kenneth G. Adler, MD (2007). He organizes the key factors of EHR implementation into three categories: team, tactics, and technology. His summary is intended as a practice guideline for practitioners of a successful EHR implementation. To a large extent it parallels the framework offered by Keshavjee et al., (2006) yet it also includes some different emphases. Although informative, these studies do not address the issue of why so many EHR implementations fail to achieve anticipated benefits.

| Critical Questions People, Process, or Technology (description) | | | | |
|-----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|
| | PRE-IMPLEMENTATION PHASE | | | |
| • Whose vision is it? | • Governance (people) - A senior management's activities or substantive personal | | | |
| • Why are we doing it? | intervention in the management | | | |
| What is the mission of project? | | | | |
| • Who is in charge? | • Project management leadership (people) – Bridge between top management and | | | |
| | other stakeholders | | | |
| | Project Manager - Plan, motivate, evaluate EMR, etc. Project Champion - Gain enthusiasm within work group | | | |
| | Within large organization – Use EMR Committee | | | |
| How does it help the organization or | Analyze state of 'organization's readiness' (process) | | | |
| employees? | • Prepare for the change | | | |
| • Does it make "my job" easier? | Demonstrate benefits to all addressing barriers or obstacles | | | |
| What do all stakeholders think? | • Involve multiple stakeholders (people) - Gain active participation and effective | | | |
| | support | | | |
| • What applications, features, etc., are | Carefully select software, hardware, databases (process) | | | |
| needed? | Conduct thorough needs analysis | | | |
| | Systematically evaluate technology alternatives | | | |
| Can all data be accessed where ever | System interoperability (technology) | | | |
| or whenever needed? | Integrate with existing information systems | | | |
| | Develop strategy to pre-load all existing data | | | |
| How is each feature used? | Technology usability (technology) | | | |
| | Hardware – placement, type, and ease-of-use of devices | | | |
| | Software –user interfaces and support of clinical workflows and processes | | | |
| | IMPLEMENTATION PHASE | | | |
| How will my job change? | Workflow and redesign (process) | | | |
| | • Understand the patient care process | | | |
| | • Fit staff and physicians clinical workflows together | | | |
| • How do I do this? | • Iraining (people) | | | |
| | • On-going required to gain expertise | | | |
| • What problems do we have? | Strong vendor partnership (neonle) | | | |
| · · · · · · · · · · · · · · · · · · · | Responsive to identified system modifications or improvements during the | | | |
| | implementation | | | |
| | Efficient and effective on-site help desk | | | |
| | Select and develop 'super-users' within the organization | | | |
| Who's going to help when you leave? | Support (process) | | | |
| - Mho do I telli to about a problem 9 | Develop strategy for ongoing support Each oak and dialogue (nearla) | | | |
| • who do I talk to about a problem? | Regular staff / raview meetings | | | |
| | Trouble-tracking systems with reports | | | |
| | Continuous implementation evaluation, monitoring, and tracking | | | |
| Whose record is it? | Privacy and confidentiality (process) | | | |
| | Must meet continually changing legal requirements | | | |
| | Requires trade-offs between confidentiality and access | | | |
| | POST-IMPLEMENTATION PHASE | | | |
| • What happens in an emergency? | Technical support and business continuity (technology) | | | |
| | venuor contract agreements specify revers of support Business continuity plan identifies roles, responsibilities, processes | | | |
| • Where do we find continuing help? | Business continuity plan identifies roles, responsibilities, processes | | | |
| • where do we find continuing nelp? | Oser groups (people) Scheduled user meetings led by EMR champions increases user acceptance | | | |
| | On-going system refinements increase user satisfaction | | | |
| • Why should I bother? | Incentives (process) | | | |
| ~ | Reinforce benefits to users and improved patient care | | | |
| | Demonstrate cost and time efficiencies | | | |

Table 1. Recommendations for Planning and Implementing EMR Systems

(Regan & Wang, 2015)

| TEAM | TACTICS | TECHNOLOGY | |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| Senior support and project champion Identify one or more EHR champions or don't implement Make sure your organization's senior executive fully supports the EHR Project manager and management Use an experienced, skilled project manager Utilize sound change management principles Goals and expectations Have clear, measurable goals Make sure users share your goals Establish realistic expectations Don't try to implement an EHR in a dysfunctional organization | Process - planning Plan, plan, plan Redesign your workflow Don't automate processes just because you can; make sure the automation improves something Design a balanced scanning strategy Process - implementation Pick a vendor with an excellent reputation for support Utilize a phased implementation Consistently enter key data into your new EHR charts Get data into the EHR electronically when possible Don't "go live" on a Monday Lighten your workload when you "go live" and for a short period afterward People Train, train, train Be flexible in your documentation strategy and allow individual differences in style Don't underestimate how much time and work is involved in becoming "expert" with an EHR Utilize "power users" at each site | Hardware If you're a small practice, consider an Application Service Provider (ASP) model. Don't scrimp on your IT infrastructure. Make sure your servers and interfaces are maintained on a daily basis. People Make sure that your IT personnel do adequate testing. Utilize expert IT advice when it comes to servers and networks. Process Back up your database at least daily. Have a disaster recovery plan and test it. | |

Table 2. The Three T's of a Successful EHR Implementation

(Regan & Wang, 2015) Taken from Adler (2007). "How to Successfully Navigate Your EHR Implementation."

Some of the myriad of variables might be considered in the category of sound planning and project management. Some may be particular to a given project; others are common across all projects. All the variables potentially influence the outcomes of any given project. However, missteps in addressing many of these factors often are correctible. The missteps may result in slowing down progress or require going back and modifying initial plans. However, they do not necessarily doom a project. Yet we also know that over half of health IT projects do fail, either falling short of intended improvements, leading to disuse, or resulting in cancellation. The question raised by our current study is whether, among all the many variables that must be addressed, it is possible to identify some that are critical to success; that is, they consistently make or break projects across many settings and projects. A related question is whether the critical success factors might change over time as implementation of health technology progresses along the adoption curve. In other words, are the factors the same among innovators and early adopters as they are among, the early majority, and will be among the late majority and laggards? For example, might the critical factors change as healthcare innovation passes the "tipping point," as the momentum and evidence build? Another interesting aspect of this question is to what extent it is realistic to expect institutions to learn from the experience of others and to what extent each institution needs to go through the tough learning curve on its own.

This second research phase has focused specifically on the 10 variables (factors) that appear to differentiate success from failure, which were identified in our original study (Regan, 2015). The research sought to provide additional insight into how and why these variables might influence project success as well as to confirm that the issues identified earlier continue to persist as methodologies for EHR implementation mature. In addition, evidence was sought for other possible variables associated with success or failure. We also sought to delve more deeply into issues related to the systemic nature of healthcare innovation. Four prior studies have been identified to date that address the same questions as the current study in trying to determine what factors distinguish health IT implementations that achieve their intended goals from those that fail or fall short (Adler, 2007; Keshavjee, 2006; Jones, 2014; Lau, 2012). Three other literature review studies focused on identifying barriers and incentives for adoption and use (Holroyd-Leduc, 2011; Mair, 2012; Lluch, 2011). However, a number of research studies and other analyses bring up issues related to contextual variables that appear to have influenced project results, which point to

organizational interdependencies and the systemic nature of sustaining major organizational changes (Heisey-Grove, 2014; Hagland, M., 2014; Marchibroda, J., 2014; McCann, E., 2012; Punke, 2014; Singh, 2014). No studies have been identified that specifically use a systems framework to analyze the effectiveness of EHRs. However, the emergence in June 2012 of a new interdisciplinary journal, *Health Systems*, promotes the idea that all aspects of health and healthcare can be viewed from a systems perspective. The journal's underlying philosophy is that health and healthcare systems are characterized by complexity and interconnectedness, where "everything affects everything else." Therefore, the editors suggest, "problems in healthcare need to be viewed holistically as an integrated system of multiple components (people, organizations, technology and resources) and perspectives." (Brailsford, Harper, LeRouge, Payton, 2012, p.2)

Recent literature on innovation in healthcare also underscores the systemic nature of transformation (Christensen, 2009). In their study of disruptive innovation in healthcare, Christensen, Grossman, and Hwang (2009), focus on the interdependent nature of transformational changes. For example, in their discussion of disruptive business models, they state, "When disruptive innovators assume that relying on the existing value network is a cheaper, faster way to succeed, they invariably find that ensconcing their "piece" of the system into the old value network kills their innovation—or it co-opts and reshapes their disruptive business model so that it conforms to that system. Vice Versa never happens."

Dr. Harvey Fineberg, past president of the Institute of Medicine, stresses in a 2012 address the importance of thinking about healthcare from a systems perspective and always putting the patient at the center of the system. He cites statistics about the high error rates in U.S. medical care, and talks about the challenges of designing for safety in a complex tightly coupled system. He suggests that although we do not know all the answers to transforming U.S. healthcare, one thing we know for sure: Our U.S. medical system is perfectly aligned to get the results we are getting! He goes on to infer that if we want different results, we need to be willing to do things differently, to rethink the models through which we deliver care. He is also a strong proponent of the view that higher quality of care will lead to lower healthcare costs, and provides many concrete examples based on redesigning systems of care (Fineberg, 2012).

Insights into success versus failure can also be gained by looking at the nature of process (workflow) changes that organizations have made with health IT. Achieving the value of EHRs involves integrating across silos of care. The more successful organizations appear to have integrated process change with EHR implementation; whereas, less successful organizations often take an approach of implementing first, then addressing work process issues later. Connected for Health, a detailed case history of Kaiser Permanente's (KP) journey to transforming care and achieving the value of EHRs, underscores the systemic nature of transformation and stresses the centrality of strategic leadership. Editor Dr. Louise Liang, MD, served as executive consultant to Kaiser Foundation Health Plan, and from 2002 to 2009, she served as senior vice president, Quality and Clinical Systems Support, where she led the development and implementation of KP's HealthConnect \$4 billion-plus transformation initiative (Liang, 2010). In his assessment of this effort, Dr. Donald Berwick, president and CEO of the Institute for Health Improvement, states, "Without clear incorporation into the actual process of care and without the re-engineering of those processes, and without the changes in norms, capabilities, and culture to allow those new systems to take root, KP HealthConnect would become what far too many other health care organizations had already discovered in their own modernization journeys: the computerization of a defective status quo" (Liang, p. xvi). Although some are quick to point out the uniqueness of KP as an integrated health system, their experience is instructive, and their former CEO George Halvorson, in reflecting on lessons learned, underscores the systemic nature of change (Liang, 2010).

Based on their targeted review of existing literature on health IT implementation and use, Rippen et al. (2013) identified five major facets of an organizational framework for providing a structure to organize and capture information on the implementation and use of health IT. The authors propose a new organizational framework for health IT implementation and use with five major facets: technology, use, environment, outcomes and temporality.

A systematic review of the health information technology research sponsored by the Office of the National Coordinator for Health IT (ONC) (Jones, Rudin, Perry, Shekelle, 2014) observed that very few studies report adequate information on implementation and context of use to determine why most health IT implementations are successful while some are not. They conclude that "it is no longer sufficient to ask whether health IT creates value;

going forward, the most useful studies will help us understand *how* to realize value from health IT (Jones, 2014, p.52). They call for researchers to shift the focus *from if to how* by promoting research that empirically studies the mediating effects of contextual and implementation factors on the relationship between health IT and key healthcare outcomes. The lack of reporting about context and implementation details raises a question of whether these important factors are being ignored during implementation or if researchers are overlooking them or consider them unimportant.

Recent research viewing IT-associated organizational change through the lens of Affordance Actualization theory shows promise of providing new insight into *how* and *why* outcomes occur, rather than on *what* outcomes occur and *what* the major barriers to those outcomes are (Strong, 2014). An affordance is defined as "what is offered, provided, or furnished to someone or something by an object" (which in our case would be an EHR system) (Volkof & Strong, 2013). Thus affordances can essentially be seen as potential benefits or value of using EHR systems. The theory shifts the view of EHR implementation as a single intervention to a greater focus on the dynamic process by which outcomes are achieved—in our view a systemic perspective. Instead of examining outcomes at a single level, it examines the multi-level dynamics of "actualization" (which in our view would be achieving the potential of health IT) focusing on how the organizational change process and outcomes emerge from individual actualization processes and their immediate concrete outcomes.

In conclusion, the growing body of research on EHR implementation identifies many variables associated with the implementation of electronic health record systems, but little evidence that may explain the wide variation in results achieved.

THEORETICAL FRAMEWORK.

The theoretical framework for this study is systems theory. System theory provides a framework for examining the fit among technology, people, structure, and process and has been widely applied in examining organizational behavior across many settings, especially in the workplace. The applicability of systems theory to research in healthcare settings has been established by a number of researchers (Brailsford, 2012; Payton, 2011; Frank & Murray, 2000). The dictionary defines a system as *a set of interacting or interdependent components forming an integrated whole*. Mingers & White (2010) provide a useful summary of the way in which the systems approach is generally understood among system researchers:^{*}

- Viewing the situation holistically, as opposed to reductionisticly, as a set of diverse interacting elements within an environment.
- Recognizing that the relationships or interactions between elements *are more important* than the elements themselves in determining the behavior of the system.
- Recognizing a hierarchy of levels of systems and the consequent ideas of properties emerging at different levels, and mutual causality both within and between levels.
- Accepting especially in social systems that people will act in accordance with different purposes or rationalities.

Phase Two of our research has focused more specifically on the systemic nature of IT-based innovation and change to gain greater insight into *how* context interacts with technology in impacting results. As the focus of IT implementation shifts to optimization (achieving the value from EHRs) and moves out of the domain of an IT project to the domain of clinical transformation, we might logically expect that process and context variables would become increasingly important in achieving healthcare improvement outcomes.

METHODOLOGY

This article addresses Phase Two of a multi-phase research project. The primary method for Phase One of the study was a systematic analysis and synthesis of published research, case studies, and other health IT implementation reports and innovation projects. The search process focused on identifying multifunctional health IT interventions

^{*} The first author is well versed in systems theory. However, an in-depth discussion is not within scope of this article primarily for space limitations. A large body of theory and practice is readily available to interested readers.

using EHRs that encompassed at least some of the functionalities required under meaningful use. Fifty studies and cases were analyzed for the first phase. The objective for Phase One was to identify a robust sampling of implementation projects. Prior research shows that "Many of the same lessons were extracted from widely different care settings" (Ludwick, 2009, p24; Lluch, 2011, p.852). Searches of several IT and healthcare databases were conducted (PubMed, Google Scholar, AHRQ, HealthAffairs). Search strategies used terms such as health IT, health information technology, health informatics, health IT implementation, EHR implementation, CPOE implementation, Meaningful Use, healthcare innovation, and similar terms.

The analysis focused on identifying people, technology, structure, and process variables associated with success or failure of health IT implementation and innovation projects. The first step was to compile a comprehensive listing of variables identified as incentives and barriers to adoption and use, including the presence or absence of factors commonly cited as best practices. The next step was to organize the different variables to eliminate redundancies due to variability in use of terminology. The refined list of variables was used to systematically study each research report or case study to analyze and catalog how the variables related to the reported results of the project. Most studies focused on only a subset of the total list of variables. Reported findings as well as the discussion, lessons learned and conclusions were used for this purpose. The final step was then to look for patterns or commonalities across the sample of reports and how they were associated with success and failure.

A similar process was used in at least three other systematic reviews we identified (Jones, 2014; Lau, 2012; Kashavjee, 2006). Overall, however, few research projects have approached evaluation of EHRs from a systemic framework. Many of these studies have focused more on user acceptance issues than on the value achieved from a healthcare outcomes perspective. Moreover, most research projects that have attempted to evaluate the effectiveness (i.e. value) of EHR implementation, have focused fairly narrowly on a specific set of factors. Findings related to context variables or other more systemic issues are often reported in relation to lessons learned rather than having been assessed as variables in the study.

Phase Two of the study has focused specifically on two strategies:

- 1. Analyzing the reported results of additional research projects and case studies published since 2012 to assess if more recent experience confirms, extends, or contradicts findings and conclusions of Phase One.
- 2. Reviewing related literature on the ten specific CSFs identified in Phase One, including health IT-related theories and models, in an attempt to gain further insight into how and why they impact the success or failure of EHR systems—and thus on the ultimate value achieved from the transition to electronic health records in terms of healthcare outcomes. Although we focused on the literature related to healthcare, this exploration took us outside of healthcare to look at achieving the value of IT in other settings as well.

The objective of Phase Two is to help ensure that we are looking at the right things and asking the right questions in subsequent, more empirical, phases of the study.

Definitions

For the purpose of this study, success is defined as targeted measurable improvements in healthcare outcomes established in advance for health IT projects. Both process and health outcomes were considered. Failure is defined as significantly falling short of targeted measurable improvements in healthcare outcomes, low buy-in among intended user population (under 60%) leading to only partial use of functionality and continuation of former (paper) practices, or reduction in project goals, or cancellation of project. This study did not make any distinctions between the terms EHR and EMR and used both terms interchangeably in selecting health IT implementations to evaluate. (Specific subsystems, such as e-prescribing and CPOE, are encompassed within our EMR/EHR definition) Studies in both hospital and multiple practice settings are included. Meaningful Use is defined in the broad sense under the intent of promoting the effective use of health IT to innovate and improve the delivery and outcomes of care. Although recognizing the specific measures used for reimbursement under the HITECH Act incentive programs, the use of the term here is much broader.

Research Questions

- 1. What factors have been associated in the literature with successful implementation of health information technology?
- 2. What factors have been associated in the literature with the failure of health information technology implementation?
- 3. What factors appear to be most common across all settings and projects?
- 4. How did contextual or implementation factors influence or mediate results of health IT implementations?
- 5. Are any interdependencies evident among variables?
- 6. Are any patterns evident in factors that differ between successful and unsuccessful implementation experiences?

FINDINGS

One of the challenges of the study analysis has been dealing with the sheer magnitude of variables associated in the literature with effectively implementing health IT in the complex healthcare environment. The major objective was to systematically analyze health IT implementation research and case studies from a multidisciplinary systems framework to determine if it is possible to identify a set of variables that are consistently associated with project success and, therefore, may be hypothesized to differentiate success from failure to achieve meaningful use of health IT.

Analysis of the selected health IT literature revealed ten facctors that consistently emerged among innovative organizations reporting significant improvement in quality of care and patient outcomes. Findings from Phase Two of the study have substantially confirmed earlier findings, although some sources classify or describe them from somewhat different perspectives. Descriptions and labels for these ten factors have been refined based on the findings of our Phase Two research. Synthesizing the prior research revealed many overlaps and different perspectives on categorizing them, which suggest interdependencies among them. In addition, the continued exploration underscores the systemic nature of large-scale organizational change (i.e., innovations and transformation). Thus, it may be more accurate to think about the factors more as "themes" or "components" of creating a culture of innovation as opposed to isolated factors that could singularly make or break a health IT project.

Realizing the Value of EHRs: What Differentiates Success from Failure?

Achieving meaningful use of health IT starts at "Go Live!" That appears to be one of the prevailing themes of organizations that achieve results and realize the value of health IT. However, the EHR implementation process itself is equally important in setting the stage for success. Even organizations that paid considerable attention to workflow (i.e. process) redesign as part of implementation saw it as just the beginning of their journey to value realization. In Phase 2, we have expanded upon the ten factors originally identified with success of health IT implementation. The expanded explanation puts more emphasis on the systemic nature of factors and *how* they influence success or failure.

Process Factors:

1. <u>Active CEO commitment</u> (with a focus on shared vision, building buy-in, and creating a compelling case for change aligned with organizational mission). Visible leadership from the top was one of the most dominant factors associated with successful implementation of EHR. Top leadership at successful organizations seemed to have a keen sense of the importance of setting the stage for major change and how challenging it would be. They were especially adept at aligning organizational goals with technology goals and communicating the big picture of how and why the transition to electronic health records was essential for moving the organization forward in today's changing healthcare environment. They were often very adept not only at creating a sense of urgency for their own organizations to change, but tying it into the need for change on the national level as well in order to achieve the goals of improved care, greater access and lower cost. They effectively tied change initiatives to achievement of clinical improvement goals and why it was in everyone's self-interest to support the initiative, thus helping to build buy-in. Effective CEO's consistently reinforced their message and persevered when the going got rough. Importantly, they also seemed to understand the implications of changes for other aspects of

hospital or practice management and acted accordingly, which proved important to eliminating barriers to change.

- 2. <u>Patient-centered care and patient engagement</u>. The most successful organizations appear to be leaders in moving to more patient-centered care (also referred to as process-centered care) models. It often encompasses the notion of putting patient safety first as well. Ultimately the success of patient engagement is determined by the quality of the interaction between patients and clinicians. It takes advantage of new tools, such as Web patient portals, shared patient records, e-consultation systems and online data access for patients, and increasingly mobile apps, home monitoring devices, and more. The distinguishing factor appears to be a focus on two-way interaction rather than information push. Some innovators see it as a major paradigm shift from today's task-focused, provider centric institutions, which is leading to emergence of new models for care, usually based on a more integrated team approach to care.
- 3. <u>Quality focus with clinical benchmarks for monitoring success</u>. The most successful organizations had clearly created a culture of quality that started at the top. Policies and benchmarks were aligned with their goals, with a top priority on clinical, health outcome goals, and also process improvement goals. It was often expressed in terms of putting patient safety first in the mission of the organization. Goals were collaboratively developed, explicitly defined, and widely shared. Goals were tracked regularly and transparently with clear benchmarks for success.
- 4. <u>Workflow (process) integration.</u> The most successful organizations clearly viewed workflow redesign as an opportunity to improve continuity of patient care, gain efficiencies, and improve care outcomes. Indeed workflow redesign was seen as key to achieving value from health IT systems for patients, providers, and the organization. Leadership for successful workflow redesign resided with physicians, nurses, and other providers with high involvement and buy-in of clinical staff. Projects were well planned, orchestrated, and resourced. Workflow redesign was an ongoing process that started with Go Live. It was also iterative; as clinicians gained experience with new systems, they gained new insight into opportunities for improving care delivery. As clinicians gained experience, innovations tended to became more integrated across former silos of care with more aggressive patient outcome goals.
- 5. <u>Strong leadership of clinical professionals (physicians and nurses)</u>. Highly successful healthcare systems inevitably had strong, visible physician leaders who had a clear vision for the potential for electronic health information and exchange to transform care in positive ways. They were effective in working with their peers and enlisting their buy-in to change by helping them see the benefits longer term for themselves, their patients, and the institution. Strong nursing leadership also appeared to be vital. Nurses clearly had a perspective of the patient care workflow different, and in many ways more detailed, than physicians. Working relationships between physicians and nurses were critical to redesigning workflows. Role changes were often indicated, especially with a shift to more team-based care. Clinicians could be both strong enablers as well as strong barriers to change.
- 6. Engagement, Training, On-going Support. Clinician engagement on all levels was critical to success. Understanding of what was required of clinicians and why it was important could NOT be assumed. Training was cited in every case as critical to success. However the quality of the training and support was equally important. Training both initial and ongoing and incremental was critical for smooth transition to a paperless patient care system. Hands-on training immediately prior to Go Live as well as on-going training was both critical. Training needs differed among clinicians and at different stages of the process. An especially distinguishing feature among the success stories was that training was also viewed as a means of engaging staff members in implementation. Training provided one to one, just in time, 24/7 minimizes frustration, provides opportunities to educate about appropriate use, identifies corrections, and allows further improvements to minimize potential medication errors (First Consulting Group, 2006). Training was also viewed as an opportunity to reinforce best practices.

Contextual Factors:

7. <u>Supportive organizational climate for innovation</u>. Successful organizations were able to create a climate or culture that was supportive of change and encouraged clinicians to try new ideas while realizing that not all ideas would prove to be effective. Recognizing that there are both technical and social aspects to technology implementation, successful organizations appear to be more sensitive to the opportunities from the viewpoint that the technology and the organization transform each other during the process. Even with a well-thought out plan, the process can actually take on a life of its own, and a system for flexibility is essential. Feedback, dialogue, interventions, and activities all play important roles; innovation is iterative.

A culture of innovation appeared to be strongest when it cascaded from the top throughout the organization and clearly aligned with the mission of the institution.

8. Collaborative culture (teamness).

Evidence suggests that participation and engagement are vital for the success of new technologies. Successful organizations tend to create a cooperative dynamic where end users solve technical problems, write templates, and teach each other about software features. Teamwork is a major pillar. Collaboration is a clear expectation. The value that seems to bring the various medical professional groups together for integration is a broad consensus about the importance of effective and efficient care. A collaborative approach is viewed as critical during design, development, implementation, and post-implementation phases (optimization). Most often the staff, not the physician, has the best knowledge of existing and optimized processes. Different members of the workforce bring different perspectives and skills; interdisciplinary approaches generally are viewed as most effective.

9. Systems perspective on change (holistic view). Success of EMR implementation and use depends on integrating the system into often complex organizational settings. "The ultimate value achievable from an investment in health IT is directly related to the breadth of integration it provides across all parts of the healthcare delivery system (Ajami& Bagheri-Tadi, 2013). Workflow redesign is critical because of the need for realignment to realize the value of technology investments and improve quality. Efforts generally affect patient--clinician relationships job roles, incentives, as well as workflows and clinical practice routines. It is more like building a new ship rather than just moving the deck chairs around. A systems perspective helps clarify interdependencies and points of interaction between what are often relative silos of operation. These are the points in the care system where patients tend to get "lost" or errors occur as hand-offs are made. The most innovative organizations focused on improving coordination of care, which generally means better communication and coordination across different functions and care units and often present the best opportunities for streamlining processes, improving coordination of care, and reducing medical errors.

Technology Factors:

10. <u>Technology reliability, responsiveness and interoperability</u>. Technology usability, reliability, responsiveness and interoperability repeatedly came up in the literature as key factors (Fellmeth, 2014). Availability of local technical support was seen as critical. EHR technical design, performance and support reportedly affected its usage and user satisfaction. Other concerns related to reliability and security. The presentation of information in the EHR was identified as a major issue, especially when it did not map to workflow. This issue underscores the importance of the EHR (or other health IT) selection processes since there are many competing systems with varied interfaces and functionality. It was not possible to assess the extent to which lack of fit of EHR technology to practice needs might be attributed to general deficiencies in all EHR systems or whether it might be attributed to a failure to make a good choice of system for practice needs. Inadequate training is also sometimes misdiagnosed as technical problems when users are unaware or incorrectly use functionality. A lack of interoperability and information exchange infrastructure and associated costs are the most common barriers to information sharing among clinicians.

Table 3 shows the frequencies for each of the ten critical success factors for meaningful use. Not all articles, case studies, or reports necessarily identified all ten success factors. Some study reports were more comprehensive in reporting on the full scope of the implementation process whereas others were more focused on less comprehensive objectives. These factores came up consistently across different projects, but the terminology and frame of reference varied. For example, for the factor "Active CEO Commitment," here are some examples of how the importance and impact of the factor was reported in different studies. (Note these are brief statements; in most cases the discussion was more detailed.)

- Support of the policy making level is required for widespread health IT adoption beyond pilot stages (Lluch, 2011).
- Governance refers to senior management's activities or substantive personal interventions in the management of the EMR implementation. It is concerned with mission, vision and top management's behaviors related to pre-implementation, implementation, and post implementation of the EMR (Kashavjee, 2006).
- Successful implementations are supported by executives (Ludwick, 2008).

- Shared vision for care delivery starts with the end in mind (ONC, 2014).
- The work of relating and engaging with users is central to the successful implementation of any new technology and starts at the top levels (Mair, 2012).
- "Sense-making" is an important aspect of implementation. Sense making deals with having a shared view of its purpose, understanding how it will affect them personally, and grasp its potential benefits (Mair, 2012).
- Vision, support, and involvement starts with upper management (Metzger, 2003).
- CEO must be on board (Metzger, 2003)
- Mindset that CPOE (or any change) is the right thing to do, not focused primarily on ROI (Metzger, 2003).
- In every hospital, much effort was expended to convince physicians that CPOE was a necessary investment in patient safety and quality (First Consulting Group, 2006).
- Coordination of business and IS planning is successful only if mandated by top management (Lederer, 1989).
- Leadership recognizes that there will be bumps in the road and will be unwavering. Commitment equals resources, multi-year effort, not expecting immediate results (Metzger & Fortin, 2003).

Table 3. CSF For Meaningful Use: What Differentiates Success from Failure?

| Critical Success Factors | Frequency of Citations | |
|---------------------------------------------------------------------------------------------------------------------|---------------------------|--|
| Active CEO commitment (with a focus on mission, vision, building buy-in, and creating a compelling need for change) | 37 | |
| Patient-centered care and patient engagement | 24 | |
| Quality focus with clinical benchmarks | 30 | |
| Workflow integration | 33 | |
| Strong leadership of clinical professionals (physicians and nurses) | 44 | |
| Engagement, training, ongoing support | 32 | |
| Supportive organizational climate for innovation | 18 | |
| Culture of collaboration | 26 | |
| Systems perspective | 38 | |
| Technology reliability, responsiveness, interoperability | 28 | |

DISCUSSION

This section addresses the six research questions addressed by the study. Table 1 and 2 underscored the complex process of implementing new health IT systems. With more than 100 factors identified in the research that are believed to influence implementation results, the two frameworks shown in Tables 1 and 2 help to clarify the many requirements for EHR implementation. However, not only have these frameworks failed to substantially improve results, neither do frameworks such as these answer the question of what differentiates success from failure for those organizations that follow them. Our study essentially asks: Out of everything that must be addressed for a successful health IT implementation, what are the critical success factors to ensure the organization achieves their clinical improvement targets? What do CEOs need to focus on to ensure they get it right? The research has identified 10 themes (CSFs) that consistently emerged from innovators that reported significant improvements in care goals and patient outcomes. The findings became the basis for classifying and describing ten critical success factors, only one of which relates directly to technology. The others are contextual and process factors. Moreover, the evidence points to multiple interdependencies among these variables, none of which have yet been empirically verified. It is not that all the myriad of factors are not important. It is more a matter of creating focus for top managers and project leaders to steer the ship.

A prevailing theme among successful organizations is a view of achieving value from health IT as a shared journey, aligning initiatives with organizational goals for clinical improvement and the institutional mission. Successful organizations tend to see challenges as opportunities rather than problems. The organizations developed a culture that encouraged innovation, supported change, and viewed failure as part of the learning process.

In addition, studying the issues from a systems framework provides insight into the complexity of clinical innovation. It shifts the perspective from viewing EHR implementation as a single event to looking at the dynamics of achieving value of EHRs as an iterative process that involves the interaction of technology, people, and process at both individual and organizational levels.

Research Limitations

Our search was limited to English language articles and cases published since 2000 (with a few exceptions). Emphasis was placed on the most recent studies because of the rapid advancement of EMR implementation in the past few years and to gain the viewpoint of medical practices that had some history of use. A structured analysis process was used to synthesize prior research. However, due to the nature of qualitative studies, it is difficult to entirely rule out biases in the analysis and interpretation of findings, and therefore may have limited generalizability. Although the research included international studies, the predominant focus was on the United States health care system, and cultural differences that might influence study findings are not specifically taken into consideration.

In addition, although not specifically documented in the study, the first author's many years of experience in implementing IT change in a variety of settings as well as knowledge of case studies, presentations at conferences, stories of innovation award winners by organizations such as HIMSS and Health Informatics Magazine, workshops, etc. also influenced and reinforced the conclusions from trends specifically identified through the structured analysis conducted in the study. Thus although as a researcher one might claim impartiality, it is hard to rule out bias in a qualitative study.

IMPLICATIONS FOR PRACTICE AND FUTURE RESEARCH

The research has direct implications for clinical practice. It addresses important questions that should be of interest to every healthcare provider engaged in IT based initiatives to improve the delivery of care, which usually require a huge investment of resources. Given the large number of projects that fail to fully achieve the intended benefits from EHR implementation, identifying factors that could help improve the success rate of initiatives would have significant and widespread benefit.

The findings of this study suggest that technology is only one of ten (or possibly more) factors that interact systemically to affect the meaningful use of health information technology. Thus, when measuring or researching the impact of health information technology, it is critical to differentiate between issues, problems and results that truly can be attributed to technology versus those related to contextual issues. Putting the technology in place, training people to use it, and converting paper records to electronic is only a necessary but not sufficient step toward achieving the value of EHR systems. It is also probably the easiest part. It sets the stage and provides new tools. Gaining the insight into *how and why* EHR systems can be used to change the way care is delivered to increase quality, improve access, and reduce cost is a dynamic, iterative process that has implications for every aspect of healthcare operations, and thus can best be viewed systemically. Making the process and organizational changes takes hard work, commitment at all levels starting at the top, engaging the entire organization, and focusing on what is best for patients.

Beyond the immediate institutional impact, projects that fail to achieve anticipated results can have consequences for progress toward transforming healthcare on a national level. Failures that are misinterpreted as failures of technology rather than failures of implementation methods or other factors, especially when reported in the health IT literature, can be counterproductive and can influence decisions of policy makers or industry leaders.

For the authors, the study is intended as a foundation for further research. It is hoped that other researchers will also find the results useful as a foundation for future research to inform understanding of *how* health IT can create value in healthcare delivery and outcomes. It is hoped that the findings will provide focus for more empirical research and

comparative effectiveness studies of contextual and organizational factors critical to the success of health IT transformation projects. Analyzing individual factors is insufficient to fully understand the dynamic relationships that affect the ability to effectively use health IT to transform care. A holistic systems approach can help deepen our understanding in ways that can help improve the success rate in using health IT to innovate and improve healthcare practice and patient outcomes.

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Understanding User Resistance to Information Technology in Healthcare: The Nature and Role of Perceived Threats

Madison Ngafeeson Northern Michigan University 1401 Presque Isle Ave, Marquette, MI 49855 Tel.: +1-906-227-2699; <u>mngafees@nmu.edu</u>

Abstract: Information technology (IT) in healthcare is here to stay. The United States government has made efforts in the past ten years to harness the power of information technologies in healthcare to improve legibility, lessen medical errors, keep costs low, and boost the overall quality of health care. However, IT user resistance in healthcare is continually cited as a major barrier to achieving desired outcomes. Understanding the nature and manifestation of resistance is clearly a key to successfully managing this industry-wide change, fostering adoption, and realizing positive outcomes. Earlier research had established *perceived threats* as a significant antecedent of user resistance; but its nature and role has remained vastly unexplored. This study draws from the *psychological reactance theory* and justice literature, to explain both the nature and relationship of *perceived threats* and *user resistance to IT* within the healthcare setting. The theoretical and practical implications of the findings shall be discussed.

INTRODUCTION

By the end of 2015, the United States healthcare sector is expected to have completely transitioned from a paper health record system to an electronic health record system. It is believed that this transition will benefit the nation in improving legibility, lessening medical errors, keeping costs low, and boosting the overall quality of care (Blumenthal & Tavener, 2010). But as some researchers have noted, the effective use of, and beneficial outcomes from information systems are not automatically guaranteed (Lee, Ghapanchi, Talaei-Khoei, & Ray, 2015). As early reports demonstrate, this IT-enabled change is meeting with resistance, not altogether uncommon. Physicians, nurses and other practitioners are resisting this change (Buntin, Burke, Hoaglin & Blumenthal, 2011). Nevertheless, success depends on the effective and efficient use of these systems in getting work done.

Researchers in information technology have recognized *user resistance to IT* as a salient concept in information systems (IS) implementation literature (Keen, 1981; Lapointe & Rivard, 2005; Lapointe & Rivard, 2012). Investigators have generally taken a two-pronged view of the concept of resistance. While some have viewed it as negative (i.e. as a hindrance to IS implementation), others have considered it to be positive—a feedback mechanism— by which the users' voice can be heard by system implementers or developers. Notwithstanding, no matter how user resistance has been conceptualized, it is clearly seen as an important reason for the failure of new systems (Kim & Kankanhalli, 2009).

Lapointe and Rivard (2005) conceptualized a generic model to demonstrate the evolution of user resistance to IT. This framework posited that *user resistance* to an information system results from *perceived threats* which in turn evolve from certain *initial conditions*. Lapointe and Rivard (2005) defined initial conditions as a complex interplay of political and interpersonal/group factors resulting from people's interaction with an IS. Simply put, resistance is caused by *perceived threats* which results from certain *initial conditions*. Though user resistance to IT and its critical antecedent, *perceived threats*, have been clearly acknowledged in literature (Lapointe & Rivard, 2012), only few studies have attempted empirical testing of these two constructs. With the exception of Bhattacherjee and Hikmet (2007), and Kim and Kankanhalli (2009); there is almost a total absence of empirically investigated frameworks. Most of the investigative studies in user resistance to technology reveal an overwhelming dominance of case studies, a clear lack of quantitative validation, and a scarcity of theory-based explanation of user resistance and its antecedents.

This study explores the nature of both user resistance to IT and *perceived threats*--its well-known antecedent. User resistance to IT is defined as covert or overt behaviors that oppose change towards the use of- or avoidance of an information system manifested as *reactance*, *distrust*, *scrutiny* or *inertia* (see Knowles & Linn, 2004). *Perceived threats*, on the other hand, is defined as negative assessments that the users make of the IT implementation. This study

seeks to answer two questions: (1.) what is the nature of user resistance to IT? And, (2.) What is the nature and role of perceived threats in user resistance to IT? To address these two questions, the *theory of psychological reactance* and key insights from justice literature are explored. The proposed model is then empirically tested within a health care setting, using partial least squares (PLS) structural equation modeling.

This current study contributes to both theory and practice. On the theory end, it enriches our understanding of user resistance through the use of a popular theory of resistance that has heretofore, not been leveraged in information systems literature or in health IT. Hirschheim and Newman (1988) had noted that resistance is a complex phenomenon which defies simple explanation and analysis; thereby requiring well accepted theories or paradigms encompassing the full range of variables associated with an individual user's resistance to IT (Martinko, Henry & Zmud, 1996). This current research, therefore, fills this gap by providing a new lens through which *user resistance to IT* and *perceived threats* can be examined. On the practice side, change managers and project leaders would find the results helpful in detecting and mitigating resistance. Additionally, health IT designers can use the results as a feedback tool that to pay attention to end-user voice.

In the following section, key literature relating to the conceptual background on user resistance to IT is reviewed. Next, the theory and model development is set forth. Third, the research method and analysis are presented. Fourth, the results, discussion are made. Lastly, the conclusions and implications of the research are presented.

CONCEPTUAL BACKGROUND

The concept of user resistance has been a well-echoed theme in IS literature. Many researchers have sought to explain why and how resistance happen. As a consequence, many models have been set forth to explain the phenomenon (Hirschheim & Newman 1988; Joshi 1991; Kim & Kankanhalli, 2009; Lapointe & Rivard, 2005). Earlier research in electronic medical records focused more on the technical than the managerial aspects of implementation; but, user resistance has continually been cited as one of setbacks to IT implementation in the healthcare industry (Lee, Ghapanchi, Talaei-Khoei, & Ray, 2015; Lin, Lin, & Roan, 2012). Since this research builds on the Lapointe and Rivard (2005) model, the literature here summarized based on the conceptual framework proposed by Lapointe and Rivard. The theory of psychological reactance is also discussed, as a theoretical lens through which to examine user resistance. According to this model, five key concepts are salient in user resistance, namely: the object of resistance, the subjects of resistance, initial conditions, perceived threats, and manifestations of resistance.

Object of Resistance

According to Lapointe and Rivard (2005), the object of resistance refers to the target of resistance behaviors. These targets include: the system itself (Wagner and Newell, 2007); system's effects e.g. in the creation of power imbalances (Markus 1983); and the implementers (Lapointe & Rivard, 2005).

Subjects of Resistance

Defined to be the actor or actors undertaking resistance behaviors, subjects might include: individuals, a group of individuals, or even an organization (see Marakas & Hornik, 1996; Martinko et al., 1996; Joshi, 1991; Lapointe & Rivard, 2005).

Initial conditions

This refers to the characteristics of the environment surrounding the system which interacts with the object of resistance to influence the users of the system make certain determinations. While Hirschheim and Newman (1988) allude to the socio-political environment of the organization that can influence the way the users can look at the situation regarding the new technology, Martinko et al. (1996) posit that the users' attitudes towards the system are influenced by prior success or failure with a similar system.

Perceived threats

These consist of negative assessments of that system users make of an IT implementation. Marakas and Hornik (1996) propose that covert resistance like sabotage, could be a result of the behavior individuals pose in response to the introduction of a new IT system workplace. Joshi (1991) gives an alternative view based on the equity theory. He explains that individuals may assess the new IT system from the standpoint of fairness or the lack thereof, due to its introduction into the work environment. In either case, perceived threats affect and influence individuals' response to a new system in the workplace.

Manifestations of resistance

Defined as a set of behaviors carried out by users to display some discontent with the new IT system being implemented. While some manifestations may be more covert like apathy or sabotage (see Keen, 1981; Moreno 1999); some may be more overt and destructive like open rebellion or formation of coalitions (Kim & Kankanhalli, 2009; Lapointe & Rivard, 2005; Ferneley & Sobreperez, 2006).

Many theories have been proposed to explain user resistance to technology over the years. Leading theories include: the interaction theory, the equity implementation theory, the attributional model of reactions to information technology, the status quo bias theory, the IT conflict-resistance theory, and the cynicism theory (see Martinko et al., 1986; Markus, 1983; Joshi, 1991; Kim & Kankanhalli, 2009; Meissonier & Houzé (2012). One theory that has not been well leveraged in IS research is the psychological reactance theory.

The Psychological Reactance Theory (PRT)

The PRT was proposed by Brehm (1966). PRT is built around the notion of "freedoms" and "free behaviors". The PRT posits that individuals generally believe that they have specific behavioral freedoms. When these freedoms are threatened, individuals are aroused by the motivation to reassert their freedoms. The psychological reactance theory assumes that people's behaviors are motivated by the desire to protect their "freedom" to carry out a particular behavior in a particular context.

A "threat to freedom", according to the PRT, refers to the perception that an event has increased the difficulty of exercising a particular freedom. Threats to freedoms have also been thought of to be social—emanating from social interactions or nonsocial—coming from the individual. Additionally, Brehm and Brehm (1981) also asserted that, "a freedom is important to a person when it has unique instrumental value of satisfaction of one or more important needs" (p. 55). Hence, the level of reactance is thought to be proportional to the relevance and number of threatened freedoms.

According to the PRT, resistance is a result of reactance. It is defined as the response to loosing freedom. The source of this resistance has been attributed to the person manifesting the behaviors as well as situation causing the resistance (Knowles & Linn, 2004, p. 6). Knowles and Linn (2004) have identified four different but probably related faces of resistance namely: *reactance, distrust, scrutiny and inertia* (pp. 7-8).

Reactance is initiated when a person's choice alternatives are threatened. This view of resistance has been found to be associated with two sides of resistance: the affective ("*I don't like it!*") and motivational ("*I won't do it!*") (p.7).

Distrust highlights the target of the change and general distrust of proposals. Here, the resisting entity questions the motive of proposal and whether the facts are indeed true. This face of resistance underlies the affective ("*I don't like it*!") and the cognitive ("*I don't believe it*!") reactions to influence.

Scrutiny refers to the face of resistance that results when people become aware of the fact that they are a target of an influence and therefore begin attend carefully and thoughtfully to every aspect of the proposal for change. Here, a thorough scrutiny is given to every proposal while each weakness is evaluated, exposed, and countered. This face emphasizes the cognitive (*"I don't believe it*!") element of resistance.

Inertia is described as a "neutral" quality whereby an individual may not necessarily resist the change, but may focus more on rather staying put. To the extent that a "call for change" comes, the *inertia* personality and attitude frustrates the change through a drag of anchor rather than with a personal antagonism. Hence, inertia is a more covert form of resistance.

The psychological reactance perspective of resistance could very informative given that the PRT's resistance seems to be a continuum of resistance based on emotional intensity. Perceived as such, we see that the emotional intensity rises from *inertia* to *reactance*. The benefit of this type of perspective is that it is likely to inform our understanding about different forms and stages of IT user resistance. For example, there is a possibility that certain types of *initial conditions* are associated with particular types of resistance. Such an understanding would then be critical in the development of persuasion messages to mitigate user resistance.

MODEL DEVELOPMENT

The proposed model in Figure 1 builds on the Lapointe and Rivard (2005) framework. The Lapointe and Rivard (L-R) model posits that resistance behaviors result from *perceived threats* that arise from the interaction between the *initial conditions* and the *object of resistance*. The model is presents as a cyclical process in which the consequences of the using a system are fed back into the initial conditions again as triggers, restarting the entire process all over again. Lapointe and Rivard (2005) viewed resistance from a longitudinal perspective of three phases namely: pre-implementation phase, implementation phase, and post-implementation phase. Regardless of the phase under consideration, the L-R model suggests that *initial conditions* interact with the object of resistance to produce resistance.



Figure 1. Research model

With the L-R model as a starting point, we discuss the proposed model from a matching perspective. First of all, the L-R model is summarized into three major parts namely: *initial conditions* (labelled "A"), *perceived threats* (labelled "B"), and *user resistance* (labelled "C"). This research focuses on the *user resistance* and the immediate antecedent, *perceived threats* (with the exclusion of *initial conditions*).

The overarching theory that informs the proposed model is the psychological reactance theory (PRT), and is based on the following fundamental assertions as proposed by Brehm (1966) that:

1. Human beings generally believe in "behavioral freedoms." That is, the freedom to perform certain behaviors: when they want it and how they want it.

2. When these freedoms are threatened, an uncomfortable motivational state known as *reactance* is created.

3. The decision to assert one's behavioral freedoms and to act in a way consistent these freedoms leads to resistance. Given these assertions, we discuss the model in terms of the nature of the *perceived threats* that engender *user* resistance within the context of a health information technology (HIT).

User Resistance

User resistance to information technology in this study refers to covert or overt behaviors that oppose change towards the use of- or avoidance of an information system manifested as reactance, distrust, scrutiny or inertia. Consistent with Piderit (2000) who suggested that user resistance should be viewed as a complex multi-dimensional construct, user resistance in this study is therefore treated in the light of the four faces (reactance, distrust, scrutiny and inertia) proposed by Knowles and Linn (2004). This study further builds on the view that a thorough conceptualization of resistance must cover cognitive, affective and behavioral realms as proposed by Lapointe and Rivard (2005) and Oreg (2006).

Perceived Threats

"When a system is introduced, users in a group will first assess it in terms of the interplay between its features and individual and/or organizational-level initial conditions. They then make projections about the consequences of its use: if expected conditions are threatening, resistance behaviors will result." (Lapointe & Rivard, 2005; p. 461).

Threats may result from perceived inequity (Joshi, 1991), the fear of the potential loss of power (Markus, 1983), stress and fear (Marakas and Hornik, 1996), or from negative or undesirable outcome expectations (Martinko et al., 1996). Previous studies have considered perceived threats as a single construct and an immediate antecedent of resistance. In this study, it is argued that perceived threats are manifested as two related, but distinct threats.

Justice literature had long postulated that people are constantly evaluating change through the lens of fairness (Konovsky, Folger & Cropanzano, 1987). If an individual believes that a particular change is not fair, a state of discomfort and dissatisfaction is created. Folger and Konovsky (1989) distinguished between two distinct types of justice in organizations namely: procedural and distributive justice. Procedural justice refers to the perceived fairness of the procedure while distributive justice focuses on the fairness of the outcomes. In the same way, Oreg (2006) has distinguished between two important elements of organizational change that are responsible for resistance. In his study, Oreg (2006) argued that two types of reactions to organizational change must be distinguished and examined separately namely: "reactions to the change process"—i.e. the procedural component, and "reactions to the outcomes"—i.e. the distributive component (p. 78). Furthermore, Lines (2005) had proposed a model of attitudes towards change based on fairness that argued for the differentiation between the "change process" and the "change content" (p. 12). Consistent with the forgone, it is argued here that perceived threats due to change would be a result of threats from the process as well as threats from the outcomes of the change in question. Again Lapointe and Rivard (2005) had pointed out that the introduction of technology in the workplace is likely to bring about change of routines, roles and even the significance of workplace interrelationships to bring about some sense of threat. Based on the

foregone, two types of threats are distinguished in this research namely: *perceived helplessness over process* and *perceived dissatisfaction with outcomes*.

Perceived helplessness over process is defined as an individual's belief that carrying out a new behavior diminishes their ability to maintain control over their current routine. According to the interaction theory (Markus, 1983), resistance can happen when an individual/organization interacts with technology in a given organizational context. The introduction of technology in the workplace is generally accompanied by new processes demanding the change of work routines and task dependencies between employees. These processes have the potential to cause power imbalances that may lead to perceived helplessness over process. The process of change due to the introduction an information system is therefore likely to be associated with reactions to process of change.

Perceived dissatisfaction with outcomes, on the other hand, denotes an individual's belief that carrying out a particular behavior will lead to unfavorable result. Perceived dissatisfaction with outcomes is generally linked to the discontentment with the espoused claims about the capability of the new system. Consequently, this perception is clearly linked to the outcome of change. *Perceived helplessness over process*, in this context, refers to an individual's belief that carrying out a new behavior diminishes their ability to maintain control over their current routine. Festinger (1957) suggests that people resist change because it is "painful", or may "involve loss." Furthermore, he asserts "the magnitude of this resistance to change will be determined by the extent of pain or loss which must be endured" (p. 25). Markus (1983) also suggested that during technology implementation, threats could arise from the dynamics of power and control. She therefore postulated that "power loss" for a group and consequently "power gain" for another will give rise to perceived threats. Perceived threats arise in this case due to the loss of autonomy brought about by these power imbalances. The perception of discontent with the process and loss of control over routine, results in a sense of discomfort described here as perceived helplessness over process. When an individual's sense of control over the process is threatened, the individual is likely to resist.

Warren et al. (1988) conducted a study in which they measured physician's perceptions of loss of control over work conditions and clinical autonomy. The results showed that loss of control over work conditions and clinical autonomy, were all significantly and negatively correlated with physician satisfaction. Additionally, this study found out that one of the strongest challenges to physician satisfaction was the yielding their clinical judgment to non-physicians. In fact 44 percent of those who sometimes must yield their clinical judgment to non-physicians were dissatisfied, compared to only 18 percent of those who need not do so. The introduction of technology in the workplace clearly disrupts routines and task management; and threatens clinicians who feel as though they have surrendered their control over work conditions and professional judgment to non-clinicians—in this case, system developers. This threat to clinical control over work conditions and autonomy is likely to contribute to user resistance to information technology in the healthcare setting.

The sweeping process changes in the healthcare system due to the introduction of electronic health records are likely to generate resistance due to the loss of control in autonomy and power over processes. This loss of control is further exacerbated by the government procedural requirements placed on medical professionals (Warren et al., 1988). Since most of these imposed changes impact work routines and task assignments, physicians and other professionals are likely to resist such changes. Hence, it is hypothesized:

Hypothesis 1: Perceived helplessness over process of use of the system will positively affect user resistance.

Warren *et al.* (1988) had also established a connection between loss of control over work conditions, clinical autonomy and lack of satisfaction. This study showed that both loss of control over work and reduced levels of clinical autonomy will both lead to greater dissatisfaction with outcomes. Hence, it is hypothesized:

Hypothesis 2: Perceived helplessness over process of use of the technology will positively affect perceived dissatisfaction with outcomes.

Poon et al. (2006) also observed that the introduction of certain HIT systems is likely to cause employee dissatisfaction due to the negative impact it has on workflows and productivity. Additionally, as the health-care providers' income is directly tied to their productivity (Poon et al. (2006), any changes that negatively affect this bottom-line are likely to result to dissatisfaction. Consequently, dissatisfaction with productivity and workflows due to implementation of new systems is likely to cause resistance to change.

Alter (1978) pointed to the positive relationship between user dissatisfaction and resistance (lack of compliance). Alter notes that the implementer's dilemma is: "How can I achieve compliance with minimal disruption and user dissatisfaction?" (p. 40). Doll and Torkzadeh (1989) had also stated that user feelings of greater control due to involvement in decision-making can lead to reduced resistance. Additionally, Martinko et al. (1996) observed that user dissatisfaction with the system is associated resistance towards the system. The introduction of a new system will affect productivity, at least in the beginning, since users must learn how to use the new system. The more users find ways to go around the system instead of actually using them, the more productivity is affected. This impact on productivity contributes to the dissatisfaction with system outcomes. Furthermore, workflow interruptions can also affect dissatisfaction with outcomes such that the greater the number of disruptions, the more dissatisfied the healthcare professional. There is an association between perceived helplessness over process, perceived dissatisfaction with outcomes and user resistance.

Dissatisfaction from the introduction of an information system in healthcare can result from threats to equity in reward systems, productivity and workflow. Regardless of the source of dissatisfaction, this generally leads to resistant behaviors. As Ford et al. (2008) have noted when employees cannot perceive a fair treatment during a change process in the work place, a loss of trust and satisfaction results. This means that the change process can affect can also affect the outcomes. For instance, if an older physician perceives that the outcome of the introduction of a system will inequitably favor a younger physician who has greater computing skills needed to work the system, they may become dissatisfied with the outcomes. This dissatisfaction is then manifested as resistant behaviors that including revenge, sabotage, theft or other aggressive behaviors (Ford et al., 2008). Evidently when employee satisfaction is threatened, resistance is likely to ensue. It is therefore hypothesized:

Hypothesis 3: Perceived dissatisfaction with outcomes of use of the technology will positively affect user resistance.

RESEARCH DESIGN AND ANALYSIS

This study was designed to respond to the study's objectives and questions. Consequently, a quantitative study design was adopted. Because of the involvement of human subjects, the Institutional Review Board approval was sought and secured. The design of study therefore encompassed three major phases. The first phase involved conducting an extensive literature review to uncover the underlying theories and determinants of user resistance. Once this was done, the determinants were then categorized and incorporated into a preliminary conceptual model. Through more theoretical insight from literature, this model was further refined to obtain a theory-based conceptual model. Second, an instrument and measures were developed to capture the concepts of the model. Lastly, different procedures were administered to accurately collect empirical data and to test this proposed model through appropriate and rigorous data analysis procedures.

Study Participants

Research in information technology resistance within the healthcare sector has often drawn from a broad population including a wide range of medical professionals, such as physicians, nurses, staff and even administrators (Bates, 2005; Bhattacherjee and Hickmet, 2007; Lapointe & Rivard, 2005; Thede, 2009; Timmons, 2003). Because this research measures cognitive and attitudinal perspectives of user resistance to information technology, the sample for the study was drawn from a similar population. The sampling frame Participants in this study include physicians, physician assistants, nurse practitioners, registered nurses, and other healthcare professionals who use electronic health record systems in daily practice. To do this, a variety of organizations and individuals were approached through personal face-to-face contacts, emails and phone calls. The final sample included health professionals from independent healthcare professionals. These participants represented large, medium, and small healthcare practices drawn predominantly from the Southwestern region of the United States of America. With such a wide range of participants, it was expected that the heterogeneity of the population would increase the external validity of the study.

Instrument Development

Burns and Grove (2010) identified three sources of content validity namely: (1) literature, (2) representativeness of the relevant population, and (3) experts. The determination of whether or not an instrument possesses content validity is subjectively based on the opinions of experts (Nunnally, 1978). It must be noted here that since the questionnaire was intended to be administered in a post-implementation phase, the questionnaire was developed thus, by tweaking the questions to reflect participants' response in retrospect. Additionally, the ability of the content of a questionnaire to measure the trait of interest and to do so effectively is also influenced by factors such as the wording of item questions. The techniques below were used in this study to improve the instrument's ability to accurately capture the variables of interest. For instance, Armstrong and Overton (1977) have suggested the use of brief and concise questions that reduce the likelihood to "read into" the question. Schuman and Pressor (1981) cautioned on the ordering of questions to ensure the proper effectiveness of a survey questionnaire. For instance, instead of saying, "I was knowledgeable enough to understand how to use the system", it was phrased as: "I had the knowledge necessary to use the system". In the former question, the participant may think that the item is intending to question their prior ability to use the system.

The instrument for this study was developed through a multi-step approach. First, to understand the key determinants of IT user resistance, an in-depth literature review was conducted to identify all the major factors. Second, each of the determinants was then carefully operationalized using existing scales or by creating new ones. Where particular words were used in new contexts, these words were clearly defined through examples. For example, in the equity evaluation constructs section, respondents were asked to compare their "benefits" versus their "stresses" with the introduction of the new system.

Measures

Existing validated scales were adopted where possible and, elsewhere, new scales were developed based on previous literature. All construct were measured on a five-point Likert scale (1=strongly disagree; 5=strongly agree) except for Perceived dissatisfaction with outcomes (PDO) where a five-point Likert scale with range (1=not dissatisfied at all; 5=extremely dissatisfied) was rather chosen. This was so done to maintain a uni-dimensional conceptualization of the construct. In the subsections below, the scales used for each construct in the model are discussed.

User Resistance (UR). User resistance is conceptualized in this study as having "four different but probably related faces" (Knowles & Linn, 2004). The four dimensions are namely: reactance, distrust, scrutiny and inertia. Items for all four dimensions we self-derived based on the definition of each individual dimension by Knowles & Linn (2004). Since all four dimensions were defined to encompass elements of affect, motivation and cognition; items from Oreg (2006) three-dimensional resistance model—encompassing cognitive resistance, affective and behavioral resistance—were adapted and modified to fit the Knowles and Linn (2004) definitions. Reactance items (UR11, UR12 and UR13) for example, are conceptualized to reflect the affective ("I don't like it") and motivational ("I won't do it") perspectives defined by Knowles and Linn (2004). In a similar manner, distrust items (UR21, UR22 and UR23) are conceptualized to depict the affective ("I don't believe it") perspectives. Scrutiny, (items UR31, UR32 and UR33), was conceptualized as cognitive ("I don't believe it"), ("I don't believe it"). Lastly, inertia is defined as a state of equilibrium with the characteristic of "staying put" rather than actual antagonism. Its items (UR41, UR42 and UR43) are also constructed accordingly.

Perceived Threat Variables. Perceived helplessness over process (PHP) made use of two important perspectives. First, it used items from the Langfred (2005) autonomy scales as well as insights from the job characteristics model extension of Hackman and Oldham (1976) and the Maastricht Autonomy Questionnaire (MAQ) (de Jonge et al., 1995). The reason for using these items was to particularly capture the "helplessness" factor which is particularly related to loss of autonomy or control. For instance, we used some of developed items by Langfred (2005) to predict individual- and team-level autonomy influences.

Perceived helplessness over process. Items that relate to the freedom of "getting work done" or "scheduling of work" benefited from this scale. The Job control scale (de Jonge, 1995) developed from the MAQ informed the perceived

dissatisfaction with outcomes construct by drawing on elements of the MAQ that deal with "method of working", "pace of work" and "work goals".

Perceived dissatisfaction with outcomes (PDO). Construct was self-derived with insights from Landeweerd and Boumans (1994) and Bankauskaite and Saarelma (2003). Landeweerd and Boumans (1994) and Bankauskaite and Saarelma (2003) particularly addressed the subject of dissatisfaction with the outcomes of healthcare services; and hence, the items seemed particularly suited for this study. However, because they looked at dissatisfaction with the healthcare services from the patient's and not the healthcare professional's perspective, the items had to be reconstructed.

Data Analysis Strategy

A pilot study was administered to 50 participant, out of which 44 were received back with valid data. Analyses were conducted to determine the reliability and validity of using PLS version 2.0 M3. Given the characteristics of the proposed model (i.e. with a maximum of 2 arrowheads to a latent variable); it will require a least sample size of 33 to yield a statistical power of 80% at 95% confidence level for a minimum R^2 of .50 (see Hair et al., 2014, p. 21).Data from this sample were analyzed for reliability and validity using smart PLS version 2.0 M3. Most of the construct items showed adequate factor loadings of .5 and greater with Cronbach's alphas that exceeded the recommended .7 threshold level (Hair et al., 2010). Items that did not load were further refined. Each of the three latent variables explained at least 20% of the predictor variables significantly. Overall the sample data fitted the proposed model quite well.

The proposed research model required a structural technique for analyzing the relationships. Two structural equation modeling approaches exist to address this (Hair et al., 2010; Hair, Ringle and Sarstedt, 2011). One of such is the covariance-based structural equation modeling (CB-SEM) and the other is the partial least squares structural equation modeling (PLS-SEM). To decide which of the SEM techniques to use, Hair, Hult, Ringle and Sarstedt (2014) have suggested that that the objectives and characteristics that distinguish the two methods be utilized. Consistent with this admonition, the data analysis tool of choice for this study was the PLS-SEM technique based on the considerations described below.

Hair et al. (2014) lay out five rules of thumb for using PLS-SEM technique namely: (1.) when the goal is predicting key target constructs or identifying "driver" constructs, (2.) when formative constructs are part of the model, (3.) when the structural model is complex (many constructs and indicators), (4.) when the sample is small and/or the data are non-normally distributed, and (5.) when the plan is to use latent variable scores in subsequent analyses. Additionally, Chin (2010) has also noted that PLS-SEM is more suited for complex models (i.e. having more constructs and indicators). Given that the objectives of this study, as stated earlier, PLS-SEM was chosen for the analyses.

The final sample of 206 health professionals consisted of physicians, physician assistants, nurse practitioners, and registered nurses in the major categories. Of this total, 156 (76%) were females while 50 (24%) were males. About 87% of the respondents operated in mandatory settings where electronic health record system use was mandated while the remaining 13% operated in non-mandatory settings. Additionally, more than a third of the settings had an installed EHR system within the last two years. Almost all the respondents (96%) had previous paper records use. More than a third of the sample had over five years of experience in their professional roles at the time of data collection. About half of the respondents had an average EHR experience of more than two years. Table 1 shows the sample distribution by profession and gender. Table 2 reveals an alternative sample distribution by profession and years of experience in their current role. The minor professional groups represented in the sample are presented in Table 3.

| Physicians Assistant | | Nurse practitioners Nurses (RI LPN, CNA | | Ns, LVN, Other profession | | essions | | | |
|-------------------------|----|--------------------------------------------|----|---------------------------|----|----------|----|----------|----|
| Male | 10 | Male | 10 | Male | 8 | Male | 22 | Male | 0 |
| Female | 13 | Female | 40 | Female | 21 | Female | 72 | Female | 10 |
| Total | 23 | Total | 50 | Total | 29 | Total | 94 | Total | 10 |
| Sample % | 11 | Sample % | 24 | Sample % | 14 | Sample % | 46 | Sample % | 5 |

Table 1: Profession and gender demographics

Table 2: Profession and experience demographics

| Physicians | Physician Nu Assistant | | | Nurse pract | titioners Nurses (RNs, LV LPN, CNA) | | Ns, LVN,) | , Other professions | |
|------------|---------------------------|-----------|----|-------------|----------------------------------------|-----------|---------------|---------------------|----|
| < 2 years | 6 | < 2 years | 44 | < 2 years | 11 | < 2 years | 16 | < 2 years | 5 |
| 2-5 years | 10 | 2-5 years | 3 | 2-5 years | 5 | 2-5 years | 30 | 2-5 years | 7 |
| >5 years | 7 | >5 years | 3 | >5 years | 13 | >5 years | 44 | >5 years | 2 |
| Total | 23 | Total | 50 | Total | 29 | Total | 90 | Total | 14 |
| Sample % | 11 | Sample % | 24 | Sample % | 14 | Sample % | 46 | Sample % | 5 |

Table 3: Other professions represented in sample

| Profession type | Representation |
|---------------------|----------------|
| EMR technician | 2 |
| Medical assistant | 2 |
| Dental assistant | 1 |
| Dietitian | 2 |
| Pharmacy technician | 1 |
| Office manager | 1 |

ANALYSIS, RESULTS AND CONCLUSIONS

The sample was analyzed using PLS-SEM. The results, conclusions will be discussed at the conference

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Does Unlearning Impact Interaction of EHR End-Users?

| Julee Hafner | Cherie Noteboom |
|-------------------------|-------------------------|
| Lake Sumter State | Dakota State University |
| (321) 352-3638 | (605) 638-0778 |
| <u>hafnerj@lssc.edu</u> | cherie.Noteboom@dsu.edu |
| - | |

Abstract: Organizations need to remain competitive in today's marketplace. Technology change impacts knowledge competencies that require alteration quickly, to reduce operating costs, and eliminate human errors. Updating computer system documentation procedures require unlearning to maintain competency. Physician end-users possess specialized competencies, or knowledge base in documentation of patient data to the degree that these operations have become automatic. To change the knowledge base of practitioners, end-users must use intellectual capital to unlearn patient care EHR documentation. This study focused on competency change, with the perceptions and influencers of unlearning of old competencies during EHR updates.

INTRODUCTION

Maintaining skill competencies while undergoing knowledge change is an ongoing problem (Nonaka, 1994). One method to develop skill competency in physician practitioners involves task repetition until errors are eliminated and learning is demonstrated (Neal, et al., 2012; Clark, 2010). Characteristics of learning have some relationship to unlearning as they both involve knowledge acquisition and change. The unlearning process involving disuse or replacement of knowledge may be related to specific types of learning or transformational change (Lewin, 1951; Hedberg, 1991).

Researchers suggest knowledge change processes are derived from learning theory, or transformational change processes, or simply part of technological advances. Individuals interact within organizations to update knowledge, trust, and competencies in healthcare practice (McInerney and Day, 2007). Turc and Baumgard (2007) suggest organizational knowledge management processes involve unlearning within the organization, but are uncertain how (McInerney and Day, 2007). Competency maintenance processes in organizations compare to individual knowledge change, or unlearning (Hafner, Ellis, and Hafner, 2014). In acquisition of knowledge, previous learning, considered knowledge base, can become obsolete, or consists of errors. This may be due to technological advances, or procedural changes from organizational mandates that change the knowledge base. In addition, organizations need to transfer new knowledge quickly to all end-users to maintain a competitive advantage. (Leibowitz, 2000, Duffy, 2003; Nonaka, 1994). End-users may have difficulty adjusting to numerous procedural changes and technological updates (Clark, 2010; Starbuck, 1996). Understanding change processes during competency acquisition is essential for the physician practitioner.

When environmental conditions change, knowledge and skills need updating to maintain competency (Rushmer and Davies, 2004; McInerney and Day, 2007; Starbuck, 1996). "In the global economy, knowledge is king"... "In such an environment, knowledge counts for more than capital or labor." (Starkey, Tempest and McKinlay, 2009, p. 74). For "knowledge organizations", there is a realization that there is value in knowledge. The acquisition of knowledge base and modification of this intellectual capital needs to be a new focus for healthcare end-users (Leibowitz and Beckman, 1998). The process of "unlearning" may be a critical element involved in physician practitioner end-user change (Starbuck, 1996; Nonaka, 1994).

Basic practitioner competency maintenance presents an ongoing problem for healthcare organizations (Leibowitz, 2000). Currently, researchers are uncertain how technological knowledge is updated (Low, 2011). Consider the process of unlearning. How technological knowledge and provider competency occurs may involve unlearning of previous competencies (Starkey, Tempest and McKinlay, 2000). Problems such as lost productivity, and re-work due to error production need to be avoided (Starbuck, 1996). With new methods of knowledge acquisition available

to develop effective physician competencies, leaders can implement them for successful change. The practitioner end-user that can use successful unlearning methods will acquire knowledge more effectively needed during change.

Organizations are challenged to improve practitioners' ability to acquire, and refine new skill competencies from outmoded computer system knowledge-base. The process of unlearning plays an undefined role in this knowledge change. Previously learned behavior and obsolete knowledge modified through unlearning may be the key to successful competency maintenance (Low, 2011).

THEORETICAL BACKGROUND

Unlearning has an undefined relationship to learning where skill change is needed (Hafner, Ellis, & Hafner, 2014). Both processes involve knowledge acquisition and change, however changing knowledge may involve personal experience with initial learning frameworks when acquiring new knowledge. Others suggest this process is merely change in pure form. Mezirow (1991) and Lewin (1951, 1989) both appear to believe that unlearning is oriented to transformational change stages. Unfreezing, change, and refreezing are the parts of active change according to Lewin (1951, 1989). The Three Stage Change Model utilizes a planned and controlled process directed by an organizational leader undergoing change (Lewin, 1989). Lewin's change model explains organizational level change theory, but fails to include specific individual knowledge acquisition change processes. McInerney and Day (2007) suggested that the learning process in an individual is important to the expression of knowledge and transmission of that knowledge, thus resulting in competency with other organizational individuals.

Completing needed end-user knowledge change requires innovation. To produce skill competency without errors allows for an organizational competitive advantage (Neal, et al., 2012). The development of functional, competent practitioners through new learning-change methodologies have been of interest, however, unlearning has not been the focus (Tsang and Zahara, 2008). Knowledge, skills, and competency research within the realm of learning change processes have produced discourse, but study regarding unlearning is often not included or completely understood (Akgun, Byrne, Lynn, and Keskin, 2007).

Transmission of knowledge organizationally to the end-user is the key to maintaining overall skill competency (Senge, 2006; Duffy, 2003). How this knowledge change process occurs and is facilitated is an ongoing problem (Nonaka, 1994). Unlearning, defined as the process of, disuse or replacement of an action, procedure, or belief, in favor of a new one (Hedberg, 1991). For the individual, the processing, retention and modification of their current knowledge base to correctly perform practitioner tasks is essential. The practitioner end-user must make specific changes in previous knowledge base that involves implementation of modified processes and new technologies. Unfortunately, the unlearning process may result in increased upset for the end-user; possible errors, and operating expenses. This process requires further investigation.

Take the case of a physician who provides healthcare to a new patient. The physician is responsible for evaluating the patient through collected data and determining a course of action, a plan of treatment. This action may involve, diagnostic testing, such as temperature and blood pressure, a blood draw for presence or absence of vitamins or other chemicals, or blood sugar testing. Historically, most data was collected by the practitioner and hand written. Another method of data collection included using dictation for data processing in the medical chart. Most physicians would agree that their ability to perform these routine services and document them have become automatic; these services are performed without conscious awareness. The latest innovation has changed procedures. This includes updates of data documentation procedures with the latest EHR (Electronic Health Record) system for data collection. Thus, the physician practitioner is the end-user of the EHR device for healthcare documentation.

This process has met with concern, frustration and generalized upset for many healthcare service providers, especially physicians. The physicians have had to change their knowledge and processes to work with the EHR as a tool for data documentation. When end-users are responsible for completing old tasks in new ways, it is important to understand the impact of how knowledge processes change when skills are no longer automatic. The previous strategy to "unlearn" to produce new knowledge competencies has been confused with learning (Hafner, 2015). In the learning process, the individual is exposed to new knowledge, acquires it, and processes this knowledge for

future use. This idea fails to address how knowledge is changed in end-users, such as physicians that have a previously acquired knowledge base and have made their actions automatic.

How modification and re-storage of knowledge is completed during knowledge change is under debate. Senge (2006) adds that knowledge is changed dependent on its usefulness (Senge, 2006). Newstrom believes unlearning begin with a "clean slate" before adding information (Newstrom, 1983). Hedberg (1991) posits that knowledge base is not only changed, but may also be discarded (Nonaka, 1994). This suggests that unneeded information is erased whereas, Starbuck (1996) views old knowledge is no longer used when it is incorrect (Starbuck, 1996; Hedberg, 1991). Klein (1991) suggests that knowledge is a cognitive process that may be situationally determined and also can be association-driven (Starbuck, 1996; Klein, 1989).

One method to allow for improved knowledge change is to combine informational bits for ease of use and storage. Cognitive load theory (CLT) suggests a complex relationship between the brain's ability to acquire and change knowledge (Merrienboer, and Sweller, 2010). This ability to acquire and store information for retrieval is limited. The informational units stored appears to be – seven – however the information deteriorates in as little as 20 seconds (Merrienboer, & Sweller, 2010). Automation is another method to compensate for difficulty in knowledge storage during change (Nissen, 2006; Starkey, Tempest & McKinlay, 2000). Repeated performance of an activity with enough frequency allows for automation and the individual, can perform activities without thinking. When updating knowledge, or unlearning, the automated knowledge base needs to be altered. Extension of knowledge storage capacity occurs because other activities can be focused on, such as in medical practice (Starkey, Tempest and McKinlay, 2000). Clark (2011) suggested unconscious unlearning occurs without awareness. Clark (2010) summarized unlearning by stating,

1) Adults may be unaware of their learning strategies they are using in general; 2) When change strategies fail, one unexamined factor is the relation of the stability of automated behaviors on new knowledge; and 3) there is limited understanding about how to unlearn automatic and unconscious knowledge in favor of new learning (Clark, 2010).

One important difference points to the fact the knowledge base has become unreliable and requires a new action or behavior to complete a task. (Hedberg; 1991; Starbuck, 1996). However, there may be other interactions in knowledge change that need to be determined. The inherent complexities of unlearning are currently not understood, supporting the need for additional research (Creswell, 2003). Explanations of unlearning are varied depending on the selected field of research (Duffy, 2003). In addition confusion remains between learning and how unlearning differs. From previous research, it was determined that unlearning was different from learning due to factors required in change and the presence of a prior knowledge base (Hafner, 2015).

Consider the increasing use of computer systems in healthcare organizations. Computer systems are responsible in a variety of automatic functions. Now computers are employed in documentation of patient data with the use of control systems prevalent in healthcare operations such as, monitoring patient data, processing drug orders, managing supply inventory, completing financial, billing and insurance transactions. In routine practice, computer systems are replaced frequently, and versions of software are changed to more closely support changing healthcare operations. As a result, EHR procedures are also updated, or replaced to correct obsolesce, thus reflecting new documentation changes.

These changes require that operations of end-users continually revise their mental models and processes to successfully use the latest EHR versions. In healthcare industries where computers are deployed to assist with work tasks, errors occur when machines are used to complete functions previously completed by humans. End-users must develop rote actions, or become automatic, in operating computing equipment no matter the frequency of changes needed (Schmorrow, Cohn, and Nicholson, 2010). With the replacement of older models with newer equipment, previously learned rote behavior may not allow for accurate operation of newer machines. The updated piece of equipment may even break due to command errors. Historically, when changing entire processes from a traditional tangible paper documentation system contained in a chart to an EHR, end users faced unlearning difficulties. These same challenges persist as end-users face technological upset attempting to make the human-computer interaction changes needed to update old processes to new.

Organizational mandates that create changes in routine may contribute to an increase in errors. Behavioral automation composed of repetitions of actions accounts of approximately 45% of daily actions (Clark, 2010). When unlearning is incomplete or unsuccessful, the result may be errors in documentation whether written or EHR generated. During change processes where actions are already in a state of flux, such as in new end-user EHR procedures, understanding error production resulting from unlearning may prove useful (Hedberg, 1991). The variety of errors may result from inaccurate use such as typing inaccuracies and other EHR errors. Additional examples of ineffective EHR use includes the low-level close approximation errors, such as the miss writing and miss typing in medical documentation to the highest possible level errors with consequences resulting in death (Walsh, and Gurwitz, 2008).

Demonstration of the automatic actions performed by end-users and commonly observed in EHR use are numerous. As the changes become more frequent, the ability to completely unlearn these automatic actions becomes more important. With the complete unlearning process in end-users defined, organizations may have the ability to acquire knowledge needed for continual updating human-computer interaction processes as often as needed. Problems such as lost productivity, re-work, and errors may be avoided (Starbuck, 1996). This then becomes the basis of new descriptive research study. With the results, consequences of incomplete unlearning during the updating of EHR knowledge change can be discovered. In addition, the results of difficulties involved with incomplete individual unlearning may establish a new link to error behavior. By determining successful unlearning methods, EHR end-users may possess the ability to change and acquire updated knowledge needed to update current competencies while maintaining productivity.

Additional benefits could lead to developing focused training in human-computer interaction systems. Unlearning of automatic actions can be facilitated by matching training materials to the end-user's knowledge change and acquisition abilities. Using knowledge about the mechanisms of unlearning may add to end-user ease of use or satisfaction.

Statement of the Problem

Skill competencies have been difficult to maintain within organizations. End-users need to keep pace with constant technological changes and industry advancements to maintain competitive advantage in today's marketplace. The amount of waste in materials, time, and human resources, not to mention the financial costs, have negatively impacted organizations who fail to understand the need for new change processes. The challenge is to develop and implement new knowledge consistently. To prepare end-users to unlearn, store and use knowledge functionally to update old outdated processes is an ongoing organizational need. Systemic change through individual unlearning is necessary solve this persistent problem. Current literature regarding the process of unlearning and its relationship to learning and has not been established or quantified. Completing the unlearning process successfully has been a challenge for end-users who modify their computer system knowledge to perform standard job functions efficiently. The confusion is that there is a difference between learning and the unlearning process when it involves practitioners that are working with updated computer processes. This study will examine unlearning to demonstrate the specific influencers that occur in the unlearning process in end-users.

There has been limited study regarding the how unlearning occurs in end-users. Although study regarding organizational unlearning has contributed to innovation processes, existing study about unlearning in humancomputer interaction processes remains limited (Becker, 2010; 2004). The idea that an individual should... "eliminate preexisting knowledge or habits that would otherwise represent formidable barriers to new learning" has not been determined (Clark, 2010, p. 5). There is disagreement within current literature about what processes impact unlearning tasks involve unconscious or automatic actions (Low, 2011; Becker, 2010; 2004).

There is a gap in the existing knowledge about the process of unlearning during change in human-computer interaction processes, such as in the use EHR's. Examination of open study issues should include: 1) demonstration of unlearning in end-users during knowledge change, 2) determining influencers in the unlearning process where previous knowledge base is updated.

The research question is: How does unlearning affect end-user performance when changing to a new system interface?

RESEARCH DESIGN

Problems persist due to disagreement regarding an agreed upon definition of unlearning. Additional confusion persists as to whether unlearning is actually learning. Without a specific accepted definition and a clear delineation of the differences between the two processes, how to successfully maintain end-user competency will remain unsolved. This study focuses on demonstration of unlearning involving a change from one EHR method of collecting and using data documentation to the use of an updated EHR. These end-user physicians are familiar with patient care in the areas of assessment, diagnosis and pharmaceutical selection to the degree that their operations within patient care have become automatic. These medical practitioner end-users possess a specialized competency and currently possess a stable knowledge base in documentation completion. The description of additional components of unlearning specific to healthcare service delivery, such as diagnosis and assessment documentation in the practice of medicine are considered as current competency and previous knowledge base. In order to demonstrate the end-user difficulties in producing unlearning knowledge change requires study.

Physician end-users of an EHR device for healthcare documentation gave responses about their use of these devices during the processes of diagnostic assessment documentation and subsequent initial care to determine and measure whether unlearning has impact on documentation system change (the EHR) in service delivery. Data was collected through an electronic questionnaire comprised of two open-ended questions asking respondents about their perceptions and experiences with electronic health record technology change.

This study uses a qualitative research method to examine physician interaction with updated EHRs. It uses Yin's (1984) case study approach, open-ended survey questions as the primary data collection and open coding for data analysis. The Yin approach was chosen as it: 1) generates relationships or theory with constant comparison literature; 2) allows emergent theory that is likely to be testable with constructs that can be readily measured; 3) has a high likelihood of valid relationships, models or theory because the theory building process is tied to data and other evidence (Yin, 1984).

Open coding is used to analyze the data and develop concepts as they relate to physician interaction with EHRs. The qualitative method and open coding analysis enables discovery of the relationships in the real world situation. Theoretical sensitivity allows the researcher to have insight into and to give meaning to the events and happenings in data. "Insights do not just occur haphazardly; rather, they happen to prepared minds during interplay with the data (Yin, 1984, p. 47)." Eisenhardt's enfolding the literature step complements the development of sensitivity (Eisenhart, 1989). "An essential feature of theory building, is the comparison of the emergent concepts, theory, or hypotheses with the extant literature" (Eisenhart, 1989, p. 544). This research utilizes theoretical sensitivity and enfolding the literature to develop the lens for the effort and to strengthen the results. That is, "it is discovered, developed, and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon" (Strauss & Corbin, 1998, p. 23). This approach is consistent with generally accepted approaches to develop relationships or theory from cases (Baskerville, and Myers, 2004; Eisenhart, 1989; Urquardt, 1989; Yin, 1984).

The hospital selected for this study is an early adopter of Electronic Health Records (EHR). It has successfully integrated all of its internal units with various modules of a single EHR vendor. Data was collected over a threemonth period in 2013 at an acute care county hospital located in the Midwestern United States. This hospital was chosen for its central location and importance in providing healthcare for the county. Seventy-three physicians were selected possessing a variety of specialties. The entire hospital physician population was surveyed.

Physician EHR device end-users responded about their perceptions of healthcare documentation processes changes during documentation of diagnostic assessment and testing processes, pharmaceutical selection and initial patient care. The researchers wanted to establish a link between routine processes completed with previous EHR technology documentation systems and unlearning of new EHR technology documentation. Would there be any impact in their service delivery using the new EHR system? More specifically, would unlearning be perceived using the new EHR

system? The two open-ended questions in this qualitative study were: 1) What works well related to the electronic health record system? 2) What are your concerns related to the current electronic health record system?

Twenty-nine female and forty-four male physicians completed the questionnaire. Ages of the practitioners fell into five broad groups. The groups were: 1) Eleven under 30 years; 2) Twenty in the range of 30-39 years; 3) Twenty-one in the range of 40-49 years; 4) Eleven in the range of 50-59; 5) Nine in the range of 60-69 years. One participant opted not to disclose age. Participation was voluntary, electronic, and solicited via email. There was no direct reward for participation.

The date was coded using the following definitions: 1) *Cognitive Processes*: defined as the end-user perception of time and accessibility that was needed to unlearn the old EHR documentation competencies and update to new EHR competencies, 2) *Data Integrity*: defined as the reduction or elimination of misleading and/or inconsistencies in the data to use the EHR documentation system. This also includes the privacy and ease of access in information, 3) *Proper Functionality*: Defined as the standardization of the EHR system needed to successfully use the system without upset, or disruption (Shneiderman & Shneiderman, 2003). This is an area where incomplete unlearning can breakdown the process as end-users struggle to update their current competencies, 4) *Errors*: defined as concern or fear of the production of medical errors created from incomplete unlearning when updating competencies.

RESULTS & ANALYSIS

The transcripts of the interviews were analyzed; "labels of meaning" were identified, and placed next to the relevant occurrence. Occurrences were events, happenings, actions, feelings, perspectives, perceptions, actions and interactions. Strauss & Corbin's (1998) open coding method analyzed the interview data. The authors used two phases to categorize and code the data. First, the interview data obtained were coded into broad categories. Then open coding conceptualized raw data by naming and categorizing the encountered phenomena through close examination of the data. In the second phase of the open coding process, all data were separated into discrete parts, closely examined, and compared for similarities and differences.

The coding process yielded 77 coded quotes. The data representing events, happenings, actions and interactions found to be conceptually similar in nature or related in meaning were grouped under abstract concepts that best represent the phenomenon. According to Corbin and Strauss (2008), although events or happenings might be discrete elements, the fact that they share common characteristics or related meanings enables them to be grouped (Urquhart, 1989). Based on their ability to explain what is going on, certain concepts were grouped under more abstract higher order concepts which Strauss and Corbin (1998) term category. Categories have analytic power because they can have the potential to explain why physicians may or may not use the technology and potentially predict the effects of certain implementations on physicians' use. The 77 labels were categorized to compare codes across the interviews. The categories were derived by tabulating the number of occurrences of related concepts.

Reliability of these groupings was achieved through theoretical sensitivity, iterative coding, and theoretical sampling. Strauss and Corbin [1998] suggest that theoretical sensitivity is required to enable the researcher to interpret and define data and thus develop relationships, models or theories that are grounded, conceptually dense, and well integrated (Urquhart, 1989). Sources of theoretical sensitivity are the literature, professional, and personal experiences. Additional reliability was achieved through the iterative use of open and axial coding to bring out the concepts and discover any causal relationships or patterns in the data.

Further reliability was achieved through theoretical sampling, which is the sampling of data on the basis of concepts that have proven theoretical relevance to evolving relationships, models or theories. The form of open sampling used was open sampling which is associated with open coding. Open sampling was used to select additional interview data. The 'slices of data' of all kinds, as Urquhart (1989) describes this process, are selected by a process of theoretical sampling, where the researcher decides on analytical grounds where to sample from next. In this, the researcher does not approach reality as a tabula rasa but must have a perspective that will help him or her abstract significant categories from the data based on the constructs identified in the literature (Strauss and Corbin, 1998). This data analysis produced technological, work, and social adaptation categories. A further analysis of adaptation at each of the three levels revealed the level the physicians are able to use EHRs to support their work practices, level

of technological comfort, and social interactions/connections. The categories, descriptions and number of occurrences are presented in Table 1.

| | Physician Unlearning of EHR's | | |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|-----|
| Category | Description | # | % |
| <u>Technological Upset</u> | Any perceptions of unbalanced skills, added stress, or frustration while completing tasks using an EHR system. | 77 | 100 |
| COGNITIVE PROCESSES | A perception that time and accessibility are needed to unlearn the old documentation competencies and update to the new EHR competencies. | 25 | 32 |
| DATA INTEGRITY | The presence of misleading, inconsistent data needed to complete EHR documentation, including security, privacy and access of information. If the end-user has data that he can use; he has reduced technical upset and may be more likely to unlearn the old competency. | 24 | 31 |
| PROPER FUNCTIONALITY | The standardization of an EHR system needed to successfully complete a task without upset, or disruption. Incomplete unlearning can create additional struggle for the end-user as they update current competencies. | 19 | 24 |
| ERRORS | The concern or fear of creating an error related to inability to update a skill competency. | 9 | 11 |
| Others | | 2 | 2 |
| TOTALS | | 77 | 100 |

Table 1. Physician Unlearning of EHR's

Cognitive Processes

Twenty-five respondents suggested that Cognitive Processes had impact on their unlearning difficulties. *Cognitive Processes* are defined as the end-user perception of time and accessibility that are needed to unlearn the old technological documentation systems to update knowledge to the new EHR competencies. 25 participant responses were concerned with their ability to change their knowledge within time frames. An additional concern was that physician end-users had difficulty with their ability to obtain the data that they required to complete competent documentation. When inability to complete new documentation processes with needed data occurred, perceptions of decreased end-user competency and upset occurred. Additional upset and confusion was identified an unlearning influencer. Physicians expressed concerns that additional work to complete the patient documentation process was due to the EHR changes.

"Most of the notes for a specific diagnosis produced by the EHR are similar if not identical to each other" (Participant 25).

"You cannot find a good nursing assessment at all... no integration to pharmacy and current assessment of medication" (Participant 32).

Participant 37 states that,..."there is a reduction in clinical information...difficult to synthesize checkboxes".

Data Integrity

Data Integrity is defined as the reduction or elimination of misleading and/or inconsistency in the data to be able to use the EHR. This also included the privacy and access of the information. Twenty-four (24) participant responses discussed this issue. When the data possesses integrity, the end-user has reduced technical upset and may be more likely to unlearn the old competency. Unlearning the documentation competency was a concern. The end-users were concerned with the potential for additional errors in documentation of assessment and treatment due to misinformation presented within the new EHR system.

One physician commented, "... for example, heights and weights are frequently incorrect, this in turn messes up some fields that pull the data through into calculation or dosages.... This could lead to potential med errors" (Participant 12).

Or another physician states, ".... Approximately 20% of the drug orders require manipulation... comments don't match the order" (Participant 8).

"Falsification of information... the templates given in the EHR system are unrealistic and way too much time to actually ask all of the question listed... the physicians assume... on behalf of the patient" (Participant 24).

Proper Functionality

With *Proper Functionality*, the end user require a system with consistency and ease of use when making the learning change. Defined as the standardization of the EHR system needed to successfully use the system without upset, or disruption, *proper functionality* was noted by 19 of the physician end-users. Several practitioners commented about the potential for upset through the lack of proper functionality. Participant 10 suggests... "Does not seem consistent with how the drop-down menu is organized". Upset is also apparent in another practitioner... "Downtime procedures and negative impact of downtime on EHR.... Massive time commitment required to maintain EHR to be congruent with current practice and guidelines, on the part of the clinician and IT staff" (Participant 4). This is an area where incomplete unlearning can breakdown the process as end-users struggle to update their current competencies. The EHR fails to support and contribute to knowledge change through a lack of standardization of the EHR for all healthcare end-users.

These unlearning influencers create additional burden on the unlearning processes. As Participant 71 states, "When electronic medical record systems are down, patient care comes to a halt". This comment points to the need for end-user ease in operation when healthcare documentation systems are changed.

Errors

The updating of documentation systems created enough technological upset about personal competency in service delivery that end-users were concerned. Practitioners reported observed errors or frustration. Nine practitioners reported possibility of medical errors production due to EHR documentation updates. This fear was related to the need for complete unlearning of previous competencies. When enough system change was present, end-users were uncertain of their documentation competency, creating upset. The potential for grievous errors created technological stress, to the point that the most affected end-users were willing to separate from their positions. Three examples of these upset end-user comments were:

"... I have seen medication errors with the system" (Participant 44).

"EHR's have contributed to some errors at out hospital as well as some frustration for our doctors" (Participant 25).

"We have older employees that decide to retire primarily due to difficulty using the system" (Participant 22).

Practitioner end-users recognized the potential for problems in the unlearning process. Their inability to unlearn completely resulted in a perception of upset, a doubt their own competencies and of the data entered. The EHR system needs to support the documentation practices efficiently enough that the physician can update their documentation system knowledge to complete patient care practice procedures. When the influencers of unlearning were present, the perceptions of technological upset, and operation of the EHR became more difficult. When the upset is heightened due to frequent changes, the practitioner may take drastic steps to avoid error potential. In the model below, EHR knowledge process updating is shown to be a cyclic interaction between replacement of obsolete documentation competencies with new current documentation competencies. The practitioner end-users remain challenged to unlearn successfully to avoid upset and maintain competency.

The model in Figure 1 illustrates knowledge competency change needed to provide patient centered care. A patient centered model of technological interaction in healthcare builds upon what we know about the challenges facing the end-user practitioner. As systems change, documentation processes in the EHR need to be updated. This can create a competency knowledge gap in the end-user leading to technological upset. While it is accepted that the patient-physician relationship is at the center of healthcare-provision process, documentation of and access to needed information, assessment techniques and data collection is a vital part of this process.



Figure 1. EHR interaction experience

Unlearning can play an important role in understanding EHR adoption processes. As new knowledge updates the obsolete, the process takes on a cyclical shape. The end-user must change competencies. This process leads to upset when the process fails to be complete. Influencers are responsible for limiting successful adoption of new EHR system changes. When there is complete unlearning of new documentation system knowledge, ease of technology use is noted by end-user practitioners. This model illustrates how integrating patient medical records with the clinical processes through EHRs with web services can enable physicians, healthcare providers and patients to

access and update current knowledge needed for "meaningful use". Adoption processes, such as the complete unlearning of new EHRs by physicians and patient end-users, can facilitate successful technology use. The opportunities for improved care through personalized medicine and tailored therapeutics by enabling all end-users to use technology and its updates is important to this process (Walsham, 1993). Understanding unlearning processes may improve quality of care as an end result of future study.

SUMMARY & CONCLUSIONS

The rising cost and decreasing quality of health care has focused the impetus of organizations towards the use of EHRs to solve these issues. The goal is to improve service delivery with the increased transparency and efficiency through the use of updated technology. However, the challenges to adoption of EHRs by physicians have tempered efforts to improve efficiency of service delivery. This study focuses on demonstration of unlearning involving knowledge change involving updated EHRs to complete patient care.

This paper has investigated: *How does unlearning affect end-user performance when changing to a new system interface?* There was a demonstration of unlearning involving a change from EHR collection and use of data in healthcare to the use of updated EHRs for the collection and recording documentation of health data. The end-users possess a specialized assessment skill and already have the ability to complete documentation in their chosen field of medicine. These end-user physicians are familiar with documentation of patient care in the areas of assessment, diagnosis and pharmaceutical selection to the degree that their EHR operations have become automatic.

Recognition of the role unlearning plays in the knowledge change process of the physician to the updated EHR is of key importance. Cognitive processes, proper functionality, and data integrity and error impact were identified as key components, or influencers, affecting physician end-user complete unlearning of the EHR system. Clearly, if one of the unlearning influencers results in negative experience, the end-user perceives 'technological upset'. As the EHR is a fluid system with frequent updates, unlearning is an essential component of the EHR interaction cycle.

Thus, continued attention to the cognitive process change, data integrity, proper device functionality, and awareness of potential errors are key to successful physician engagement with the EHR. If these four unlearning influencers result in positive experience, the practitioner is likely to achieve "technological ease" (Hafner, 2015). Technological ease enables the physician end-user to update their technological knowledge and facilitates data documentation. The ease of EHR use may lead to enhanced collaboration and support as physicians assess and verify data, solve problems, and find innovative solutions to patient conditions.

In order to achieve better quality of care, the electronic health records with web services can provide the transparency needed as physicians utilize the technology to exchange content. With improved patient interaction, patients are enabled to access their information to make better healthcare decisions. This study focuses on four influencers creating negative perceptions of unlearning of old competencies during EHR updates. Further research will need to assess complete unlearning processes to create ease of access of EHR technology.

Problems persist due to disagreement regarding how end-users can adapt quickly to changing conditions using unlearning processes. When end-users process new knowledge changes correctly, upset and inconsistencies in EHR use are reduced, creating successful knowledge updating. Without the specifics about the influencers of complete unlearning, how to successfully maintain end-user and organizational competency will remain unsolved. The process of unlearning automatic actions to produce successful human-computer interaction continues to require further study.

Changing knowledge requires organizations to alter knowledge base in favor of new competencies for organizational efficiency. Competitive advantage involves rapid knowledge acquisition and revision from current knowledge, skills and competencies through unlearning. Complete unlearning may allow end-users to adapt more quickly to changing systems and organizational processes.

This research study demonstrates the impact of the unlearning process to knowledge change. With organizations realizing change needs to occur quickly to reduce operating costs, maintain patient satisfaction and eliminate errors, factors of unlearning have become important. Computer systems, EHR systems, and documentation procedures require continual frequent updating to maintain patient care changes. Knowledge base of end-user practitioners, require change in intellectual capital to unlearn previous EHR documentation procedures and reduce technological upset. Effective EHR use by physicians can enable better healthcare documentation and service delivery. With greater understanding of unlearning, and its unique differences from learning, new methods of effective knowledge change for physician competency updating can be implemented. By addressing the end-users technological upset during unlearning, the updated requirements needed for efficient documentation and service delivery can be realized.

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A Case Study Perspective toward Data-driven Process Improvement for Balanced Perioperative Workflow

| Jim Ryan | Barbara Doster and Sandra Daily | Carmen Lewis |
|---------------------------------|-------------------------------------------|------------------|
| Auburn University at Montgomery | University of Alabama Birmingham Hospital | Troy University |
| jryan@aum.edu | bdoster@uabmc.edu | cclewis@troy.edu |

Abstract: Based on a 143-month longitudinal study of an academic medical center, this paper examines operations management practices of continuous improvement, workflow balancing, benchmarking, and process reengineering within a hospital's perioperative operations. Specifically, this paper highlights datadriven efforts within perioperative sub-processes to balance overall patient workflow by eliminating bottlenecks, delays, and inefficiencies. This paper illustrates how dynamic technological activities of analysis, evaluation, and synthesis applied to internal and external organizational data can highlight complex relationships within integrated processes to identify process limitations and potential process capabilities, ultimately yielding balanced workflow and improvement. Study implications and/or limitations are also included.

INTRODUCTION

The perioperative process yields patient end-state goals: (1) a patient undergoes a surgical procedure; (2) minimal exacerbation of existing disorders; (3) avoidance of new morbidities; and (4) subsequent prompt procedure recovery (Silverman & Rosenbaum, 2009). To these end-state goals, a hospital's perioperative process provides surgical care for inpatients and outpatients during pre-operative, intra-operative, and immediate post-operative periods. Accordingly, the perioperative sub-processes (e.g. pre-operative, intra-operative, and post-operative) are sequential where each activity sequence paces the efficiency and effectiveness of subsequent activities. Furthermore, perioperative sub-processes require continuous parallel replenishment of central sterile supplies and removal of soiled materials. Given the multiple sub-processes and associated dynamics, Fowler et al. (2008) views a hospital's perioperative process as complex and the workflow complexity as a barrier to change and improvement. Nonetheless, integrated hospital information systems (IS) and information technology (IT) provide measurement and subsequent accountability for healthcare quality and cost, creating a dichotomy (e.g. quality versus cost) that represents the foundation for healthcare improvement (Dougherty & Conway, 2008).

The challenge of delivering quality, efficient, and cost-effective services affects all hospital stakeholders. Perioperative workflow tightly couples patient flow, patient safety, patient quality of care, and hospital stakeholders' satisfaction (i.e. patient, physician/surgeon, nurse, perioperative staff, and hospital administration). Consequently, implementing improvements that will result in timely patient flow through the perioperative process is both a challenge and an opportunity for hospital stakeholders, who often have a variety of opinions and perceptions as to where improvement efforts should focus. Furthermore, perioperative improvements ultimately affect not only patient quality of care, but also the operational and financial performance of the hospital. From an operational perspective, a hospital's perioperative process requires multidisciplinary, cross-functional teams to maneuver within complex, fast-paced, and critical situations-the hospital environment (McClusker et al., 2005). Similarly from a hospital's financial perspective, the perioperative process is typically the primary source of hospital admissions, averaging between 55 to 65 percent of overall hospital margins (Peters & Blasco, 2004). Macario et al. (1995) identified 49 percent of total hospital costs as variable with the largest cost category being the perioperative process (e.g. 33 percent). Managing and optimizing a quality, efficient, flexible, and cost-effective perioperative process are critical success factors (CSFs), both operationally and financially, for any hospital. Moreover, increased government and industry regulations require performance and clinical outcome reporting as evidence of organizational quality, efficiency, and effectiveness (PwC, 2012).

This 143-month longitudinal case study covers a clinical scheduling IS (CSIS) implementation, integration, and use within an academic medical center's perioperative process. Empowered individuals driven by integrated internal and external organizational data facilitate the case results. The resulting systematic analysis and subsequent contextual understanding of the perioperative process identified opportunity for improvement. Specifically, the

extension of data mining into the analysis and evaluation process of CSIS' data feedback from particular perioperative sub-processes provides the framework for the discovery and synthesis of redesign and reengineering within perioperative workflow to yield continuous process improvement. This paper investigates the research question of how data-driven continuous improvements can balance perioperative sub-process workflow to improve overall patient flow. Furthermore, investigation of the research question in this paper explains how analysis of perioperative performance metrics (e.g., key performance indicators), evaluation of perioperative sub-process constraints and capabilities, and synthesis of perioperative sub-process redesign implemented to balance perioperative workflow can attain: (1) improved workflow, efficiency, and utilization; (2) tighter process to hospital IS coupling; and (3) patient care accountability and documentation. This study highlights operations management practices of continuous improvement, workflow balancing, best practices, process reengineering, and business process management within a hospital's perioperative process. Measured improvements across intra-operative, pre-operative, post-operative, and central sterile supply also distinguish complex dynamics within the perioperative sub-processes nested in the hospital environment.

The following sections review previous literature on data design and data mining, process redesign, business process management, and perioperative performance metrics. By identifying a holistic model for evaluation, analysis, and synthesis between data and process design, this paper prescribes an a priori environment to support continuous process improvement. Following the literature review, we present our methodology, case study background, as well as the observed effects and analysis discussion of the continuous improvement and workflow balancing efforts. The conclusion addresses study implications and limitations.

LITERATURE REVIEW

First mover advantage on innovations, adaptation of better management practices, industry competition, and/or government regulations are examples of the many factors that drive process improvement. Traditionally, the hospital environment lacked similar industrial pressures beyond government regulations. However, hospital administration currently face increasing pressure to provide objective evidence of patient outcomes in respect to organizational quality, efficiency, and effectiveness (CMS, 2005; CMS, 2010; PwC, 2012), all while preserving clinical quality standards. Likewise, hospitals in the United States must report and improve clinical outcomes more now due to the American Recovery and Reinvestment Act of 2009, the Joint Commission on Accreditation of Healthcare Organizations (TJC), and the Centers for Medicare & Medicaid Services (CMS). These performance and reporting challenges require leveraging information systems (IS) and technologies (IT) to meet these demands.

Hospital administrators and medical professionals must focus on both the patient quality of care as well as management practices that yield efficiency and cost effectiveness (PwC, 2012). To this end, operations management practices of continuous improvement, best practices, process reengineering, workflow balancing, and business process management (BPM) provide improvement approaches (Jeston & Nelis, 2008; Kaplan & Norton 1996; Tenner & DeToro, 1997). However, such approaches yield significant variations in implementation success.

Data, Design, and Data Mining

Data is a prerequisite for information, where simple isolated facts give structure through IS design to become information. Early in the IT literature, embedded feedback as a control to avoid management misinformation was proposed in IS design (Ackoff, 1967). Likewise proposed was the selection and supervision of defined data as key performance indicators (KPIs) to assist management in qualifying data needs to monitor CSFs that subsequently manage organizational action (i.e. business processes) through IS feedback (Munroe & Wheeler, 1980; Rockart, 1979; Zani, 1970). Similarly, the perioperative process is becoming increasingly information intensive and doubt exists as to whether perioperative process management is fully understood to meet the increasing hospital environmental demands for value and cost management (Catalano & Fickenscher, 2007). Understanding how IS design and particularly how CSIS design embeds processes into data input and information output is a first step toward understanding data as a resource for heuristic development (Berrisford & Wetherbe, 1979).

Given that people perform organizational action, people develop IS, people use IS, and people are a component within IS (Silver et al., 1995); understanding the human mind is a requisite in understanding how organizational action via CSIS occur. Ackoff (1988) proposed a hierarchy of the human mind, where each category is an aggregate of the categories below it. Wisdom descends to understanding, knowledge, information, and then data. Other

authors of knowledge management literature share similar hierarchical views of human mind content (Earl, 1994; Davenport & Prusak, 1998; Tuomi, 2000).

Achieving wisdom requires successively upward movement through the other four human mind categories, with each level drawing content from prior levels. Data, information, knowledge, and understanding relate to past events and wisdom deals with the future as it incorporates vision and design.

The IT literature contains volumes of studies to offer opinions on system design. For this study, the intent is to provide a basic understanding of system design activities and substantiate the need for iterative improvement through heuristic development. Blanchard and Fabrycky (2010) recognize system design as a requisite within the systems life cycle where technological activities of analysis, evaluation, and synthesis integrate within iterative applications to minimize systems' risk from entropy, obsolescence, and environmental change.

Under ideal terms, an individual's wisdom recognizes that an IS solution can meet an organizational need. Subsequently, individual understanding and knowledge create the IS design, develop the IS, and implement it to meet the organizational need. This ideal situation is hypothetical, yet it does illustrate that during the design, development, and implementation stages of an IS (i.e. the systems life cycle), understanding, knowledge, and information are decontextualized into detached data and semantic data structures that are accessible by IS' processes. Tuomi (2000) called this set of human mind sequences a reversed hierarchy from the traditional model (e.g. data leads to information, on to knowledge, understanding, and wisdom).

Ackoff (1988) concluded that wisdom might well differentiate the human mind from the IS. Consequently, it is understanding and knowledge of the business process that system stakeholders use to develop information requirements and subsequent data requirements for IS design. Furthermore in reverse logic, it is data within the deployed IS that knowledge workers can use to assist in the organizational action of discovery to develop the knowledge and understanding of how to redesign business processes. Udell (2004) compared data to Play-doh—a tangible substance that can be squeezed, stretched, and explored directly. Witten and Frank (2005) define data mining as the process (i.e. automatic or semiautomatic) of discovering patterns (i.e. structure) within data, where the data already exists within the IS' databases in substantial quantities and the discovered patterns have organizational importance.

Holistic Model for IS Design and Discovery

Data mining can explore raw data to find organizational and environmental connections (bottom up), or search data to test hypothesis (top down) producing data, information, and insights that add to the organization's knowledge (Chung, 1999). Figure 1 depicts data mining as discovery to use the traditional model of the human mind to churn data, existing within the IS, into information that leads on to knowledge, understanding, and possibly wisdom. Unfortunately, the healthcare industry has not fully embraced data as a resource and utilized data mining as a knowledge discovery tool (Wickramasinghe & Schaffer, 2006; Catalano & Fickenscher, 2007; Delen et al., 2009; Liu & Chen, 2009; Ranjan, 2009).

Figure 1 also depicts a proposed holistic model for IS design and discovery, which demonstrates the logic for mining perioperative data for business process analysis and redesign. The model incorporates the IT literature we have discussed over data as a resource, system design, and data mining. As stakeholders design a new IS, the system designers draw upon the hierarchy (Tuomi, 2000) to embed and encapsulate organizational actions into the new application. Collected data within an implemented IS represents organizational action (i.e. business processes). Captured and stored CSIS data reflects current and past perioperative actions (i.e. perioperative sub-processes and patient workflow) that is available for heuristic development.



Adapted from R. L. Ackoff's (1989, page 3) hierarchy of the human mind

Data mining analyzes associations and data patterns for meaningful structure. Data mining in this study's context yields perioperative knowledge workers analyzing CSIS data for data discovery via online analytical processing (OLAP) and data visualization to identify data associations, clusters, and patterns. Using the reversed hierarchy (Tuomi, 2000), evaluation of the meaningful data pattern structures leads to synthesis (i.e. redesign) of improved or new organizational action. The model in Figure 1 depicts the iterative nature of system design and discovery that is similar to continuous improvement. With respect to this study, the applications of data mining techniques occur within a perioperative data mart (e.g. CSIS data archived to a separate database) for heuristic associations and clusters. OLAP and data visualization of perioperative data occurs via comparisons between capacity constraints and/or industry benchmarks to allow pattern recognition of anomalies, which in turn trigger and justify the synthesis of improvements. Specific anomaly examples are highlighted later under the observed effects section.

Process Redesign

Specifically, this study examines process redesign approaches over continuous improvement, best practices, and reengineering (Tenner & DeToro, 1997). Continuous process improvement (CPI) is a systematic approach toward understanding the process capability, the customer's needs, and the source of the observed variation. The incremental realization of improvement gains occur through an iterative cycle of analysis, evaluation, and synthesis or plan-do-study-act (Walton, 1986) that minimize the observed variation. CPI encourages bottom-up communication at the day-to-day operations level and requires process data comparisons to control metrics. Tenner & DeToro (1997) views CPI as an organizational response to an acute crisis, a chronic problem, and/or an internal driver. CPI rewards are low (i.e. between 3 to 10 percent) with low risk and cost, easy implementation, and short durations. Within a CPI effort, doubt can exist as to: whether the incremental improvement addresses symptoms versus causes; whether the improvement effort is sustainable year after year; and/or whether management is in control of the process (Jensen & Nelis, 2008).

An alternative to CPI is best practices, which offers higher rewards (i.e. between 20 to 50 percent) with similar low risk, longer duration, as well as moderate costs and implementation difficulty (Tenner & DeToro, 1979). Camp (1995) differentiates best practices from benchmarking as finding and implementing industry standard practices that lead to superior performance as opposed to benchmarks that are metric standards or key performance indicators (KPIs). Best practice encourages the imitation or adaptation of external industry standards coupled with internal expertise. However, best practices requires more resource allocations versus CPI and a higher degree of understanding about the targeted process, which can lead management to under-estimate the resource requirements necessary for best practice success.

Hammer (1990) summarizes process reengineering in his article, "Reengineering Work: Don't automate, obliterate." Reengineering offers more radical redesign when compared to CPI or best practices (Tenner & DeToro, 1979), assuming more risk with greater reward potential. Hammer & Champy (1993, p.32) defined process reengineering as the fundamental rethinking and radical redesign to achieve dramatic improvements in critical measures of performance (e.g. cost, quality, service, and speed). Three key terms in the definition differentiates reengineering from CPI or best practices—fundamental, radical, and dramatic. Reengineering is a project-oriented effort that utilizes top-down improvement, managed by external and internal expertise, to achieve breakthrough improvement. Reengineering a process offers the highest reward potential, with upwards of 1,000 percent. However, the high potential rewards have very high risk, longer durations, as well as very high costs and the highest implementation difficulty (Tenner & DeToro, 1979). A reengineering project requires extensive resource allocations as opposed to CPI or best practices, as well as seeking an order of magnitude improvement by questioning the relevance of every activity and reinventing new ways to accomplish necessary work.

Business Process Management (BPM)

Specifically, this study uses business process management (BPM) techniques to monitor process KPIs and measure process improvement within perioperative sub-processes. This study uses the BPM definition provided by Jensen and Nelis (2008, p. 10) as "the achievement of an organization's objectives through the improvement, management, and control of essential business processes." The authors further elaborate that process management and analysis is integral to BPM, where there is no finish line for improvement. Hence, this study views BPM as an organizational commitment to consistent and iterative process performance improvement that meets organizational objectives. To this end, BPM embraces the concept of CPI aligned to hospital strategy.

As BPM requires alignment to strategic objectives, a balanced scorecard (BSC) approach (Kaplan & Norton, 1996) embraces the ability to quantify organizational control metrics aligned with strategy across perspectives of: (1) financial; (2) customer; (3) process; and (4) learning/growth. Business analytics is the body of knowledge identified with the deployment and use of technology solutions that incorporate BSCs, dashboards, performance management, definition and delivery of business metrics, as well as data visualization and data mining. Business analytics within BPM focus on the effective use of organizational data and information to drive positive business action (Turban et al., 2008). The effective use of business analytics demands knowledge and skills from subject matter experts and knowledge workers. Similarly, Wears and Berg (2005) concur that IS/IT only yield high-quality healthcare when the use patterns are tailored to knowledge workers and their environment. Therefore, BPM success through BSCs and dashboards has a strong dependence on contextual understanding of end-to-end core business processes (Jensen & Nelis, 2008).

Perioperative Key Performance Indicators (KPIs)

An integral part of CPI is process information before and after intervention. Hence, performance measurement is essential for purposeful BPM. As we previously mentioned, control feedback in IS avoids management misinformation (Ackoff, 1967) and IS feedback as KPIs (Munroe & Wheeler, 1980; Rockart, 1979; Zani, 1970) assists management in monitoring critical success factors (CSFs) for organizational action (e.g. business processes). However, the perioperative process is complex and information intensive (Fowler et al., 2008), so doubt exists as to whether perioperative management can meet increasing demands for cost effectiveness (Catalano & Fickenscher, 2007).

The following scenario illustrates the complexity, dynamic nature, and nested operational, tactical, and strategic relationships among perioperative KPIs. Operating room (OR) schedules are tightly coupled to an individual OR suite, patient, and surgeon. When preoperative tasks are incomplete or surgical supplies are not readily available at time of surgery, the scheduled case is delayed as well as the subsequent scheduled cases in the particular OR suite or for the particular surgeon. Operational and tactical KPIs in managing and optimizing a hospital's perioperative process include: (1) monitoring the percentage of surgical cases that start on-time (OTS), (2) OR turn-around time (TAT) between cases, (3) OR suite utilization (UTIL), and (4) labor hours per patient care hours or units-of-service (UOS) expended in surgical care (Herzer et al., 2008; Kanich & Byrd, 1996; Peters & Blasco, 2004; Tarantino, 2003; Wright et al., 2010). Tarantino (2003) noted how OR TAT and a flexible work environment are CSFs for physician satisfaction, which in turn is a CSF for hospital margin. Poor KPIs on operational and tactical metrics

(i.e., OTS, TAT, UOS, or UTIL) affect strategic CSFs of patient safety, patient quality of care, surgeon/staff/patient satisfaction, and hospital margin (Marjamaa et al., 2008; Peters & Blasco, 2004).

RESEARCH METHOD

The objective of this study is to investigate how data-driven continuous improvements can balance perioperative sub-process workflow to improve overall patient flow through the analysis of perioperative performance metrics (e.g., key performance indicators), evaluation of perioperative sub-process constraints and capabilities, and synthesis of perioperative sub-process redesign. Furthermore, the continuous improvements to yield balance perioperative workflow can attain: (1) improved workflow, efficiency, and utilization; (2) tighter process to hospital IS coupling; and (3) patient care accountability and documentation. To this end, case research is particularly appropriate (Eisenhardt, 1989; Yin, 2003). An advantage of the positivist approach (Weber, 2004) to case research allows concentrating on specific hospital processes in a natural setting to analyze the associated qualitative problems and environmental complexity. Hence, our study took an in-depth case research approach.

Our research site (e.g. University Hospital) is an academic medical center, licensed for 1,046 beds and located in the southeastern United States. University Hospital is a Level 1 Trauma Center, having a robotics program encompassing over eight surgical specialties, as well as a Women's/Infant facility. University Hospital's recognition includes Magnet since 2002 and a Top 100 Hospital by U.S. News and World Report since 2005. Concentrating on one research site facilitated the research investigation and allowed collection of longitudinal data. During the 143-month study, we conducted field research and collected data via multiple sources including interviews, field surveys, site observations, field notes, archival records, and document reviews.

This research spans activities from August 2003 through June 2015, with particular historical data since 1993. Perioperative Services (UHPS) is the University Hospital department that coordinates the perioperative process. Initially, the perspective of this research focused on University Hospital's perioperative process for its 32 general operating room (OR) suites in the main OR campus with Admissions; Surgical Preparations (PRE-OP) having 42 beds; OR Surgery, Endoscopy, and Cystoscopy; Post Anesthesia Care Unit (PACU) having 45 beds, and Central Sterile Supply (CSS). University Hospital administration consolidated all OR management and scheduling within the University Hospital Health System (UHHS) under UHPS in 2008, including cardio-vascular and off-site surgical clinics. In 2011, hospital administration added the Pre-admissions and the preoperative assessment consultation and test (PACT) clinic (Ryan et al., 2012) to UHPS' scope. Currently, UHPS manages 35 general OR suites (GENOR), 6 cardio-vascular OR suites (CVOR), 16 OR suites on the Highlands campus (HHOR), 2 OR suites at Women & Children (WaCOR), and 8 OR suites at the CAL Eye Foundation Hospital (CEFOR). In total, UHPS manages 67 OR suites having a combined FY2014 surgical case volume of 42,741.

CASE BACKGROUND

UHPS implemented a new CSIS in 2003, after using its prior CSIS for 10 years. The old CSIS and its vendor were not flexible in adapting to new perioperative data collection needs. The old CSIS did not have an online analytical processing (OLAP) capability and the perioperative data mart was multiple Microsoft Access databases. The new CSIS from vendor C supports OLAP tools, a proprietary structured query language, and both operational and managerial data stores (i.e. operational data and a separate perioperative data mart). The new CSIS has flexible routing templates (i.e. from 4 to 36 segments to capture point of care data), customizable over generic and surgeon specific surgical procedures, documented in the CSIS as surgeon preference cards (SPCs). Since the new CSIS implementation in August 2003, University Hospital has maintained over 7,775+ SPCs across the surgical specialty services (SSS) represented in Table 1.

Table 1. Surgical Specialty Services (SSS) withSurgeon Preference Cards (SPCs)

| Surgical Specialty Service | SPCs |
|-------------------------------------------|-------|
| BURN – Trauma burns | 26 |
| CARDIO -Cardiovascular & Thoracic | 946 |
| ENT - Ear, Nose, & Throat | 1,030 |
| GI – Gastro-intestinal | 460 |
| GYN – Obstetrics, an cology, incantinence | 611 |
| NEURO - Neurological | 763 |
| ORAL - Oral Maxil Facial | 236 |
| ORTHO – Orthopedic, jaint/device | 1,208 |
| PLAS - Plastic surgery | 681 |
| SU RG ON C - Surgical oncology | 329 |
| TX – Transplants (liver, renal) | 194 |
| TRAUMA - Trauma, MASH | 203 |
| URO – Urology | 533 |
| VASCULAR - arteries & blood vessels | 558 |
| Combined Total | 7,778 |

November 2004

University Hospital opened a new surgical facility in November 2004, with ORs located over two floors and CSS located on a third. The move expanded UHPS to cover an additional floor and nine additional ORs (i.e., 33% capacity increase). The new facility housed 40 state-of-the-art OR suites, each having new standardized as well as surgical specialty equipment. Within six weeks of occupying the new facility, a scheduling KPI reflected chaos. Surgical case OTS plunged to 18% during December 2004. Within a highly competitive hospital industry, having only 18% OTS was unacceptable, as 82% of scheduled surgeries experienced delays and risked patient care and safety.

In January 2005, UHPS expressed concerns before a quickly convened meeting of c-level executive officers and top representatives of surgeons and anesthesia. The

meeting yielded a hybrid-matrix management structure and governance in the formation of a multidisciplinary executive team, chartered and empowered to evoke change. The executive team consisted of perioperative stakeholders (i.e., surgeons, anesthesiologists, nurses, and UHPS staff). The executive team's charter was to focus on patient care and safety, attack difficult questions, and remove inefficiencies. No issue was off-limits.

University Hospital's executive team launched a process improvement effort in 2005 to address the perioperative crisis through soft innovations (Ryan et al., 2008). As a result, the executive team enlisted numerous task forces to address specific problems and/or opportunities, which was the foundation for their BPM approach. All initiatives were data-driven from the existing integrated hospital IS. Supporting data identified problem areas, strengths to highlight, and direction for improvement. Each identified problem area presented a new goal proposal and strategy for implementation.

OBSERVED EFFECTS OF PERIOPERATIVE CPI

Since 2005, UHPS has focused on data-driven, systematic analysis of perioperative KPIs to gauge process variance and improve end-to-end workflow balance. Perioperative KPI feedback occurs at strategic, tactical, and operational levels via balanced scorecards and dashboards, aligned to hospital strategy (Ryan et al., 2014b). Using this BPM approach, perioperative CPI efforts have documented OR scheduling (Ryan et al., 2011a); hospital-wide electronic medical record (EMR) integration (Ryan et al., 2011b); preoperative patient evaluations (Ryan et al., 2012); radio-frequency identification (Ryan et al., 2013); CSS/OR supply workflow (Ryan et al., 2014a); unit-of-service charge capture via EMRs in the CSIS (Ryan et al., 2015); and instrument/device reprocessing and tracking (Ryan et al., 2015). Table 2 depicts 14 of the UHPS initiated CPI efforts as well as the specific associated sub-process workflow and implementation year from 2003 to 2015.

Due to the perioperative CPI efforts in Table 2, a balanced workflow exists upstream and downstream of the ORs, yielding improved patient flow throughout the perioperative process via Pre-admissions; Admissions; Surgical Preparations (PRE-OP); Central Sterile Supply (CSS); OR Surgery, Endoscopy, and Cystoscopy; as well as Post Anesthesia Care Units (PACU and PACU Phase-II). Surgical patients move through the perioperative workflow via events: (1) A clinic visit resulting in surgery scheduling, (2) PACT Clinic evaluation, (3) day of surgery admission, (4) PRE-OP, (5) Intra-operative, Endoscopy, or Cystoscopy procedure, (6) PACU, (7) PACU Phase-II, and (8) discharge or movement to a medical bed. The following sections highlight particular CPI efforts from Table 2 that reduced or eliminated bottlenecks, delays, and inefficiencies within a specific sub-process workflow. These particular CPI efforts on Table 2 have a green tone. Also noted on Table 2 with a red tone is the perioperative process governance change which facilitated and chartered all the CPI efforts.

| Perioperative CPI Effort | Sub-process Workflow | Year |
|--------------------------------------------------------|-------------------------------|------|
| Implemented Clinical Scheduling IS (CSIS) | OR Surgery, ENDO, CYSTO, CSS | 2003 |
| Relocated ORs to NP Building | All | 2004 |
| Changed governance and initiated CPI efforts | All | 2005 |
| Heuristic/Modified Block Scheduling | OR Surgery, CSS | 2006 |
| Hospital-wide EMR Integration via Project IMPACT | PRE-OP, OR Surgery, PACU. CSS | 2007 |
| Established perioperative performance dashboards | All | 2008 |
| PACU Nursing Record | PACU | 2010 |
| Preoperative Assessment Consultation and Test (PACT) | Pre-admissions, PRE-OP | 2011 |
| Radio-frequency Identification Phased Implementation | OR Surgery | 2012 |
| Redesigned CSS / OR Supply Workflow | CSS, OR Surgery, ENDO, CYSTO | 2013 |
| PRE-OP and PACU Phase-II Nursing Records EMRs | PRE-OP, PACU Phase-II | 2014 |
| ICU/After-Hours PACU Overflow Record EMR | PACU | 2014 |
| Completed UOS CSIS charge capture via EMRs | PRE-OP, PACU, PACU Phase-II | 2014 |
| Redesigned Instrument/Device Reprocessing and Tracking | CSS, OR Surgery, ENDO, CYSTO | 2015 |

| Table 2. Perioperative | e Continuous | Process I | mprovement | Timeline |
|------------------------|--------------|-----------|------------|----------|
|------------------------|--------------|-----------|------------|----------|

Heuristic/Modified Block Scheduling

In November 2004, University Hospital allocated OR suites by SSS (i.e. for SSS listing refer to Table 1) scheduling blocks of time for an OR suite between 7 a.m. to 4:30 p.m., regardless of the SSS caseload. Scheduling OR suites by SSS assigned blocks did not reflect actual SSS cases occurring within the scheduling blocks (i.e. the scheduling method did not reflect the OR data collected by the CSIS). The inefficient practice of block scheduling OR suites was directly attributable to University Hospital reaching 100 percent of OR capacity in December 2004, even though the new facility had increased existing OR capacity by 33 percent.

The actual OR hours used by SSS cases (i.e. specific SSS caseload) from the data mart were analyzed against OR hours allocated to each SSS block assignment. The resulting data patterns showed the need to re-design the OR scheduling process. Hence, UHPS discontinued straight SSS block scheduling. Given that physician satisfaction is linked to OR block scheduling by SSS (Peters & Blasco, 2004), block assignments were kept for outside-of-two-weeks planning purposes. However, review of SSS block hour assignments for OR suites occur every three months to reflect the actual SSS caseload history and to reflect individual SSS patient population, similar to marketing segmentation among demographic groups. The perioperative scheduling heuristic review process routinely modifies the block scheduling release rules by analyzing actual SSS caseload versus respective SSS block schedule. SSS with wide variability in scheduling are given consideration and a reduction in the number of early release blocks of OR suites.

Current OR heuristic rules release unscheduled hours of any SSS OR suite block time within: (1) 7 days out to any SSS for robotic rooms, (2) 72 hours out to a surgeon within the same SSS, and (3) 48 hours out to any SSS. Furthermore, any SSS averaging more than 6% of unused OR suite hours per

| Scheduling Window | OR cases scheduled (%) | Cumulative OR Cases Scheduled |
|-------------------|------------------------|-------------------------------|
| Beyond 14 days | 15.4% | 100.0% |
| 7 to 14 days | 14.2% | 84.6% |
| 1 to 7 days | 34.6% | 70.4% |
| 24 to 72 hours | 18.1% | 53.9% |
| Within 24 hours | 33.1% | 35.8 % |
| Day-of-surgery | 2.7% | 2.7% |

| Table 3. | Heuristic / | Modified Block | Release Rules Ol | R Scheduling W | Vindows |
|----------|-------------|----------------|-------------------------|----------------|---------|
| | | | | | |

day-of-surgery are penalized during the next OR scheduling heuristic review. Table 3 lists the resulting scheduling windows of OR suite time and the corresponding percentage of OR cases scheduled in each window. Overall, 29.6% of the surgical cases performed were scheduled outside a week and only 2.7% of the cases were scheduled the day-of-surgery (e.g. emergency cases). Over two-thirds of surgical patients were able to schedule their surgical
procedure during the week of their surgery, which indicates the success of the heuristic/modified block release rules for scheduling flexibility.

Hospital-wide EMR Integration via Project IMPACT

Project IMPACT, encompassed 11 task forces covering surgeon's orders (CPoE), clinical documentation, electronic medical records (EMRs), pharmacy, physician workflow, critical care, knowledge and content, technical metrics, communications, and testing / training / transition. The hospital-wide integration effort extended the CSIS across the perioperative subprocesses into ancillary hospital processes as well as perioperative tracking information on surgical patients (e.g. outpatient and in-patient) from Admissions through PACU discharge, including the in-patient's location after PACU discharge.

Beyond the enterprise application integration and software coding efforts, the most visible interface into the dissemination of perioperative process information across Admissions, PRE-OP, and PACU were electronic patient status boards. The deployed boards



Figure 2. CSIS Patient Status Boards in PACU



Figure 3. Family Link Boards in OR Waiting Rooms

were in each functional area and the perioperative patient information adhered to HIPAA (e.g. Health Insurance Portability and Accountability Act of 1996) compliant formats. Figure 2 depicts Clinical IS departmental views of the electronic boards in PACU.

Additional flat panel displays on wall mounted information boards in each OR waiting room also provided patient tracking status for patient's family members or friends. Clinical staff give documentation to all patient family members, which explains the information boards and how to track your patient. Extending the clinical scheduling IS integration across the hospital gives all stakeholders access to the CSIS modules and tracking of surgical patients. The coded patient information boards in each OR waiting room also ensures patient privacy and HIPAA compliance. Figure 3 depicts patient information boards in one of the OR waiting rooms.

Preoperative Assessment Consultation and Test (PACT) Clinic

Project IMPACT integrated EMRs from Admissions through PACU in 2007, but omitted parts of the preoperative evaluation documentation such as external medical records (MRs), preoperative assessment consultation (PAC), patient medical history (PMH), surgical history (SH), and former medication history (FMH). Figure 4 represents University Hospital's preoperative patient evaluation flow as of FY2010. Inefficient processes and decision points (see gray areas on Figure 5) delayed scheduled surgical case starts while PRE-OP staff obtained incomplete information. CSIS data reflected incomplete patient information delays for over one out of six surgical cases. As a result, UHPS launched a PACT Clinic task force to reengineer preoperative patient evaluations. Task force members visited four leading academic medical centers in the United States, as well as the two internal University Hospital sites, to gather a transparent and bottom-up view of different perspectives to preoperative evaluation processes. The external sites were located in: (1) Baltimore, MD; (2) Boston, MA; (3) Rochester, MN; and (4) Cleveland, OH.

Essential elements of the preoperative patient flow reengineering required EMR inclusion of all pertinent external records with the initial University Hospital referral as the preoperative evaluation appointment is made simultaneously with the initial surgeon appointment. Patient screening and standardized co-morbidity risk stratification occurs by telephone, the Internet, or by the surgical clinic making the referral. The best practices identified during the site visits afforded University Hospital the opportunity to reengineer their preoperative patient evaluation into a preoperative assessment, consultation, and treatment (PACT) clinic. A "clinic without walls' in that the PACT clinic exists only within the CSIS and evaluations can occur anywhere within University Hospital.

Figure 5 reflects the reengineered PACT Clinic workflow. All surgical patients receive a PACT Clinic evaluation prior to their scheduled procedures. During the same surgeon appointment, a comprehensive preoperative evaluation is performed and recorded via the PACT Clinic ambulatory EMR to include: a complete preoperative history and physical exam (H&P), confirmed informed consent and signed release on surgical procedure (ROS), optimized medications, and patient education. Prompt cardiac/diagnostic testing or cardiac/medical consultations may also occur during the PACT and surgical appointment.



Figure 4. Preoperative Patient Evaluation FY2010

Figure 5. Reengineered Patient Evaluations PACT

Redesigned CSS / OR Supply Workflow

Within the perioperative process, CSS pushes supply/instrument inventory to all ORs via three channels: 1) Case carts stocked specifically for a scheduled surgical case according to a specific SPC pick list (i.e. standardized supply/instrument bill of material); 2) standard supplies moved to an OR Core holding area on each OR floor; and/or 3) a specific requisition from OR staff. As early as 2006, UHPS noted multiple inventory receipts within the perpetual inventory for every inventory usage across particular perioperative supplies. In 2010, the executive team launched an initiative to assess the status of perioperative supply/instrument inventory and workflow due to increasing inventory values and slowing inventory turns metrics. The processes reviewed included: (1) inventory/Par level management, (2) replenishment processes, and (3) technology. The sub-process CSIS data reviewed identified inventory reduction as well as improvement opportunities to sustain reduced perioperative supply/instrument costs. The analysis of the assessment yielded the following themes:

- Scheduling inaccuracy due to lack of SPC maintenance and SPC inaccuracies.
- Work duplication in CSS case cart picking due to lack of trust in case scheduling and SPC.
- Charge capture issues where items left off the SPC may not get charged.

- Abundance of unused supply/instrument returns to CSS after case completion produce CSS inefficiencies.
- Breakdown in the supply workflow process effects overall inventory management.

Perioperative inventory turns had slowed to 3.7 against an industry average of 9, which represented 3.2 months supply. These KPIs reflected a breakdown in the supply/instrument workflow process. However, responsible actors (e.g. nurses and UHPS staff) interact among the OR case carts, OR Core inventory locations, and CSS. The BPM efforts among CSS and OR perioperative actors yielded a CSS/OR instruments/supplies workflow redesign to ensure effective instrument/supply inventory management. Likewise, a major task force recommendation was for scheduled surgical cases to have specific and required inventory information that includes accurate location, procedure, specific equipment, and supply needs from consistently updated SPCs.

A review of each of the SPCs yielded the removal of 1,937 SPCs, which reduced the SPC total by 20 percent (e.g. down to 7,778 from 9,315 SPCs) and scrubbed the SPC routings to ensure accuracy. Table 1 lists the frequency counts of current SPCs by SSS. The perpetual maintenance of SPCs, redesigning the perioperative supply workflow, decreasing closing suture and hand-held instrument inventories to industry standards, and managing perioperative inventory turns to 10 turns per 18 months targeted opportunities and evoked changes to the perioperative instruments/supplies inventory in excess of \$6.6M over two years.

Completed UOS CSIS charge capture via Nursing Records | EMRs

UHPS developed and configured unique CSIS nursing records as EMRs to manage patient care documentation across the perioperative workflow. UOS standards reflect perioperative staff labor hours associated with particular patient care activity units—one hour of patient care time, an Endoscopy procedure, or a sterilized instrument load. UOS metrics reflect patient care hours in each workflow segment. Table 4 lists the current CSIS nursing record documentation via EMR, the fiscal year of the UOS charge capture implementation, UOS standard labor hours, and UOS unit.

| CSIS Documentation via EMR | FY Start | UOS Standard | UOS Unit |
|------------------------------------------|----------|--------------|------------------|
| Ancillary Services Record - Family | 2007 | | |
| Preop Nursing Assessment | 2012 | 1.93 | Time |
| Endo Preop Nursing Record | 2014 | | Procedure |
| Endo Sedation Nursing Record | 2014 | 2.1 | Time |
| Regional Block Nursing Record | 2014 | 2.21 | Time |
| CSS | 2003 | 3.52 | Sterilized Loads |
| OR Nursing Record - CVOR | 2007 | 9.04 | Time |
| OR Nursing Record - Cardiac Perfusion | 2012 | 4.22 | Time |
| OR Nursing Record - GENOR | 2003 | 7.45 | Time |
| OR Nursing Record - ENDO | 2014 | 6.92 | Procedure |
| Ancillary Services Record – Room Cleanup | 2005 | | Time |
| PACU Nursing Record | 2010 | 2.71 | Time |
| ICU/After Hours PACU Overflow Record | 2014 | 2.71 | Time |
| PACU Phase-II Nursing Record | 2014 | 1.93 | Time |

Table 4. CSIS Nursing Record Documentation via EMR with UOS Standards

Prior to the implementation of each real-time UOS charge capture via EMR documentation, perioperative staff manually batch-keyed UOS charges. As of March 2014, all CSIS nursing documentation via EMRs capture UOS charge data (e.g., UOS standard multiplied by UOS units) using the appropriate UOS standards and units. UHPS use the granularity in the aggregated UOS charge data for perioperative sub-process OLAP to offer contextual understanding to analyze sub-process variances, target improvement areas, and justify resource allocations. CSIS nursing records with UOS standards differentiate staffing labor hours for different levels of patient care (e.g. acute versus ambulatory).

Within PACU, the Phase-II and ICU nursing records also facilitate PACU workflow balancing and bed/resource utilization. Within PRE-OP and PACU, a finite number of acute care beds are valued resources, when compared to ambulatory care beds. The PACU Phase II Nursing Record allows ambulatory nursing documentation via the CSIS in any University Hospital ambulatory bed. Hence, PACU Phase II patients are transferable to PRE-OP or floor beds when PACU beds are in critical supply. Moreover, the ICU Overflow record identifies ICU bed capacity issues to avoid unplanned ICU discharges (Utzolino et al., 2010).

CSIS nursing records without UOS standards facilitate information and data collection on patient family/advocate, Endoscopy patient status, or surgical case OR suite TAT. All OR Nursing Record EMRs also provide documentation for OR suite OTS and UTIL measures.

DISCUSSION OF PERIOPERATIVE CPI FOR BALANCED WORKFLOW

Figures 6 and 7 depict the resulting patient flow and integrated IS across University Hospital Health System (UHHS) per the CPI efforts described in table 2 of the observed effects section. As depicted in Figure 6, patient admissions are either medical or surgical. Surgical patient admissions occur via three venues: 1) diagnostic office visits to physicians within the TK Clinic, 2) non-UHHS physician referrals to the PACT clinic, or 3) patients seeking treatment through the Emergency Department. All surgical patients receive a PACT Clinic evaluation prior to their scheduled procedures. The PACT Clinic exists virtually in the CSIS, so the TK Clinic allocated physical space to facilitate PACT evaluations.

All IS depicted in Figure 7 are integrated with either bi-directional data exchange or uni-directional for limited exchange. The seven IS clustered around the CSIS are modules that directly support and extend the CSIS suite, where the Clinical Charting IS houses CPOE and EMRs. The HIPAA compliant Web services and biomedical device interface bus (BDIB) integrate ancillary IS, clinical data sensors, and bio-medical equipment. The institutional intranet serves as a single entry secured portal to extend each IS according to particular user-IS rights and privileges negotiated via user authentication.



Balanced Workflow Results Achieved

Figure 7. UHHS Integrated IS

Figure 8 depicts CPI efforts to achieve perioperative workflow balancing across sub-processes of pre-operative, intra-operative, post-operative, and CSS. The five CPI efforts described in the observed effects section removed inefficiencies and delays in particular perioperative sub-processes to support balanced patient flow through the perioperative process as well as information flow as depicted in Figure 7. The following discussion explains the



Figure 8. Particular CPI efforts to balance patient flow through perioperative sub-processes

7. The following discussion explains the holistic impact of the workflow balancing efforts.

UHPS is the primary source of admissions to University Hospital and the state of UHPS in early 2005 prohibited streamlining hospital-wide patient flow without first streamlining patient flow through the ORs (e.g. intraoperative). Likewise, the modified block scheduling via heuristic release rules improved the perioperative process planning where OR scheduling yielded a tighter coupling between projected versus actual surgical cases. The structural, process, procedural, and cultural changes achieved in UHPS intra-operative sub-processes over

FY2005 and FY2006 allowed the executive committee to move forward in early 2007 to extend the CSIS across University Hospital and address hospital-wide patient flow.

Extending the CSIS across the entire perioperative process in FY2007 through Project Impact provided the basis for perioperative data collection and subsequent CPI efforts. However, Project IMPACT omitted many of the preoperative evaluation activities. The FCOTS KPI for FY2010 was 55.8 percent versus a target of 70 percent. Upon closer analysis of the surgical case delays, 17.5 percent of surgical delays (e.g. more than one out of six cases) were preventable through improved preoperative patient evaluation and improved electronic integration of preoperative documentation and communication. Hence, UHPS identified the need to address the chronic problems in preoperative patient evaluations through a process reengineering effort to yield the Preoperative Assessment, Consultation, and Test (PACT) Clinic to evaluate all surgical patients prior to day-of-surgery.

In May 2011, UHPS identified perioperative supply inventory levels of \$15.5M, where inventory turns had slowed to 3.7 versus an industry average of 9, yielding 3.2 months supply. These KPIs reflected a breakdown in the CSS/OR workflow sub-processes. However, responsible actors (e.g. nurses and UHPS staff) interacting within and among the CSS and intra-operative sub-processes yielded a process redesign effort for an effective solution to improved instrument/supply inventory management and workflow.

Nursing documentation as EMRs with UOS standards differentiate staffing labor hours for different levels of patient care in PRE-OP and PACU. Within PACU, the Phase-II and ICU nursing records facilitate PACU workflow and bed/resource utilization, allowing more critical patients additional surgical recovery time. Moreover, the ICU Overflow record identifies ICU capacity issues to avoid unplanned ICU discharges, while allowing critical patients time to recover in both PACU and ICU. Also Nursing EMRs without UOS standards facilitate information collection on patient family/advocate, Endoscopy patient status, or surgical case OR suite TAT. Similarly, all OR Nursing Record EMRs provide documentation for OR suite OTS and UTIL measures (e.g. KPIs).

Data Visualization of Balanced Perioperative Workflow

Figures 9, 10, and 11 depict aggregated surgical case (e.g. patient) data for perioperative process performance on OTS, UTIL/OTS/TAT, and UOS, respectively. Figure 10 depicts the yearly OTS averages for GENOR, CVOR, and HHOR surgical cases since FY2006 (i.e. UHHS fiscal year begins in October). The chart helps visualization of aggregate workflow performance improvement in providing efficient perioperative patient care while limiting unnecessary patient safety risk. From a BPM approach, these charts also help visualize where perioperative teams

and task forces should target CPI efforts. Since the full implementation of the PACT Clinic during FY2012, over 70% of surgical cases in GENOR, CVOR, and HHOR started on time. Prior to FY2013, the OTS 70% target was elusive, in part to incomplete PREOP documentation, which PACT Clinic evaluations eliminated (Ryan et al., 2012).



Figure 9. Surgical OTS FY 2006 to FY 2015



Figure 10. OTS/UTIL/TAT by SSS (June 2015)



Figure 11. Perioperative UOS FY2006 to FY 2014

Figure-10 details UTIL, OTS, TAT, and modified- block released time (Ryan et al., 2011a; Peters & Blasco, 2004) by SSS for June 2015. The chart demonstrates granularity and dimensionality of aggregated patient data used in the systematic analysis of process performance. UHPS uses the detailed dimensionality of KPI data to identify specific performance results as well as target specific improvement opportunity.

Aggregated UOS data offers similar analysis capabilities for contextual understanding of patient care workflow dynamics and complexity. Figure-11 reports the UOS patient hours for GENOR and CVOR workflow since FY2006. In Figure-12, the FY2013 spike in PACU hours, up 12K hours (i.e., 32% increase) from FY2012, is attributable to ICU overflow patient care in PACU (i.e., extended-stay PACU patients waiting for an ICU bed or ICU patients over-nighting in PACU). UHPS use PACU beds to relieve Trauma-ICU and Surgical-ICU patient workflow congestion, moving PACU Phase-II patient care to PREOP beds. In December 2013 (e.g., FY2014), UHPS implemented Phase-II and ICU Overflow nursing records in PACU via the CSIS to document the workflow flexibility and capture UOS charges. As a result, FY2014 hours reflect the virtual PACU flexibility and tightened the CSIS-to-PACU workflow coupling.

Goal Setting and Process Improvement Aligned to the Hospital Strategic Plan

Reach for Excellence (RFE) goals coordinate and align individual department and employee actions to the UHHS strategic mission and vision of becoming the preferred academic medical center of the 21st century. RFE goals are revised each year as quantitative targets, designed to measure objective outcomes. RFE goals must be aggressive and realistic, where fewer, rather than more, is better. RFE goals change focus as AMC21 progress advances. Consequently, each year UHHS administration reviews opportunities for improvement and identifies the most important outcomes needed. As a result, many perioperative KPIs and CPI efforts become RFE goals. As such, UHPS stakeholders focus on RFE process outcomes aligned to AMC21 strategy yielding aligned stakeholder action across departments and employees alike—a very powerful process management tool.

CONCLUSION

Empowered individuals (e.g. nurses, surgeons, anesthesiologists, and perioperative staff), integrated IS, and a holistic model for evaluation, analysis, and synthesis of process data allows UHPS to take control and continuously improve the perioperative sub-processes to balance patient workflow. The perioperative KPIs provide feedback control loops to reflect the perioperative workflow balance as well as identify inefficiencies, delays, and areas for

improvement. The RFE goal layer affords UHPS opportunities for process improvement aligned to AMC21 vision. The balanced perioperative workflow improved efficiency, effectiveness, and utilization of .perioperative subprocess dynamics within pre-operative, intra-operative, post-operative, and central sterile supply (CSS) activities. Through the CPI efforts, the balanced workflow reflects tighter sub-process to hospital IS coupling as well as patient care accountability and documentation.

Enlisting CPI efforts at strategic, tactical, and day-to-day operations levels further educates hospital stakeholders on the benefits of integrated IS for process measurement, control, and improvement. The cycle of analysis, evaluation, and synthesis reinforces communication and stimulates individual as well as collective organizational learning.

Our case study contributes to the healthcare IT literature by examining how data mining, business analytics, process redesign, and process management are applicable to the hospital environment. This study prescribes an a priori framework to foster their occurrence. This paper also fills a gap in the literature by describing how hospital process data is both a performance measure and a management tool. Furthermore, this study highlighted the complexity and dynamics with the perioperative process.

This study was limited to a single case, where future research should broaden the focus to address this issue along with others that the authors may have inadvertently overlooked. The case examples presented in this study can serve as momentum for healthcare CPI and balanced workflow methodology, comprehension, and extension. The study's results should be viewed as exploratory and in need of further confirmation. Researchers may choose to further or expand the investigation; while practitioners may apply the findings to create their own version of CPI for balanced perioperative workflow.

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Examining the Performance of Older and Younger Adults When Interacting with a Mobile Solution Supporting Levels of Dexterity

Ayidh AlqahtaniAbdulwhab AlsalmahAhmad Alaiadayidh1@umbc.eduabdul16@umbc.eduaalaiad1@umbc.edu

Department of Information Systems College of Engineering and Information Technology University of Maryland-Baltimore County

Baltimore, Maryland, USA

Abstract: The purpose of this research is to develop and evaluate a mobile game to support the needs of adults aiming to strengthen their perceptual and dexterity skills. The game itself is an advanced version of a Whack-A-Mole style game, in which the user is required to select visual targets, as quickly and accurately as possible. In this version of the game, the user is able to modify the speed, target size, and availability of distracters. In this paper, the performance between older and younger users has been compared. Older adults had spent more time and missed more compared to the youth adults, highlighting the challenges with manual dexterity faced by older adults. Therefore, different ways were examined in which features of the game can be designed to better meet the needs of older adults. The paper has significant implications for elderly patients, physicians, technology designers and service providers.

INTRODUCTION

Individuals with physical disabilities represent a large number in our societies. According to Johns Hopkins Public Health Library, there are approximately 5.3 million Americans live with a long-term disability as a result of traumatic brain injury (TBI), and about 200,000 people with spinal cord injuries or dysfunction (Johns Hopkins Public Health Library, 2014). Usually, the reasons behind physical injuries include car accident, falls, and sometimes, extreme sports. People with physical disabilities cannot easily accept the fact of being disabled, especially those who have permanent disabilities. They might experience several difficulties in their daily life and they could not perform basic tasks without reliance on others. Physical therapy plays a pivotal role to help in the recovery of injuries, and bring back the patients to their normal states in order to resume their ordinary lives. It also teaches individuals with permanent disabilities on how to exploit their remaining abilities to adapt with their situations for the rest of their lives. Physical therapy includes physical exercises that would help the patients to move and stretch their muscles.

According to the physical disability council of New South Wales (NSW), physical disability is the state of losing totally or partially a part of body or some body functions whether the disability exists from birth or individuals acquire the disability later in their life due to car accident or stroke (Physical disability council of NSW, 2013). Unlike those who were born with physical disabilities, individuals who have acquired a severe physical injury would find difficulties to adapt with their new situations, especially if the disability is permanent. They face both the trauma that caused the injury and the fact of being physically disabled (Quale et al., 2010). People with physical disability suffer from several challenges in different aspects of their daily life (Lai et al., 2002), which prevent them from performing their tasks autonomously. These challenges vary from a situation to another depending on the severity of disability and the amount of assistance provided by a surrounding environment. They range from personal needs (Lai et al., 2002) through social interactions (Thomas et al., 1988) to computer accessibility in which they cannot use conventional input devices like mouse and keyboard because of their abnormal postures and limited movements (Wu et al., 2002).

Usually, people without physical disabilities are more likely to be active and conduct physical exercise than those who have physical disabilities due to limitations in their movement, and sometimes the lack of exercise facilities nearby. According to the Healthy People 2010 report, 56% of adults with chronic back conditions do not practice physical activity in any leisure-time compared to 36% among adults without disability. Furthermore, the level of education plays an important role in increasing the motivation among individuals with disabilities to engage in physical activities. The report also indicated that 27% of disabled adults with college education are not physically active in their leisure time and the rate increases among those who have less than high school education to reach 56%. Although the physical

therapy is at utmost importance for patients in order for them to get better, they remain inactive most of their days after injury or stroke. More importantly, the amount of exercise provided during the physical rehabilitation session is not sufficient (Lang et al., 2007). However, Haughnessy et el. (2006) shows that only 31% of individuals with physical disabilities reported their adherence to the regular physical exercises (four times a week) as recommended by therapists.

With the development of information technology, we can expect that physical exercises, to a larger extent, will be performed with the help of computer systems and portable devices. The potential benefits of these exercises mainly depend on the psychological readiness and the positive response of the patients toward the treatment. However, most patients do not have the desire to engage in a physical rehabilitation session (Lang et al., 2007). So, the role of researchers is to find ways to motivate those patients and get them involved in physical exercises. The goal of this paper is to develop and evaluate a mobile game, which enables users to strengthen their dexterity, in a fun and engaging way. Considerations have been made relating to ways in which users can be motivated to continue playing the game. The game itself is an advanced version of a Whack-A-Mole style game where the user is required to select visual targets, as quickly and accurately as possible. In this version of the game, the user is able to modify the speed with different levels, target size, and availability of distracters.

The paper provides the following contributions to the literature. First, it is of the first attempts to develop user interfaces that mix entertainment with exercise to help target people to cure or help themselves get through their injuries; second, it helps technology designers and service providers better meet old people's needs and preferences to use smart phones and exercise using these phones; third, the proposed system is the first mobile application that can be used in rehabilitation to help target people to exercise and cure; fourth, the system could be used in rehabilitation centers to help doctors in physical therapy treatment especially it is easy to use and very.

The paper is organized as follows: next section discusses the related work. Section three describes the design of the system followed by evaluation method and results in sections four and five, respectively. Section six provides a discussion of the major findings. The paper concludes by section seven.

RELATED WORK

This section briefly discusses the related work and the major limitations of existing systems. Wu et al. in 2002 proposed procedures called computer access assessment (CAA) that can be used as evaluation guidelines for therapists and developers who want to develop devices to enable people with physical disabilities to easily access computers. They should take in considerations the positioning and seating needs of the individuals with disabilities and develop input devices accordingly. The keyboard and mouse should be adjusted so that they can be appropriately used by the functioning body parts of individuals with disability who have severely impaired hand function. The Online-Gym system was proposed by (Cassola et al., 2002) to provide new possibilities for improving the physical and social wellbeing of people with restricted mobility. The Online-Gym is built based on an online 3D virtual world's platform, which allows users to participate and interact with the system through the use of a motion capture device, which is a Microsoft Kinect. Further, the objective of this system is to create an "online gymnasium" which is a virtual threedimensional space where different users are physically apart, participate in a shared workout session coached by a monitor, all of the users connected over the Internet and directly animated by the movement captured by the Kinect devices which are connected to each personal computer. The experiment results for this system showed that there are some requirements stemming from existing systems integration, especially in the synchronization of the movements and their impact on the network for other users, but also regarding the need to have a clear identification of the monitor and custom controls for him/her.

A Kinect-based system was developed by (Chang et al., 2013) to assist people with cerebral palsy and physical disabilities. The system was developed using the Microsoft Kinect connected to a laptop in which its audio system and screen are used to interact with users. The screen provides visual interaction, as it displays real-time movements that help the users to control and adjust their actions. The study was carried out using 2-phases ABAB model where A indicated the baseline and B indicated the intervention phase. The participants demonstrated improvement in the number of the correct actions when exercising with the Kinect. Levels of motivation were found to be higher when exercising with the device. Considerable effort is not needed to use or learn the system. In order to motivate usage, users could see their favorite cartoons each time a correct action was achieved and listen to music when a type of movement was completed. However, the results were achieved based on only 2 participants and hence, the overall

conclusion might not be accurate regarding the efficacy of the system. A virtual reality-based system was proposed by (Jack et al., 2000) to facilitate exercises for people who survived a stroke and living with physical impairments. In particular, it is used for rehabilitating hand functions in stroke patients. The system used two hand input devices, a CyberGlove and a force feedback glove, to enable users to perform and interact with system. The CyberGlove is used to track and capture finger bends and wrist flexion, and the force feedback glove is used to measure the position of the fingertips in relation to the palm. There are four virtual reality exercises that concentrate on four parameters of hand movement including range, speed, fractionation, and strength. The first three parameters are evaluated by the CyberGlove whereas the last parameter, strength of hand movement, is evaluated by the force feedback glove. The system seems to be enjoyable as the exercises take the form of simple, interactive game to motivate users to continue using it. On the other hand, both gloves are costly and complicated and may not be affordable to many people with motor disabilities.

A system was also developed by (Lin et al., 2014) to help children with cerebral palsy to promote physical activities. The system consists of conductive material and a Makey-Makey circuit board that is connected to a personal computer. Both the conductive materials and the Makey-Makey circuit board (which is used to convert physical touches into digital signals to be interpreted by the computer as keyboard presses or mouse clicks) are used as an input device. The system communicates with users through using Flash and Scratch multimedia software in which it was automatically set to play for 5 seconds then, pause waiting for the next interaction from the users. The idea of the system is that the users can touch the conductive materials and then listen to (or watch) the desire multimedia for 5 seconds. This means that the users are motivated to make a movement each 5 seconds which leads to stretch and strength their muscles. The system is easy to use in which users just need to touch the conductive materials to interact with it. The users can enjoy using the system since it has interactive multimedia as a response to their actions. However, the system needs to be customized for each individual according to their condition. For example, individuals with upper body physical impairments will need to customize their version of the software differently to those who have lower body physical disabilities. The study was evaluated and the results were achieved based on just 2 participants which might not be convinced for audiences of this study.

In addition, a study was undertaken examining motor development of disabled children. The researchers developed a framework, which is based upon tracking devices for the Kinect sensor (Meleiro et al., 2014). The proposed framework can assist children with spastic diplopia and hemiparesis in the rehabilitation process. Further, it enables physical exercising for the children in a stimulating environment and with an adequate progress space with the respect to their disabilities. The researchers tested the framework on target people consisted of five aged between 8 and 12 old. The participants were asked to perform different tasks including raising the arm above the head, sequence of pose, side step, and scissor jump. The results show that the Kinect sensor has potential to be used in the motor rehabilitation context and the impaired children were able to benefit from the proposed system. However, there are some limitations for this proposed system including some detection inaccuracies, and some difficulties in keeping tracking of the exercises during continuous execution. The developed framework seems to be effective for the physical rehabilitation for children with disabilities and the study shows some good results. However, there are some limitations have to be taken in consideration and validate the given results on different group of target people. Standen et al (2011) evaluated the use of a Wii Nunchuk as an alternative assistive device for people with physical disabilities who used typical switches such as roll ball, mouse, and wobble stick to interact with computers. The Wii Nunchuk is a device used in contemporary gaming technologies to interface with personal computers. The number of participants was 23 students with physical disabilities who were selected according to certain criteria. They were asked to do three different tests including the activation, the release, and the repetition tests. The results showed that there was no significant difference between the performance of the participants using familiar devices and the Wii Nunchuk except for the release test where they did better using their familiar devices. Some participants encountered several difficulties using Wii Nunchuk, which can be addressed with different positioning or sensitivity of the trigger switch. However, the Wii Nunchuk can be easily grasped by individuals with physical disabilities as opposed to typical switches which are surface-based devices. In addition, the Wii Nunchuk is considered to be a low cost alternative compared to other custom made devices.

(Yeh et al., 2012) developed a game, which used a Kinect sensor device to interact with the virtual environment. The main goal of the proposed system is to implement the practice of the upper limb action. Further, it is mainly used to maintain rehabilitation training for those people who suffer from the stroke. The researchers stated that their system has many advantages more than the traditional rehabilitation such as: it is not very expensive and the training time is short comparing by the traditional rehabilitation therapy. The developed system uses the Kinect sensor device to

interact with the virtual environment. The Kinect sensor device is used to recognize the upper limb action of the patient. Moreover, the patient who is under the test has to let Kinect be able to detect his action through the extension of the arm and the controlling of the ball receiving direction by the virtual figure is then corresponded in the virtual reality environment. In addition, the researchers conducted different experiments in the academic examination department of the University of Southern California. They tested the proposed system on different patients. Additionally, the results of these experiments are promising. Patients have shown great improvement in terms of balance of upper limb action. Therefore, it's a good sign of starting a new era for rehabilitation therapy with the modern technology.

Guillaume and Nadine (2010) studied the influence of age on user's performance using touch screen interface. The main part of the interface is the colored target area where users should click on the required color (according to some instructions) within a specific period of time. There were two groups of populations participated in the experiment. The first group included 63 people aged from 15 to 52 years. In the second group, 24 older adults aged between 63 and 88 years were recruited for the experiment. In general, the results indicated that the number of clicks on wrong targets increased according to age (i.e. the people of high age would have more wrong targets). A brain computer interface system (BCI) (Jiang et al., 2011) was developed to translate the user's mental condition such as the attention state, into game control. The researchers have leveraged the advanced technologies and virtual reality to measure a user's attention level to control a virtual hand's movement and exploit 3D technology. Moreover, the proposed system is important for training people who suffering Attention Deficit Hyperactivity Disorder (ADHD). Furthermore, the developed system is designed to simulate a hand to pick up a fruit. In this study, 10 participants were employed to test the game. The results of this study showed the proposed game was very interesting, easy to use, and accurate. In addition, this study showed that the developed game could be helpful for those people whom suffering from ADHD, however, they did not mention that they tested it on the target people.

Kobayashi et al. (2012) conducted an experiment to evaluate the interaction of elderly users with mobile touch-screen interfaces, including pinch and spread tasks. They used tablet and phone-size touch screens to complete the experiment. They reported task execution times. They found that spreading tasks were more difficult than pinching tasks for their participants. In general their results showed that mobile touch-screen interactions are enjoyable for seniors, and their performance has increased when provided with one week of training. More recently, Findlater et al, (3013) compared the spread and pinch performance of older adults to younger adults on an iPad device. They reported both task execution time and error rates, and found the opposite result of Kobayashi et al. in which their participants were faster on the spreading tasks than the pinching tasks. Stößel et al. (2010) compared old users to young users in 42 different gesture inputs for touch-screen devices and measured their speed and accuracy. They found that older users tend to perform touch gestures more accurate than younger users but move slower.

In summary, existing works have major limitations and gaps that require a further exploration. Most of the proposed systems are neither cheap nor easy to use and learn. Further, these systems need to be customized by the patients according to their condition. For instance, individuals with upper body physical impairments will need to customize their version of the software differently to those who have lower body physical disabilities. Additionally, researchers and clinical staff have to be with the patients while exercising using existing systems. Some systems are also complicated and may not be affordable to many people with motor disabilities. Limited research provided a comparison between different groups of users in using the systems and used usability questionnaire.

In order to fill the knowledge gap, this paper aims to answer the following research questions: How to develop a mobile game to strengthen elderly people's perceptual and dexterity skills? What do motivate elderly people to continue playing a mobile game? To this end, we developed and evaluated a mobile game to support the needs of adults aiming to strengthen their perceptual and dexterity skills.

SYSTEM DESIGN

The prototype system has been developed for Google's Android operating system using App Inventor application. App Inventor is an open source application that offers graphical interface and drag-and-drop blocks for Android programmers. It was first developed by Google and now maintained by Massachusetts Institute of Technology (MIT). As the system is intended to help and motivate people with physical disabilities to engage in physical activities and perform practical exercise, we take in our consideration that not all situations should be treated equally, and physical disabilities could vary from one situation to another in terms of the ability of movement and reaction. Accordingly,

the system was designed to satisfy the needs of different situations by including several levels of speed and different image sizes.

The system consists of four interfaces. The first interface is used to allow the users to login the system. The second one allows the users to specify the game settings according to their needs. Another interface would be the screen where the users can actually play the game. The last one is used to track the highest and the lowest scores, which implicitly encourages the users to exert more effort to attain the highest score. During design, the priority was to optimize the order of interfaces and support navigation between them. So, the system was designed to enable the users to seamlessly navigate between the interfaces. Users can navigate from the login to settings interface. Then, they can go back and forth between the settings screen and game interface. Also, it is possible to access the score interface from the game interface, and go back from the score to the settings interface. Figure 1 illustrates the interface structure of the system.



Figure 1. Interface structure

The system interfaces will be explained in detail in the following subsections.

Interface 1: Settings

The interface is intended to allow the users to specify the settings of the system according to their needs. It consists of several buttons and a check box. The first six buttons are dedicated to change the speed level of the target to be selected (image of a mole). The movement speed of image around the canvas is measured in milliseconds, which means that the level1 indicates the lowest speed while the level6 is the highest. The large and small buttons allow the users to select the size of image that is suitable for them. Once any button is selected, the text color of the button is changed to red indicating that the button is active. The last button in the interface is the start button, which moves the user to the whack-a-mole mash interface to start playing the game. The check box is used to indicate whether or not the users want to play with a distracter. It means that if the users check this box, then they will have another image moving around the canvas along with the main image (in mole mash interface). Figure 3 shows a screenshot of the settings interface.

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Figure 3. Setting Interface

Interface 2: Whack-a-Mole Mash

The whack-a-mole mash is considered as the main interface of the system where the users can actually play the game. The majority of the screen is occupied by the canvas where the image moves around to different randomized positions in a timed sequence. The properties of the image (speeds, size) are exported from the setting interface. Directly below the canvas, there are three labels; score label that is used to hold the score and increases it each time the user successfully hits the image, missing label that holds the number of hits on canvas, and level label to show the current level number. Furthermore, when the user chooses to play with distractor, the distraction label appears to show the number of hits on an on-screen distractor. The users can move from level 1 to level 2 once they reach the specified score of level 1 which is 20, also the score does not reduce if the user misses the target. Similarly, the score that the users must gain to move to level 3 was set to 40 and so on. The interface also contains several buttons. The reset button is used to reset the score to zero. The system provides the users with a way to select their own images by clicking on the pick an image button. Also, the user can restore default settings by using the default button. The setting button enables the user to go back to the setting interface. By pressing the show score button, the user will move to the score interface, which holds the highest and the lowest score. The exit button allows the user to terminate the game. Figure 4 shows a screenshot of the mole mash interface.

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| TOUCHDOWN | 50 30 40 20 43 30 | TOUCHDOWN |
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| Show Score | e | Exit |

Figure 4. Mole Mash Interface

Interface 3: Show Score

The goal of this interface is to show the highest as well as the lowest score that the users have gained over time. It consists of two labels and one button. The labels are used to hold the highest and lowest score. The go back button allows users to go back to the settings interface to select their preferred settings and start the game over. Figure 5 shows a screenshot of the Show Score interface

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Figure 5. Show Score Interface

EVALUATION METHOD

A small study was conducted to examine the feasibility and usability of this prototype. One variable was defined for the number of missing scores which corresponds to the number of times the participant targets canvas instead of the target image. There were two independent variables, which are age group (younger and older adults) and types of game (large image, small image, distraction with large image, and distraction with small image). Furthermore, three hypothesizes were formulated:

irthermore, three hypothesizes were form

- Main affect for age group.
- Main affect for the type of game.Interaction affect between age and game.

Participants

18 participants were recruited for the study, who were divided to two groups by age. The first group has 9 young participants aged between 22 and 35 years. In the second group, 9 older adults aged from 60 to 75 years were recruited to perform the experiment.

Procedure

The procedure of the study consists of three tasks, and participants were asked to complete each task within five minutes. The first task was to play the game at different levels (different speeds). They were then asked to play the game using different target sizes. The third was to play the game with distraction. Upon finishing these tasks, participants were encouraged to experience other features of the prototype such as: see what the highest score for the game is, and change a picture in the game. Furthermore, they were encouraged to think aloud and provide feedback about their experience that they had regarding the system's use, the design of the interfaces, and the efficacy of the functionality. Additionally, the participants were asked to complete a usability questionnaire after they finished these three tasks. The description of these tasks and the usability questionnaire are given as below.

Task 1: Play the game with different levels of speed without a distractor

Before the participants begin the first task, they were provided a brief overview about the system's objective and how the system would motivate users to maintain levels of activity. Moreover, the system was installed on a Nexus 1 android phone and the participants were allowed to familiarize themselves to interact with the application. At the beginning of the tasks, the participants were given a list of instructions to know how to interact with the game application along with username and password to login into the application. The subject can choose the desired level of the game to play with. Then, the subject has to proceed with the game and try to target the graphical stimuli presented, to improve their score. The game will automatically move from one level to another when the subject reaches the required score designated for each level. The task ends when the specified time (5 minutes) is up.

Task 2: Play the game with different size of images

The subject asked to choose different sizes of graphical stimuli (e.g. small or large images of a mole) from the setting screen. He/she played the game at his/her desired level of speed (based on his/her experience from Task 1). Additionally, subjects picked a different image from the gallery and played with it instead of using the default image in the application.

Task 3: Play the game with a distractor

The subject asked to check the distractor check box in the setting screen to play the game with an on-screen distractor (e.g. other images appearing on the mobile interface). The subject had to avoid selecting the distractors. The distractors were added in the game to make it more challenging for the users. After the participants completing this task, they were given a usability questionnaire to evaluate the system.

Data Analysis

The data that was collected for this study is composed of the responses to the usability questionnaire, feedback, and suggestions from the participants, and the observations that made by the researchers about how participants interacted with the application.

Feedback and Observations

The researcher's notes were organized into three main categories including feedback, suggestions, and errors. The feedback that was provided and errors that were made during the experiments were revealed through analysis. Further, these categories will be discussed in the result section in this paper.

Usability Questionnaire

The usability questionnaire that was used to evaluate the system was inspired from IBM computer usability satisfaction (IBM Computer Usability Satisfaction Questionnaires: Psychometric Evaluation and Instructions for Use). We manipulated the questionnaire little bit to quite fit with our system. It is a 22- question scale survey in which participants can select a number ranging from 1 which indicates strongly disagree to 5 which indicates strongly agree.

RESULTS

We did not consider the results of task 1(the speed level) as it can be done in task 2 and task 3. The game has four levels of game including large image, small image, distraction with large image, and distraction with small image.

| ANOVA Summary | | | | | |
|---------------|---------|----|---------|-------|--------|
| Source | SS | df | MS | F | Р |
| Age | 2913.39 | 1 | 2913.39 | 25.68 | <.0001 |
| Games | 1306.06 | 3 | 435.35 | 3.84 | 0.0136 |
| r x c | 420.27 | 3 | 140.09 | 1.23 | 0.3061 |
| Error | 7261.78 | 64 | 113.47 | | |
| Total | 11901.5 | 71 | | | |

| Figure 0. 1 wo-way ANOVA result | Figure 6 | . Two-way | ANOVA | results |
|---------------------------------|----------|-----------|-------|---------|
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By using two-way ANOVA analysis on the missing scores of age group for different types of games, we found that younger adults made significantly fewer errors (M=15.06) compared with older adults (M=27.78), F (1, 64) =25.68, p<0.01 as can been seen in Figure 6. Also, two-way ANOVA analysis of the missing scores on different levels of game revealed that there was a significant difference for the number of mistakes for the different types of games, F (3, 64) =3.84, p=0.01. Moreover, Tukey post hoc test showed that participants accessing the small image (M=25.05) made significantly more errors than in the large image with distracter condition (M= 14.28), and that participants interacting with the small image with distracter condition. However, there was found that no interaction affect between age group and the type of game, F (3.64) =1.23, p=0.31. Figure 7 shows the average number of mistakes for both groups in this experiment.



Figure 7. Game average mistakes for both groups

DISCUSSION

Statistical analysis provided valuable information on the performance of participants. These also permit us to confirm some hypotheses. The analysis of missing scores shows that the number of these missing scores increased among older people. Some research that is relevant to this issue provides some support for this assertion. Guillaume and Nadine (2010) found that the number of clicks on wrong targets rises according to the age. In addition, the number of missing scores are significantly affected by image size and by the on-screen distractor. The subjects realized more errors when they played with a small size image along with on-screen distractor. More importantly, the game can be a useful tool to train users' attention as well as their dexterity. The design of the interfaces was the main area that the participants criticized and gave suggestions for improvements. This result was inferred from analyzing usability questionnaire and from the direct feedback of the participants as well.

The analysis of responses, feedback, and suggestions of participants along with usability questionnaire reveals that the system was easy to use, and they were generally satisfied with its functionality and graduality of complexity. They also praised the flexibility and easiness of navigation between the interfaces of the system and switching between different tasks. Further, most the participants stated that their focuses were increased during playing this game and they are willing to play it after completion of the experiment. Participant number 15 said that his attention was increased during the test and he was able to make fewer errors in the last two tasks. However, they had hard time to chase and hit the target image when they selected to play the game using high-level speed (level 6). Participant number 2 showed that the level 6 of the game is too fast for him, and that's why he made a lot of errors (missing hits). He recommended to put reward for those people who play well, also he suggested to see other's score to get motivated to play the game to see how he/she is doing compared to others. Participant number 12 stated that the game improves the focus and concentration. Participant number 13 stated that the game is great for keeping my arthritic fingers loose and keeps them moving. Further, it keeps her/his eyes on the target and not stray. She/he felt like exercising his/her hands in addition to the brain training. It employed the eye, hand, brain attention and focus in the meantime which is good as he/she said. Participant number 4 stated that the game keeps him/her focus. He/she likes the different options that the game has and its design. Participant number 10 stated that the game increases hand/eye coordination and it can be entertaining. One of the older adult participants did better during experiments and his errors were few in number compared to his group. He was in good health. We investigated more and found out that he exercises in the daily basis and walks more 10 miles every day which most people do not. So his focus was high. However, some of older adult participants were worried about their dexterity and they said that the game was a good exercise for them to improve their dexterity.

The paper provides several theoretical and practical implications. Theoretically, it enriches the disability literature by proposing a new mobile system for elderly people, it enhance the theoretical foundation of existing literature by extending previous work with usability questionnaire. In practice, the findings of the paper provide various practical implications for elderly people, physicians, technology designers and service providers. It helps elderly to break all the barriers for playing a mobile games, it help physicians to use the system as smart method in the rehabilitation process or physical therapy since the system merges entertainment with exercising and finally it provides some design implications and practice toward an easy to use system.

CONCLUSION

This paper discusses the development of an android-based system to strengthen dexterity skills among older adults. We make a comparison study to compare performance of younger and older users using a mobile interface. Our study permits to show that the age has a clear impact on performance. There were 18 participants tested this system. Further, the findings showed that the system is an easy to use software to train users' attention and their dexterity. The paper has significant implications for elderly patients, physicians and technology designers and service providers.

For future work, the researchers are planning to evaluate the application with large sample of participants, to better understand the differences between both older and younger populations. More importantly, the improvement of the interface design will be in the top of our priorities. Furthermore, the researchers will add many features to the current system. First, they are going to determine time for the game in which a specific time will be assigned to each level and a user has to reach the targeted score within this period of time. Second, to make the game more interesting, it will start over if the number of missing scores reaches a specific score (the half) with respect to the targeted score of the current level. Finally, a multiplayer mode feature will be added to the system in future to allow more than one user to play the game in the meantime.

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Forecasting the Potential for Emergency Department Overcrowding

Jeff Skinner BSN, RN, CEN Corresponding Author Spectrum Health 100 Michigan Ave NE Grand Rapids MI, 49503 4674 Egypt Valley Ave NE Ada MI, 49301 <u>skinneje@mail.gvsu.edu</u> (810) 820-5862

Raymond J. Higbea, PhD, FACHE Grand Valley State University 410 Fulton St. W Grand Rapids, MI 49504-6431 1414 Forrester Street SE Grand Rapids, MI 49508 <u>higbeara@gvsu.edu</u> (616) 350-6353

Abstract: This research study used the Dixon Forecasting Model (DFM), a Bed Ratio (BR), and the National Emergency Department Overcrowding Scale (NEDOCS) to establish a reliable two-hour overcrowding forecasting tool within the Emergency Department. The DFM and BR were used together to predict severe overcrowding based on current census data. This two hour prediction was then be validated by the real-time NEDOCS and real-time Bed Ratio scores. Data analysis indicates that the two-hour predicted BR is moderately correlated with a real-time NEDOCS (correlation coefficient 0.508) and real-time BR (correlation coefficient 0.492) at the forecasted time. Further data analysis revealed a strong correlation between the real-time NEDOCS and the real-time BR, as evidenced by a correlation coefficient of 0.949. The results of this study suggest that the DFM can be used with additional data to calculate a two hour forecasted BR and that using either BR or NEDOCS in real-time to determine overcrowding is effective.

Key words: Emergency Department, Overcrowding, NEDOCS, Bed Ratio, Forecasting

INTRODUCTION

Background

In 2001, the Institute of Medicine (IOM) released their publication; *Crossing the Quality Chasm: A New Health System for the 21st Century.* Prepared by the IOM's Committee on the Quality of Health Care in America, this instrumental piece of literature outlined key components lacking within the current health system. Specifically, the report outlined six aims for improvement to impact the quality of care. These aims focus on care that is safe, timely, effective, efficient, equitable, and patient focused (IOM, 2001).

During the release time of the IOM's six aims, electronic health records (EHR) were in place and starting to increase in use. This advancement allowed for improved efficiency, throughput, and quality data metrics (IOM, 2007). According Jones et al (2009) "The IOM recommends that hospitals utilize information technology and use operations research methods to become more efficient". One area of our current healthcare system that could benefit from improved efficiency is the Emergency Department. Failure to improve efficiency and patient throughput are key components contributing to the problem of overcrowding (Hoot, 2006).

Overcrowding

Emergency Departments are open all day, every day and they are an essential access point for patients seeking emergency treatment (Weiss, 2004). According to the IOM's 2007 publication, *Hospital-Based Emergency Care; At the Breaking Point*, overcrowding is an important issue that needs attention within the current health system (IOM, 2007). Annually, Emergency Department visits have been growing at an exponential rate. According to the American Hospital Association (AHA) Trendwatch Chartbook, 2013, from 1993 to 2013 the number of Emergency Department visits increased by forty one million (see figure 1).



Figure 1 Source: American Hospital Association. Avalere Health for the American Hospital Association. (2013). Trendwatch Chartbook 2013: Trends Affecting Hospitals and Health Systems.

It is important to note that even though patient volumes are increasing, the number of Emergency Departments available to provide treatment is not (Morganti, 2013). As a result, Emergency Departments must maintain efficient throughput in order to meet the demands of incoming patients. Failure to meet this demand results in overcrowding (Hoot, 2006). As this continues to be a problem, Emergency Departments are faced with extreme challenges to eliminate overcrowding. Understanding what overcrowding is and how to predict the likelihood of its occurring is necessary for its prevention (Jones, 2006).

Overcrowding in Emergency Departments put patients at risk for increased length of stay, increased cost of care, and diminished quality of care (IOM, 2007). Through research and data analysis, tools to identify overcrowding in real time have been established. Unfortunately, there is limited research to support forecasting and predicting of overcrowding (Hoot, 2007). As health care leaders, the ability to forecast overcrowding can provide Emergency Departments with early recognition and resource allocation. Keeping in line with the IOM's *A New Health Care System for the 21st Century*, this type of advancement could essentially prevent overcrowding.

METHODS

Design

The following research study was submitted to the Grand Valley State University Internal Review Board for exempt status under Quality Improvement Management. This research study will utilize tools that identify overcrowding in real time, along with department data, to forecast overcrowding two hours into the future. Tools utilized include the Dixon Forecasting Model (DFM), a subset of Real-time Emergency Analysis of Demand Indicators (READI), and the National Emergency Department Overcrowding Scale (NEDOCS). For the purpose of this experiment, the

READI subset that will be utilized is Bed Ratio (BR). The DFM will be utilized to assist in the calculation of a forecasted BR two hours into the future. This two hour prediction will then be validated by a real-time NEDOCS and real-time BR, both of which have been acknowledged in the identification of overcrowding (Jones, 2006).

Research Question

Can as established demand indicator of Bed Ratio be leveraged with the Dixon Forecasting Model to accurately predict Emergency Department overcrowding two hours into the future?

Hypothesis

H1: The Dixon Forecasting Model will forecast Emergency Department overcrowding two hours into the future

H0a: Use of a forecasted BR two hours into the future will predict Emergency Department overcrowding.

H0b: A forecasted BR two hours into the future will be validated with real-time NEDOCS scores.

H0c: A forecasted BR two hours into the future will be validated with real-time BR scores.

Environment

This study will be conducted at Spectrum Health's Butterworth Emergency Department in Grand Rapids, Michigan. The Butterworth Emergency Department has an annual visit volume of 107,000 patients, with an average daily census of 294. This makes the Butterworth Emergency Department one of the highest volume Emergency Departments within the state of Michigan. Additionally, the Butterworth Emergency Department is a designated Level 1 Trauma Center, Certified Chest Pain Center, Certified Stroke Center, and designated Burn Center. In order to handle the large volume of presenting patients, the Butterworth Emergency Department has 68 designated care spaces. This includes 49 general care spaces, 14 Rapid Assessment Zone/Express Care spaces, three trauma bay spaces, and two triage rooms. The Butterworth Emergency Department utilizes an Electronic Health Record, which makes collecting and gathering data manageable for this study.

TOOLS

The following three tools will be used by the Spectrum Health Butterworth Emergency Department Charge Nurse group, consisting of 16 members. Charge Nurses were trained how to use each tool, when to use the tool, and how to record data generated by the tools. The three tools will be used over the course of a two week interval. Data collected during the two week interval will be reviewed and analyzed. To conclude the study, the potential for a reliable two hour forecasted BR to predict Emergency Department overcrowding will be evaluated.

Dixon Forecasting Model

The Dixon Forecasting Model (DFM) is a "home grown" tool developed by the Butterworth Emergency Department Data Analyst, Bill Dixon. The tool was first conceived by Dixon after discussion with management to improve the Butterworth Emergency Department's staffing model. Staffing in the Butterworth Emergency Department is based on 2.55 Hours per Patient Visit (HPPV). In a changing health care climate, fiscal responsibility forced leadership to assess, analyze, and redesign staffing. The forecasted data provided by Dixon allowed leadership to redesign the staffing grid to be more efficient and effective. The ability to assess staffing needs also aided Charge Nurses in resource allocation.

Dixon took historical department census data and built an excel matrix. From these data Dixon created a linear regression model for forecasting future arrivals. This model was then formatted into a data entry tool used by Charge Nurses to enter current department census at pre-determined times in four hour blocks. These four-hour block timeframes were chosen because of the two-hour forecasting ability of the DFM and alignment with Butterworth Emergency Department's staffing model. Department data analysis of the DFM shows that the tool is able to use the current daily census to forecast a daily census two hours into the future. As such, the study design uses the current DFM data with predicted DFM data to calculate predicted arrivals in two hours. This information

will be required for calculating Bed Ratio, which can determine overcrowding (Jones, 2006). Currently, this model has only been tested at Butterworth's Emergency Department thus; its findings are not yet generalizable. Future plans include testing the DFM throughout the Spectrum System and, once any refinements are made based on the testing data, move to broader testing and validation of the model.

Bed Ratio

Real-time Emergency Analysis of Demand Indicators (READI) scores have been used as objective measures for predicting Emergency Department demand and overcrowding (Hoot, 2006). Scores evaluate treatment spaces, patient acuity, and physician productivity. Together these scores are used to give an overall demand of the department. Evaluation of treatment spaces is calculated through a Bed Ratio (BR). This ratio assesses the number of patients and available treatment spaces (Reeder, 2003). BR is calculated by taking the total number of ED patients, adding the number of predicted arrivals, subtracting the number of predicted departures, then dividing that by the number of treatment beds. A BR of greater than 1 suggests that there may be inadequate number of treatment spaces available Hoot, 2007). In general, overcrowding occurs when there are not enough care spaces for current and presenting patients. The calculation for BR used in this study is as follows:

BR = (*Total ED Patients* + *Predicted Arrivals* – *Predicted Departures*) / *Total Number of Treatment Spaces* (Hoot, 2007). (1)

NEDOCS

The National ED Overcrowding Study (NEDOCS) was discussed in 2004 by Weis et al. The NEDOCS is a simple screening tool that can be quickly utilized to determine the degree of ED overcrowding in real-time. The NEDOCS creates a saturation score accounting for a variety of factors including the number of Emergency Department patients, beds, admissions, and Emergency Department throughput. Over the past decade, numerous studies have included the NEDOCS tool in an effort to define overcrowding and assess patient throughput. As a result, the tool has changed since initial implementation in 2004. The calculation and scoring scale used for this study are as follows:

NEDOCS = -20+85.8 * (Total patients/ED Beds) + 600 * (Admits/Hospital Beds) + 13.4 * (ventilators) + .93 * (longest Admits) + 5.64 *(Last Bed Time).

Scores 0.50 = Not Busy, 51-100 = Busy, 101-140 = Overcrowded, 141-180 = Dangerous, and above 180 = Disaster (Bhardwaj, 2010). (2)

DATA ANALYSIS

Data was collected from June 17 until June 30, 2015. The necessary data for calculating a forecasted two hour BR was recorded by the Charge Nurse group at four-hour intervals. This included current number of patients in the Emergency Department, DFM two hour predicted arrivals, two hour predicted departures, and the total number of treatment spaces two hours into the future. Criteria for potential discharges used by the Charge Nurse group consisted of the following: patients with discharge written, patients with a current inpatient bed assignment, patients with inpatient admission request placed, patients with observation admission request placed, patients that could potentially leave within the next two hours.

A forecasted two hour BR was calculated using Excel equations. At the forecasted timestamp (0300, 0700, 1100, 1500, 1900, and 2300), the Charge Nurse collected and gathered data needed to run a real-time NEDOCS and real-time BR. This data was entered into an excel spreadsheet and the real-time NEDOCS and real-time BR were calculated using Excel Equations. After the two week time period, data analysis was completed using Excel's Data Analysis Tool Pack. The two hour forecasted BR was analyzed against the Real-time NEDOCS and real-time BR. In addition, the Real-time NEDOCS and real-time BR were analyzed against each other for validation of overcrowding.

Results

A total of 69 observations were recorded during the studies timeframe. Excel's Data Analysis tool pack was utilized to generate descriptive statistics, correlation, and regression analysis for the two hour forecasted BR, real-time NEDOCS, and real-time BR. Descriptive Statistics generated for all three are listed in Table 1. Analysis indicates that the two hour forecasted Bed Ratio is moderately correlated with a real-time NEDOCS score and a real-time Bed Ratio. This is evidenced by a correlation coefficient of 0.508 and .492. Further analysis of the real-time NEDOCS and real-time BR shows a strong correlation evidenced by coefficient of .949 (see table 2). A comparison of data collected was used to create two scatter charts that reflect the aforementioned correlations. See figure 1 for results of the forecasted two hour BR and the real-time NEDOCS. See figure 2 for results from the real-time BR and the real-time NEDOCS.

| | Bed Ratio | RT-NEDOCS | RT-BR |
|-------------------------|-------------|-------------|-------------|
| Mean | 0.946164915 | 61.69565217 | 0.860075914 |
| Standard Error | 0.035096997 | 2.641502997 | 0.027136134 |
| Median | 0.930232558 | 65 | 0.873015873 |
| Mode | 1.253968254 | 80 | 0.535714286 |
| Standard Deviation | 0.291537554 | 21.94197183 | 0.22540966 |
| Sample Variance | 0.084994145 | 481.4501279 | 0.050809515 |
| Range | 1.384920635 | 100 | 1.071428571 |
| Minimum | 0.107142857 | 14 | 0.392857143 |
| Maximum | 1.492063492 | 114 | 1.464285714 |
| Count | 69 | 69 | 69 |
| Margin of Error (95.0%) | 0.070034967 | 5.271037164 | 0.054149313 |

Table 1

| Table | 2 |
|-------|---|
|-------|---|

| | Bed Ratio | NEDOCS | RT BR |
|--------|-----------|----------|-------|
| Bed | | | |
| Ratio | 1 | | |
| NEDOCS | 0.508728 | 1 | |
| RT BR | 0.492642 | 0.949171 | 1 |





60 Real-Time NEDOCS 80

100

120



Regression analysis shows that a forecasted two hour BR has statistical significance in predicting future overcrowding. This was validated real-time NEDOCS score and is evidenced by a P-value < .001. Further regression analysis between the two hour forecasted BR and the real-time BR also supports significance in predicting future overcrowding as evidence by a P-value < .001. Results for this analysis are shown below in Table 3.

| Table 3 | 3 |
|---------|---|
|---------|---|

| | P-value |
|-----------------------------------|-------------|
| BR and Real-Time BR | 1.70788E-05 |
| BR and Real-Time NEDOCS | 8.07326E-06 |
| Real-Time BR and Real-Time NEDOCS | 2.36642E-35 |

Limitations

0 -

20

40

Based on the size and volume of the Butterworth Emergency Department, the number of observations recorded in comparison is low. Increasing the number of observations in relation to annual visit volume could improve accuracy

of the results. The criteria set forth for predicted departures in two hours are variable and subject to Charge Nurse interpretation. Creating an automated forecasting tool similar to the DFM or in accordance with the DFM could prove beneficial. Automation of these data would require extensive historical data collection, which could not be constructed during the timeframe of this research project. Lastly, during the recording of data by the Charge Nurse group, timestamps to be recorded were missed due to department needs. The complexity of the Charge Nurse role coupled with high volumes and acutely ill patients creates the potential for inaccurate data recording.

CONCLUSION

The results of this study suggest that the DFM can be used with additional data to calculate a two hour forecasted BR. This data would also indicate that using either BR or NEDOCS in real-time to determine overcrowding is effective. When using a forecasted two hour BR, the ability to identify overcrowding is not as strong as real-time identification of overcrowding. Regardless, it is significant in determining the likelihood of overcrowding two hours in the future.

This two hour timeframe for predicting overcrowding has the potential to impact how Emergency Departments deal with resource allocation. One way to ensure appropriate resource allocation is to develop a surge plan. The use of forecasting to assist in development and implementation of surge plans to prevent future overcrowding could prove beneficial (Moseley, 2010). However, with a moderate correlation, forecasting alone will not be sufficient for design and development.

It will be essential to have adequate supplementation when attempting to forecast over long expanses of time. Development of responsive staffing model will be necessary to safeguard staff and patients. The use and implementation of a flexible staffing model could prove beneficial when looking for responsiveness. Also, the development of a staffing algorithm and complimentary standard work could supplement decision making. Solutions and supplementation material like this should be taken into consideration, along with consulting key stakeholders. Further research is needed to determine if these resources coupled with the forecasted two hour BR have the potential to reduce overcrowding.

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Can Psychology Research Inform Health Information Data Collection?

A. Michelle Wright, PhD Office of the Vice President for Research Western Michigan University michelle.wright@wmich.edu

Abstract: Conclusions drawn from electronic medical records (EMRs) are only as accurate as the data provided. Recent findings by psychologists and health researchers may help streamline health information data collection and subsequent data analysis. Specifically, four areas will be discussed: (1) Standardization of terms between the patient and the health professionals, (2) Impact of patient inattention and fatigue when responding to health measures, (3) Importance of source labeling within the medical record (e.g., self-administered questionnaire, responded via phone, etc.), (4) Cognitive load on patients when using mobile health technology (e.g., apps, tablets, online patient portal, etc.). Research suggests consideration of these potential biases could provide the patient with a better health care experience, assist the health care provider in diagnosis and treatment, conserve time and resources, and aid researchers as they consider health outcomes.

INTRODUCTION

Electronic medical records (EMRs) offer opportunities to access and analyze unprecedented amounts of health data, including information from laboratory tests, pharmacy records, medical histories, billing information, and immunization records. For much of this data, the potential for psychological biases is relatively low. However, some aspects of the EMR contain patient reported outcomes (PROs) which may be subject to bias (e.g., a patient reporting drinking behavior). These PROs are frequently used by physicians, researchers, and other health care professionals, yet the impact of potential psychological bias on these outcomes is rarely addressed by those concerned with EMRs and health information technology (HIT). The following paper outlines several areas of psychology research that can reduce potential bias in PROs which, in turn, could allow for more streamlined data collection, assist in diagnosis and treatment, aid researchers, and improve the patient experience.

Standardization of Terms

Previous health technology researchers have emphasized the need for standardization of healthcare and medical terms across providers, hospitals, and researchers (Skrocki, 2013). Yet, other opportunities exist for standardization, including standardization and clarity of terms between patients and providers when patients are reporting health information. The patient reported definition of binge drinking, for example, varies by gender and average alcohol use with almost 40% of frequent binge drinkers reporting that males needed to drink 10 or more drinks to be considered a binge drinker (Wechsler & Kuo, 2000). Other definitions of medical terms are also subject to bias, such as expectations about cognitive decline (Connell et al., 2007; Giebel et al., 2015) symptoms of poor mental health (Hinton & Lewis-Fernández, 2011), and the perception of obesity (Paeratakul et al., 2002; Sutcliffe et al., 2015). Social psychologists suggest these differences between patient definitions and health care provider definitions stem from different social or cultural norms (Aarts, & Dijksterhuis, 2003; Sherif, 1936). For example, those who belong to social groups where binge drinking is considered normative (e.g., fraternity groups, colleges where binge drinking is common, etc.) are much more likely to binge drink themselves (Cashin, Presely, & Mielman, 1998) but not necessarily view this behavior as problematic or as meeting the criteria of binge drinking (Wechsler & Kuo, 2000). Similar patterns of bias have been found for obesity (Barnett, 2015; Carnell et al., 2005). When combined, these studies suggest patients may be biased to underreport PROs and that this bias may stem from a wide array of norms-including norms that may not be immediately obvious to the health care professional (e.g., membership in a social club like a fraternity).

These potential biases could be mitigated by having the health professional offer a clear definition to the patient when asking for PROs, such as: "Do you engage in binge drinking? Binge drinking is defined as 5 or more drinks for men

and 4 or more drinks for women in a 2-hour period" (Centers for Disease Control and Prevention, 2015). Research indicates individuals who are given new anchor points or new information (e.g., maximums about binge drinking) are responsive to this new information and use these new anchor points when assessing subsequent situations (Dikemann, Przepiorka, & Rauhut, 2015; Haines & Spear, 1996). Furthermore, data suggest a single intervention-type training session can reduce these types of social and cognitive bias (Morewedge et al., 2015). These studies suggest decreasing response bias and standardizing patient definitions does not require any special tools or costly interventions. Instead, standardized terms between patients and providers offers many benefits with relatively little cost. Use of properly standardized terms when collecting patient reported outcomes could allow for better patient care and more precise diagnosis. Additionally, introduction of standardized term also offers opportunities for health practitioners to improve future health behaviors by clarifying medical terms for patients.

Patient Fatigue and Concise Measurement

Prior researchers have found the quality of the responses decline as participants grow fatigued or bored with questionnaires. This phenomenon has been referred to as participant or respondent fatigue (Ben-Nun, 2008) and has been documented across a range of populations and survey content. Participants who are fatigued often decline to respond to survey items (Hoerger, 2010), misrepresent or inaccurately report responses in order to complete the survey (Lehnen & Reiss, 1978), or engage in "straight-line" responding where they respond to all the items with the same answer (Galesic & Bosnjak, 2009). Specifically, prior research has found questions at the end of a questionnaire may be responded to differently than if they were at the beginning of the survey (Helgeson & Ursic 1994). Although no absolute rule exists, researchers examining participant fatigue suggest questionnaires of no more than 20 minutes to ensure quality data (Rathod & LaBruna, 2005).

How does one balance the need for quantity of health data and quality of health data? One avenue for decreasing questionnaire length is the use of single-item questionnaires in place of traditional, longer questionnaires. Research examining mental health indicates single-item assessment, e.g., "How would you rate your mental health today?", can serve as a brief screening tool for those at risk for mental health problems (Hoff, Bruce, Kasl, & Jacobs, 1997; Jang et al., 2012). Researchers have also suggested the use of single-item questions to assess quality of life (Fayers & Hand, 2002), physical activity level (Milton, Bull, & Bauman, 2011), and stress (Elo, Leppänen, & Jahkola, 2003). Historically, single-item measures had been considered psychometrically inferior to longer measures (Allen & Yen, 2006). However, use of single-item visual analog scales when assessing health (i.e., ranging from 0 to 100) are gaining statistical support as they have been found to be reliable over time, offer a range of response alternatives, and offer both discriminant and convergent validity (De Boer, et al., 2004). Financial data also support the use of single-item measures. For example, De Salvo and colleagues (2009) found a single-item measure of general self-rated health predicted future medical expenditures as well as longer, established measures of health. When combined, these studies point toward an approach that may benefit all involved participants. More accurate health information data and shorter surveys provide a better patient experience and streamlining the EMR through concise measurement is cost effective for the provider.

Source Labeling and Questionnaire Administration Format

Patients are asked to respond to self-administered health questionnaires (e.g., paper and pencil forms, completing patient information online through a patient portal), respond to health questions in-person to a health professional, and asked to answer health related questions over the phone. For many health practitioners and researchers, the common assumption is that so long as the patient is disclosing health information to health professionals, the responses will be consistent. As such, the questionnaire administration format should not impact the quality of the data. However, research suggests the participants respond to sensitive questions differently depending on the administration format. Responses to mental health questions are given more positive responses (i.e., better mental health) when answered via phone than when answered in using a self-administered questionnaire (Feveile, Olsen, & Hogh, 2007). Additionally, mental health symptom scores responded to using self-report on pencil and paper are almost double the symptom scores when responding orally to a mental health professional (Wright et al., 2015). Research also indicates that mental health measures are more sensitive to administration format than questions focused solely on physical health (Cheung et al., 2011; Lungenhausen et al., 2007). These inconsistencies in response patterns are likely due to social desirability bias where patients feel there is some correct or "healthy" response and adjust their answer accordingly (Bowling, 2005).

Two possible solutions may minimize the impact of administration format of health questionnaires. First, those collecting health information data and those conducting health research should consider the impact that administration format may have on patient responses. Measures of mental health and mental health related behaviors (e.g., alcohol consumption, recreational drug use, etc.) may be especially vulnerable to underreporting and social desirability bias. As such, questions about mental health should be administered using self-report whenever possible with the patient completing the questionnaire on his or her own in a private setting. Second, EMRs should offer opportunities for labeling the source of the data. Although the administration format of the questionnaires may not be modifiable, plainly labeling how the data were acquired would allow health professionals and researchers to make appropriate comparisons and more accurate diagnoses.

Cognitive Load and Mobile Health Technology

A recent survey conducted in partnership with American Hospital Association's (AHA) Health Forum and the College of Healthcare Information Management Executives (CHIME) reports 79 % of hospitals have online patient portals accessible through an app (Weinstock & Hoppszallern, 2015). Similarly, many hospitals are evaluating the utility of patient data collection using tablets, such as iPads® (e.g., Cook et al., 2014; Kaka et al., 2015). The role of apps and mobile devices for health care practitioners has been examined (e.g., Divall, Camosso-Stefinovic, & Baker, 2013; Segal et al., 2015; Ventola, 2014), yet relatively little research has examined mobile health technology from the patient perspective (for rare exception see Martin et al., 2015). Research from cognitive psychology, however, suggests that patient familiarity or literacy with mobile health technology may significantly impact PROs when using these "new" mobile platforms. Cognitive load theory, for example, suggests that when an individual's working memory becomes too taxed, learning becomes hampered (Sweller, 1994) and the individual may provide inaccurate responses to relatively simple questions (Ashcraft & Kirk, 2001). This tendency to become cognitively overburdened is most likely to occur when the individual views the information as unfamiliar or "new" (Stolovitch, & Keeps, 2006). Research also suggests that individuals can be "primed" to be cognitively overburdened by a task. For example, something as simple as how a health care provider frames mobile health technology can affect how the patient performs when using the technology (e.g., "new, data driven mobile health platform" vs. "a useful health tool") (Chasteen et al., 2005). Finally, research examining working memory indicates an individual who is less cognitively burdened tends to respond to problems using reason (e.g., "I am not sure which button to press-I should ask for help."). Conversely, when the individual is cognitively taxed he or she will respond using emotion (e.g., "I don't know how to use this thing! I quit!") (Shiv & Fedorikhin, 1999).

Assessing patient literacy and familiarity with mobile health technology is uncharted territory. Indeed, to date, only one in-progress dissertation specifically addresses this new research area (Ahmed, 2015). However, the newness of this field does not mean that health care providers should assume that all patients are either, a.) completely adept at using mobile health technology, or b.) completely incapable of utilizing the benefits of mobile health technology. Instead, many patients fall somewhere in the middle of this spectrum with each patient having his or her own set of costs and benefits to using mobile health technology. Additionally, health care providers should be cognizant of different skill levels within the same individual across different mobile technology platforms. For example, patients that are comfortable using online patient portals at a desktop computer may not necessarily be comfortable with a mobile health app or data collection using an iPad® (HealthIT.gov, 2014). The potential for mobile health technology is great, yet the data provided through these platforms hinges on the patient utilizing these services and providing accurate PROs. As such, providers should not make assumptions about patient literacy and familiarly with technology, but should instead ask targeted questions to ensure the patient feels comfortable using the specific mobile health technology in question.

CONCLUSION AND FUTURE DIRECTIONS

While not exhaustive, the following recommendations may reduce bias when collecting patient reported outcomes for EMRs:

- 1.) Be cognizant of social and cultural norms when defining health. When in doubt, define.
- 2.) Keep questionnaires and data collection instruments to 20 minutes or less.
- 3.) Use validated single-item measures whenever possible.
- 4.) Administer sensitive health questions and questions about mental health using self-report questionnaires.
- 5.) Plainly label the source of the patient reported outcome in the EMR.

6.) Assess patient familiarity with mobile health technology. Do not assume all patients are comfortable using this "new" technology.

Moving forward, HIT researchers and those that work with EMRs should consider the role of psychology and the inherent biases that occur when requesting PROs. Although patient reported outcomes only comprise a relatively small portion of the data in EMRs, the cost of implementing and utilizing EMRs is high (Fleming et al., 2011). As such, any opportunity to streamline EMR data collection could prove financially beneficial. Additionally, according to a 2013 RAND report, EMRs are underperforming compared to their projected goals (Kellerman & Jones, 2013). Considering psychological biases when collecting patient reported outcomes will not assist in many of the concerns with EMR implementation and utilization (e.g., network security). However, consideration of these biases may assist EMR developers as they work toward adaptive HIT systems that are more user friendly and take social and cognitive aspects of the patient/provider experience into account (Denning, 2013). Finally, previous researchers have examined many of the possible problems with using EMRs (e.g., reduced emotional responsiveness during patient interactions (Margalit et al., 2006)). However, as this paper details, other areas of bias exist, such as bias that occurs before the patient health information is even entered into the EMR. As such, simply acknowledging PROs may be subject to bias could help patients, health practitioners, and health researchers.

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Smart Home Healthcare Settings: A Qualitative Study of the Domain Boundary

Ahmad Alaiad aalaiad1@umbc.edu Department of Information Systems College of Engineering and Information Technology University of Maryland-Baltimore County Baltimore, Maryland, USA Dorsa Ziaei dorsaz1@umbc.edu Department of Computer Science College of Engineering and Information Technology University of Maryland-Baltimore County Baltimore, Maryland, USA Muhammad Al-Ayyad mayyad@ammanu.edu.jo Department of Biomedical Engineering College of Engineering Al-Ahliyya Amman University Amman, Jordan

Abstract: Addressing the health problems of the 21st century will require individuals to use a new set of medical and public health resources that extend beyond historic and traditional medical devices and are built on current and smart information technologies. Much of these new medical tools was originally designed by device manufacturers to be used only in clinical settings and by trained healthcare professionals but recently are finding their way into the home nevertheless. Their migration to the home poses many challenges to both caregivers and care recipients. In order to facilitate their migration to the home, it is very important to first understand the domain boundary, its components and their interactions. Little research discusses the context of smart home healthcare and its surrounding entities to date. This paper aims to fill the knowledge gap by developing a framework of smart home healthcare context. To this end, we conducted semi-structured interviews with patients and health professionals served for or by home healthcare agencies on the east coast in the United States. We analyzed the content applying thematic approach. The findings revealed four major components of the framework including person, tasks, technologies, and environments. The findings also revealed us to define the interactions between these components. The findings have significant implications for smart home designers and manufacturers, and service providers.

INTRODUCTION

In the United States, healthcare devices, technologies, and care practices are rapidly moving into the home (Manhattan, 2009). Health Information Technology (HIT) is the key facilitator for this migration. It is impossible to see this migration into practice without HIT (Lewis, 2001). HIT can be defined as an umbrella framework to describe the comprehensive management of health information across computerized systems and its secure exchange between consumers, providers, government and quality entities, and insurers (Karsh et al., 2011). If the target domain is the patient home and the used technology is smart, then we call it smart home healthcare information technology (sH²IT).

The healthcare delivery system is rapidly changing today, and individuals are assuming an increasing role in management of their own health (LaPlante et al., 2011). In these settings, individuals are expected to perform a range of healthcare tasks and interact with a vast array of medical devices and technologies in residential settings (LaPlante et al., 2011). Thus, healthcare that occurs at home is a complex experience, involving various types of persons, tasks, technologies, and environments.

All of these elements—the persons, tasks, technologies, and environments—affect the safety and quality of the healthcare that occurs in the home. To ensure that healthcare in the home is safe, efficient, effective, and responsive to individual needs, it requires identifying potential user groups who will be interacting with home health systems; understanding the capabilities, limitations, needs, and preferences of these populations; and matching these capabilities, needs, and preferences to the demands generated by healthcare and health management tasks, technologies, and the environments in which these tasks occur.

Addressing the health problems of the 21st century will require individuals to use a new set of biomedical and public health resources that extend beyond historic and traditional medical devices and are built on current and emerging information technologies (Hesse, 2005; Karami & Gangopadhyay, 2014, Karami et al., 2015). These new information

technology tools will enable the future healthcare system to become predictive, preemptive, and personalized to the needs of individual providers, care recipients, and caregivers to an extent not previously possible (Gibbons, 2007).

Much of these new medical tools was originally designed by device manufacturers to be used only in clinical settings and by trained healthcare professionals (U.S. food & drug administration, 2010) but recently are finding their way into the home nevertheless (Rialle et al., 2010). Their migration to the home poses many challenges to both caregivers and care recipients (Rialle et al., 2010).

In order to facilitate their migration to the home, we first need to better understand the domain boundary, its components and their interactions. Little research discusses the context of smart home healthcare domain and its surrounding entities using qualitative evidences to date. Domain context enable us to understand and define the important human factors. This paper aims to fill this significant knowledge gap by answering the following research question: How to build a conceptual framework of the domain context? In order to answer this question, we need to first address the following related question: How to classify sH²IT? To this end, we propose a classification scheme of sH²IT that covers the whole range of home healthcare context and conduct a qualitative study to build and discover the main components of the smart home healthcare context.

The paper provides several contributions to the literature. First, it enhances the theoretical foundation of smart home healthcare context, second; it proposes a categorization scheme of sH^2IT making it possible to generalize the findings to different types of HIT; third, it develops a conceptual framework of smart home healthcare contexts by identifying the major entities of the domain and the interaction between these entities, fourth; it creates various design artifacts that have significant implications for smart technology designers and manufacturers to improve the provided services.

The paper is organized as follows: next section introduces the home healthcare initiative. Section three proposes a categorization scheme of smart home healthcare context. Section four describes the method design including participants and procedures followed by results and discussion in sections five and six, respectively. The paper concludes by section seven.

HOME HEALTHCARE

Healthcare can form a significant part of a country's economy. The healthcare industry consumed an average of 9.0 percent of the gross domestic product (GDP) across the most developed OECD countries in 2008. The United States (16.0%), France (11.2%), and Switzerland (10.7%) were the top three spenders (Squires, 2012). Health expenditures in the United States neared \$2.6 trillion accounted for 17.9% of nation GDP in 2010, over ten times the \$256 billion spent in 1980 (Kaiser family foundation, 2012). The rate of growth in recent years has slowed relative to the late 1990s and early 2000s, but is still expected to grow faster than national income over the foreseeable future (Davis et al., 2007, Office of the assistant secretary for planning and evaluation, 2013). Addressing this growing burden continues to be a major policy priority. Furthermore, the United States has been in a recession for much of the past decade, resulting in higher unemployment and lower incomes for many Americans. These conditions have put even more attention on health spending and affordability (Blavin et al., 2012, AHIP center for policy and research, 2010).

Refocusing medical delivery systems to be patient-centered, funding for comparative effectiveness research, and supporting for wider use of health IT in the delivery system are all proposals discussed in a debate to reduce the nation healthcare costs (Davis et al., 2007, Kaiser family foundation, 2012). Part of the patient-centered medical delivery system proposal is the home healthcare which aims primarily not only to control healthcare cost through reducing readmission costs and transportation costs, but also improve post-hospitalization healthcare quality and increasing patient independency (National academies of science, 2010, AHIP center for policy and research, 2010).

Home healthcare can be defined as a system of care provided by skilled practitioners to patients in their homes under the direction of a physician (Ellenbecker et al., 2008). Home healthcare services include nursing care, physical, occupational, and speech-language therapy, and medical social services (Ellenbecker et al., 2008). The main goals of home healthcare services are to help individuals to improve function and live with greater independence, to promote the client's optimal level of well-being, and to assist the patient to remain at home, avoiding hospitalization or admission to long-term care institutions (Ellenbecker et al., 2008).

One of the key facilitators for the success of this home healthcare initiative (Rialle et al., 2010) is Health Information Technology (HIT). It is almost unimaginable to consider this initiative without HIT. HIT is in general increasingly viewed as the most promising tool for improving the overall quality, safety and efficiency of the health delivery system (Wu et al., 2006). Clinical decision support systems, computerized provider order entry, electronic medical records are all different forms of general HIT that have been widely used in most developed countries today. Recently, more attention is being devoted to more potential, specialized, domain-specific and emerging HIT (Poon et al., 2006) that can be used to improve healthcare delivery particularly at home. These technologies are still at early stage of adoption and usage in the United States. These technologies are called smart Home Healthcare Information Technology (sH²IT).

PHASE I: CATEGORIZATION SCHEME OF sH²IT

Although there are no generally accepted categorizations of different sH^2IT , there are several related attempts. The National academies of science (2010) classified the technology relevant to home healthcare into two major categories: medical devices and health information technologies (HIT) as shown in Figure 1.



Figure 1. National Academy of Sciences' Categorization of H²IT

Medical devices refer to an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar article that is intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment or prevention of disease (U.S Food and Drug, 2010). Medical devices are further classified into five main categories: medication administration equipment (e.g. medication preparation), telehealth (e.g. facilitating patient-doctor communication), infant care equipment (e.g. sudden death monitoring), test kits (e.g. pregnancy test), and finally non IT devices (e.g. bed, chair and walker). HIT, which refers to electronic records herewith, are further classified into the different subcategories (National alliance for health information technology, 2008): electronic medical record (EMR), electronic health record (EHR), personal health record (PHR), health information exchange (HIE), health information organization (HIO) and regional health information organization (RHIO). One of the major limitations of this classification is that it considers non-IT equipments such as bed, mattress, walker, and wheelchair and is based on whether the technology has a physical presence (i.e. hardware) or not (i.e. software) instead of what the broad functionality of the technology is.

Another classification of H^2IT (Cepro, 2008) has been suggested based on the broad functionality of H^2IT as shown in Table 1. This classification contains five main categories, namely monitoring systems, medication management tools, A/V communication solutions, telehealth/telemedicine and electronic health records. One of the major limitations of this classification is the comprehensiveness and limited focus primarily on emerging technologies.

| Category | Description | | | | | | | |
|-------------------------|--------------------------------------------------------------------------------|--|--|--|--|--|--|--|
| Monitoring Systems | This category includes Personal Emergency Response (PERS) and activity | | | | | | | |
| | monitoring systems that utilize broadband to collect and information about the | | | | | | | |
| | resident. These systems include wearable monitoring and wireless biometric | | | | | | | |
| | devices that collect physiological information for analysis and reporting. | | | | | | | |
| Medication Management | This category provides automated reminders to take prescriptions. | | | | | | | |
| Tools | | | | | | | | |
| | | | | | | | | |
| A/V Communications | The poster boy for this category is a videophone. | | | | | | | |
| Solutions | | | | | | | | |
| | | | | | | | | |
| Telehealth/Telemedicine | This category includes a central device that is connected with broadband to | | | | | | | |
| | care providers. Products include glucometers, blood pressure cuffs, | | | | | | | |
| | electrocardiogram monitors, weight scales, respiratory devices, pulse | | | | | | | |
| | oximeters, thermometers and digital cameras. | | | | | | | |
| Electronic Health | This is not really a device, but a recurring revenue tool for an integrator to | | | | | | | |
| Records | store medical information for clients, such as allergies, medications, medical | | | | | | | |
| | history and doctor information. | | | | | | | |

Table 1. Cepro's Categorization of H²IT

We propose a classification scheme of sH²IT based on the intersection between the two existing schemes, and on the functionalities where sH²IT plays a key role, Figure 2. Specially, we made the following major changes to the two schemes. First, although medication administration deals with the proparation process of the medication (National academies of science, 2010) and medication management deals with the process of reminding the patients to take the medication (Cepro, 2008), these two categories are closely relevant and accordingly combined into one category. Second, both A/V communication and monitoring are separate components of telemedicine and thus they are classified under this category, and relabeled as patient-professional communication and remote monitoring, respectively. Person is the primary component of home healthcare context. Person includes both patients and home healthcare professionals. sH²IT is primarily used to facilitate the connection between them using advanced technologies. Further, patients may be monitored remotely by sH²IT without physical interactions with home healthcare professionals. They can stay independent without any effect on the quality of their life. Third, the various types of electronic records are merged into one. Electronic record is a tool for data storage of individual historical and medical data regardless whether it is a personal health record, electronic medical record, health medical record or others. Their primary goal is to record and store the patient medical information to be accessed by other front-end technologies. Fourth, those non IT items such as durable equipment (e.g., bed, chair and walker) are removed due to low relevance.



Figure 2. Categorization Scheme of sH²IT

As shown in Figure 2, we classify sH²IT into three main categories: medication administration and management, telemedicine and electronic records. Telemedicine is further categorized into patient-professional communication and remote monitoring. Among other tasks of telemedicine, these two tasks are the most common where sH²IT plays a key role (National academies of science, 2010). Table 2 describes the key tasks of each category, which are defined based on existing categorization schemes and the related literature.

| Category | Key Tasks | | | | | | |
|---------------------------|-----------------------------------------------------------------------------------|--|--|--|--|--|--|
| Medication administration | Preparing medication and sending automatic reminders (National | | | | | | |
| and management | academies of science, 2010, Cepro, 2008, Smarr, Fausset, & Rogers, 2010, | | | | | | |
| | Skilligent, 2013). For instance, preparing medication by mixing certa | | | | | | |
| | level of a drug concentration with others. Sending automatic alarm message | | | | | | |
| | to the patient to take the medicine or to the doctor to take care of the patient. | | | | | | |
| Patient-professional | Facilitating the communication between patients at one side and the | | | | | | |
| communication | doctor/physician at the other side through the use of A/V and enable them | | | | | | |
| | to conduct diagnostic capabilities such ultra sound and image (National | | | | | | |
| | academies of science, 2010, Cepro, 2008). | | | | | | |
| Remote monitoring | Collecting information automatically about the resident and posted them | | | | | | |
| | on a central device for viewing, analysis and treatment/behavior changes. | | | | | | |
| | An alarm message is sent to care provider in case of emergency (National | | | | | | |
| | academies of science, 2010, Cepro, 2008, Baker, Armijo, & Belka, 2007, | | | | | | |
| | Xuemei, Liangzhong, & Jincheng, 2008). | | | | | | |
| Electronic records | Storing medical information for clients, such as allergies, medications, | | | | | | |
| | medical history and doctor information (National academies of science, | | | | | | |
| | 2010, Cepro, 2008, Hennington, &Janz, 2007, Morton, 2008). | | | | | | |

Selection of representative sH²IT

To achieve the goal of this paper, it is important to ground and select appropriate representative smart technologies. Selecting representative sH²IT that fits into the above categories is a difficult task. This is because some complex sH²IT cuts across more than one category and such trend is only increasing. We selected the following two

representative smart technologies: Home healthcare robots (HHR) and wireless sensor network-based home healthcare systems (WSN-HHS).

The mapping of these technologies to the categories of sH²IT is shown in Figure 2. Electronic records can be treated as the backend for both HHR and WSN-HHS. HHRs are primarly used to facilitate patient-professional communication (Wada et al., 2013, Skilligent, 2013) and WSN-HHSs for remote monitoring (Baker, Armijo, & Belka, 2007, Xuemei, Liangzhong, & Jincheng, 2008). In addition, HHRs are also used for medication administration and management tasks (Smarr, Fausset, & Rogers, 2010, Skilligent, 2013). Thus, the two selected technologies can cover all the major categories of sH²IT.

To address the issue of overlap in the tasks between the technologies, we draw on the related literature. For instance, although both HHR and WSN-HHS may function for the remote monitoring task, sensors are predominantly used for the task (Baker, Armijo, & Belka, 2007, Xuemei, Liangzhong, & Jincheng, 2008). Additionally, we compared the google search results for the query "sensor, healthcare, monitoring" to those for "robot, healthcare, monitoring", the number of retrieved papers was much greater for the former than the latter query. To further clarify the tasks associated with selected sH²IT, we designed scenarios in correspondence to the categories that the technologies are mapped to in the user study.

To support further home healthcare research, it is very important to understand the entire context of the home healthcare. Next section aims to define the components of home healthcare context by conducting a qualitative study with different users.

PHASE II: A CONCEPTUAL FRAMEWORK

In this phase, a qualitative study has been conducted to develop the conceptual framework of smart home healthcare context. Next sections describe the method design, results and discussions of major findings of this second phase.

METHOD DESIGN

To answer the research question, the study's data was collected through semi-structured interviews with different users in the home healthcare domain. This qualitative method was selected because relevant domain entities have not yet been identified. Semi-structured interviews gather detailed information about each user's beliefs without preconceived factors; the method provides opportunities for identifying unanticipated outcomes and is effective in understanding the main components in the situated context (Creswell, 2003). Hence, the results of this qualitative study enable the development of theories and framework of the smart home healthcare context.

Participants

We conducted semi-structured interviews with patients and health professionals served for or by home healthcare agencies on the east coast of the United States. The latter includes any of the following: doctors, physicians, nurses, social workers, therapists, pharmacists, dentists. There were about 150 agencies distributed over 50 cities, which are broadly classified into non-medical (e.g., home aid) and medical homecare (e.g., certified nurse and hospice) categories (Home health compare, 2013). The medical agencies offer nursing care, physical, occupational, speech, and respiratory therapy as well as social services and hospice care; and the non-medical agencies offer primarily home care services such as housekeeping, shopping and meal preparation as well as some health homecare services such as medication administration and assistance in health promotion exercises. Members belonging to these agencies include both patients and health professionals. Their participation was voluntary.

Networking was used to obtain a purposive sample of individuals who 1) participated in home healthcare services (e.g., members of the homecare agencies) and 2) preferably was receiving or providing long-term homecare services; and for patients, who also 3) were preferably elderly, and 4) had the ability to understand the interview questions. A purposive sample is deemed appropriate for exploratory research designed to query respondents who have experienced a domain of interest. Using the networking technique, the researchers identified individuals who have experienced in home healthcare services (e.g., served for or by one of the home healthcare agencies). These respondents were then asked to name additional individuals who have experienced the domain services as well. We used scenarios along

with storyboards in the interviews representing different use contexts of HIT in the home healthcare domain. Scenarios have been selected as a research method by many previous studies (Pommeranz et al., 2011, Znagui-Hassani, 2010). An example of one scenario and storyboard is provided in Appendix A.

Procedure

The current study was designed to employ the qualitative interview technique. With this data collection technique, the respondent is encouraged to describe in depth the personally experienced phenomenon. In using this method rather than attempting to investigate users' opinion by obtaining forced-choice responses to decontextualized variables, the researcher can attempt to learn the respondent's meaning of the experience. The goal is to discover patterns of experiences using interviews that define the context components (Thompson et al., 1989). The interview has been found to be a powerful tool for attaining in-depth understanding of another person's experience (Kvale, 1983). Research analysis of interview-derived information is considered valid because respondents' own words are used for understanding their experiences. Accordingly, respondents in this study were presented with a set of open-ended questions designed to encourage them to discuss and describe their experiences in the domain.

This study was approved on by the UMBC/Institution review board. The study approval ID is Y14LZ12112. All the stored data is deidentified. We used inductive method of analysis to discover the main components of the smart home healthcare domain. Kvale's approach (Kvale, 1983) was used for data collection and analysis, which has seven steps: thematizing, designing, interviewing, transcribing, analyzing, verifying, and reporting.

The guidelines were designed before interviews being conducted with the participants. A simple demographics questionnaire was administered after each interview. During each interview, notes and audio were recorded. Upon completion, collected data were analyzed. All the interview discussions were transcribed and processed by the principal researcher and independent researchers. During processing, pronouns and other indexical terms were replaced with their nominal meanings, so that their surrounding concepts would be clear.

Content analysis applying thematic approach (Ritchie & Spencer, 1994) was used to analyze the conversations between the researchers and participants in the semi-structured interviews. Content analysis is the systematic, objective, and quantitative analysis of message characteristics by inductive methods.

RESULTS

Fifteen users were interviewed including both home healthcare patients and health professionals. The later includes physicians, nurses, therapists and social workers. Specifically, we interviewed six patients, and the rest were health professionals with experiences in home healthcare mostly for long-term home healthcare services. Among them, four are males, seven of the participants belonged to the 60+ years old age group, about three-fifth of the participants had a graduate degree. The statistics also show that all the participants used the Internet and the computer several times a day. The diversity of the participants is beneficial for the purpose of this study. Surprisingly, health professionals provided us with feedback not only about themselves, but also about their patients by assuming that the professionals knew what their patients might think.

The qualitative analysis reveals four major components of the smart home healthcare context and explore the interactions between them. Table 3 shows some sample quotes taken from the in-depth interviews for each component. These quotes are evidence bases to support the validity of each component in the framework. The four major artifacts that have been discovered are:

- Person
- Task
- Technology
- Environment

| Component | Sample quotes |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Person | • If the machine sends me (<i>caregiver</i>) information about him (<i>patient</i>), then it will be helpful to me and him. |
| | • It is very efficient when it comes to the <i>medical professional</i> but it might not be as |
| | effective as being present with the <i>patient</i> . |
| | • It is an efficient system for both the <i>physician</i> and the <i>patient</i> . |
| | • Doctors can interact with the patient, but he is also limited from what he can see from the screen and limited by what the patient can say |
| Tack | If it's just monitoring and sending an alart in case If something wrong happen to |
| 1 45K | • If it's just <i>monitoring</i> and <i>senaing an aleri</i> in case it something wrong happen to him, then sure it will be helpful. |
| | • I know some robots used for <i>medicine management</i> and <i>reminding</i> patient to take it |
| | What an awesome opportunity for a clinician to be able to actually <i>look at a patient</i> a <i>hundreds of miles far away</i>. |
| | • A lot of our patients live alone, so it would be nice to be able to <i>check</i> in with them periodically and not have to actually drive down and make an actually face to face visit. |
| | • If it can <i>facilitate communication</i> between the patient and their primary care |
| | physician, thats very important to a homecare company. |
| Technology | <i>Technology</i> can vary from a very simple to a more complex technology. I have <i>a hospital bed type</i> which has sensors to monitor things like your body but it doesn't send messages to anybody. |
| | • It is not that the <i>technology</i> won't be sophisticated, but you will still have someone who will understand what the patient need. |
| | • I will use the <i>technology</i> as an auxiliary mechanism to help with working with the patient on a more regular basis. |
| | • The <i>technology</i> helps you see more patients with fewer providers. |
| Environment | • It will not be really difficult for me to use the emerging technology because I have support from <i>my wife, daughters and doctors.</i> |
| | • We've gone to different <i>areas or states</i> to see how they're using programs that we have |
| | • The <i>infrastructure</i> at my home is very modern |
| | A lot of these homes we go into, the patients are hoarders, the home are unept, and you have to worry about <i>the family members and the dogs and the other animals. And children, grandchildren.</i> |
| | • Healthcare is highly regulated so you're not going to get something into the healthcare system without probably <i>some sort of regulation</i> . |

| Table 1. Sam | ple comments | categorized | according to | the framewor | k component |
|--------------|--------------|-------------|--------------|--------------|-------------|
| | | | | | 1 |

To provide a better understanding of the whole context, it is very important to put all its elements together. Figure 3 shows a high level conceptual framework of the smart home healthcare domain context.



Figure 1. A Conceptual Framework of Smart Home Healthcare Context

As depicted in the framework, people have different characteristics, skills/ abilities, education, experiences, culture and attitudes. As a result, they vary with respect to their cognitive, and physical capabilities with which to interact with tasks and technology. Interactions are represented by the double arrows in the framework. Tasks and technology also have different characteristics. The type of technical and contextual demands placed on people by these tasks and technology vary and are directly related to personal capabilities. The multiple environments in which the person, tasks, and technology reside interact with each other and are represented by overlapping circles in the framework. These environments also have different characteristics and place varying enablers and barriers on a person's successful completion of tasks and use of technology.

DISCUSSION

All the four components of the conceptual framework guide and support further home healthcare research and thus discussed in details in the following sub-sections.

• Person

The roles involved in healthcare in the home include people receiving care, who may care for themselves, and those providing care, who may be professionals (Montgomery et al., 2005). The population of people who receive care is

very diverse and possesses variable skills, knowledge, and experiences. They also differ on a number of other characteristics, such as age, cultural and ethnic backgrounds, education, and living arrangements (Humprey & Milone-Nuzzo, 2009). These individuals have a wide range of personal and health literacy skills, social needs, and economic and social resources. People have different perceptions of the power differential between care recipient and the healthcare system, different cultural views about health and illness, and different language capabilities and preferences. All of these can affect the form and quality of healthcare received from healthcare system and professional caregivers.

The majority of people providing care in the home varies and may include physicians and physician assistants, nurses, nurse practitioners, social workers, physical, occupational and speech therapists, pharmacists, and home health aides (Montgomery et al., 2005). They also differ on a number of characteristics, such as age, cultural and ethnic backgrounds, education, variable skills, resources, knowledge, and experiences (Humprey & Milone-Nuzzo, 2009). The design of the technology component or the specification of the task component is driven by how the person perceives them. Therefore, the different kinds of human factors related to person such as emotional and cognitive factors, resulted from the complex interactions with other components, are worth for further exploration.

• Task

In general, these tasks involved in caring for oneself or others at home may be quite simple, such as taking brisk walks to promote cardiovascular fitness (Annett & Duncan, 1967). At the other extreme, they may be far more complex, such as recovery from major surgery or acclimating to new chronic care regimens (Lewis, 2001). Complex tasks often require nuanced understanding of a health condition and its treatment as well as the ability to manage symptoms, detect complications, provide hands-on care, offer emotional support, and communicate effectively with healthcare providers to participate in decisions and manage logistical aspects of healthcare.

The three common tasks that broadly cover the different activities of home healthcare context are patient-professional communication, remote monitoring and medication administration and management. In the home settings, the patient health status needs to be continuously monitored and the professionals need updated information about these status. Further, in case of emergency, the patients, especially elder patients, need to communicate remotely with the professionals. Although it is possible to accomplish some of these tasks using traditional methods, HIT can potentially make executing these tasks more effectively and efficiently.

• Technology

The devices and technologies for healthcare in the home cover a vast range, from simple first aid tools to respiratory equipment, and from meters and monitors to computer equipment, software associated with interconnected electronic systems to emerging technologies such as robots (Smarr, Fausset, & Rogers, 2010) and sensors (Hao & Foster, 2008). Some of this equipment was designed only for professional use but is finding its way into the home nevertheless (Rialle et al., 2010).

In connecting the technology with task component discussed earlier, the emerging technologies that cover all the tasks are HHR (Wada et al., 2013, Skilligent, 2013) and WSN-HHS (Baker, Armijo, & Belka, 2007, Xuemei, Liangzhong, & Jincheng, 2008). In the home settings, WSN-HHS are used to keep monitoring patient health status and alarm the professional in case of emergency such as patient fall. HHR are used to facilitate the communication between patients and professionals remotely especially for elder people who are unable to visit the hospital repeatedly.

The person interacts with the technology to achieve certain tasks; these interactions are influenced by the technician issues associated with the nature of the technology itself such as security and privacy issues. In addition, given that these technologies are used for different purposes, they vary in terms of several factors such as cost, size, interactivity, and legal and emotional support.

• Environment

The environments of healthcare delivered in the home also have subcategories: physical, social and organizational environments as shown in the framework. With few exceptions, they are not designed for this use and often contain numerous barriers, such as stairs that block a wheelchair user, low lighting that makes device controls difficult to see,

or insufficient electrical supply for power-hungry medical equipment. If the home does not have Internet access, the occupants lack connectivity to enable any type of telehealth activity (e.g., data transfer, remote monitoring, information seeking) (Rialle et al., 2010). Each physical home environment resides within its respective social environment of family, friends, or colleagues, which is affected by the community environments of neighborhood and town and by the health policy environment defined by the presiding health and social service organizations and governmental bodies.

All these above surrounding environmental conditions influence the user's adoption decision making process (Drury, 2010). For instance, if the infrastructure support is not sufficient, then the person has no choice to use the emerging technology. Further, if the governmental policy does not provide a support to the use of emerging technologies due to legal issues, then no need for manufacturers to design them. Therefore, understanding all these environmental issues is the key for success of the technology.

CONCLUSION

This research aims to develop a conceptual framework of smart home healthcare context. The study's data was collected through semi structured interviews with patients and health professionals served for or by home healthcare agencies on the east coast in the United States. Content analysis applying thematic approach was used to analyze the conversations between the researchers and participants. The findings reveal four major components of the framework including person, tasks, technologies, and environments. The findings also revealed us to define the interactions between these components. The findings provide significant implications for smart technology designers and manufacturers, and service providers.

This research has various limitations. The categorization scheme was built based on the existing literature not based on empirical evidences. The framework was developed using qualitative feedback collected from samples located on the east coast of the US, generalizability of findings to other states or cultures isn't guaranteed. Sample size of the research was small. In the future, we plan to include more samples and collect the data from participants resided in different states of the US. Further, we plan to conduct qualitative study to test the validity of the framework.

APPENDIX A

Scenario and storyboard of remote monitoring for fall detection:

"Joan, 75, lives by herself. She suffers from visual impairment in addition to general health problems that come with aging. One day while she was trying to go to the toilet she suddenly fell down. She tried to get to landline phone but could not stand. Fortunately, there was a mobile phone next to her. She called 911 seeking help. She is better now but worried what could have happened if there were no mobile phone next to her. To address this concern, she has purchased a sensor based system for detecting fall automatically. The system consists of a set of sensors embedded in furniture, shelves and walls throughout the home. The system is primarily designed to monitor behavioral changes resulting from sudden fall by detecting motion and heart acceleration. Whenever a fall is detected, the system automatically sends an alert message to the doctor. She is now safe in case of emergency."



1) Joan is trying to go to the toilet



2) Joan suddenly fell down



3) Bed sensors detect Joan falling by recognizing her sudden change in movement



 Also, wall sensor detects
 Joan falling by recognizing her heart rates acceleration



5) An Alert message is sent from the sensors to the doctor desktop at his office



6) Help arrives immediately

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Exploring Cloud Computing Implementation Issues in Healthcare Industry

Sadaf Ashtari College of Technology Eastern Michigan University Ypsilanti, MI 48197 sashtari@emich.edu

Ali Eydgahi College of Technology Eastern Michigan University Ypsilanti, MI 48197 aeydgahi@emich.edu

Huei Lee Department of Computer Information Systems Eastern Michigan University Ypsilanti, MI 48197 Huei.Lee@emich.edu

Abstract: Nowadays, cloud computing—as a flexible, collaborative, cost effective and scalable computational approach—is being applied within different public and private organizations. Furthermore, the use of cloud-based applications is becoming more widespread on both the organizational and individual level than it has been in the past. Healthcare is one discipline that could benefit from cloud-based applications; however, because of various privacy and security issues, it has been adopted more slowly than in many other disciplines. The purpose of this preliminary study is to investigate the related literature in order to explore the cloud computing implementation issues in the healthcare industry. Technological, Organizational, Environmental and Human factors are considered as the most important factors in implementing cloud computing in healthcare. The early framework for implementing cloud applications in healthcare is addressed to administrators and healthcare managers at the end of this study; however, the complementary study will be needed in the future to examine our hypotheses and research questions with collected data.

INTRODUCTION

According to the study from Transparency Market Research (2011), the global cloud computing market in the healthcare industry was valued at 1.82 billion USD in 2011 and is expected to reach 6.79 billion USD by 2018. From this, it is obvious that the health informatics systems trend is towards cloud-based applications; cloud-based medical record is one of the necessary and high demand application, which users such as physicians, nurses and hospital staff should adapt. However, knowing more about the user attitudes, organizational structure, cloud characteristics and environment factors could help healthcare administrators implement cloud-based applications more smoothly and increase their effectiveness.

As a new trend of technology, cloud computing is focus more on applications, information and people and this trend could be extended to serve emerging global demands in digital health care applications (Liu & Park, 2013). There are different effective factors that have an impact on the implementation of cloud computing in the healthcare industry; however, two theories of Tornatzky et al. (1990) Technology-Organization-Environment (TOE) and Yusof et al. (2008) Human-Organization-Technology fit (HOT-fit) is applied in this study to offer the framework for implementing cloud computing technology in the healthcare industry.

Ketikidis et al. (2012) addressed the role of the user in health information technology (HIT). They explained that the reactions of people in dealing with new technologies in health informatics have a huge impact on accepting these technologies. Also, the low acceptance of health information technology (HIT) applications would result in delays in,

or failure of, successful implementation of HIT and/or achieving organizational goals such as effective patient data management and storage.

In order to offer a preliminary framework for implementation of cloud computing in healthcare, we would like to explore the following research questions:

- 1. Which cloud computing model (i.e. SaaS, PaaS, and IaaS) is more suitable for healthcare organizations?
- 2. Is security a concern for using cloud computing by healthcare organizations?
- 3. Is privacy a concern for using cloud computing by healthcare organizations?
- 4. What are the obstacles for using cloud computing by healthcare organizations?

LITERATURE REVIEW ON CLOUD COMPUTING

This section covers cloud computing definition and services, different technology implementation framework and technology, organization, environment, human aspects of cloud computing implementation in the healthcare industry.

Cloud Computing

Cloud computing is a challenging concept in that the technology is still evolving, and there is much disagreement as to how to best define it for study. While the final definition will likely continue to evolve along with the technology, there are some characteristics of cloud computing that seem to be common to most of the literature. The similarities between cloud computing and other types of high performance computing (HPC) such as Cluster computing, Grid computing, Peer-to-peer computing, Service-Oriented Computing and Market-Oriented Computing also add complications to the efforts to create a standardized cloud computing definition and methodology.

The National Institute of Standards and Technology (NIST) defined Cloud Computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell & Grance, 2011). Jing et al. (2013) on the other hand addressed cloud computing as a new operation rather than a new technology. Jing et al. (2013) argued that cloud computing is actually a set of existing technologies that are operating businesses in a different way. Zissis & Lekkas (2012) discussed the convergence of grid computing, utility computing and Software as a Service (SaaS) as a new concept of cloud computing. Furthermore, Belgolazov, Abawajy &Buyya (2012) introduced the design of next generation data centers as an objective for cloud technology application. They argued that by intentionally designing data centers as networks of virtual services (hardware, database, user-interface, application logic), users could gain access to their applications from everywhere. Tebaa, El Hajji & El Ghazi (2012) defined cloud computing as an information technology model for computing and explained that Information Technology components (hardware, software, networking and services) are necessary to deliver cloud services via the Internet or a private network.

Cloud Computing Services

Based on Mell & Grance (2011), cloud computing can be viewed as a triad of service models consisting of Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). The SaaS model of cloud computing involves the cloud provider offering the application to the end user on or through a cloud infrastructure. In this case the consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or data storage. Cloud applications using the SaaS model can either be accessed through a program interface in the way that Dropbox works or directly through a client interface as is the case with web-based email like Gmail.

PaaS model of cloud computing provides the consumer a platform to deploy applications into the wider existing cloud infrastructure. PaaS gives the end user a space to build their own application using shared languages, libraries and services that are either supplied or supported by the cloud platform provider. Examples of this model include Herkou and the Google App Engine.

The IaaS cloud technology model provides the processing, storage, networks, and other fundamental computing resources that allow consumers to deploy and run the software of their choice. This can include programs and

application and can even extend to running operating systems via the cloud infrastructure service. Amazon Web Services and Microsoft Azure are prominent examples of the IaaS providers.

Cloud Computing Deployment Model

Mell & Grance (2011) described four distinct deployment models for cloud technology applications including private cloud, community cloud, public cloud and hybrid cloud. Dillon, Wu & Chang (2010) explained that a private cloud is operated solely within a single organization and that either the organization or a third party could manage the infrastructure. Concerns about security issues are one of the main reasons for choosing a private cloud deployment model in an organization (Dillon, Wu & Chang, 2010). In an academic setting, the ability to build a private cloud to keep proprietary materials secured and to facilitate an online educational community is another advantage of a private cloud deployment.

In community cloud, several organizations jointly use the same cloud infrastructure and a third party or one of the organizations could host the infrastructure. The advantages of a shared cloud include minimizing loss or failure risks by spreading the resources and decreasing costs by utilizing shared scalable resources. At the same time, to be successful, sharing resources requires a higher degree of agreement and cooperation, which can be challenging among higher educational institutions that are each trying to best promote their own needs and may actually be viewed as competitors to one another.

A public cloud is the most common form of cloud deployment with which students, instructors or faculty have experience. In a public cloud deployment, the service provider has full ownership of the infrastructure. Many of the most popular cloud services fit into the public cloud deployment model; these services include Amazon EC2, Amazon S3, Google Drive, and Microsoft One Drive. The final deployment model, hybrid cloud, is a combination of two or more of the other cloud deployment models (private, community, or public) that aims to address the limitation of each approach by combining aspects of each model. As a general rule, hybrid cloud deployments have more flexibility and range of use than either public or private clouds.

Lian, Yen & Wang (2014) explained that healthcare industry is dealing with patient's data and it is so important for healthcare administrators to control the user access to these information and facilitate healthcare services. They addressed that in Private cloud, there are relative less security and privacy concerns than public cloud computing. Because the data will be stored in the hospital or the trusted third company and managed by the hospital staff or an authorized users.

Cloud Computing Adoption

Borgman et al. (2013) mentioned in their paper that the Tata Consultancy Services (TCS) found regional differences in cloud adoption rates. Latin America has the most adoption rate by 40% of using SaaS in the large enterprise. The adoption rate of large enterprise in Asia Pacific is 28%. Surprisingly, large firms in the United States have only shifted 19% of their applications to the cloud and the rate in Europe is near to 12%.

Kuo (2011) mentioned that cloud computing has an effect on healthcare IT implementation. Electronic Health Record (EHR) as one of the most popular IT application in healthcare is affected by cloud computing dramatically. There are some example of cloud computing adoption in different countries all around the world. For example, NEC and Fujitso working on cloud computing solution for hospitals in Japan (Japan-NEC, 2012). Microsoft Europe have been working on the quality of patients' care with cloud computing technologies. Furthermore, they found a way to reduce the costs of pediatric research and treatment center in Italy by applying cloud computing (Lisa, 2011). IBM is another tech company that invest on healthcare cloud computing in the United States to develop a new clinical information management system (Ostrovsky, 2010).

Cloud Computing Benefits

AbuKhousa, Mohamed, & Jaroodi (2012) listed some benefits of cloud-computing application in healthcare, which are giving incentives to the health administrators to adopt cloud computing in their organization. They specifically mentioned the benefits of collecting patients' data in a central collection by applying cloud computing:

- **Patient care:** the staff has access to the patient's record everywhere and at any time. There is a unified patient medical record that let the healthcare providers to view the patient's history in a centralized place.
- **Cost:** using cloud computing create a collaborative economic environment and it is the best solution for the small and medium sized healthcare providers to reduce their costs.
- **Resource scarcity:** applying cloud enables providers to use remote medical services and data in a rural places or anywhere that don't have access to health services.
- **Quality:** healthcare providers will be informed about the quality indicators such as infection rate, lengths of stay, and readiness percentages by using the central cloud services.
- **Research:** the cloud could store the huge amount of patient's data, which can be accessed uniformly and the researcher can conduct their research by using this database. Also, they can find a new research idea from this depository.
- **National security:** by storing lots of information, the news about the infection diseases will be spread very fast. The healthcare providers can monitor the news very fast by this way.

Cloud Computing Risks

Like any other technologies, cloud computing has some benefits and some risks and disadvantages. For having a successful implementation of cloud in the healthcare, the health providers should solve the problems related to the cloud risks. AbuKhousa, Mohamed, & Jaroodi (2012) listed some of the cloud computing risks in healthcare:

- **Data security:** patient's data is the most sensitive assets of the hospital; so accessing these data by unauthorized users is an important risk for the health administrators. According to HIPAA compliance, the unauthorized users should not access the patient's data. Still, more work is needed to enhance the data security and increase the user's trust level.
- Loss of data: lots of work has been done to improve the database management system, but still for reducing the risk of losing data, the healthcare providers should pay more attention to backups and disaster recovery sites.
- **System unavailability:** in the healthcare industry, system unavailability could lead to the irreversible damages. Losing an electronic health services is a major issue in an emergency situation.

RESEARCH CHALLENGES

Adopting cloud computing in industry is not a new paradigm. Cloud computing have been implemented in different organizations and companies and have been started to use from several years ago. However, cloud computing adoption and implementation in healthcare is not similar to other industries. Because of different barriers, cloud computing is not implemented in many hospitals or health institute. Therefore, there are not enough examples or literature review related to implementation of cloud computing in healthcare.

As a preliminary study, we have tried to search and categorize the implementation issues of healthcare cloud from different journal articles and scientific magazine and at the end give some recommendation to healthcare administrators, who want to implement health cloud in their hospitals. The further studies will be needed to examine the hypotheses and research questions, which we found in this study:

- 1. Which cloud computing model (i.e. SaaS, PaaS, and IaaS) is more suitable for healthcare organizations?
- 2. Is security a concern for using cloud computing by healthcare organizations?
- 3. Is privacy a concern for using cloud computing by healthcare organizations?
- 4. What are the obstacles for using cloud computing by healthcare organizations?

Based on the above research questions, we have proposed the following hypotheses:

- H1: There is no difference among three cloud computing for healthcare organizations.
- H2: There is a negative relationship between security concern and adoption of cloud computing in healthcare organizations.
- H3: There is a negative relationship between privacy concern and adoption of cloud computing in healthcare organizations.

Research Framework

For categorizing the cloud computing implementation issues in the healthcare industry, several studies such as Gangwar, Date & Ramasway (2013), Borgman et al. (2013), and Lian, Yen & Wang (2014) have suggested different frameworks for implementation and adoption of cloud computing. These framework included Tornatzky et al. (1990) Technology-Organization-Environment (TOE) and Yusof et al. (2008) Human-Organization-Technology fit (HOT-fit) and Davis (1986) Technology Acceptance Model (TAM). Lian, Yen & Wang (2014) addressed that TOE is a good framework to determine the critical factors in IT adoption in any organization. On the other hand, the main focus of HOT-fit framework is on healthcare information system adoption in hospital. Therefore, this study summarized both frameworks to explore the effective factors in implementing cloud computing in the healthcare industry. Lian, Yen & Wang (2014) mentioned that TOE framework is not designed for adoption of technology in the healthcare but it is useful to understand the IS adoption in the health industry. Furthermore, the HOT-fit framework is developed specifically for the adoption of information technology in the healthcare. So, the combination of these two frameworks could cover most of the factors that has an impact on the implementation of cloud computing in the healthcare. Based on these frameworks, the impact of technological, organizational, environmental and human factors on the adoption and implementation of cloud computing in the next section.

Technological Issues

Lian, Yen & Wang (2014) explained that he technology issues have some internal and external effects on the adoption of cloud in the healthcare. Some of these issues related to the nature of cloud computing as a technology. The privacy and security issues are very important, when we are talking about cloud. Actually, the major barrier of adopting and implementing cloud in the healthcare is the privacy and security issue that still is not desirable for health providers to adopt cloud in their organization. Establishing a secure environment for sharing and integrating patient's data is challenging and needs more work to solve the problems.

Complexity and compatibility are two other elements of technology that have an impact on adopting and implementing cloud in the industry (Borgman et al. 2013). Installing cloud applications and equipment in health industry is complex when it combines with health equipment. Based on Lian, Yen & Wang (2014) study, in terms of compatibility, it should be checked that how much cloud applications and infrastructure is compatible with the existing IT systems in the hospitals.

Like any other investment, technology cost is another issue that should be addressed in terms of having a successful implementation of healthcare cloud. Cloud implementation needs different investment in hardware, software, and system integration (Lian, Yen & Wang, 2014). Therefore, the health administrator should think about it before starting to migrate to cloud.

Organizational Issues

The organizational factors have a huge impact on the successful implementation of healthcare cloud. Based on Borgman et al. (2013), the size of organization is one of the challenging issues that could facilitate the adoption of cloud. Large organization should invest more and take a bigger risk of failure for implementing healthcare cloud. The small and med-size firms are more dynamic and could adjust with cloud configuration faster and easier. Also, they don't need to spend a lot on the implementation.

Borgman et al. (2013) referred to the top management support as one of the important element in the organization aspect of cloud implementation. Without top management support, the success rate of cloud implementation in healthcare would be very low. Cloud computing will effect on budgets, processes, and responsibilities, so the administrator support will be needed for this transformation. Top managers are responsible for allocating adequate resources to support cloud implementation.

Borgman et al. (2013) addressed that cloud/IT skills of non-IT employees have an impact on adopting cloud. If the organization has enough IT/cloud skill employees, it has a better chance to implement cloud more successfully. The employee with IT knowledge could help in migrating to healthcare cloud more easily.

Environmental Issues

The environmental issues are related to "in which a firm conducts its business - its industry, competitors, access to resources supplied by others and dealing with government" (Tornatzky et al., 1990). Based on Borgman et al. (2013), competition intensity and regulatory constraints are the two important factors in the environmental aspect. There is a competition between hospitals now. Some smaller hospitals are migrating to information technology services and systems and this will force other hospitals to adopt new information systems more quickly.

Abukhousa, Mohamed, & Al-Jaroodi (2012), addressed that the regulatory constraints mostly related to the privacy and security of the patient's data. It is essential for organizations to verify that the underlying cloud infrastructure is secure. Proving that the physical and virtual infrastructure of the cloud can be trusted and becomes even more difficult when those infrastructure components are wholly owned and managed by external service providers. The Health Insurance Portability and Accountability Act (HIPAA) requires the health data be processed in certain prescribed means. HIPAA asked health provider to ensure that the privileged user access is controlled and monitored. However, it is difficult to demonstrate that the cloud infrastructures are secure and tested for HIPAA compliance.

Human Issues

Focusing on the human aspects of cloud implementation in the healthcare is very important, because at the end the users such as patients, healthcare professionals, administrators and insurance personnel should accept and be able to work with cloud applications. Different users have different behaviors and attitudes. However, most of them have a resistance against the new technology. The professional training session is a necessity before cloud implementation in the healthcare. The users should be evaluated based on their information technology literacy. Some users have a narrow knowledge of technology and others have a better IT skill, so the administrators should pay attention to this issue.

FUTURE STUDY

After reviewing around fifty articles, we could say that there is a gap in the literature review of cloud computing implementation in healthcare. There are different types of literatures, which are close to this topic. Some of them are related to the adoption of cloud computing in various industries and some others are about the implementation of Information Technology in healthcare. Although these two area are very close to our research but still there are some differences in the implementation of IT versus cloud in healthcare, because of the nature of cloud computing technology. The privacy and security issue is one of the most important barriers for implementing cloud applications in the healthcare industry, which was not that serious in implementing other technologies. As a result, we could not find any large-size hospitals around the nation that implemented cloud computing in their hospitals. We interviewed with three hospital staff in the state of Michigan and found that by the federal law (regulation like HIPAA) and their own policy, they are not allowed to use any kind of cloud applications for storing patients' data. The HIPAA compliance in the United of States enacts strict regulations for accessing the patient's data and the cloud providers are reluctant to sign a contract with healthcare provider, because the law and regulations are so rigid. As a future study, we want to benchmark the cloud computing implementation and adoption in the healthcare industry in different countries in Europe and Asia versus United State. It seems that US among other progressed countries has a much more strict law and regulations in this field. There are 241 healthcare facilities in the state of Michigan based on the statistics of Health Resources and Services Administration. For the further investigation, we want to select 40 of them randomly and explore if they are using any kind of cloud computing technologies in their work.

RECOMMENDATION

Based on this study the top management support is a necessity for implementing healthcare cloud. Top managers should allocate appropriate resources and support the process transformation in the organization. Training the staff is an important task that the managers should consider. Without the professional training the users could not be able to work with cloud applications and during the time, this could be frustrating for them and they may give up using it. Users per se have resistance against the new technology; however if they have been trained well, it has a good impact

on their perceptions and it may reduce their resistance. Users should learn that the new technology will help them to do their task easier, faster and with less energy consuming.

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Patient Handoffs: A Review of Current Status in the USA

Farzad Rafi Razi Kalamazoo College Farzad.Razi15@kzoo.edu

Abstract: The goal of this paper is to highlight the status of patient handoffs in the United States. A summary of what patient handoffs are, and the current processes through which handoffs are carried out will be described, as well as the benefits and limitations of each approach. In addition, this project will describe some major flaws in the handoff system, and suggestions to how they may be remedied. This paper will conclude by mentioning a new system which has reduced handoff errors, and propose an extension to this research in order to instigate further developments.

INTRODUCTION

The world of healthcare is a highly complex and constantly evolving field. In conjunction with technological advances that society has made, the state of medicine around the world has reached immense heights. This expanding domain forces physicians and individuals working with them to adapt in order to make patient care safer and more comprehensive than ever before. For example, hospitals and private practices throughout the nation have started to convert PMR (Paper Medical Records) into EMR (Electronic Medical Records) in order to increase the efficiency with which different centers can transfer patient information. In regards to technology and surgery, there are cases nowadays where a surgeon does not need to be in the operating room with his patient. Instead, he is able to manipulate a robot to help him carry out the procedure.

In accordance with the examples above, it is easy to perceive how technology has touched many parts of medicine for the better. However, one aspect of healthcare in which technology has not readily been implemented is during the patient handoff process. Patient handoffs, which encompass the transfer of a patient from one facility, or one person to another, are a critical part of treatment. The slightest error during this proceeding could mean serious injury or even death for a patient.

Although research has not conclusively proven whether technological improvements or a restructured oral/written procedure will lead to safer patient handoffs, it is safe to assume that the current state of handoffs has gaping holes. An investigation by the Minnesota Medical Association states, "We found errors were common in resident handoff sheets. Only 83 (19%) of 428 handoff sheets contained no errors" (Aylward 2011). As surprising as it is, such staggering figures are actually common in hospitals throughout the nation, and the handoff process needs to be revamped to ensure patient safety.

This paper will focus on an overview of the current state of patient handoffs. The roles of both paper-based handoffs and electronic handoffs will be evaluated, as well as a few incoming/outgoing correspondence procedures that clinical professionals use to transfer patient information. A summary of HIT's potential in improving the handoff process in order to reduce medical errors will also be provided. This review will conclude by addressing a few key issues that will make IT-based handoffs effective in improving healthcare services.

Current Status of Patient Handoffs in the USA

An essential part of healthcare, the patient handoff system is commonly used when caring for patients. Due to its large role in establishing a set of rules for care providers to follow when transferring patient information, even minor errors committed while using these guidelines could results in major consequences. Given the importance of patient handoffs, it would seem as though medical schools would strive hard to make sure its students could navigate this mechanism with ease. However, an article by the American Congress of Obstetricians and Gynecologists states, "Accurate communication of information about a patient from one member of the health care team to another is a critical element of patient care and safety; it is also one of the least studied and taught elements of daily patient care"

(ACOG 2012). This of course, poses a huge problem because a majority of the habits that physicians pick up come from the schools at which they studied. Improving technological or oral aspects of the handoff system without taking care of the heart of the issue will not better it by much. Medical schools around the world need to focus more energy on teaching their students the ins and outs of patient handoffs so that other advancements in this area may have more of a positive impact.

There are two types of patient handoffs that exist in healthcare today, specifically written/ oral, and computer-based handoffs. Written handoffs are commonly used in hospitals today (ACOG 2012), and employ the use of paper when transferring patient information from one care provider to the next. The transmission of information orally is used in conjunction with written handoffs, because the two must be used concurrently in order to reduce handoff errors and also serve two very different purposes. While written handoffs provide detailed information that serve as a reference for the receiving provider, oral handoffs supplement that allowing for discussion and cross-checking to make sure the receiving provider understood the information may be relayed over a hospital network. Although this method eliminates the need for paper and allows for increased efficiency, a network that regulates patient handoffs between two hospitals with different EMR systems is incredibly difficult to implement because it requires individuals with unique skillsets to maintain.

Taking a look at the kinds of handoff errors that occur in hospitals, one will quickly come to realize that there is no shortage of these mistakes. In order to get an idea of how frequently healthcare workers omit crucial information when transferring patients and how big of an impact could occur, an analogy may be drawn to the children's game "Telephone" (Lane-Fall 2014). The objective of the game is to verbally pass a message around in a circle. Of course, as this speech travels from person to person, it changes a little bit each time. At the end however, the final result in most cases is nowhere near the initial phrase. Similarly, as a patient goes from one care provider to the next, there may be minor omissions of his information. If the patient's handoff chain is not very long, then the chances are that no injury will come to him. On the other hand, if multiple physicians must see the same patient, then the risk of harm or even death is much greater.

Challenging Issues in the Handoff Process

One of the main issues that the handoff process faces resides in physician-to-physician communication. Key information may be misinterpreted or entirely absent if there is a language barrier between two patients. "International medical graduates constitute 25.3% of all physicians in the US" (Datta and Miller 2012), and although doctors speak a universal medical language, a difference in native language can be detrimental to the patient handoff process. However, the use of translators could remedy this issue.

The medium of communication and time consumption are also two important barriers in the handoff process. Oral handoffs may be beneficial, in the sense that physicians may associate facial features and tone of voice with how a patient should be dealt with. Errors may easily be reduced when a doctor's intentions are made clear to his colleague. However, the use of e-mail or telephone eliminates facial features and voice altogether. Nonetheless, electronic handoffs are preferred when time is a limited resource. In order to dissolve this barrier, it is important that researchers find common ground between handoff efficiency, and a safe method of communication between physicians.

Another issue with the handoff process is discontinuity; the fact that different providers care for a patient around the clock, because of how impossible it would be for one individual to work twenty four hours a day. The Patient Safety Network states that "Nurses change shift every 8 to 12 hours…" (PSNet 2014), so it's commonplace for one patient to see two to three different nurses every day. This of course, causes the "telephone effect", where information may be lost during an oral transfer. The likelihood of miscommunication increases as the length of a "telephone line" increases.

Individuals may offer a quick fix for this problem: simply increase the number of hours a provider has to work and adjust their pay to reflect this increase. The length of the "telephone line" should substantially decrease, resulting in fewer handoff errors. Since many physicians work "...28 hours in one shift..." (Schultz 2012), it would not be

unreasonable to ask others in the healthcare system to put in some extra effort. A response to this argument may be supplied in the graphic shown below.



Figure 1. A bar graph that shows the relationship between the length of a nurse's shift, and the number of errors that either occurred, or almost occurred. Taken from PSNet, 2014. Web.

This graph shows that merely increasing the amount of hours a nurse works will not solve the problem, because the number of errors that are made increase with an increasing shift length. In order to combat this problem, experts in this field must find a reasonable balance in shift length and cut down "telephone line" range at the same time.

Given the problems above, let's calculate about how many patients are affected by poor patient handoffs every year as a result of these barriers. An article by Kim K. Wheeler states that, "In a typical teaching hospital, there are an estimated 4,000 patient handoffs every day..." (Wheeler 2015). The research conducted by Dr. Aylward, referenced in the introduction, found that 81% of 428 handoff sheets compiled in a Minneapolis internal residency program contained errors in them. Since this is quite a large sample size, we can expand this data and assume that an error rate close to 81% is common in hospitals around the country for our purposes. If this is true, then a staggering 3,240 patients are endangered in an American hospital every day because their health records are error-laden. Every year, each hospital in the United States has 1,180,170 individuals walk through its doors that face this same risk. Fortunately, for many, these faults will never come to light, but the lives of the unlucky few could change drastically. Unsurprisingly, the Boston Children's Hospital reports that, "Medical errors are a leading cause of injury and death in America, and an estimated 80 percent of serious medical errors involve some sort of miscommunication, particularly during the transfer of care from one provider to the next" (Underwood 2013).

To get an idea of how unhappy the global population is with the medical system, which is directly influenced by patient handoffs, it's essential that we analyze a graphic published by the Commonwealth Fund.



Figure 2. A graph showing how individuals in different countries view the health care system in their respective nations. Overall Views of the Health Care System, 2013, from Commonwealth Fund, 2013. Web.

This graph shows that many citizens of those respective nations feel that there should be some degree of change in their country's health care system, possible due to a high incidence of medical errors in each nation. As a result of these unacceptable errors, researchers are working meticulously to bring the rates of patient handoff errors down. We will take a look an outcome of their research in the next section and discuss how it has improved the patient handoff process.

HIT-enabled Patient Handoff System

A team of researchers from the Boston Children's Hospital, clearly unimpressed with the handoff system set their sights on reducing errors that came through this process and came up with the mnemonic I-PASS to help care providers remember the kind of information they must pass on when handing off a patient.

| BETTER HANDOFFS. SAFER CARE. | | | | | | | |
|------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|--|--|
| Ι | Illness Severity | • Stable, "watcher," unstable | | | | | |
| Р | Patient Summary | Summary statement Events leading up to admission Hospital course Ongoing assessment Plan | | | | | |
| A | Action List | To do list Time line and ownership | | | | | |
| S | Situation Awareness and Contingency Planning | Know what's going on Plan for what might happen | | | | | |
| S | Synthesis by Receiver | Receiver summarizes what was heard Asks questions Restates key action/to do items | | | | | |

Figure 3. A Detailed Breakdown of the I-PASS Mnemonic, from Pediatrics, Official Journal of the American Academy of Pediatrics, 2012. Web.

According to their results, I-PASS was a tremendous success. The Children's Hospital states that there was a "40 percent reduction in medical errors after implementation, doctors spent more time with patients, and handoffs were twice as likely to occur in a private or quiet location" (Boston Children's Hospital 2012). I-PASS has now been implemented in ten different pediatric training programs across North America for further testing. An HIT-based tool such as I-PASS comes with its own set of pros and cons, however. Hospitals may not want to revamp their entire system, as they may state that their current policy is "good enough". In order to implement an entirely new process, every physician in the institution must be willing to learn it, and quite frankly, many of them just don't have the time to do so. However, research shows that the patient handoff system has major flaws, and a pro of implementation is that errors will most likely be reduced, resulting in fewer patient deaths. When taking this into account, the pros far outweigh the cons.

Although significant improvements had already been made to the written handoff process, the use of computers to aid handoffs hadn't been explored in depth until recently. A team of physicians led by Dr. David K. Vawdrey implemented an electronic patient handoff application in two academic medical centers in order to assess the future of technology in the handoff process. Dr. Vawdrey's team didn't compare the number of handoff errors that occurred before and after the implementation of the electronic handoff application, but they did perceive a rise in the number of nurses that were willing to use this method instead of the written approach. According to his results, electronic handoffs were adopted because of the "time savings experienced by users…" (Vawdrey 2013).

CONCLUSION

The patient handoff system is widely used and a critical aspect of the medical field. However, there are major flaws in this system that can have a detrimental effect on the health of a patient, even leading up to medical malpractice. This problem has developed roots in the very manner in which medical students are taught. Studies show that patient handoffs are the least studied and taught subjects in medical school. In order for change to occur in this field, physicians must learn the ins and outs of this process.

Physician-to-physician communication also contains problems that must be addressed. Barriers such as that of native language play a big role in missing information during a handoff. Since one-fourth of all U.S. medical students are

international, this issue may need to be addressed by hiring translators. In addition, the modes with which physicians hand off patients also need to be scrutinized. Transferring patients to another doctor in person may take more time, but also minimizes the chance of errors that could occur over the phone or via e-mail.

Healthcare providers must be taken care of themselves if they are expected to administer quality service to their patients. This means that the length of each shift cannot be extensive, because research shows that an increased shift length is proportional to the number of errors ensue. However, shorter shifts lead to more nurses that take care of one patient, which could develop in the "telephone effect". To remedy this problem, researchers must be able to find a suitable compromise.

Since studies have determined that a modified written handoff approach, such as I-PASS can be implemented to reduce the amount of handoff errors in hospitals, we must take it upon ourselves to develop similar systems in hospitals around the country for further testing. As an extension to this paper, it would be interesting to perform a case study at a local hospital, such as Borgess or Bronson, on the handoff procedures implemented there. First, data would be gathered on the number of handoff errors, and what aspects of the current system are causing these mistakes. The researchers would then develop a new strategy with the aim of reducing blunders.

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Socio-economic Dimension of Indoor Radon Gas in West Michigan - A Public Health Discourse and Merit to Use HIT in Shaping Health Behavior

Azizur R. Molla Department of Public Health, College of Health Professions Grand Valley State University 301 Michigan Street, NE, Grand Rapids, MI 49503 mollaziz@gysu.edu; Phone 616-331-8934

Abstract: This study focuses on indoor radon levels and socioeconomic data from West Michigan, MI. It was designed to: i) analyze the relationship between indoor radon levels and socioeconomic status of the participating households, and ii) assess the degree of public awareness about the danger of indoor radon gas. The study participants expressed that they knew that radon was negative, and a health risk, but were not equipped with the knowledge to test for or mitigate radon. With nearly half of the participants affected in some way by cancer, radon is a concern and a source for worry among many citizens. Health information technology (HIT) will be an effective tool to shape people's health behavior along with accelerating awareness about radon gas, its health risks, and measures to mitigate unsafe radon level.

INTRODUCTION

Radon is an odorless, tasteless, invisible carcinogenic radioactive gas that is affecting the health of homeowners across the country. Radon is the second leading cause of lung cancer in America and claims about 20,000 lives annually" (www.epa.gov/radon). Despite this, radon is a threat that receives relatively little attention by American society. Despite some efforts by the government and EPA to advertise radon testing and mitigation, many people are unaware of radon and how to test for it. Thousands of homes across the country today potentially have dangerous, carcinogenic levels of radon that is un-mitigated. The threat is not so much the high levels of radon, but the lack of awareness and resources to fix the problem in homes. Radon is a correctable problem, but few households have testing and mitigation systems. This research project aims to obtain data on radon levels of the selected areas and the public's awareness of radon in order to understand what people know, and also what they don't know. This will help us to understand how programs can be improved and created to increase radon awareness. The World Health Organization (WHO), published WHO Handbook on Indoor Radon, "the book focuses on residential radon exposure from a public health point of view and provides detailed recommendations on reducing health risks from radon and sound policy options for preventing and mitigating radon exposure. The material in the "Handbook" reflects the epidemiological evidence that indoor radon exposure is responsible for a substantial number of lung cancers in the general population." (WHO, 2009). A community based sustainable intervention supported by HIT will reduce radon risks and ensure better health.

PREVIOUS STUDIES

Many Americans are aware of the dangers of cigarette smoke inhalation, but they are unaware that radon gas is a naturally occurring cancer-causing element that kills thousands annually. According to the Environmental Protection Agency's website, "Radon is a cancer-causing natural radioactive gas that you can't see, smell or taste... Radon is the leading cause of lung cancer among non-smokers. Radon is the second leading cause of lung cancer in America and claims about 20,000 lives annually" (www.epa.gov/radon). This pollutant affects individuals of all socioeconomic levels. According to one study, radon "is responsible for about 2% of all deaths from cancer in Europe" (Darby et al., 2004). Radon causes thousands of deaths every year which could easily be prevented, but the majority of the public does not understand the risks of radon.

Radon is a gas that we cannot see or smell. "Radon is a noble and inert gas resulting from the decay of naturally occurring uranium-238" (Samet and Eradze, 2000). Although it is a daughter element of uranium, radon does

contain all of the same characteristics of the uranium decay chain. However, unlike other components of the uranium chain, radon is able to seep through the soil and contaminate earth and water alike. "It is unlike all other members of the uranium decay chain which...are bound as mineral compounds in the soil, and tend to stay put" (Ginevan, 1988). Since radon is not restricted to being present solely in the soil, it can penetrate air pockets present in the ground level or basement level of buildings.

Because of the propinquity to the source of the radon, these levels are often the ones which contain the highest levels of radon within a household. All of the research that has been done on radon agrees that radon levels are more highly concentrated on the ground floor or below. "In homes, the principal source is soil gas, which penetrates through cracks or sumps in basements or around a concrete slab" (Samet and Eradze, 2000). Radon can also become present in the groundwater because of its concentration in the soil. "Water is a secondary source [of radon gas] which can be significant when water requirements are met from radon-contaminated private water supplies" (Teichman, 1988). It is important to test the amount of radon present. Radon occurs in groundwater naturally as it does in the soil. The existence of radon in either substance does not indicate human interference.

Because radon is a radioactive gas which occurs naturally, humans do not cause its presence within the environment. As was mentioned, radon is a daughter element of uranium, which means that it contains some but not all of the characteristics of uranium. Uranium concentrates in small spaces which accordingly fill with gas faster than larger spaces. Radon concentrates in some areas more than others because of this. "Whenever rock is heated in the presence of fluids, uranium has a tendency to move with the fluid... [until] it stops and becomes concentrated. The end result across the geologically varied U.S. landscape is widely varying concentrations of uranium in [rocks and sediments] that the rock generates" (Kerr, 1988). The variety of radon and amounts present changes from location to location because of this fluidity as well as other factors, such as the incidence of phosphates.

Areas which have phosphate deposits have been found to have a positive correlation between the presence of phosphates and radon gas. This relationship between radon and phosphates has been shown in Israel where radon testing was done at a Jerusalem school. According to the evidence provided by the researchers who worked in this school, phosphate deposits "are a recognized source for radon gas and its daughter products" (Richter et al., 1997). This school had multiple subterranean levels, which increased the amount of radon gas present in the building because of radon's status as an inert gas. The lowest levels of the school also contained the highest levels of radon, as would be expected. The existence of radon inside buildings is not news to scientists. In fact, "Radon was found to be present in indoor air as early as the 1950s, but potential health implications received little notice until several decades later" (Samet and Eradze, 2000).

A male member of the janitorial staff and a female faculty member in the Jerusalem school contracted cancer after spending a decade and a half working in the subterranean levels. These individuals eventually died from breast cancer and myeloma, forcing the school to test radon levels. What the researchers discovered was in line with the understanding of radon's operation as an inert gas. "Radon concentrations were generally higher in rooms in the four levels of the building that were below ground level" (Richter et al., 1997). The radon testing yielded high amounts of radon, 1000 to 15,000 Bq/m^3, resulting in the temporary closure of the school.

Despite the results of these individuals, officials declared that "no valid conclusions can be drawn from this observed relationship between the high basement exposures of these two individuals and their tumors" (Richter et al., 1997). Radon only affects the respiratory system. If both of the individuals had developed lung cancer, then the school would have been held accountable for their deaths through excessive radon exposure. However, it has not been shown that radon causes cancers other than lung cancer because exposure comes from inhalation, directly affecting only the lungs.

Radon is inhaled, meaning that the damage is concentrated in the respiratory system. "Inhaling radon, or more accurately its decay products or 'progeny,' can expose lung tissue to significant doses of ionizing radiation, which may in turn cause lung cancer, a usually fatal disease" (Ginevan, 1988). Because radon obtains its entrance through the respiratory system, individuals who participate in high stress conditions such as jobs performing manual labor will breathe in more radon particles than individuals at rest. This puts miners especially at risk for radon exposure due to their occupation within the earth in a physically active profession.

Many studies have been done to assess the amount of radon miners encounter in their career. It is not only the close proximity to radon-infused soil on all sides of them which erodes the quality of their work environment but also, "the decay products are all metal ions, and as such, they tend to 'stick' to dust particles. A mine is a rather dusty place, so most radon progeny are 'stuck' or attached to dust particles. Small particles are much easier to inhale than large particles" (Ginevan, 1988). This means that not only are they surrounded by radon-containing soil and breathing heavily because of physically exerting themselves, but they are also inhaling more radon because it is easier to inhale in a dusty environment.

The miners are at high risk for radon inhalation without a means to mitigate the problem, but it is possible to mitigate the amount of radon present in a household. "At present the 'active level' recommended by the United States Environmental Protection Agency is 0.02 working levels (a unit of radon progeny exposure rate). Essentially if your house is at or above this level, EPA suggests that you should take action to reduce it" (Ginevan, 1988). If the house tests below the active level, no mitigation is necessary. It is important to note that although radon levels can be reduced drastically, it is not possible to completely remove all traces of radon within a building.

A simple way to reduce the multiplicative effect of radon is to diminish the amount of cigarette smoke in the home. The combination of radon and cigarette smoke on an individual's lungs is much worse than if the individual were being exposed to only one pollutant. A large portion of sample groups used for radon research comes from a community of smokers or former smokers. Research has been done to compare the risks of radon exposure taken from separate studies in different areas of the world, New Jersey, Stockholm, and Shenyang (China). The result of the study allows the possibility that "there was a suggestive positive relationship between radon exposure and lung cancer risk among former smokers" (Lubin et al., 1994).

Several studies have been performed on the interaction between radon and cigarette smoke. One studied concluded that "cigarette smokers have very much higher risks than nonsmokers for a given level of radon progeny exposure" (Ginevan, 1988). By ceasing to smoke cigarettes, the probable risk of contracting lung cancer decreases significantly, even for individuals who are regularly exposed to radon. "If the 40-year-old male continues smoking and exposure to 296 Bq/m^3 (8 pCi/L) of radon indefinitely, his lifetime risk of lung cancer is 23.5%. He can reduce this risk to 19.2% by eliminating radon exposure, but he can reduce it to 4.9% by ceasing to smoke even with continuing exposure to radon" (Ennever, 1990). The increase in lung cancer probability can be assumed to be related to radon exposure and cigarette smoke.

Radon gas and cigarette smoke interact multiplicatively rather than additionally. Accordingly, the resulting effects are increased. "48% of males are smokers with 12 times the lung cancer rate of male nonsmokers, and 36% of females are smokers with 10 times the lung cancer rate of female nonsmokers" (Ennever, 1990). However, Ennever does mention that quitting the habit can drastically reduce the probability of lung cancer regardless of continued exposure to radon gas. It must be noted that a non-smoker will still have less of a chance of contracting lung cancer than a former smoker.

The causes of lung cancer cannot be simplified to only include amount of exposure to radon and cigarette smoke. The majority of studies which have been done to examine the relationship between these two factors have not included many non-smoking individuals. As a result "there remains a paucity of subjects who are not current or former smokers" (Upfal et al., 1995). Because of this, it is an obligation of the researchers performing studies on radon gas to include nonsmokers in their population to balance the results.

Individuals should realize that radon exists atmospherically outside of buildings, mines, and other structures. The level of atmospheric radon present varies, as was discussed in conjunction with phosphate deposits. Measurements have been taken to determine the average amount of atmospheric radon. "The worldwide, population-averaged radon concentration is estimated to be 10 Bq/m^3 (0.3 pCi/l) outdoors and 40 Bq/m^3 (1.1 pCi/l) indoors. In the United States, these averages are estimated to be 15 Bq/m^3 (0.4 pCi/l) outdoors and 54 Bq/m^3 (1.5 pCi/l) indoors" (Steck et al., 1999). The world averages are slightly lower than the averages in the United States, but this variability has to do with landscape rather than culture.

Radon mitigation systems are available to view on the EPA's website. In general, these treatments are rather inexpensive household renovations. According to the EPA, "The cost of a contractor fixing a home generally ranges from \$800 to \$2,500, depending on the characteristics of the house and choice of radon reduction methods. The

average cost of a radon reduction system is about \$1,200" (<u>www.epa.gov/radon</u>). One method is to simply provide a ventilation pipe to the outside, while another method is to literally suck the air out of the room via a fan system. It is recommended that houses should be well-insulated. However, "it cannot be generalized that tight (i.e. low infiltration rate) energy efficient households will have high indoor radon levels and loose, less energy-efficient houses will not" (Teichman, 1988).

An additional but more costly alternative to self-improvement is to consult a radon contractor who has experience in modifying buildings to diminish structural faults which allow radon pockets to develop. The EPA is very instructive in how to consult a radon contractor as well as detailing what elements should be present in a contract between the parties involved. These guidelines are helpful for individuals who are unsure how best to mitigate the amount of radon present in their household. Radon contractors are often good to consult because they understand which types of houses need which mitigation system.

For house structures, there are three main types which builders use to determine the mitigation treatment. These structures are: houses with a basement, houses with a crawlspace, and "slab-on-grade" homes. Slab-on-grade refers to houses which rest on a layer of concrete between the floor and the dirt, rather than on top of a basement or crawlspace structure. Additionally, some houses have a basement/crawlspace combination, such as a house with a basement that also has a crawlspace under the front porch. Regardless, the mitigation system is tailored to fit the house's structural context.

The most efficient way to reduce radon's intrusion into the house is to use a ventilation fan to circulate it back outside. "Soil gases do not simply diffuse into a house, the house literally sucks them in...The suction effect is driven by air pumped outside by clothes dryers, fireplaces, or furnaces, as well as by wind blowing around the house and...warmer air rising through the house and out through openings in the top" (Kerr, 1988).

In the previously mentioned case of the Jerusalem school, an elaborate mitigation system was put into place. "A step-by-step program of local venting of underground air pockets in rock was introduced to control and eventually eliminate high levels" (Richter et al., 1997). Unfortunately, this system is a poor choice because slight earthquakes could open new pockets for radon. "Later spikes in the below-ground levels above E-4 suggest that radon gas entered other parts of the building from pockets of gas in high concentrations disturbed somewhere inside the underlying rock...The gases remained in the soil only to penetrate the building along new paths" (Richter et al., 1997).

OBJECTIVES

Radon is problematic in two ways: that it can be present in homes at dangerous levels, and many people do not know about it or understand the health risk. This study aim to understand people's awareness about radon and its health risk. It also aim to explore how radon knowledge is associated with socioeconomic factors of the residents.

METHODS

The author also along with Grand Valley State University students sent out fliers in the surrounding communities of Holland and Grand Rapids, Michigan. In addition several talks have been given at Housing Association offices, Churches, and Heath Fair.

Each student researcher was provided surveys complete with informed consent forms, surveys for the participants, a flier on the radon study itself, and a radon report card. In addition each of them was also provided with three digital radon-testing devices. The device was installed at the basement or belowground closed room. The households ensured that the room is closed 12 hours before the device is set for the test. The test was left to run for forty-eight hours. At the completion of the forty-eight hours, the researcher would again return to the participant's home, record the radon level of the home, inform the participants and obtain signatures on both the survey and the radon report card. The radon report card was given to the household for their record. All surveys were assigned a de-identification number and all information was kept strictly confidential.

Surveys were then reviewed, and data was analyzed using both statistical analysis and qualitative analysis. The data were analyzed using simple statistics. In this particular research, factors such as age of the participant's home, participant's education level and annual household income, and awareness about radon were examined and analyzed to understand any patterns that may exist in relation to radon levels and radon testing. These responses were compared, analyzed and compiled to answer questions about radon awareness in the area and attitudes towards radon and radon testing.

RESULTS

The sample consists of 290 households in the Grand Rapids area, 40% males and 60% females being interviewed. The educational levels are as follows: 14% have no college education, 39% have some college, 27% have obtained a four year college degree and no more education, and 20% have a graduate school degree. The type of employments are: 20% are in business, 28% in education (teacher or student), 8% are in administrative or government positions, 10 are retired, and 35% are in other types of employment. The percentage of interviewees that are White/Caucasian is 91%, 2% are Black/African-American, 6% are Asian, and the other 1% are other nationalities. The percentage of interviewees that are currently married is 59%, with 52% of the houses currently having children in the house. The mean age is 42.57 with a standard deviation of 15.71. The percentage of houses that are owned is 76%. For income, 18% were below \$20,000, 16% had incomes between \$20,000 and \$47,000 and the other 63% had incomes over \$47,000 (out of 279 that responded). The mean number of years living in the house is 11.21 with a standard deviation of 12.05 years.

When asked "Do you know what radon gas is?" 68% answered *yes* and 32% said *no*. In addition, 58% of the households had a family member that has died of cancer and 27% have a family member that smokes. Of the households sampled, 93% have health insurances while 7% do not. Whenever the house had a basement (90%), the radon gas level was recorded in the basement; otherwise, the level was recorded in the living room (10%). The radon level in the air had a mean of 2.437 with a standard deviation of 2.20. Fifteen percent of these reading were over the EPA suggested value of 4.0. The largest value recorded was 21.9 while two houses had the minimum radon gas level of 0.0. A histogram of the radon gas levels is given in Graph 1. The radon gas levels have a skewed right distribution with a number of large outliers.



Figure 1. Histogram of Radon Gas Levels

Are there differences in radon gas levels due to demographics or the knowledge about radon gas of the interviewee? Due to the shape of the distribution and the outliers present, parametric tests that assume normality cannot be used in order to run statistical tests to answer this research question. As a result, Spearman's Rho correlation will be used

when comparing radon gas levels in the air with quantitative variables, the Mann-Whitney U-test will be used for categorical independent variables with 2 levels and the Kruskal-Wallis test will be used when categorical independent variables have 3 or more levels.

Spearman's Rho was found to measure the strength of the relationship between the radon gas level in the air and each of the three numerical demographic variables (age, years living in the house, and the number of children living in the house). There is a significant positive relationship between each pair of variables except for *radon gas* with *the number of children living in the house* (r = 0.051, p = 0.408); however, the only significant pair that doesn't have an extremely weak relationship is *age* and the *number of years living in the house* (r = 0.717, p < 0.001). Age is moderately related to the number of years the person has been living in the house. The correlation coefficients and p-values are summarized in Table 1. If the test is considered significant at the 0.05 level, an asterisk is given beside the p-value.

| Variables | Correlation | p-value |
|-------------------------------------|------------------|---------|
| | Coefficent | - |
| Radon gas and Age | r = 0.197 | 0.001* |
| Radon gas and Years living in house | r = 0.142 | 0.017* |
| Radon gas and Number of children | r = 0.051 | 0.408 |
| Age and Years living in house | <i>r</i> = 0.717 | <0.001* |
| Age and Number of children | <i>r</i> = 0.174 | 0.004* |
| Years living in house and Number of | r = 0.205 | 0.001* |
| children | | |

| Tab | le | 1. 9 | Spear | man' | s R | ho C | orre | lation | Coe | fficients | 5 |
|-----|----|------|-------|------|-----|------|------|--------|-----|-----------|---|
|-----|----|------|-------|------|-----|------|------|--------|-----|-----------|---|

* denotes significance at the 0.05 level

Mann-Whitney U-tests and Kruskal-Wallis tests were performed separately with radon gas levels in the air as the dependent variable and each of the demographics and knowledge questions being the independent variables. A summary of the results can be found in Table 2. For each independent variable, the table contains a list of the groups used, the test statistic, the degrees of freedom (df), and the p-value. If the test is considered significant at the 0.05 level, an asterisk is given beside the p-value.

The only variables that show a significant difference in the radon gas in the air between the levels of the variable are employment (p = .018), race (p = .004), Children living in house (p = 0.048), house ownership (p = .043), income level (p = .014), and knowledge of radon gas (p = .006). For race, the average amount of radon gas in the air is significantly higher for Caucasians than for minorities. The mean level of radon gas in the air for Caucasians in this study is 2.52 (median = 2; std. dev. = 2.24) while the minorities have a mean level of 1.66 (median = 1.2; std. dev. = 1.55). When considering whether children live in the house, the average amount of radon gas in the air is significantly higher for those with children than for those that don't have children in the house. The mean level of radon gas in the air for houses with children in this study is 2.65 (median = 2; std. dev. = 2.49) while those without children have a mean level of 2.19 (median = 1.7; std. dev. = 1.78). For house ownership, the average amount of radon gas in the air is significantly higher for those that own the house than for those that rent the house. The mean level of radon gas in the air for home owners in this study is 2.61 (median = 2; std. dev. = 2.41) while the renters have a mean level of 1.89 (median = 1.6; std. dev. = 1.16). When considering reported knowledge of radon gas, the average amount of radon gas in the air is significantly higher for those that say they know what it is than for those that don't. The mean level of radon gas in the air for those that know what it is in this study is 2.65 (median = 2.1; std. dev. = 2.42) while those that don't know have a mean level of 1.98 (median = 1.6; std. dev. = 1.55). When considering employment, there are five different categories being considered. Using a Bonferroni adjustment on the significance level in order to get an overall significance of .05, the average amount of radon gas in the air is significantly higher for those in "other" types of employment (other than business, education, administrative, or retired) than for those in business. The mean level of radon gas in the air for those in the "other" category in this study is 2.86 (median = 2.25; std. dev. = 2.78) while those in business have a mean level of 1.92 (median = 1.6; std. dev. = 1.50). When considering income, there are three different categories being considered. Using a Bonferroni adjustment on the significance level in order to get an overall significance of .05, the average amount of radon gas in the air is significantly lower for those with an income under \$20,000 than for the other two income categories (between \$20,000 and \$47,000 and over \$47,000). The mean level of radon gas in the air for those with an income
below \$20,000 in this study is 1.83 (median = 1.4; std. dev. = 1.49) while those with incomes between \$20,000 and \$47,000 have a mean level of 2.55 (median = 2.1; std. dev. = 1.57) and those with incomes over \$47,000 have a mean level of 2.56 (median = 2; std. dev. = 2.46).

| Independent | Levels of the | Test Statistic | df | p-value |
|------------------------------|---------------------|----------------|-----|---------|
| Variable | Variable | | | |
| Gender | Male | -0.27 | N/A | 0.791 |
| | Female | | | |
| Education | No College | 2.24 | 3 | 0.525 |
| | Some College | | | |
| | 4 year Degree | | | |
| | Grad Degree | | | |
| Employment | Business | 11.89 | 4 | 0.018* |
| | Education | | | |
| | Administrative | | | |
| | Retired | | | |
| | Other | | | |
| Race | Caucasian | -2.86 | N/A | 0.004* |
| | Not Caucasian | | | |
| Married | Married | -0.70 | N/A | 0.484 |
| | Not Married | | | |
| Children living in house | Yes | -1.98 | N/A | 0.048* |
| | No | | | |
| House Ownership | Own | -2.03 | N/A | 0.043* |
| - | Rent | | | |
| Income | < \$20,000 | 8.53 | 2 | 0.014* |
| | \$20,000 - \$47,000 | | | |
| | >\$47,000 | | | |
| Knowledge of radon gas | Yes | -2.73 | N/A | 0.006* |
| | No | | | |
| Family Member died of cancer | Yes | -1.33 | N/A | 0.184 |
| | No | | | |
| Family member that smokes | Yes | -0.31 | N/A | 0.759 |
| - | No | | | |
| Have Health Insurance | Yes | -0.74 | N/A | 0.458 |
| | No | | | |
| Radon tested before | Yes | -1.08 | N/A | 0.281 |
| | No | | | |

| Table 2. | Comparing | radon gas | in the air | r for levels | of the inde | ependent | variable |
|-----------|-----------|------------|------------|--------------|-------------|----------|-----------|
| I ubic 2. | Comparing | i auon guo | m une an | | or the may | penaene | val lable |

* denotes significance at the 0.05 level

ETHNOGRAPHIC FINDINGS

It is important to share the social meaning of the numeric data. As it appears in table 2 that households with children have higher radon level and families that own a house have higher radon level. While the same table showing people's knowledge about radon is pretty good.

It was an opportunity explains the numerical facts through ethnographic explanations. While people are saying they are knowledgeable about radon; it basically means they heard that radon is a gas and while you buy or sell a house all should measure radon level. Almost all of them do not know what is standard level or safe of radon gas. They are not sure why they should test their radon levels, what is the health risk associated to higher radon level is not even known to them.

This is common to all the communities we have covered, for example, in wealthy "Ada Township", people earn on an average 83,000 in compare to 47,000 in the township's Kent County. People are very aware about carbon-monoxide gas as it can be noticed by smell but radon gas does not have any odor or we cannot see it.

Many households with children make bedroom(s) for the children in the basement where the radon accumulate the most amounts. When they hear that it is not sage to live in a place where the radon in indoor air 4 per litter of air, if anyone inhale such gas with radon more than 4 are susceptible to cancer. People were surprised when they came to know that radon gas causes lung cancer and about 25,000 people die each year in US due to that. It is the 2nd cause of lung cancer.

People usually hear about this gas in January – the government declared radon month. People hear about the radon gas from Radio, TV, and newspaper. It seems the news on radon could not convey the unexpected facts. Society is not having enough knowledge to be aware about the danger of the gas.

SUGGESTED STRATEGIES

Based on the data analyzed from the survey and ethnographic record from the ten participants, it can be suggested that the government or local government should introduce new policies concerning radon testing and mitigation in homes. Despite previous efforts of the government to address the radon problems, i.e., the EPA's campaign, few things have been implemented in communities to enforce regular testing. Before someone purchases a home, or even places it on the market to sell, the home should be tested for radon as a mandatory part of the home buying and selling process. On the same note, all new construction should be tested for radon, and a mitigation system should be installed before the home is placed on the market for sale. However, as seen in the data, testing and mitigation is useless without proper education of the public. Programs should be put in place to educate the public about the risks and realities of radon. This could include sending out education fliers or pamphlets from the health department, placing ads on local television and radio stations, providing an informational website, and starting town meetings and programs. These meetings could occur during regular town meetings and be publicized on local access channels, and could include a radon expert from the government, health department, or a local university that would talk on the dangers, realities, and facts of radon. The program could show what radon testing and mitigation systems look like, and explain how they work. With education, radon and its risks could become a part of the culture as prominently as the danger of smoking cigarettes.

HEALTH INFORMATION TECHNOLOGY (HIT) – TOOL TO SHAPE HEALTH BEHAVIOR

There is a missing link between the wonderful educational resources that we have on radon and people's perception about it. Most of the people do not know the safe radon level which is below 4 pCi/L as recommended by the US EPA. People consider radon testing in buying or selling houses, it is done simply to see if they can reduce the home price when the radon level is high. People see radon level is an item of negotiating home price rather than the risk of disease like cancer. It will be highly effective to use health information technology in educating people on health concerns like risk of indoor radon and how to reduce unsafe radon level. Institutions like the WHO, US EPA, NGOs have prepared very useful educational tools like book and website with easy to use text. All these excellent resources need to be reached to the target population. Mobile phones, internet, social media can be used to convey important lessons on radon, its health risk, and how to mitigate it in a cheaper price.

CONCLUSION

Throughout the radon research project, it has become clear that radon can be anywhere and awareness about radon is very superficial. More than half, 62%, of participants knew of radon, and 86% of those who were aware of radon knew of the risks. The participants expressed that they knew that radon was negative, and a health risk, but were not equipped with the knowledge to test for or mitigate radon. With nearly half of the participants affected in some way by cancer, radon is a concern and a source for worry among many citizens. It is clear that local resources are not

easily accessible or not available to the community, and radon is not being mitigated as effectively as it should be. High levels of indoor radon do exist, and intervention programs need to be implemented to address this risk. Members of the community are not receiving the education or information about basic health-related topics, and this poses a threat to community residents. Communities should have a full understanding and command of the various aspects of their lives, including their indoor air quality. With proper education, radon can be introduced into American culture as not a mysterious killer, but a routine test for all homes. HIT is definitely an efficient and effective tool in taking care of radon risk on our health.

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First Generation College Students and Mobile Device Acceptance in Nursing Education

DeAnna Gapp, RN, PhD Candidate, Eastern Michigan University, Ypsilanti, MI 48197 734.487.2310 <u>dgapp@emich.edu</u>

Tsu-Yin Wu, RN, PhD, Eastern Michigan University, Ypsilanti, MI 48197 734.487.2310 twu@emich.edu

Abstract: The National League for Nursing (2009) states that nurse educators must commit to diversity in education by reviewing practices that favor and exclude students. First generation college students (FGCS) have a background that may hinder success and require support to overcome barriers in a nursing programincluding mobile device acceptance. A cross-sectional survey of 37 students showed significant differences; FGCS have higher results than non-FGCS in six of the eight key constructs of mobile device acceptance. Mobile devices may help bridge the digital divide. By increasing emphasis on mobile device functioning in the nursing curriculum, nurse educators can continue to promote diversity.

INTRODUCTION

According to the National League for Nursing (2009), nurse educators must be committed to diversity in nursing education by examining and assessing practices that may favor some and exclude others. First generation college students (FGCS) are those who have a background that may hinder success and may need extra support to overcome barriers in a nursing program. FGCS are those whom neither parent received a Bachelor's Degree. Currently, educational practice is beginning to incorporate mobile devices into the nursing curriculum. Mobile devices are highly portable electronic devices, i.e. smart phones or tablets that can access the internet. Mobile devices can enhance how students learn nursing content (Airth-Kindree & Vandenbark, 2014; Wu, 2014) and improve how nurses practice safe patient care (Pemmasani, Paget, van Woerden, Minamareddy, & Siri, 2014; Wray, 2013). In contrast, many higher education professors discourage or ban mobile devices in the classroom because of the distraction that the devices bring to the learning process (Dahlstrom & Bichsel, 2014). Even practioners are concerned with the distractions that mobile devices bring to the clinical setting (McBride, 2015). However, the advent of mobile devices in nursing education has benefited the students by increasing the sources for evidence-based practice contributing to stronger patient centered care, thus providing more evidence to incorporate devices into this setting (O'Connor & Andrews, 2015; Raman, 2015).

With the emphasis of incorporating mobile devices into the nursing curriculum, some students may be at a disadvantage. Some nursing students may be excluded from using mobile devices due to the cost of owning a device (Cibulka & Crane-Wider, 2011; Wittmann-Price, Kennedy, & Godwin, 2012). Also, not all students are technology literate (Kowalski & Smith, 2012; Lai & Wu, 2012). The digital divide is the disparity of technology in regard to access, use, and knowledge based on certain demographic characteristics. The research question is "Are there differences among FGCS versus non-FGCS in regard to the educational practice of incorporating mobile devices into the nursing curriculum?".

To our knowledge, no current studies focused on mobile devices in higher education and FGCS. Many studies focused on other barriers of FGCS. Some of these students may have attended high schools that did not adequately prepare them for college (Contreras, 2012). They may need to take remedial courses during college; they are working more hours to pay for college, attending college part-time, and/or commuting to college (Contreras, 2012; Dumais, Rizzuto, Cleary, & Dowden, 2013; Stephens, Fryberg, Markus, Johnson, & Covarrubias, 2012; Wilson & Kittleson, 2013). For example, non-FGCS are twice as likely to complete calculus or pre-calculus in high school than FGCS, which is a major factor on test scores for college (Contreras, 2012). If FGCS attend college, the underlying values and norms of independence propose a barrier for academic success because their cultural norm may be one of interdependence (Stephens et al., 2012). FGCS have a harder time adjusting to college (Hertel, 2010). Because FGCS are the first to obtain a degree in their family, they also may lack the social support systems at home

that encourage, promote, and support attending college and finishing a degree (Contreras, 2012; Wang, 2012; Wilson & Kittleson, 2013). FGCS tend to be African-American or Hispanic and come from low socio-economic backgrounds (Contreras, 2012; Hertel, 2010). However, FGCS are also optimistic about the future with hope of climbing the social ladder and are persistent in overcoming obstacles in their education (Contreras, 2012; Dumais et al., 2013; Wang, 2012; Wilson & Kittleson, 2013). Despite this optimism, Vuong, Brown-Welty, and Tracz (2010) found that FGCS have lower college self-efficacy affecting academic success and less persistence than non-FGCS. FGCS face many barriers that impact academic success.

To our knowledge, there were no nursing studies focused on mobile devices and FGCS. The current study is a pilot to examine the proposed Mobile Device Acceptance (MDA) theoretical framework among nursing students and their educational experiences of MDA in the classroom, lab, and clinical settings. Because the cost of the device and technology literacy may be obstacles for FGCS, as well as the unique characteristics of this group, this study will hypothesize that there will be a difference in MDA among its subscales between FGCS versus non-FGCS.

CONCEPTUAL FRAMWORK

This study's framework incorporates the Technology Acceptance Model (TAM) (Davis, 1989) and Self-Efficacy (SE) (Bandura, 1997) in examining MDA. The TAM model has been tested in a variety of disciplines with different types of technology. Chow et al. (2013) tested the TAM in nursing education with electronic imagery software. Kowitlawakul, Chan, Pulcini, and Wang (2014) tested the TAM using an electronic health record with simulation patients.

Based on TAM and SE, there were eight constructs that influences overall Mobile Device Acceptance. The end construct is Behavior Intention, which is the desire to use mobile devices to enhance nursing education. Perceived Usefulness is the students' beliefs that mobile devices actually can assist in enhancing nursing education. Attitudes toward MDA are the feelings students possess about using a mobile device for nursing education. Perceived Ease of Use is the effortless incorporation of mobile devices for nursing education. Each of these constructs has a direct impact on Behavior Intention. Mobile Device Self-Efficacy is the students' beliefs in their own capabilities in using a mobile device for nursing education, which has an indirect and potential direct impact with Behavior Intention. The following constructs are sources of SE which includes Past Accomplishment (defined as the successful use of mobile devices in prior experiences to enhance nursing education), Vicarious Experiences (defined as modeling from others on the use of mobile devices) and Social Persuasion (defined as the voiced influences that support using mobile devices for nursing education).

STUDY INSTRUMENT

The 52 items of the mobile device acceptance (MDA) scale measures the strength of the participants' self-reported perceptions of mobile devices and consists of eight subscales (Perceived Usefulness, Perceived Ease of Use, Attitude, Behavior Intention, Mobile Device Self-Efficacy, Past Accomplishment, Vicarious Experiences, and Social Persuasion). The scale used a five-point Likert scale, ranging from 1-Strongly Disagree to 5-Strongly Agree. A sample item measuring Perceived Usefulness is "A mobile device can improve my learning efficiency for nursing school," and for Behavior Intention, "I would become too dependent on a mobile device if I used it for nursing curriculum" (reverse order). The study instrument had a good-to-excellent reliability except the Vicarious Experience subscale (Cronbach's α =.71), whereas the Cronbach's alpha of the overall MDA scale was 0.96 and alphas' range from 0.75-0.92 for seven subscales. This approach measures the degree to which the test items represent the domain or universe of the trait or property being measured. In order to establish the content validity of the MDA scale, a panel of content experts, one in nursing education and two with mobile devices, were asked ask to examine the content of scale items. In addition, eight nursing students examined the items and provided input on item clarity and appropriateness.

DESIGN AND SAMPLE

The university's institutional review board reviewed the study protocol and granted approval for the study. The study sample consisted of 37 Junior and Senior-level pre-licensure BSN nursing students at a Mid-western

university where mobile devices are not mandatory for the curriculum. They completed an electronic survey, with a 33% response rate. The sample consisted of: 87% female students, 17% minority students, and the average age of 28 years. Only two of these students did not own a mobile device. 76% of the sample owned two or more mobile devices. Twenty nursing students self-identified themselves as FGCS.

RESULTS

An independent t-test was conducted to see the difference in MDA between FGCS and non-FGCS. The results showed that in six of eight subscales, there were significant differences with FGCS having higher levels in Perceived Usefulness (M=4.36 vs. M of non-FGCS=3.54), Perceived Ease of Use (M=3.96 vs. M of non-FGCS=3.54), Behavior Intention (M=3.94 vs. M of non-FGCS=3.41), more positive Attitudes (M=4.37 vs. M of non-FGCS=3.54), and higher levels of Social Persuasion(M=3.36 vs. M of non-FGCS=2.83), with all the statistical significance at p<.05 level.

CONCLUSION

FGCS had a significantly higher MDA score than non-FGCS. Mobile devices may bridge the digital divide. Although cost of a device was a barrier in previous nursing research, current ownership of a mobile device in the young adult age bracket is 97% (Fox & Rainie, 2014). On further research in other disciplines with technology literacy, it was found that the African-American and Hispanic population, which has the propensity to be considered FGCS, uses more smartphone functions, such as online banking, social networking, and health related apps, significantly higher than Caucasians (Kratzke & Cox, 2012; Smith & Zickuhr, 2012).

Because there are no other studies on mobile device use and FGCS in nursing or other disciplines, results from current study has implications in nursing education. FGCS will benefit from the use of mobile devices. Mobile devices help support FGCS in their learning and academic success. According to Swenty and Titzer (2014), there is an urgency in Master's Degree Nursing programs to use mobile devices in the curriculum. This same urgency must happen in pre-licensure programs. There is not only the benefit of increased evidence based practice with safer patient outcomes (O'Connor & Andrews, 2015; Raman, 2015), but supporting diverse nursing students must also occur. These results can inform nursing educators to incorporate mobile devices into the nursing curriculum, especially as some educators are reluctant to embrace this practice (Raman, 2015). Educators may attend workshops on mobile device use as an educational tool and not as a distraction in the learning environment or a violation of patient confidentiality in the clinical sites. Educators may appreciate the advantages of nursing students using mobile devices for clinical rotations, to allow all nursing students the use of mobile devices on the clinical floor (Raman, 2015). Educators, students, and clinical sites can implement best standard practices of mobile device use. Specifically, course activities using mobile devices for increased learning must occur. Raman (2015) recommends using faculty who are "super users" of mobile devices to model to their peers how to incorporate mobile devices into the nursing curriculum. Web sites and course management systems must have a mobile device version with content easily seen and manipulated. These specific outcomes will not only aid in student learning, but also support FGCS.

The limitations of this study included a small sample size, self-report questionnaire, the need for further psychometric testing of the instrument, and one setting that limited generalization. MDA does not present a barrier for FGCS. However, nurse educators can support FGCS by the continued use and promotion of the devices to enhance the nursing curriculum. Because the NLN (2009) advocates for flexible, open, and inclusive environments, universities that do not require mandatory mobile devices for the nursing curriculum must continue to use mobile devices in the pedagogical approach. With the increased emphasis on mobile devices through expansion of functioning in the nursing curriculum and health care practice, nurse educators can continue to propitiate diversity.

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The Expert Survey-Based Global Ranking of Management- and Clinical-Centered Health Informatics and IT Journals

Michael S. Dohan*, Alexander Serenko Faculty of Business Administration, Lakehead University 955 Oliver Rd, Thunder Bay, ON P7E 4B1 Canada msdohan@lakeheadu.ca, aserenko@lakeheadu.ca

Joseph Tan DeGroote School of Business, McMaster University 1280 Main St W Hamilton, ON L8S 3C5 Canada <u>tanjosep@mcmaster.ca</u>

*corresponding author.

Abstract: The goal of this study is to develop an expert survey-based journal ranking for the Health Informatics & Information Technology (HIIT) field. Journal of the American Medical Informatics Association and Journal of Medical Internet Research were ranked as top HIIT management-focused journals, and BMC Medical Informatics & Decision Making and IEEE Journal of Biomedical & Health Informatics were ranked as top HIIT clinical-focused journals. This ranking benefits academics who conduct research in this field because it allows them to direct their research to appropriate journals, convey their accomplishments to tenure and promotion committees, and experience other benefits.

INTRODUCTION

Ranking the quality of journals in academia continues to provide various benefits, especially for scholars that are interested in pursuing careers in specific areas. It can be a good way for promotion and tenure committees to inform themselves (Coe & Weinstock, 1984; Lowry, Humphreys, Malwitz & Nix, 2007). Academics who publish in highly ranked journals earn more than their counterparts (Gomez-Mejia & Balkin, 1992; Mittal, Feick, & Murshed, 2008), and some universities have instituted policies for rewarding faculty members that publish in highly ranked journals (Manning & Barrette, 2005). Besides faculty members, MBA students at faculties whose members publish in highly ranked journals earn more after graduation (O'Brien, Drnevitch, Crook & Armstrong, 2010).

Although rankings are helpful in these ways, they do have their share of criticism. First, policies exist that restrict faculty members to publish in only highly ranked journals, limiting their options for publications (Suchan, 2008). Researchers will then be discouraged from studying areas whose journals are excluded from these rankings or do not rank highly enough, for instance Business and Management Communication (Rogers, Campbell, Louhiala-Salminen, Rentz & Suchan, 2007). Rankings also encourage tenure and promotion committees to favor publications in higher ranked journals (Starbuck, 2005), yet the knowledge contribution is in the content of the paper rather than the journal. Publishing in a top-tier journal is not a guarantee of the quality of knowledge contribution of a paper or a guarantee that it will be cited, and rankings may encourage researchers to seek publication in highly ranked journals rather than making important scientific discoveries.

Despite the criticism of journal rankings, their utility seems to be important. Therefore, it is critical for scholars to ensure that the methods used to rank academic journals are valid and rigorous. Two of the predominant methodologies for ranking journals have been based on either expert surveys or citation impact factors (Lowry et al., 2007; Lowry, Romans & Curtis, 2004; Truex, Cuellar & Takeda, 2009). It is not clear whether the results of these two ranking methodologies agree at an acceptable level, with studies yielding results suggesting that citation impact factors can be used as substitutes (e.g., Thomas & Watkins, 1998), and some that suggest that there is no relationship between the two (e.g., Maier, 2006). Further, there is evidence that researchers rank journals differently depending on their own

research focus, suggesting that the outcome of an expert survey-based ranking will be different, based on the personal factors of the participants (Catling, Mason, & Upton, 2009; Donohue & Fox, 2000; Olson, 2005).

Despite various issues associated with journal rankings, journal ranking lists have been produced in most scholarly domains. At the same time, there have not been many efforts to rank journals in the area of HIIT. One that is known to the authors is maintained by SCImagoⁱ, which uses several forms of citation impact factors, and it was last updated in 2014. No known rankings of HIIT journals are based on expert surveys. As HIIT continues to emerge as a focus for research for many academics, so is the importance of these rankings. Thus, the purpose of this study is to develop a ranking of HIIT peer-reviewed journals based on an expert survey, which has become a popular method to assess the quality and contribution of academic outlets.

LITERATURE REVIEW

As an academic field, Health Informatics & Information Technology is increasing in popularity with researchers, academic institutions, practitioners, and software vendors. Despite the drawbacks of journal ranking lists, we feel that such a list for those interested in HIIT will be beneficial because it will guide and encourage scholars in their HIIT research endeavors. Ranking studies have been performed in a multitude of academic areas, including decision and management science (e.g., Donohue & Fox, 2000), international business (e.g., DuBois & Reeb, 2000), knowledge management/intellectual capital (e.g., Bontis & Serenko, 2009), medicine (e.g., Saha, Saint & Christakis, 2003), and many others. The two methodologies for developing journal ranking lists – those based on expert surveys and those based on citation impact factors - will be described in detail below.

Expert Survey Methods

The expert survey method of journal ranking involves engaging field experts to rank each journal in a discipline against certain criteria, usually through surveys. This method can result in a representative sentiment of the importance of a journal to its field because it is based on the opinions of the experts. There are, however, several disadvantages to this approach. First, authors may tend to rank journals based on their familiarity with them (Serenko & Bontis, 2011), internal ranking lists (Adler & Harzing, 2009), or the opinions of experts (Rogers et al., 2007) rather than pre-specified criteria, resulting in a source of bias for the ranking. Second, those who conduct ranking studies tend to base their lists off of pre-existing rankings, which introduces the possibility of leaving out new and newly relevant journals (Truex, Cuellar & Takeda, 2009). Third, methodological shortcomings may prevent researchers from achieving a representative sample. Fourth, the role of practitioners in these rankings are unclear; nevertheless they provide a valuable perspective on how research is used, yet may be underrepresented in the sample (Saha, Saint & Christakis, 2003).

Citation Based Methods

In addition to using the opinions of experts to formulate journal rankings, various citation-based measures have been used as the basis for a multitude of journal ranking lists. These include the Journal Impact Factor (JIF) (Franceshet, 2010), h-index (Hirsch, 2005), g-index (Egghe, 2006), hc-index (Sidiropoulos, Katsaros & Manolopoulos, 2007), for a few examples. When constructing these indices in their various unique ways, citation data from third-party sources are used, such as Thomson Reuters, Google Scholar, or Scopus. Although it can be viewed as a less subjective method than those that are based on expert surveys, it has several shortcomings. First, the impact of self-citations – occurring when authors cite other articles in the same journal (Rousseau, 1999) – on these indices is not clear. Journal editors may encourage authors to self-cite when submitting articles for publication (Sevinc, 2004), raising ethical questions. Second, the citation numbers that are reported by the third-party sources may be incorrect (Elkins et al., 2010), leading to inaccurate results. Third, journals that have a few highly-cited articles yet many uncited ones may produce a skewed result (Calver & Bradley, 2009; Seglen, 1992). Fourth, niche journals may not have a high number of citations, but may be highly important for researchers in subgroups or different communities of researchers, rather than researchers

in a grander field. Fifth, the quality of all articles in journal is not necessarily reflected in a ranking list. Sixth, journals that have been in-print longer may accumulate more citations (Seglen, 1997). Seventh, irrelevant factors such as the presence of an acronym in a journal name may impact the number of citations a journal has (Jacques & Seibre, 2010).

As such, both methods (expert surveys and citation-based approaches) have their own limitations. In this study, the expert survey method was selected. Moreover, it is argued that it is too early to establish citation-based rankings of HIIT journals. A brief overview of the currently existing HIIT journals showed that many of them have been launched very recently. For example, almost one-third of the HIIT management-focused journals ranked in the present study were launched within the previous three years, which is insufficient to attract a high number of citations and generate h-indices that truly reflect each journal's overall contribution to the HIIT discipline. Generally, new journals are not covered by Thomson Reuters and excluded from its Journal Impact Factor reports. Thus, recently launched HIIT journals, which represent a large proportion of all HIIT journals, may be disadvantaged in citation-based ranking lists. At the same time, given a small, niche nature of the HIIT field, it is likely that active researchers are aware of all HIIT outlets, including new ones, read them, and, therefore, may accurately assess their scientific contribution.

METHODOLOGY

This study adapts the previously used methodology of Serenko & Dohan (2011). A list of ranked journals was developed by means of a comprehensive search of the Ulrich's Periodicals Directory, the SCImago Journal & Country Rank (SCImago) Portal (available at http://www.scimagojr.com), major journal publishers, and Google Scholar. To be included in the list, each journal had to meet the following criteria: 1) be peer reviewed; 2) concentrate on various aspects of health informatics & IT; 3) be currently in-print; 4) be published in English; 5) be excluded from the Beall's List of predatory publishers and journals (available at http://scholarlyoa.com). Each journal was classified as either management- or clinical-focused depending on the following key considerations:

- Journal mission and reviews of the Call for Papers descriptions of the journal as well as Special Issue Topics of the journal, yielding directions to areas of journal paper contributions and focus of published topics in the HIIT field throughout the life of the journal;
- The appeal of the respective journal to certain groups of HIIT readers as well as its appeal to soliciting contributions in the different research domains specific to either management of HIIT or clinical applications of HIIT;
- Composition of editorial review board members, their expertise, and their known published areas of expertise;
- Composition of contributors whose papers have been accepted for publications, their expertise and field of HIIT concentrations either on management-focused or clinical-focused side;
- Similar expertise demanded of peer reviewers who are asked to review contributions submitted to journal for publication considerations; and,
- Key citations of work published in the journal drawing either from management-related IT disciplinary journals or clinical-oriented disciplinary journals.

It should be noted that some journals do have a somewhat "split" focus albeit it is not difficult for a learned expert in health informatics who have published in both camps to detect a tendency towards one side or the other (clinical or management) as evidenced among authors of this particular work. As a result, two journal lists were developed: 1) management-focused (35 journals) and 2) clinical-focused journals (28 journals). Respondents were asked to rank journals within each group separately on a 7-point Likert-type scale. To exclude the order-effect bias (Serenko & Bontis, 2013a), the order of journals was automatically randomized for each respondent. To avoid the "path dependency" problem (Truex, Cuellar, & Takeda, 2009), respondents were able to add and rank up to three additional journals for each group. At the end of the survey, basic demographic data were also solicited (See Appendix 1 – Research Instrument).

To make sure that each journal was equally represented, 50 author names and email addresses were randomly selected from each journal. No discriminatory criteria (e.g., author position, affiliation, seniority, paper title, etc.) were applied. Generally, the names were first selected from the most recent volumes. Each author's name was selected only once. As a result, the list of respondents contained names and email addresses of 3,150 unique authors who published at least one article in one of the ranked journals. Overall, it was believed that these individuals were active HIIT

researchers who were familiar with and were qualified to judge the quality of journals in this field. Each respondent was sent an email invitation to complete the survey followed by three weekly reminders. IP addresses were recorded and used to remove duplicate submissions.

The ranking instrument by Serenko & Bontis (2013b) was adapted. To minimize cognitive load on respondents, they were asked to rate each journal's overall contribution to the Health Informatics & IT field on a 7-point Likert-type scale. The responses were converted to a quantitative measure as follows: none -0; marginal -1; some -2; average -3; good -4; very good -5; and outstanding -6; and the scores were aggregated for each journal.

RESULTS

Out of 3,150 email invitations, 303 messages bounced back. Four hundred and twenty-nine people attempted to complete the survey. After removing 31 empty, partially complete, and duplicate entries, 398 usable responses were retained for analysis. This yielded the response rate of 14%, which is considered acceptable in online survey research. The actual response rate was higher because 270 automatic 'on-vacation' replies were received, and it was unknown whether these individuals read the survey invitation emails. In addition, it is likely that some email invitations were mistakenly identified as unsolicited messages by spam filters and removed before reaching the recipients. Forty-six percent of responses came after the initial invitation; and twenty-seven, fourteen, and thirteen percent arrived after reminders one, two, and three, respectively.

Researchers from 46 different countries participated in the study. Most were from the USA (33%), Canada (10%), the UK (8%), Australia (6%), Germany (4%), Italy (4%), and India (3%). Thirty-three percent were female. Eighty-three, fourteen, and three percent had a doctoral, master's, and bachelor's degrees, respectively. Seventy-eight, eight, and five percent were academics, practitioners, students, respectively. Nine percent were scholarly administrators, researchers at non-academic institutions, consultants, medical writers, clinical experts, physicians, etc. Thus, some degree of participation by active industry practitioners (i.e., non-academics) was assured. Table 1 (below) summarizes academic and research experience of the survey respondents.

| | Avg. | Min. | Max. |
|-----------------------------------------------------------------------|------|------|---------|
| Years of academic full-time work experience. | 12 | 0 | Over 30 |
| Years of non-academic full-time work experience. | 8 | 0 | Over 30 |
| Years of research experience in the field of Health Informatics & IT. | 9 | 0 | Over 30 |
| The number of peer-reviewed journal published. | 39 | 1 | 450 |

| Table 1. Academic and Research | Experience | of Participants |
|--------------------------------|------------|-----------------|
|--------------------------------|------------|-----------------|

Overall, the respondents did not report any difficulty completing the online survey. In addition to the listed journals, the respondents occasionally added and ranked new journals. However, most of them were reported only a few times. Whereas these journals had published health informatics and IT-relevant articles, health informatics and IT was not their major area of concentration. Examples include IEEE Transactions on Biomedical Engineering, Medical Decision Making, European Journal of Health Economics, British Medical Journal, Ultrasound in Medicine & Biology, etc. Studies in Health Technology and Informatics was mentioned by several respondents, but it was published as a book (not as a peer-reviewed journal) and, therefore, excluded from the ranking list. Several non-English language journals and professional (non-peer-reviewed) magazines were also reported. Thus, no new journals were added to the list of ranked outlets. At the same time, a number of respondents indicated that the survey presented Journal of Innovation in Health Informatics under its former name "Informatics in Primary Care (formerly The Journal of Informatics in Primary Care)." Thus, adjustment in the name of this journal and its score was made in the final ranking list.

Tables 2 and 3 (below) present the ranking of Health Informatics & IT management-focused and clinical-focused journals, respectively. As suggested by Gillenson and Stafford (2008), tiers were assigned so that the list contains 5 percent of A+, 20 percent of A, 50 percent of B, and 25 percent of C level journals.

| Tier | Rank | Title | Year | Score |
|------|------|-------------------------------------------------------------------|----------|-------|
| | | | Launched | |
| A+ | 1 | Journal of the American Medical Informatics Association | 1994 | 1,270 |
| A+ | 2 | Journal of Medical Internet Research | 1999 | 930 |
| А | 3 | JMIR Medical Informatics | 2013 | 695 |
| А | 4 | Methods of Information in Medicine | 1962 | 544 |
| А | 5 | Journal of Telemedicine & Telecare | 1995 | 493 |
| Α | 6 | JMIR mHealth and uHealth | 2013 | 492 |
| Α | 7 | Health Informatics Journal | 1995 | 473 |
| Α | 8 | Telemedicine and e-Health (formerly Telemedicine Journal, | 1995 | 453 |
| | | formerly Telemedicine Journal and e-Health) | | |
| Α | 9 | Journal of Medical Systems | 1977 | 452 |
| В | 10 | Health Policy and Technology | 2012 | 338 |
| В | 11 | Journal of Health & Medical Informatics | 2010 | 331 |
| В | 12 | IIE Transactions on Healthcare Systems Engineering | 2011 | 330 |
| В | 13 | International Journal of Healthcare Information Systems and | 2006 | 313 |
| | | Informatics | | |
| В | 14 | International Journal of Healthcare Technology and Management | 1999 | 285 |
| В | 15 | Journal of the International Society for Telemedicine and eHealth | 2013 | 272 |
| В | 16 | Informatics for Health and Social Care (formerly Medical | 1976 | 271 |
| | | Informatics) | | |
| В | 17 | International Journal of Technology Assessment in Health Care | 1985 | 261 |
| В | 18 | International Journal of Telemedicine and Applications | 2008 | 258 |
| В | 19 | Health Informatics: An International Journal | 2012 | 251 |
| В | 20 | Technology and Health Care | 1993 | 236 |
| В | 21 | International Journal of Computers in Healthcare | 2010 | 233 |
| В | 22 | Online Journal of Public Health Informatics | 2009 | 231 |
| В | 23 | Journal of Medical Informatics & Technologies | 2000 | 230 |
| В | 24 | International Journal of Medical Engineering and Informatics | 2008 | 214 |
| В | 25 | Electronic Journal of Health Informatics | 2006 | 210 |
| В | 26 | Health Information Science and Systems | 2013 | 194 |
| С | 27 | Journal of Health Informatics in Developing Countries | 2007 | 189 |
| С | 28 | International Journal of E-Health and Medical Communications | 2010 | 187 |
| С | 29 | International Journal of Electronic Healthcare | 2004 | 180 |
| С | 30 | Indian Journal of Medical Informatics | 2006 | 170 |
| C | 31 | International Journal of Privacy and Health Information | 2013 | 140 |
| | | Management | | |
| С | 32 | Journal of Health Informatics in Africa | 2013 | 123 |
| C | 33 | International Journal of Reliable and Quality E-Healthcare | 2012 | 113 |
| C | 34 | International Journal of Monitoring and Surveillance Technologies | 2013 | 83 |
| | | Research | | |
| C | 35 | International Journal of User-Driven Healthcare | 2011 | 79 |

Table 2. Ranking of Health Informatics & IT Management-Focused Journals

As expected, positive Spearman (1904) Rank Correlations between a journal's score and its longevity (years in-print) were observed ($\rho = 0.40$, p < 0.05 for HIIT management-focused journals and $\rho = 0.33$, p < 0.1 for HIIT clinical-focused journals).

| Tier | Rank | Title | Year | Score |
|------|------|----------------------------------------------------------------------|----------|-------|
| | | | Launched | |
| A+ | 1 | BMC Medical Informatics and Decision Making | 2001 | 787 |
| A+ | 2 | IEEE Journal of Biomedical and Health Informatics (formerly the | 1997 | 731 |
| | | IEEE Transactions on Information Technology in Biomedicine) | | |
| Α | 3 | International Journal of Medical Informatics (formerly International | 1970 | 633 |
| | | Journal of Bio-Medical Computing) | | |
| Α | 4 | Journal of Biomedical Informatics (formerly Computers and | 1967 | 596 |
| | | Biomedical Research) | | |
| A | 5 | Applied Clinical Informatics | 2009 | 414 |
| Α | 6 | Computer Methods and Programs in Biomedicine (formerly Computer | 1970 | 324 |
| | | Programs in Biomedicine) | | |
| Α | 7 | Journal of Innovation in Health Informatics (formerly Informatics in | 1991 | 302 |
| | | Primary Care, formerly The Journal of Informatics in Primary Care) | | |
| A | 8 | Applied Medical Informatics | 1995 | 270 |
| В | 9 | CIN: Computers, Informatics, Nursing (formerly Computers in | 1983 | 253 |
| | | Nursing) | | |
| В | 10 | Computers in Biology and Medicine: An International Journal | 1970 | 242 |
| В | 11 | Computer Methods in Biomechanics and Biomedical Engineering | 1997 | 203 |
| В | 12 | Acta Informatica Medica | 1993 | 197 |
| В | 13 | Journal of Digital Imaging | 1988 | 179 |
| В | 14 | Journal of Computational Medicine | 2014 | 171 |
| В | 15 | Computer Methods in Biomechanics and Biomedical Engineering: | 2013 | 159 |
| | | Imaging & Visualization | | |
| В | 16 | The Open Medical Informatics Journal | 2007 | 141 |
| В | 17 | International Journal of Computational Models and Algorithms in | 2010 | 137 |
| | | Medicine | | |
| В | 18 | Computerized Medical Imaging and Graphics (formerly Computerized | 1977 | 129 |
| | | Radiology, formerly Computerized Tomography) | | |
| В | 19 | Canadian Journal of Nursing Informatics (formerly Canadian Nursing | 2006 | 119 |
| | | Informatics Journal) | | |
| В | 20 | International Journal of Computer Assisted Radiology and Surgery | 2006 | 118 |
| В | 21 | Network Modeling Analysis in Health Informatics and Bioinformatics | 2012 | 111 |
| В | 22 | Journal of Computer Assisted Tomography | 1977 | 109 |
| С | 23 | Computer Aided Surgery (formerly Journal of Image Guided Surgery) | 1995 | 102 |
| С | 24 | Journal of Pathology Informatics | 2010 | 99 |
| С | 25 | Radiologic Technology | 1929 | 90 |
| С | 26 | Bio-Algorithms and Med-Systems | 2005 | 86 |
| С | 27 | Journal of Computational Surgery | 2014 | 83 |
| С | 28 | International Journal of Computerized Dentistry | 1998 | 58 |

Table 3. Ranking of Health Informatics & IT Clinical-Focused Journals

DISCUSSION AND CONCLUSION

The assessment of academic journals is a very important yet risky endeavor continuously surrounded by debate, controversy, and ambiguity (Chen & Holsapple, 2013). Therefore, the reader of this paper should keep several issues in mind when evaluating the ranking lists presented above. First, similar to other journal ranking methods, the expert survey approach has several limitations. For example, in their journal ranking decisions, survey respondents are often influenced by the opinion of leading academics (Rogers et al., 2007), their familiarity and personal affiliation with the journal (Peters et al., 2014; Serenko & Bontis, 2011), intra-institutional politics (Adler & Harzing, 2009), and personal research interests (Serenko & Dohan, 2011). Second, a ranking position is not an indication of the goodness of a

journal's content. Most importantly, the scientific community has not agreed on a definition of a journal's quality because of the subjective nature of the concept (Chen & Holsapple, 2013). Third, the mere publication of a paper in a highly-ranked journal does not automatically endorse its significance, quality, and impact. There are many examples of papers appearing in the most prestigious outlets that receive few citations (Rousseeuw, 1991), and top journals often reject submissions that are later published elsewhere and become "citation classics." Fourth, there are other methods, such as the Uncitedness Factor (Egghe, 2010), the Publication Power Approach (Holsapple, 2008), and Author Affiliation Index (Cronin & Meho, 2008; Gorman & Kanet, 2005), which may potentially generate different results. As such, the present study does not make a claim that a particular journal is of high (or low) quality; instead, it merely offers the ranking lists developed based on a single inquiry method that is considered acceptable in scientometrics.

Regrettably, some users of journal ranking lists have little grasp of the shortcomings of various journal ranking methods and, as a result, interpret the findings literally. This is especially dangerous when academic administrators and members of hiring, tenure & promotion, and merit pay committees base their judgement of someone's scholarly contribution solely on their publication in a 'highly-ranked' basket of journals. Whereas journal ranking lists may be consulted, this should be only one of the many criteria used to assess an applicant's overall academic portfolio.

This study developed a ranking list of Health Informatics & IT peer-reviewed journals. To the best knowledge of the authors, no such ranking had been published earlier. Journal of the American Medical Informatics Association and Journal of Medical Internet Research were ranked as top HIIT management-focused journals, and BMC Medical Informatics & Decision Making and IEEE Journal of Biomedical & Health Informatics were ranked as top HIIT clinical-focused journals. Consistent with prior studies, a positive correlation was observed between a journal's longevity (years in-print) and its ranking score. This happens because they have had more time to publish high-quality papers, attract well-known scholars as their board members, increase their readership, and establish their scientific brand. At the same time, there are exceptions. For example, JMIR Medical Informatics and JMIR mHealth and uHealth, both launched in 2013, received a strong A level ranking. Thus, newer journals may quickly achieve good standing and recognition.

APPENDIX 1 – RESEARCH INSTRUMENT

Instructions

- Note: If you are UNFAMILIAR with a particular journal, simply SKIP it (do NOT rank it).

There are two separate ranking lists: 1) Health Informatics & IT Management-Focused Journals and 2) Health Informatics & IT Clinical Journals.

Part 1. Health Informatics & IT Management-Focused Journals

This journal's overall contribution to the Health Informatics & IT field is: (rank each journal)

1 – None, 2 – Marginal, 3 – Some, 4 – Average, 5 – Good, 6 – Very Good, 7 – Outstanding

List of 35 Health Informatics & IT Management-Focused Journals.

If you wish, you may also add and rank up to three additional journals (not listed above):

Add Journal 1

Rank Journal 1: 1 - None, 2 - Marginal, 3 - Some, 4 - Average, 5 - Good, 6 - Very Good, 7 - Outstanding

Add Journal 2

Rank Journal 2: 1 - None, 2 - Marginal, 3 - Some, 4 - Average, 5 - Good, 6 - Very Good, 7 - Outstanding

Add Journal 3

Rank Journal 3: 1 - None, 2 - Marginal, 3 - Some, 4 - Average, 5 - Good, 6 - Very Good, 7 - Outstanding

Part 2. Health Informatics & IT Clinical Journals

This journal's overall contribution to the Health Informatics & IT field is:

1 - None, 2 - Marginal, 3 - Some, 4 - Average, 5 - Good, 6 - Very Good, 7 - Outstanding

List of 29 Health Informatics & IT Clinical-Focused Journals.

If you wish, you may also add and rank up to three additional journals (not listed above):

Add Journal 1

Rank Journal 1: 1 – None, 2 – Marginal, 3 – Some, 4 – Average, 5 – Good, 6 - Very Good, 7 - Outstanding Add Journal 2

Rank Journal 2: 1 – None, 2 – Marginal, 3 – Some, 4 – Average, 5 – Good, 6 - Very Good, 7 - Outstanding Add Journal 3

Rank Journal 3: 1 - None, 2 - Marginal, 3 - Some, 4 - Average, 5 - Good, 6 - Very Good, 7 - Outstanding

General Information

Your Current Country of Residence

Your Gender (Male; Female)

Your highest degree earned (Doctoral; Masters; Bachelor; Other - Please enter)

Major field for highest degree earned

How many years of academic full-time work experience do you have?

How many peer-reviewed journal articles have you published?

How many years of non-academic full-time work experience do you have?

What is your primary current position? (Academic; Practitioner; Student; Other - Please Explain)

What is your primary research area? (if applicable)

What is your secondary research area? (if applicable)

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ⁱ http://www.scimagojr.com/journalrank.php?category=2718

Revisiting an Integrated Health Informatics and Technology Curriculum Model

Bernard T. Han, PhD Western Michigan University, Haworth College of Business, Kalamazoo, MI 269.387.5428, bernard.han@wmich.edu

> Tracy L. Johnson, MEd Van Buren Intermediate School District 269.539.5103; tjohnson@vbisd.org

Kenneth D. Bobo, JD Kalamazoo County Government, Kalamazoo, MI 269.383.6434; kdbobo@kalcounty.com

Abstract: The shortage of health information technology workforce is quite significant in the health industry. The traditional education approach may not be effective enough to train college students to be an HIT workforce that requires both academic knowledge and extensive hands-on experiences in both healthcare and information technology. This paper presents an Integrated Health Informatics and Technology Curriculum Model to collapse the campus boundaries between regional Intermediate School Districts, Community Colleges, and a Four-Year health informatics and information management program to support expedited education with sufficient hands-on experiences in health informatics and technology. This model has been pilot tested by the Health Informatics and Information management Program at Western Michigan University. Early findings are very positive. More study and promotion of this curriculum model shall be continued.

1.0 INTRODUCTION

The lack of qualified health information technology (HIT) workers, whether perceived or real, is an urgent and legitimate concern for many healthcare stakeholders (e.g., hospitals, EMR/EHR consulting firms). A recent survey conducted by *HIMSS Analytics* shows the demand for qualified HIT workers is as high as it has ever been, and is projected to continue in the foreseeable future (HIMSS Analytics, 2014). Unlike other industries, healthcare is quite unique and service-driven. Most importantly, healthcare services spread across multiple disciplines and are delivered by professionally trained clinicians and technicians with a variety of knowledge and skills in HIT that is far beyond those normally required for any single discipline (e.g., nursing, marketing, etc.) in higher education (Fenton *et al.*, 2013). Moreover, similar to many health science disciplines, employers in healthcare expect the entry-level HIT workforce to have a certain degree of field experiences (e.g., clinical hours or practice) in, and understanding of, the healthcare environment before they join the organization and begin working with clinical professionals. Therefore, a blended knowledge and skills in *health informatics* and *information technology* are not only essential, but require solid academic preparation for a college HIT graduate to be qualified for employment, whether earning an associate or a bachelor degree. This finding-has been echoed by many studies for more than a decade, e.g., Buernsed (2010), Jackson (2013), and Burrows (2014).

Due to the unique nature of the healthcare industry, having hands-on experiences, via field trips or real-world internships, becomes an integral part of the learning process for students with a career interest in health informatics and information technology. With the emergence of HIT programs and the increasing demand for entry-level HIT workforce, there is an influx of students entering these programs who do not have any clinical backgrounds or sound training of information technology, then "*how shall these individuals be prepared to succeed with proper training and experiences before they enter the real world?*"

This, which in fact, is the research question of this paper. Given the more than tripling of college tuition over the past 25 years (Lorin, 2014) and, the need for more hands-on experiences, field internships will not be possible for everyone, yet will very likely delay the completion of defined coursework and ultimately, the graduation. Thus, it will not be economically feasible, or timely possible for us to employ a traditional curriculum model (i.e., a four years high school and a four-year collegiate curriculum – whether online or in-place) to tackle the problem highlighted by our research question. Any resolution proposed (to be detailed hereinafter) must assure that students will acquire hands-on and field experiences as soon as students identified their career interests or, at the very least, in parallel with

their study throughout the learning process, which may occur continuously from the beginning (when career interests identified) to the end (when college degrees conferred). Most of all, the whole learning process will ensure the newest generations become highly employable to join the health industry at affordable costs.

In this paper, an Integrated Health Informatics and Technology (**IHIT**) Curriculum Model is presented to demonstrate how education resources can be virtually combined and coordinated across campuses, from regional intermediate school districts to community colleges to a four-year university, to expedite the preparation of the HIT workforce for the unmet market demand in the healthcare industry. While this model mimics early educational proposals recommended by the National Center for Public Policy and Higher Education (Policy Alert, 2004) and by the National High School Center (Bangser 2008), our curriculum model reflects the conceptual framework that can be fulfilled through actual teaming with resources that are already available in the community (Carroll *et al.*, 2010).

The paper is organized in the following manner. The next section, section Two provides a background of our IHIT curriculum model – its major stakeholders and how it can be accomplished through teaming with teaching and learning of juniors and seniors in regional high schools to graduates from regional community colleges, and, if academically desirable for better career preparation, to the completion of a bachelor degree from a four-year higher education institute that offers a comprehensive IHIT undergraduate program. Section Three presents the infrastructure of the IHIT curriculum model with some highlights on how teaching of courses and learning of IHIT subjects can be started in junior/senior years at a regional intermediate school district with some dual enrollment of courses that can be credited toward high school graduation, the earning of an associate degree, and finally, a bachelor degree from a four-year university. Section Four gives a quick revisit of our developed IHIT curriculum at Western Michigan University. In specific, it highlights the growth of this majors at WMU along with anecdotal data and career placements of our early graduates from this new undergraduate major. Section Five summarizes lessons learned with additional discussion on challenging issues, and the final section concludes our findings from pilot testing of the proposed IHIT curriculum model.

2.0 BACKGROUND

As maintained by the findings from Carroll *et al.* (2010), "education is frequently fragmented and disconnected: professional development is not aligned with student and teacher needs, curriculum is not aligned with assessment, and standards are not aligned with curriculum." This fragmentation prevents any substantial education reform from taking place because change in one area do not affect another. Collaborative teaching could bridge these gaps, but the reality is that today's teachers work alone." This finding is not new and, in fact, was well recognized in higher education (Evans & Malina, 2014) due to the specialization of disciplines and subsequently the formation of educational silos that prevent coordination and sharing of teaching resources.

Despite governmental initiatives such as the American Graduation Initiatives, *No Child Left Behind* and *Race To The Top*, far too many failed and we are left with a post-secondary population unprepared for the workforce or successful transition to postsecondary education (e.g., associate or bachelor degrees) and entry into an ever more competitive and technological employment (Bangser 2008; Barnett, *et al.* 2012; Johnson 2015). In addition, the skyrocketing increase in higher education (Lorin 2014) has further created financial difficulties for high school students to access to advanced education opportunities to complete their college education, let alone their readiness toward the future workplace. Hence, it is time that a new curriculum model shall be employed such that it will achieve the following goals:

- Eliminate discipline silos to prepare students with blended knowledge and skills
- Offer an integrated curriculum plan that will promote effective teaching and learning necessary knowledge and skills to get students ready for the future workplace
- Permit "virtual" sharing of teaching resources that will establish an education pipeline, i.e., support students' learning of required knowledge and skills whether to join the workforce in time or to advance their education to seek higher degrees for better career achievement.

The above three goals are generally applicable to all careers, but are even more true and critical to the new workforce to join the healthcare industry, which is currently faced with a shortage of employees with HIT training. As addressed earlier, the healthcare industry is quite different from others. It is service-driven and services are delivered by

professionals that are multi-disciplinary with a variety of specialties and licensures. Any employee plans to join the healthcare industry will need to have the following knowledge, skills, and experiences (Falan & Han, 2011):

- 1. Understanding of healthcare (e.g., medical environment, culture, terminologies, etc.)
- 2. Basic sciences (e.g., statistics, biology, anatomy, etc.)
- 3. Medical applications (e.g., EMR/EHR, etc.)
- 4. Computing and technology (e.g., system modeling, database, data analysis, etc.)
- 5. Healthcare administration (e.g., finance management, resource planning, etc.)
- 6. Hands-on experiences (e.g., field trips, hospital volunteers, internships, etc.)

Of these, the first five are related to the coursework that may be taken by students once they have shown interests in joining the healthcare industry. Nevertheless, knowledge and skills learned from the coursework are only essential, but not sufficient, for students to be ready for their career placement. The last component (i.e., hands-on experiences) is relatively crucial and could become the deciding factor, especially in healthcare, if a student is able to obtain an internship or a full-time position from a healthcare organization. This, in fact, was recognized by our experiences (to be detailed later). How can all these knowledge, skills, and experiences be acquired by a student who would like to consider HIT as his/her academic major in order to become the new workforce for the healthcare industry. Compared to other disciplines, the HIT major, by nature, is cross-disciplinary and will need to be covered by a very organized and integrated curriculum plan, which may be completed if a student is not clear about his/her major when he/she enters the college. In fact, if a student does not have any prior hands-on exposures (e.g., served as a volunteer in hospitals) to the healthcare, it may turn out to be a handicap for him/her to be successful in getting an internship during the school years. To overcome these potential constraints and to ensure a smooth learning process, an IHIT curriculum model can be used by joining (sharing) the teaching and learning processes (resources) from a regional Intermediate School District (ISD) with nearby community colleges and, furthermore, with a four-year hosting university. Figure 1 highlights the teaching and learning environment of an IHIT curriculum model:



Figure 1. Teaching and Learning Environment of IHIT Curriculum Model

The reality is that the prevalent model of schooling today supports neither continuous job-embedded learning for teachers nor collaborative learning among teachers. Education is frequently fragmented and disconnected (Evans & Malina, 2014): professional development is not aligned with student and teacher needs, curriculum is not aligned with assessment, and, furthermore, standards are not aligned with curriculum.

The crisis in healthcare industry has been well recognized in mid 1980s. With more than 20 years of verbal services, no action was taken until February 17, 2009, the date that ARRA was signed into law. The urgency of healthcare needs, raised by a call from the community of healthcare professionals, prompted the faculty of Haworth College of Business to work with the faculty of College of Health and Human Services at Western Michigan University (WMU) to jointly developed a cross-disciplinary undergraduate major, Health Informatics and Information Management (HiiM), that has been approved by the Presidential Academic Council of the State of Michigan in Spring 2011 and officially put in place in Fall 2012. Details about this new academic major and its design philosophy are reported in Falan and Han (2011). While this new program (i.e., HiiM) collapses the academic silos in higher education, its success cannot be reached without collapsing the campus boundaries between education partners, i.e., an Intermediate School District (ISD), nearby community colleges, and the new program hosting university - WMU. In fact, over the past three years, the HiiM program has closely partnered with the ISD at Van Buren County, Michigan and two community colleges (i.e., Lake Michigan College at Benton Harbor and Kalamazoo Valley Community College at Kalamazoo) at southwest Michigan to pilot test the IHIT Curriculum Model, which allows sharing of teaching resources in order to pipeline student learning and incentivize ISD students to choose HIT (e.g., HiiM) as their future career when they are still a junior or a senior in high school. The details about course sharing across educational units are summarized in Table 1.

| ISD | Community College | Western Michigan University |
|-------------------------------|-----------------------------|-----------------------------------------------|
| Health Occupations | Intro to Health Care Career | Intro to Health and Human Services (HSV1040) |
| Medical Terminology (Reading) | Medical Terminology | Medical Terminology (MDSC 2010) |
| Biological Sciences (Biology) | Introductory Biology | Principles of Biology (BIOS 1120) |
| | Computers in Business | Introduction to Business Computing (CIS 1020) |
| | Anatomy and Physiology | Human Anatomy (BIOS 2110) |
| | Physiology | Human Physiology (BIOS 2400) |
| | Probability & Statistics | Introduction to Statistics (STAT 3660) |
| | Ethics (Philosophy) | Introduction to Ethics (PHIL 2010) |

Table 1. Course Sharing between ISDs, Community Colleges, and the HiiM Program at WMU

As seen in Table 1, eight courses required by the HiiM program at WMU can be learned by students by taking courses from either ISDs or any nearby community colleges. These courses are primarily the basic science or service course that meant to be taken by college students when they are either a fresh or a sophomore. Due to the increasing education costs (e.g., credit hour charge, lab charge, etc.), it is most desirable for incoming WMU students, especially those high school juniors or seniors who have identifies their career interest in health and information technology, to take these courses at a local ISD or nearby community colleges.

Note that the above course sharing is the results of many dialogues and course "content validation" by faculty coordinators at each partner. After a careful administrative approval process conducted by WMU, this above course credential agreement lays the foundation and serves as the blueprint for all education partners to implement the IHIT curriculum model. In fact, it is the beginning of our task that was started in Fall 2013. How can the above agreement be effectively implemented in order to ensure students are well prepared to be the new HIT workforce? The infrastructure and the implementation details of IHIT are presented in the next section.

3.0 AN INTEGRATED HEALTH INFORMATICS AND TECHNOLOGY MODEL

As pointed out in the previous section, due to the unexpected high demand for HIT workforce, it is imperative for educators in the health area to expedite the training of students who have potential and interest in learning health informatics and information technology. To fulfill this education process, we do need a new education (curriculum) model that will not only collapse the academic silos within a university campus (Falan & Han, 2011), but also pull together teaching resources across multiple campuses from regional ISDs to community colleges to a four-year university that hosts the health informatics and information management program (e.g., the HiiM program at WMU). However, to ensure quality training and preparation of new HIT workforce, the HiiM program at WMU was designed according to the standards defined by the CAHiiM curriculum standards (CAHiiM, 2014). In brief, a student who

chooses to have a HiiM as his/her academic major will be required to take, in total, at least 51 credit hours course load in the basic science, health informatics, and information technology and management area. With the course credential agreement (see Table 1), the demanding requirements for HiiM could be alleviated since students from a local high school will be able to complete anywhere between 8 and 22 credit hours of coursework before they enter WMU. Note that these credit hours transferable to the HiiM program do not include other credit hours that may be taken from a nearby community college and transferable toward a bachelor degree to be earned from WMU. Obviously, the above "mutual recognition agreement" in coursework makes teaching resources sharable among the education partners in the community. Nevertheless, the true merit of the IHIT curriculum model (see Figure 2) is to provide students with ample opportunities in gaining hands-on experiences at the early stage when students are still in a high school. Their early exposures to (or experiences in) the health industry grant them competitive advantages in securing an externships or internships in a healthcare organization when they continue to pursue an *associate degree* from a community college or a *bachelor degree* from a four-year university.



Figure 2. An Integrated Healthcare and Information Technology (IHIT) Curriclum Model

As shown in Figure 2, the middle part of the diagram indicates students hands-on experiences could be obtained when high school students attend a program offered by an ISD, which may be carried on and converted into job shadowing, externships, and internships when they attend a community college and further complete a HiiM major at WMU. If students are guided well by advisors from ISDs to community colleges and to WMU, then a student with an early career identification could finish a college bachelor degree in five years. In a traditional curriculum model, a junior in a high school will normally take eight years (i.e., two plus two plus four) to complete his/her college education. Using the proposed IHIT model, if all go well, it will save a high school junior at least three years to get a bachelor degree – a great time saving in education. Apart from huge savings in education costs, the college graduates under this IHIT curriculum model will have a much higher probability in finding a job. The expected benefits from cooperative education have been reported in an existing study (Jiang *et al.*, 2015).

The IHIT curriculum model has been applied to the HiiM Program at WMU. How does it impact the education of the HiiM majors and how has it influenced our graduates in terms of their job placement? The next section summarizes what we have experienced over the past three years.

4.0 THE IHIT EDUCATION AT WMU - EXPERIENCES OF EARLY SUCCESS

The IHIT curriculum model was started immediately after the HiiM Program put in place in Fall 2012. The education concept was raised in a special gathering about how HIT education can be expedited through collaboration between education partners in the Greater Kalamazoo Area in ICHITA-2011, held at the Fetzer Center at WMU. One of the attendees, as well as the co-author, Kenneth Bobo, introduced this model to the Curriculum Director of a rural Michigan secondary school system, the Van Buren Intermediate Schools District's Early College Health Alliance (VBECHA). At that moment, VBECHA was seeking to accelerate and augment post-secondary matriculation of students interested in health care fields, and later served a springboard in launching high school students onto an accelerated path and provided a pathway to the implementation of a Middle College program (Johnson, 2015), a component of the IHIT curriculum model. To some degree, the IHIT model provides learning experience that has been offered by the Kettering University, which was founded by Charles Kettering, the head of research at General Motors Corporation in 1919. More details about the learning model can be found in references (Adelman, 1999; Allen & Dadger, 2012)

In brief, the early findings at VBECHA show that combination of rigorous high school coursework (e.g., advanced placement), demanding courses (e.g., physics and calculus) and dual-enrollment have a demonstrated a direct correlation to collegiate success (Adelman, 1999), and there is a strong correlation that participation in dual enrollment is positively related to GPA, persistence to second year, and ultimately, first-degree attainment (Allen & Dadgar 2012; Karp *et al.*, 2007; Swanson 2008). Moreover, rigorous coursework in high school leads to higher persistence and success rates in college (Struhl & Vargas, 2012). Indeed, in two years of operation at VBECHA, the 18 students enrolled in the program earned a combined 576 college credits; nine of the students earned more than 40 credits, each. The students earned an average collegiate coursework GPA of 3.5 and upon high school graduation, earned in excess of \$300,000.00 in scholarships to baccalaureate institutions.

As for the HiiM Program at WMU, Figure 3 shows the number of HiiM majors and graduates from 2012 to 2015. The number of students has grown from one student in 2012 to 52 students in 2015, and the number of graduates, from 2 in 2013 to 10 in 2015. The growth rates of both are much higher than what we expected, though they may not grow like this in the coming years. With the current resources, our program goal is to have 80 to 100 students by the year of 2017 and it is remained to be seen. With respect to the job placement, Figure 4 highlights the number of graduates in each organization types in the healthcare industry. Note that the results are based on a small sample of all graduates, 16, and data only indicate ten graduates who have been contacted with their current placement.



The placement results indicate that 50% of HiiM graduates have joined the Electronic Medical Record (EMR) software firm, and the remaining recruited by health insurance firm and healthcare providers. Only one graduate joined a non-health organization. While these results may not be statistically proven, with these early signs we can make the following comments:

- The health market is relatively strong and job placement is very good
- The HiiM Program has a fast growth and expects to grow in the coming years.
- There is no guarantee that all HiiM graduates will be able to find a job in health-related industries.

What we have learned and challenges to healthcare informatics and information technology education are presented in the next section.

5.0 LESSONS LEARNED AND CHALLENGES

It has been a great journey for the faculty at WMU to develop a cross-disciplinary undergraduate program – Health Informatics and Information Management (HiiM) by eliminating the academic silos within the MMU campus (Falan & Han 2011). It is more like an exploratory voyage for us to cross the campus boundary to pilot text the IHIT curriculum model in the community by combining resources from ISDs to community colleges with the HiiM Program at WMU. The lessons we have learned include the following:

- It is possible to integrate teaching talents by partnering all education units (i.e., ISDs, community colleges, and a four-year university) to expedite education process and better prepare students to be the HIT workforce for the healthcare industry.
- It requires the commitment from both faculty and the administrator (i.e., deans of colleges, program director) in order to implement the IHIT curriculum model across multiple campuses.
- Extra support (e.g., a program staff for student monitoring and advising) will be needed to track student progress from campus to campus. This function is essential to students' success when they migrate from one campus to another. In addition, students shall be guided to gain hands-on experiences, which may require a designated staff to work closely with healthcare organizations in the community.

Though the above lessons (i.e., Points two and three) may be seen as challenges as well, the additional challenges facing the IHIT curriculum model include:

- Students may enter the HiiM program without any experiences, i.e., they are not students with an early exposures as students from ISDs. Then, they need to be advised to make efforts in gaining externships and internships in some health-related organizations during the summer time as early as possible. For now, there are students join the HiiM program, without any experiences, when they are junior at WMU. They will have difficulties in finding jobs at the graduation time.
- There is a competition between community colleges and WMU in terms of getting student enrollments. Our experiences show that many community colleges have health-related programs and have high potential in access to local healthcare providers. Given the difference in tuition charges and early exposures to healthcare, more dialogues and academic cooperation between community colleges and WMU will help HiiM students in gaining hands-on. Similarly, more cooperation between ISDs and community colleges should be pursued as well.
- Lastly, the HiiM Program is truly a blended program that integrates health informatics with information technology from three areas basic sciences, health and human services, and college of business (computer information systems). Currently, many accreditation organizations (e.g., AHIMA, AMIA) do not have capacity in accrediting programs such as HiiM at WMU. This may slow down the education for training of real capable HIT workforce.

6.0 CONCLUSIONS

Healthcare industry is in need of qualified HIT workforce to transform healthcare meeting the Triple-Aim of healthcare – *Improved health, Lower costs,* and *Better care.* The traditional education approach may not be fast

enough to train college students due to the curriculum is multi-disciplinary and, in particular, the HIT workforce needs extensive hands-on knowledge and skills in health and information technology. This paper presents an Integrated Health Informatics and Technology (IHIT) curriculum model to collapse the campus boundary between regional Intermediate School Districts, Community Colleges, and a Four-Year University in order to support expedited HIT education with sufficient hands-on experiences in health informatics and information technology. This model was pilot tested by a newly developed Health Informatics and Information Management Program at Western Michigan University. Early findings from involved education partners are very positive. More research work and promotion of this curriculum model shall be continued. Challenges to this model are also summarized.

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