Spring 5-4-2006

UNDERSTANDING INTERRUPTIONS IN HEALTHCARE: DEVELOPING A MODEL

Juliana J. Brixey
University of Texas Health Science Center at Houston, School of Health Information Sciences,
Juliana.J.Brixey@uth.tmc.edu

Understanding Interruptions in Healthcare: Developing a Model

A

DISSERTATION

Presented to the Faculty of
The University of Texas
Health Science Center at Houston
School of Health Information Sciences
in Partial Fulfillment
of the Requirements

for the Degree of

Doctor of Philosophy

by

Juliana J. Brixey, RN, MPH, MSN

Committee Members:

Jiajie Zhang, Ph.D.[1]
Todd R. Johnson, Ph.D.[1]
Craig W. Johnson, Ph.D.[1]
James P. Turley, Ph.D., R.N.[1]
David J. Robinson, M.D.[2]

[1]School of Health Information Sciences, The University of Texas Health Science Center at Houston, Houston ,Texas, USA
[2]Memorial Hermann Hospital, Houston, Texas, USA

ABSTRACT

Understanding Interruptions in Healthcare: Developing a Model

Interruption is a known human factor that contributes to errors and catastrophic events in healthcare as well as other high-risk industries. The landmark Institute of Medicine (IOM) report, *To Err is Human*, brought attention to the significance of preventable errors in medicine and suggested that interruptions could be a contributing factor. Previous studies of interruptions in healthcare did not offer a conceptual model by which to study interruptions. As a result of the serious consequences of interruptions investigated in other high-risk industries, there is a need to develop a model to describe, understand, explain, and predict interruptions and their consequences in healthcare. Therefore, the purpose of this study was to develop a model grounded in the literature and to use the model to describe and explain interruptions in healthcare. Specifically, this model would be used to describe and explain interruptions occurring in a Level One Trauma Center. A trauma center was chosen because this environment is characterized as intense, unpredictable, and interrupt-driven.

The first step in developing the model began with a review of the literature which revealed that the concept interruption did not have a consistent definition in either the healthcare or non-healthcare literature. Walker and Avant's method of concept analysis was used to clarify and define the concept. The analysis led to the identification of five defining attributes which include (1) a human experience, (2) an intrusion of a secondary, unplanned, and unexpected task, (3) discontinuity, (4) externally or internally initiated, and (5) situated within a context. However, before an interruption could commence, five conditions known as antecedents must occur. For an interruption to take place (1) an intent to interrupt is formed by the initiator, (2) a physical signal must pass a threshold test of detection by the recipient, (3) the sensory system of the recipient is stimulated to respond to the initiator, (4) an interruption task is presented to recipient, and (5) the interruption task is either accepted or rejected by

the recipient. An interruption was determined to be quantifiable by (1) the frequency of occurrence of an interruption, (2) the number of times the primary task has been suspended to perform an interrupting task, (3) the length of time the primary task has been suspended, and (4) the frequency of returning to the primary task or not returning to the primary task.

As a result of the concept analysis, a definition of an interruption was derived from the literature. An interruption is defined as a break in the performance of a human activity initiated internal or external to the recipient and occurring within the context of a setting or location. This break results in the suspension of the initial task by initiating the performance of an unplanned task with the assumption that the initial task will be resumed. The definition is inclusive of all the defining attributes of an interruption. This is a standard definition that can be used by the healthcare industry. From the definition, a visual model of an interruption was developed.

The model was used to describe and explain the interruptions recorded for an instrumental case study of physicians and registered nurses (RNs) working in a Level One Trauma Center. Five physicians were observed for a total of 29 hours, 31 minutes. Eight registered nurses were observed for a total of 40 hours 9 minutes. Observations were made on either the 0700–1500 or the 1500-2300 shift using the shadowing technique. Observations were recorded in the field note format. The field notes were analyzed by a hybrid method of categorizing activities and interruptions. The method was developed by using both a deductive *a priori* classification framework and by the inductive process utilizing line-by-line coding and constant comparison as stated in Grounded Theory.

The following categories were identified as relative to this study:

- Intended Recipient - the person to be interrupted
- Unintended Recipient - not the intended recipient of an interruption; i.e., receiving a phone call that was incorrectly dialed
- Indirect Recipient – the incidental recipient of an interruption; i.e., talking with another, thereby suspending the original activity
- Recipient Blocked – the intended recipient does not accept the interruption
- Recipient Delayed – the intended recipient postpones an interruption
- Self-interruption – a person, independent of another person, suspends one activity to perform another; i.e., while walking, stops abruptly and talks to another person
- Distraction – briefly disengaging from a task
- Organizational Design – the physical layout of the workspace that causes a disruption in workflow
- Artifacts Not Available – supplies and equipment that are not available in the workspace causing a disruption in workflow
- Initiator – a person who initiates an interruption

Interruption by Organizational Design and Artifacts Not Available were identified as two new categories of interruption. These categories had not previously been cited in the literature.

Analysis of the observations indicated that physicians were found to perform slightly fewer activities per hour when compared to RNs. This variance may be attributed to differing roles and responsibilities. Physicians were found to have more activities interrupted when compared to RNs. However, RNs experienced more interruptions per hour. Other people were determined to be the most commonly used medium through which to deliver an interruption. Additional mediums used to deliver an interruption

included the telephone, pager, and one's self. Both physicians and RNs were observed to resume an original interrupted activity more often than not. In most interruptions, both physicians and RNs performed only one or two interrupting activities before returning to the original interrupted activity.

In conclusion the model was found to explain all interruptions observed during the study. However, the model will require an even more comprehensive study in order to establish its predictive value.

DEDICATION

To

my loving husband, Jack, whose love and patience never cease to amaze me

my beautiful daughters, Jenifer and Jacqueline, who realize that learning is a life-long journey

my mother, Rosemary, for the belief that there are no limits to what one can accomplish

my sisters and brother who know that there must be another paper for me to begin

my extended family for their thoughtfulness and encouragement

ACKNOWLEDGMENTS

"A successful person is a dreamer whom someone believed in" (author unknown)

Many individuals have given of their time and expertise to help me realize my dream of completing a PhD in health information science. Each member of my dissertation committee gave freely of their time to help guide me throughout this experience. I wish to express my heartfelt gratitude to my mentor, Dr. Jiajie Zhang. Thank you for your tireless patience in answering my questions and for your guidance in assisting me to work through the details of my dissertation.

Dr. James Turley, please accept my deepest gratitude for helping me establish a worldwide network of colleagues. Jim, without your encouragement to submit my papers to international conferences, I would not have had the opportunity to travel to the Virgin Islands, Japan, Australia, and China. It was awesome to climb the Great Wall in China, ride the bullet trains in Japan, and watch the penguins make their way onto the beach at Philips Island. I can only hope there are more international conference adventures to come.

I wish to express my appreciation to Dr. Todd Johnson for not only helping me with the research related to my dissertation but also for the opportunity to participate in other research projects. Those experiences have given me the opportunity to gain additional research skills.

A successful dissertation requires the input and guidance of a knowledgeable statistician. Dr. Craig Johnson played that role and has my sincere thanks.

Dr. David Robinson, thank you for sharing your expertise in emergency medicine. Your knowledge and insight were invaluable throughout this investigation. Your enthusiasm for the project never wavered and kept me inspired.

True friends never complain even when they are tired and wonder if there will be an end to the madness. My research partner and colleague, Zhihua Tang was always willing to help me complete another observation in the emergency department. I never heard Zhihua say “my feet hurt” or “my hands are tired from writing” even after standing for twelve hours recording activities occurring in an emergency department where the activity was non-stop. I am sure you were happy when you heard that theoretical saturation had been reached and the observations were complete. I can never fully express my gratitude for helping with data collection and analysis. It is my heartfelt wish that this is only the first of many research projects where we work together.

The entire administrative staff at the School of Health Information Sciences has always been extremely supportive in helping me navigate the system. I wish to express my genuine gratitude to Debbie Todd who has always had a smile for me even when I have had yet another question. Debbie has always been in her office when I needed someone to listen; thank you for always being there for me. Randy Scott helped me gain an understanding of the financial aspect of research. I wish to convey my appreciation to Randy for helping me manage the intricacies of my fellowship as well as my GRA status.

A major strength of the School of Health Information Science begins with the Dean and extends to all the faculty members. Dean Emeritus Doris Ross, please accept my appreciation for your leadership and for the high academic standards you have set for the school. You are truly an inspiration to all the students. I would like to acknowledge the current Dean, Dr. Jack Smith, for his support of my research. Also, I most certainly want to recognize Dr. Kim Dunn for her contagious enthusiasm and can-do spirit. Kim, you have given me the insight to always look beyond what might appear to be limitations for the possibility of opportunities.

An important asset and perhaps an unrecognized benefit within the School of Health Information is to be found amongst the graduate students. Dr. Constance Johnson and Dr. Rachel Richesson, as the first two students to graduate with doctoral degrees in Health Information Sciences, you are inspirations to all of us who follow. In addition, I have truly appreciated the support and encouragement from my pre-doc colleagues: Dr. Jung-Wei Chen, Dr. Yang Gong, Muhammad Walji, Zhong Xie, Arunkumar Srinivasan, and Min Zhu. I will miss our weekly meetings.

Adults with established professional careers often face financial challenges when they return to school because of reduction in earnings. My financial concerns as a pre-doctoral student were lessened as the recipient of a training grant from the Keck Center for Computational and Structural Biology of the Gulf Coast Consortia (NLM Grant No. 5 T15 LM07093). I have also received funding from Grant R01 LM07894 from the National Library of Medicine as a graduate research assistant to the project. Additional financial assistance was gained as the recipient of the following scholarships from The University of Texas Health Science Center at Houston:

- 2001-2002 Environmental Awareness Scholarship from The University of Texas Health Science Center at Houston
- 2001 – 2002 John P. McGovern Competitive Academic Scholarship from The University of Texas Health Science Center at Houston
- 2003 – 2004 Environmental Awareness Scholarship from The University of Texas Health Science Center at Houston
- 2003 – 2004 Adopt a Student Scholarship from The University of Texas Health Science Center at Houston
- 2005 Travel scholarship awarded by The University of Texas Health Science Center at Houston

Additional support has been provided my employer, The Methodist Hospital. The hospital and my colleagues have been supportive and considerate in accommodating my school schedule.

To my editor, Ruth Sellers, you are a saint!! You read and critiqued my manuscripts until they achieved perfection. Writing the dissertation gained momentum once we started the weekly meetings at

the infamous but dissertation-friendly and always accommodating Bad Ass Café. I was always re-energized to start writing after only one cup of that hot, black Kona coffee. The combination of scheduled weekly meetings and excellent coffee forced me to be prompt in doing the revisions that you suggested. I am grateful not only for the time you spent with me as my editor but as my friend.

I am forever indebted to the many individuals that helped me complete my dream of earning a PhD in health information science.

"Go confidentially in the direction of your dream. Live the life you have imagined"

(Henry David Thoreau)

TABLE OF CONTENTS

INTRODUCTION

Interruption, 'work-fragmenter', 'work-disrupter', and 'time-hacker' are a few of the names assigned to events that unexpectedly fragment workflow. In 1999, the Institute of Medicine (IOM) released *To Err is Human* in which interruptions were recognized as factors that contribute to preventable medical errors. The IOM report served as a motivation to conduct a comprehensive study of interruptions in a clinical setting.

Three manuscripts are presented as a PhD dissertation for the study of interruptions. The research combined the study of interruption as an abstract concept with a real-world situation by examining the interruptions that physicians and registered nurses (RNs) encounter within the context of a clinical setting. A Level One Trauma Center was chosen as the setting in which to study interruptions because emergency departments (EDs) are characterized as intense, life-critical, stressful, and interruption-laden due to a fluctuating workload of critically ill patients.

This research began with a current, ongoing, and very real problem – interruptions in workflow occurring in a Level One Trauma Center. There has been very little research dedicated to the scientific examination of this fairly common problem with an eye to improving this real-world situation. While I initially conceptualized this project as strictly an ethnographic study of interruptions that occurred in the ED, my mentors guided me towards first exploring interruption as an abstract concept by:

- developing a definition of interruption
- developing a framework of the interruption
- developing a method to categorize an interruption

These points resulted in the first two of three manuscripts. The customary dissertation model at the University of Texas Health Science Center at Houston, School of Health Information Sciences requires the submission of three papers (synthesis of the literature, methods, and results) to peer-reviewed journals. The first manuscript entitled "*A Concept Analysis of the Phenomenon Interruption*" addressed developing a definition and a framework of interruption using a concept analysis of interruptions. The purpose of a concept analysis is to explicitly identify the defining attributes of a term. Walker and Avant's eight-step method of concept analysis was used to clarify and define an interruption and develop a conceptual model of interruption. An interruption is defined as a break in the performance of a human activity initiated by a source internal or external to the recipient with the occurrence situated within the context of a setting or location. This break results in the suspension of the initial task by initiating the performance of an unplanned task with the assumption that the initial task will be resumed. This is a standard definition that can be used by the healthcare industry. The definition is inclusive of all the defining attributes of an interruption. The five defining attributes acknowledge that interruption is (1) a human experience, (2) an intrusion of a secondary, unplanned, and unexpected task, (3) discontinuity, (4) externally or internally initiated, and (5) situated within a context. Use of the defining attributes will be extended to form a category of interruption within a taxonomy of activity.

The derived definition of interruption was used to create a model of interruption. The diagram succinctly explains the interruption process. The process begins with the pre-interruption phase, a period of time during which no interruption is experienced. This is followed by a time at which the interruption is perceived and either accepted or rejected. If the interruption is rejected, the primary task continues. If the interruption task is accepted, the task is performed.

Once the interruption task has been accomplished, the original task is resumed and completed. However, not all interrupted tasks are resumed which can result in the original interrupted task being forgotten and perhaps left undone.

This paper is targeted to those interested readers of Advances in Nursing Science. This manuscript is in press for publication in 2006.

The second, or methods paper, is described in "*Towards a Hybrid Method to Categorize Interruptions and Activities in Healthcare*". The analysis of non-numeric data is a challenging task during the data analysis phase of qualitative research studies. As a way to accomplish this, I developed a hybrid method of categorizing activities and interruptions using both a deductive *a priori* classification framework with the provision of adding new categories discovered inductively in the data. The inductive process utilized line-by-line coding and constant comparison as stated in Grounded Theory. The two processes were merged and resulted in a hybridization of a deductive *a priori* classification framework with the provision of adding new categories discovered inductively in the data using grounded theory. The method is called the Hybrid Method to Categorize Interruptions and Activities (HyMCIA). The categories of activities and interruptions were organized into a three-tiered hierarchy of activity based on Rosch's model for concepts. Rosch's concept hierarchy was extended to categorize activities and interruptions. Activity became the name for the Superordinate Category. This category made no distinction as to whether an activity was or was not interrupted. It was determined that additional specificity was needed to code and classify an activity. This resulted in the creation of a Basic Category. The Basic Category was used to classify whether or not an activity had been interrupted. This category was divided into those activities that were performed without interruption and those that had been interrupted. These categories were named Uninterrupted and

Interrupted. To categorize an interruption for more detail, specific instances of interruptions were identified, thereby forming the Subordinate Categories. The hybrid model of categorization is more complete than either a deductive or inductive method alone. This paper was determined to be of international interest because interruptions are a universal phenomenon and was therefore submitted to the International Journal of Medical Informatics.

The third and final paper for this dissertation reports the findings from an instrumental case study of physicians and RNs working in a Level One Trauma Center. The purpose of the study was to observe, record, and contextualize activities and interruptions by shadowing the physicians and the RNs. The observations were analyzed using the Hybrid Method to Categorize Interruptions and Activities (HyMCIA). No new categories of interruptions or activities were identified in the data. By categorizing interruptions, it was found that physicians received slightly fewer interruptions per hour when compared to RNs. Both physicians and RNs were interrupted by other people, pagers, and the telephone. The introduction and use of mobile telephones in the ED is an example of a new technology that has not yet been studied to determine how it interrupts and therefore requires additional studies, evaluations, and means by which to make their use as efficient as possible. It was also possible to learn in this study that physicians and RNs usually resumed the original task after performing one or two interrupting tasks. The target audience for this paper is those specifically interested in clinical informatics: and for this reason the third manuscript was submitted to the Journal of the American Medical Informatics Association (JAMIA).

Together, the three papers represent the spectrum of this dissertation research for the study on interruptions. This dissertation has resulted in a standard definition of interruption and a framework by which to depict the interruption process as derived through concept analysis. In

addition, a hybrid method has been developed by which to categorize interruptions and activities. And finally, an instrumental case study was conducted to observe, describe, and categorize interruptions for physicians and RNs within the context of an ED. These three manuscripts present a fuller, more comprehensive look at the concept interruption as it applies and affects the workplace, specifically in a healthcare setting.

Juliana Brixey
March 27, 2006

MANUSCRIPTS

A Concept Analysis of the Phenomenon Interruption

Juliana J. Brixey, MSN, MPH, RN[1]

David J. Robinson, MD[1,2]

Craig W. Johnson, PhD[1]

Todd R. Johnson, PhD[1]

James P. Turley, PhD, RN[1]

Jiajie Zhang, PhD[1]

[1] School of Health Information Sciences, The University of Texas Health Science Center at Houston, Houston, TX
[2]Memorial Hermann Hospital, Houston, TX

Corresponding author
Juliana Brixey, MSN, MPH, RN
Juliana.J.Brixey@uth.tmc.edu
University of Texas Health Science Center at Houston
School of Health Information Sciences
7000 Fannin Suite 600
Houston, TX 77030
281.451.8206
713.500.3907 (FAX)

A Concept Analysis of the Phenomenon Interruption

ABSTRACT

An interruption was found to have no consistent definition in either healthcare or non-healthcare literature. Walker and Avant's eight step method of concept analysis was used to clarify and define an interruption and develop a conceptual model of interruption. The analysis led to the identification of five defining attributes which include (1) a human experience, (2) an intrusion of a secondary, unplanned, and unexpected task, (3) discontinuity, (4) externally or internally initiated, and (5) situated within a context. Use of the defining attributes will be extended to form a category of interruption within a taxonomy of activity.

Key words: Interruption, concept analysis, nursing, healthcare

INTRODUCTION

Interruptions are recognized by human factors experts as conditions that reduce efficiency and productivity, and contribute to errors in industries such as aviation,[1] nuclear power plants,[2] and healthcare.[3] These errors have contributed to catastrophic events which may include the loss of life. In 1999, the Institute of Medicine[3] in *To Err is Human* raised the concern that interruptions were factors that could contribute to medical errors. This report was among the first to suggest that interruptions had a negative impact on performance and as such is still in the beginning stages of investigation. In nursing, the negative influences of interruptions extend beyond the bedside to any other area that Registered Nurses' (RNs) work. For example an interruption for a nursing administrator could result in a budgetary error when an incorrect number is entered into a spreadsheet after completing an unexpected conversation. A nurse informatist could experience both a reduction in efficiency in productivity by receiving a large number of unexpected,

interrupting telephones while trying to resolve a system failure. The unexpected increase in telephone calls contributes to interruptions in workflow. The change can cause the RN to forget to reset a critical function resulting in an error by interruption. For RNs to communicate the negative effects of an interruption, it is necessary that all attributes of the interruption be described using consistent terms when describing the event. This uniform use of terminology is most important when describing an interruption in an error report. A shared, controlled, and accepted vocabulary by which to describe the interruption event increases the generalizability and usefulness of the report. This in turn supports nursing's leadership role in improving patient safety by understanding factors such as interruptions and how those elements reduce efficiency and productivity, and how they contribute to medical errors.

A review of the healthcare literature uncovered a number of healthcare researchers who have begun to study interruptions in the clinical setting.[4-10] However, the usefulness of the studies is limited because each study utilizes a unique definition of interruption. The lack of consistency in defining an interruption hinders a thorough understanding of the phenomenon. An accepted theoretical definition would assist researchers when comparing and contrasting findings from both research studies of interruption and medical error reports, thus gaining a more complete understanding of how interruptions contribute to decreased efficiency and productivity and contribute to medical errors. Therefore, a need exists for an accepted theoretical definition of interruption in a healthcare setting in which the defining attributes are explicitly stated and could be structured in a format that would support computer-assisted data analysis. In addition the theoretical definition would support the construction of a conceptual model of an interruption.

The theoretical definition and a conceptual framework arise from a specific concept. A concept is a mental representation of an object or an action used to organize and categorize

phenomenon in the environment.[11] Wilson suggests that the process of concept formation begins during childhood when we begin to form mental representations of objects.[12] The ability to categorize and group things begins in childhood as a child becomes cognizant that objects have different properties. Words become associated with concepts and allow us to communicate with others through a shared understanding. However, communication is influenced by how we use and understand words.[12] Over time, differences in the use or new understandings of a concept diminish the common agreement which can subsequently result in communication errors. For that reason, a collective meaning and understanding of a concept is essential to successful communication. For example, the term interruption, is commonly used when indicating that an unexpected task is performed. The *Webster's 1913 Dictionary*[13] defines an interruption as:

1. the act of interruption, or breaking upon
2. the state of being interrupted; a breach or break, caused by the abrupt intervention of something foreign; intervention; interposition
3. obstruction caused by breaking upon course, current, progress, or motion; stop; hindrance
4. temporary cessation; intermission; suspension

Similarly, the 2002 edition of the Oxford English Dictionary (OED)[14] defines an interruption as:

1. a breaking in upon some action, process or condition, (esp. speech or discourse), so as to cause it (usually temporarily) to cease; hindrance of the course or continuance of something; a breach of continuity in time; a stoppage

2. a breach of continuity in space or serial order; a break; the formation or existence of a gap or void interval
3. the action, or an act, of hindering or thwarting; hindrance, obstruction

The dictionary definitions provide evidence that the meaning of the concept interruption has remained relatively stable over the last century. However, research studies demonstrate great variability and a lack of consensus within the healthcare industry.

The following examples illustrate how researchers in healthcare have operationally defined an interruption:

1. "anything that disturbed the continuity of the nurse's work when already engaged on a task or caused a distraction during a consultation with a patient."[15(p34)]
2. "the ringing of the phone, any opening of the door to the surgery, or any action of the physician not directly related to the patient."[9(p220)]
3. "the cessation of productive activity before the current prescription-filling task was completed for any externally imposed, observable, or audible reason."[8(p321)]
4. "any event that briefly required the attention of the subject but did not result in switching to a new task."[4(p1240)]
5. "an event that diverted the physician's attention from the task at hand."[5(p148)]
6. "a communication event that was not initiated by the observed party and occurred using a synchronous communication channel such as face-to-face conversation or the telephone."[16(p2),17(p270)]

7. “a communication event in which the subject did not initiate the conversation, and which used a synchronous communication channel.”[7(p416)]
8. “the usurpation of control.”[18(p1029)]

Additional specificity is being used to define an interruption. In a study examining interruptions occurring during conversation, Alvarez and Coiera[10] identified two specific types of interruptions. Those interruptions are: conversation-initiating interruption (CII) and turn-taking interruption (TTI). A CII was defined as “a communication event that is not initiated by the observed subject, and occurs using a synchronous communication channel such as face-to-face conversation or the telephone.” In contrast a TII was defined as “when one individual communication event, when one individual begins speaking before the other finishes.”[(p792)] These definitions add to our understanding of how interruptions affect conversations.

The definitions reveal that in research, the concept interruption is study specific. The researchers frame their definition around a specific observable phenomenon relative to some event that interferes with the person’s task performance. This specificity impedes comparison of research findings and reduces generalizability of results.

A similar situation is found in other studies of interruption. Researchers in non-healthcare studies of interruption have defined it as:

1. “an interruption is nothing more than unanticipated event. It appears in two forms, either in-person or over a communication medium (email, phone, faxes, etc.).” [19(p2)]
2. “any distraction that makes a developer stop his planned activity to respond to the interrupt’s initiator.[20(p98)]

3. "can be seen as situations in which one person intends to continue speaking, but is forced by the other person to stop speaking at least temporarily, or the continuity or regularity of that person's speech is disrupted."[21(p1872)]
4. "a break in the organization of activity arising from a change of (task) environment."[22(p1)]
5. "human interruption is the process of coordinating abrupt change in people's activity."[23(p119)]
6. "any disturbance to the normal functioning of a process in a system."[24(p4)]

These definitions illustrate the variation in how researchers define an interruption. The definitions have less specificity and are more general than those used in healthcare. Nonetheless, the definitions exhibit a degree of research study specificity. The lack of consensus in the literature illustrates the need for an accepted definition of interruption to be used in research studies. Therefore, the purpose of this analysis is to clarify the concept of interruption by developing a definition of interruption grounded in the literature. A uniform definition will reduce ambiguity in use of the term interruption.

METHODS

Qualitative Paradigm

This concept analysis was guided by Critical Theory within the context that competing power interest between groups and individuals influences and supports an identification of a shift in power.[25] There will be those who will experience an increase in power while there will be those that will experience a decrease in power. In the case of an interruption, the initiator of the interruption may be perceived to be in a superior position while the recipient of the interruption

is thought to be in a subordinate position. However, it can be argued that the recipient retains the control to choose whether or not to accept an interruption. Within the definitions of interruption, the role of the recipient becomes acknowledged once the person accepts the definition. This immediately implies the recipient has relinquished power and control of their current task to accommodate the initiator. Therefore, a possible power struggle could arise between the initiator and the recipient. In turn, the resultant conflict and anxiety could result in decreased productivity and efficiency in the workplace as well as in errors. These are issues that will require additional examination in future research.

Search method

We sought to identify the meaning of interruption as grounded in the research literature of healthcare and other disciplines such as human factors, aviation, nuclear power plants, management, psychology, and cognitive science. These domains were systematically searched using the World Wide Web (WWW), Medline, and reference lists from studies of interruption. The following search terms were combined: ‘interruption’, ‘task’, ‘error’, ‘nurses’, and ‘doctors’. The purpose was to maximize the capture of interruption studies to eliminate studies that were outside the interest of this study, and reduce the number of returns not relevant to the study. The search included any healthcare research study of interruption or study of task interruption published in English or with an English translation. Since the goal was to develop the most comprehensive definition of interruption, explicit definitions from psychology and human factors were included. Year of publication was not a deciding factor for inclusion or exclusion in this study. One hundred twenty citations were reviewed for this analysis.

Data analysis

Concept analysis was chosen as the method by which to analyze the various definitions of interruption. The primary goal of concept analysis is to explicitly identify the defining attributes.[11] According to Walker and Avant[11] and Wilson,[12] concept analysis is a technique used to examine word usage coupled with an explanation of its similarities and differences with related words or terms. The process is concerned with both actual and possible uses of the word that convey a consistent meaning and serve to develop a standardized language for use in communication. The strategy supports a theoretical as well as an operational definition for use in theory and research. Furthermore, Walker and Avant[11] maintain that concept analysis can be used to refine ambiguous concepts in theory and to clarify overused or vague terms resulting in a precise operational definition that increases the validity of the concept.

Wilson introduced an 11-step process to guide concept analysis.[12] The process is summarized and described in the following steps:

1. isolating questions of concept – involves separating the objective from the subjective values of a concept
2. right answers - identifies the primary and central uses of a concept as opposed to derived and borderline uses
3. model cases – exemplifies all the defining attributes of the concept
4. contrary cases – clearly demonstrates an instance that is not the concept
5. related cases – has a fundamental relationship with the concept through an association with another concept
6. borderline cases - lack one or more of the essential attributes
7. invented cases – imaginary examples of the concept

8. social context - the setting and situation of use
9. underlying anxiety - the mood or feeling of the person using the concept, the connotation of the concept
10. practical results – the degree to which answering the question adds any usefulness beyond an academic exercise
11. results in language - reduces the ambiguity of use in language

The process is a useful tool in understanding not only the denotation but the connotation of a concept. The result is a clear and unambiguous understanding of the phenomenon.

Walker and Avant[11] streamlined Wilson's[12] method into an 8-step procedure. The researchers maintain that their method utilizes key elements from Wilson's process resulting in a method that is less complex and easier to learn. The following elements were chosen from Wilson's process:

1. select a concept
2. determine the aims or purposes of analysis
3. identify all uses of the concept
4. determine the defining attributes
5. identify a model case
6. identify borderline, related, contrary, invented, and illegitimate cases
7. identify antecedents and consequences
    a. an antecedent is a situation that must transpire prior to the occurrence of the concept and cannot be a defining attribute
    b. a consequence is the outcome of the event
8. define empirical referents – classes or categories of actual occurrence

a. is useful in instrument development

b. strengthens content and construct validity

Walker and Avant's[11] process has been used extensively in nursing to guide concept analysis. The methods outlined by Walker and Avant best supported the aim of this analysis to explore the concept of interruption. The Walker and Avant process was used exclusively for this concept analysis.

RESULTS

Results of literature search

One hundred twenty journal articles were reviewed and examined to identify if the concept was explicitly defined in the study and how the researcher defined interruption. Definitions were entered into an Excel spreadsheet to facilitate organization and analysis of the definitions.

Defining attributes

Defining attributes are a cluster of characteristics that are most often associated with a concept. These specific characteristics assist in differentiation between similar concepts.[11] Five defining attributes were identified for an interruption: (1) a human experience (2) an intrusion of a secondary, unplanned, and unexpected task (3) discontinuity, (4) externally or internally initiated, and (5) situated within a context. The defining attributes of an interruption will be discussed in the following sections.

Interruption: A human experience

Both humans and machines can be interrupted but it is the human experience of interruption that has interested researchers for approximately 100 years. Lewin and his students were among the first to study the human experience of interruption in a controlled laboratory setting.[26] Beginning in the 1940s researchers began to study the human experience of interruption in the workplace. Military aviation was among the first areas to be studied.[1] Investigation of aviation accidents found that interruption contributed to pilot error. More recently, the study of interruption has extended to the healthcare environment. A small number of researchers have begun to examine the human experience for nurses, doctors, and pharmacists in the clinical setting. In either the laboratory or the workplace, it is the human who is interrupted.

The purpose of these studies is to gain a deeper understanding of the human experience of interruption from the perspective of the recipient. In each study the human becomes the recipient of an interruption by accepting an unexpected secondary task to perform.

Interruption: Intrusion of a secondary, unplanned, and unscheduled task

An interruption occurs as the intrusion of a secondary, unplanned, and unscheduled task into the primary task. The intrusion of the interruption task can occur at any time during the task performance. Norman[27] explains task performance through the Seven Stage Action Cycle. The Action Cycle shows that performing a task begins with the formation of a goal. The goal is converted into an intention to achieve an action. In turn, the intention is transformed into an action sequence that is executed to satisfy the intention. The cycle is completed upon evaluation of the process. Zhang, Patel, Johnson, and Shortliffe [28] show how the model can be used to depict the actions involved in programming an infusion pump. This is shown in Figure 1.

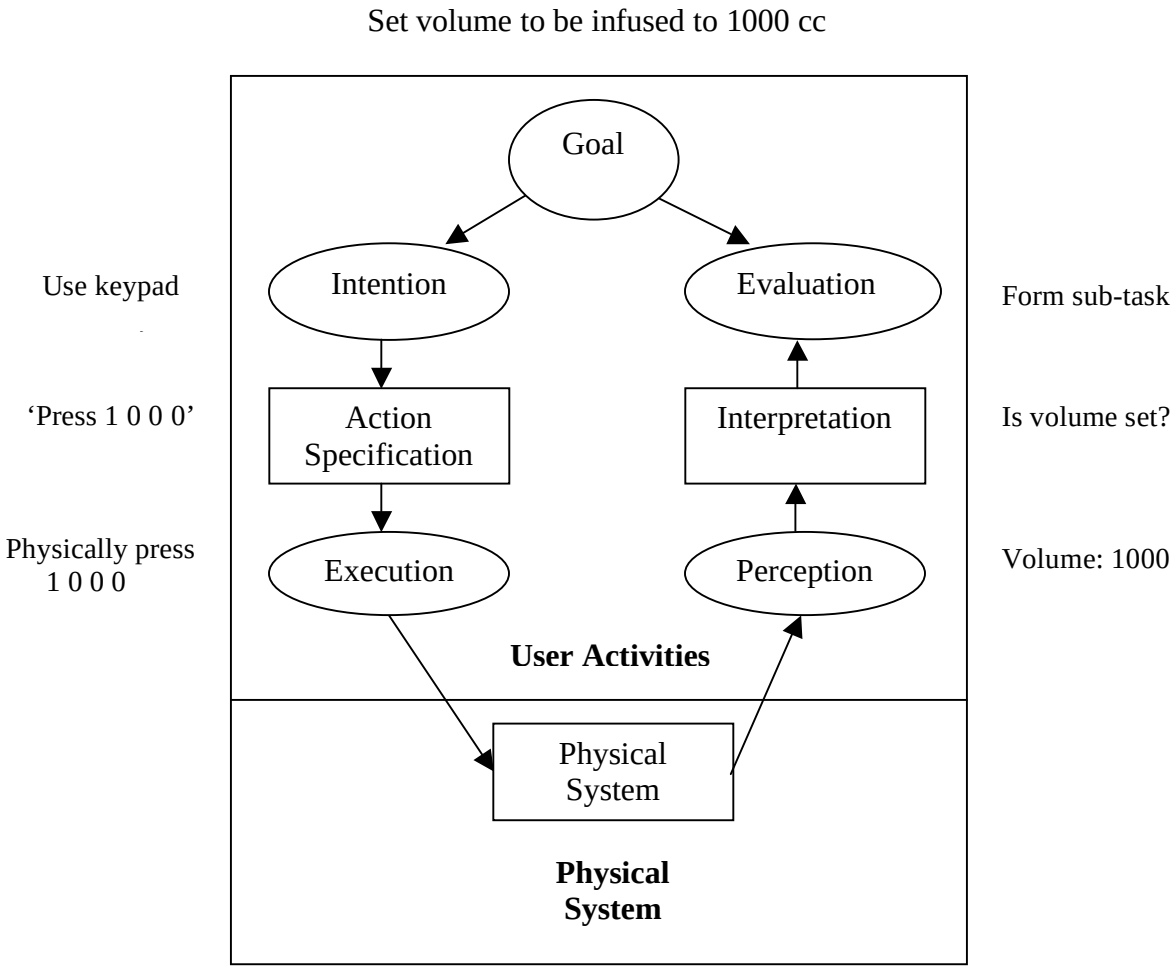

Figure 1. Norman's Action model depicting programming an infusion pump as depicted by Zhang, Patel, Johnson, and Shortliffe. Used with the permission of Dr. Jiajie Zhang.

Not all stages of the Action Cycle are directly visible to an observer who wishes to pinpoint when a person has received an interruption. Those stages when interruptions are not observable are designated by an asterisk (*) as shown in Figure 2. During the non-observable stages of the Action Cycle the recipient of the interruption may be performing an internal task such as forming a goal.

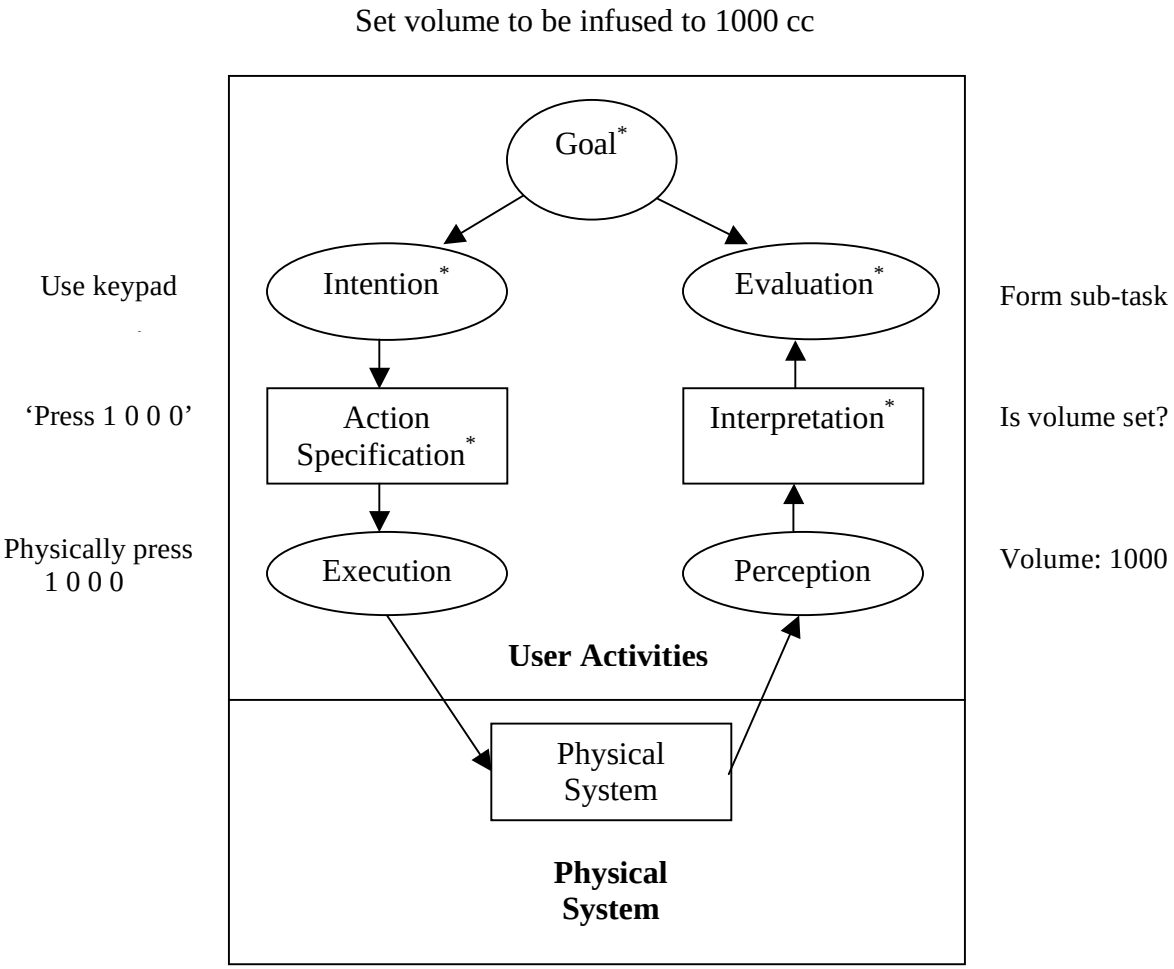

Figure 2. Non-observable stages in the Action Cycle during the programming of an infusion pump as depicted by Zhang, Patel, Johnson, and Shortliffe. Used with the permission of Dr. Jiajie Zhang.

The inability to observe an interruption during the states designated as not observable in the Action Cycle present challenges in studying interruptions. It is obviously easier to study an interruption during an observable step than during a non-visible step in the Action Cycle. For example, an interruption that occurs during the task execution stage is detectable if the task requires some physical action on the part of the person receiving the interruption. The ability to detect at what point in the Action Cycle the interruption was received indicates when the person

suspends the primary task, performs the interruption task, and ultimately returns to the primary task.

The Seven Stage Action Cycle is useful to illustrate and explain the intrusion of an interruption into the primary task space such as when programming an infusion pump. The utility of the Action Cycle is most beneficial when the interrupted task is observable. Interruptions in non-observable states are more difficult to link to a specific step in the Action Cycle.

Interruption: Discontinuous task performance

An interruption causes discontinuity in task performance. Discontinuity is defined as "producing discontinuity; breaking continuity between parts; gaping."[29] Task performance is understood to be a continuous process accomplished through a series of actions without interruption. An interruption breaks the continuity of task performance resulting in the primary task being unexpectedly suspended at some step prior to completion.

The first period of discontinuity in performing a task occurs when the interruption recipient receives notification that an interruption is about to occur. At this point the recipient begins to prepare to suspend the primary task and begin the interrupting task. The preparatory time is known as Interruption Lag.[30]

The second period of discontinuity occurs upon completion of the interrupting task and resumption of the suspended primary task. As a result of the discontinuity introduced by an interruption, there is a necessary period of recovery to resume the suspended task. This time of discontinuity is designated as the Resumption Lag.[30]

Interruption: Occurs external or internal to the individual

Studies of interruption have focused exclusively on external sources that interrupt an individual. The definitions of interruption used in the studies operationalize an interruption as

generated external to the recipient. External sources are observable and measurable by the researcher. The source of the interruption may come directly from another individual or may be delivered through a medium such as the telephone. An external source of interruption is not limited to humans but can come from a device such as an infusion pump.

The distinction should be made that a ringing telephone and the device alarm are not the source of the interruption but the medium through which the interruption is delivered. The interruption is initiated by a person. The initiator uses a physical signal to alert the recipient that the interruption is about to occur. An impending telephone call is preceded by a physical signal such as a ring, a beep, or a vibration. An interruption in conversation may be announced by a phrase such as “sorry to interrupt”.

In contrast, interruptions can occur internal to an individual. Internal interruptions are more difficult to observe, measure, and study. This type of interruption occurs within the thought process. For example, an internally-generated interruption occurs as a daydream or an intrusive thought unrelated to the primary task. These interruptions are experienced privately within the mind of the individual. Those who teach meditation techniques such as those taught by Zen and Chen Buddhists know that intrusive thoughts can interrupt the meditative state. Students are taught to control intrusive thoughts in order to decrease the number of interruptions while meditating.

Interruption: Situated in a context

An interruption occurs within the context of a setting or location. The laboratory has been the primary location used to study interruptions. Results from these studies provide information about interruptions in a controlled setting free of confounding variables and complexities found in a real world setting such as the workplace. Workplace studies provide information about the

working conditions for the employees. Studies of interruptions experienced by nurses have been conducted within the context healthcare organizations such as primary clinics,[15] hospitals,[6] and specific departments such as the emergency department (ED),[7, 16, 17] and the intensive care unit (ICU).[10] Each of the settings can be characterized by high-volume and unpredictable workloads.

Interruptions in healthcare organizations have found to be initiated through the use of technologies such as pagers and telephones but also through face-to-face contact with other people.[6, 7, 10, 15-17, 31] These findings support Coiera's argument that healthcare professionals prefer synchronous communication channels. Consequently, the use of synchronous communication suggests that the initiator of an interruption does not necessarily consider how the interruption may affect the workload of the other person. Such observation supports the idea that the healthcare environment can be characterized as interrupt-driven.[4, 5]

MODEL CASE

The model case is taken from the Agency for Healthcare Research and Quality (AHRQ)[32] to illustrate the five defining attributes of an interruption. "*A 55-year-old man with acute myelogenous leukemia and several recent hospitalizations for fever and neutropenia presented to the emergency department (ED) with fever and hypotension. After assessment by the emergency physician, administration of intravenous crystalloid and empiric broad-spectrum antibiotics, the patient was assessed by his oncologist. Based on the patient's several recent admissions and the results of a blood culture drawn during the last admission, the oncologist added an order for Diflucan (fluconazole) 100 mg IV to cover a possible fungal infection. Because intravenous fluconazole was not kept in the ED, the nurse phoned the pharmacy to send the medication as soon as possible. A 50 ml bottle of Diprivan (propofol, an intravenous sedative-hypnotic*

commonly used in anesthesia) that had been mistakenly labeled in the pharmacy as "Diflucan 100 mg/50 mL" was sent to the emergency department. Because the nurse also worked in the medical intensive care unit, she was quite familiar with both intravenous Diflucan and Diprivan. When a glass bottle containing an opaque liquid arrived instead of the plastic bag containing a clear solution that she expected, she thought that something might be amiss. As she was about to telephone the pharmacy for clarification, a physician demanding her immediate assistance with another patient distracted her. Several minutes later, when she re-entered the room of the leukemia patient, she forgot what she had been planning to do before the interruption and simply hung the medication, connecting the bottle of Diprivan to the patient's subclavian line. The patient's IV pump alarmed less than one minute later due to air in the line. Fortunately, in removing the air from the line, the nurse again noted the unusual appearance of the "Diflucan" and realized that she had been distracted before she could pursue the matter with the pharmacy. She stopped the infusion immediately and sent the bottle back to the pharmacy, which confirmed that Diprivan had mistakenly been dispensed in place of Diflucan. The patient experienced no adverse effects—presumably he received none of the Diprivan, given the air in the line, the infusion time of less than a minute, and the absence of clinical effect (Diprivan is a rapidly-acting agent). None the less, the ED and pharmacy flagged this as a potentially fatal medication error and pursued a joint, interdisciplinary root cause analysis, which identified the following contributing factors: (i) Nearly 600 orders of medication labels are manually prepared and sorted daily; (ii) Labels are printed in "batch" by floor instead of by drug; (iii) The medications have "look-alike" brand names; (iv) A pharmacy technician trainee was working in IV medication preparation room at the time; and (v) The nurse had been "yelled at" the day before

by another physician—she attributed her immediate and total diversion of attention in large part to her fear of a similar episode". (Reprinted with permission from AHRQ WebM&M).

The interruption of a nurse in the model case shows the five defining attributes of an interruption. The five defining attributes are:

1. a human experience
2. the intrusion of an unplanned, unexpected, interrupting task
3. discontinuity in task performance
4. initiated external or internal to the recipient
5. situated within a context

In this example, the human experience is that of the nurse as she works in the emergency department (ED). The nurse's plan to telephone the pharmacy to clarify a medication is superseded by a physician's need for assistance. The external source of the interruption results in a discontinuity in task performance in making the call. The lack of continuity in the medication administration process results in a near-miss medication event. The occurrence is within the context of a high-volume department with an unpredictable workload. As required, the model case includes all the defining attributes.

RELATED CASE

A related case illustrates fundamental elements which are similar to those found in the model case but are found to differ when scrutinized.[11] An organization can experience an interruption

in much the same way that an individual does. A business performs the task of producing goods and services to achieve organizational goals. Conditions, either internal or external, can interrupt an organization. Severe weather conditions have been shown to cause organizational interruption. The flooding event of June 8-9, 2001, which occurred as a result of Tropical Storm Allison was one the most intense rainfalls to ever hit the Texas Medical Center (TMC).[33] The delivery of healthcare services for 9 of 13 hospitals in the TMC was interrupted due to those flooding conditions. In June 2001, Allison crossed the Texas Gulf Coast in the Houston-Galveston area and over a 5-day period the area received 37 inches of rain. The rainfall caused catastrophic flooding within the ground floors as well as the basement areas in the TMC. The lower level floors housed critical diagnostic equipment, medical research laboratories, electrical infrastructures (including back-up power, generators, and switchgear), and heating, ventilation, and air conditioning (HVAC) equipment. Many facilities lost both primary and back-up power. These conditions resulted in the evacuation of 1000 patients from the nine affected TMC hospitals. The area was closed to motor vehicle traffic for approximately 9.5 hours, and the two Level 1 trauma centers in the TMC lacked any street access.

The case of organizational interruption contains all the significant attributes assigned to an interruption except the human experience. Although humans were involved, they were indirect recipients of the interruption. Nurses still continued to provide nursing care to patients until they were evacuated from the hospitals. Nurses from the evacuated facilities became temporary employees to help fill the increased staffing needs of hospitals throughout the Houston area not affected by the flood. In the weeks following the flood, the evacuated hospitals were repaired and the delivery of healthcare services resumed.

BORDERLINE CASE

The concept distraction illustrates not only a borderline case but the use of distraction as a synonym for an interruption. According to the OED[34] distraction is defined as "the drawing away (of the mind or thoughts from one point or course to another, diversion of the mind or attention. Usually in adverse sense; less commonly = end, relaxation (as in Fr.)". A review of any issue about healthcare begins with a search of Medline/PubMed. Medline is organized by Medical Subject Headings (MeSH).[35] MeSH is a controlled vocabulary used for indexing, cataloging, and searching for biomedical and health-related information and documents. Distraction has not been used as a concept that is searchable in MeSH to direct the search to journal articles about interruptions. Similarly, a search using the concept interruption does not point to distractions.

Healthcare agencies such as the United States Pharmacopecia (USP) and Joint Commission on Accreditation of Healthcare Organizations (JCAHO) are using the term distraction as a workplace factor contributing to medical errors. In root cause analysis of 23 reports of deaths or injuries involving long-term ventilator patients, JCAHO reported distraction in the form of environmental noise as a contributing factor in 22 percent of the cases.[36] Distractions have also been cited as a contributing factor in wrong site surgery errors.[37]

In the analysis of confidential medication error reports submitted to the USP by hospitals, clinics, nursing homes, and retail pharmacists, the USP found that workplace distractions were frequently cited as a contributing factor.[38] Among issues in the workplace contributing to medications errors, distractions were cited as the leading cause at 43 percent. Staffing issues accounted for 36 percent while workload contributed for 22 percent.[39]

The statistics indicate that distractions are environmental causes that contribute to medical errors. The use of the term distraction as a synonym for interruption leads to confusion in

searching the literature. Research studies use interruption as a key word while agencies such as USP and JCAHO use the term distraction. The examples taken from medical errors show the need for consensus in the use of a concept. Without consistency in terminology, important information is missed when searching the literature for a specific concept.

CONTRARY CASE

Continuous is undoubtedly an antonym for interruption. Continuous is defined as "characterized by continuity; extending into a space without interruption of substance; having no interstices or breaks; having no parts in immediate connexion; connected; unbroken."[40] Healthcare has elected to use the term Continuous Quality Improvement (CQI) to designate a set of principles used to improve clinical processes and enhance patient satisfaction. Other industries use the term Total Quality Management (TQM) to identify the process. Healthcare organizations use CQI not only to improve clinical quality but also to improve patient satisfaction, reduce error rates, reduce cost, and improve productivity.

CQI relies on a constant vigilance to processes which are designed to detect and reduce errors and defects. The sole purpose of TQM is to meet customer expectations and specifications. Expectations and specifications are met by checking for unusual variation in manufacturing through the use of the Shewhart, Deming, or the PDCA Cycle (Plan, Do, Check, and Act). Deming, as a student of Shewhart, used the same model in his teaching of TQM.[41] The PDCA model relies on four steps:

1. Plan – analyze the process for problems and devise a plan for change
2. Do – pilot the changes to minimize disruption in the process

3. Check – to see if changes made a difference
4. Act – fully implement the change within the process

CQI process is an example of uninterrupted process. The process is operationalization in the PDCA cycle and is used to improve quality both in healthcare and in manufacturing. The process illustrates that defect reduction requires a constant uninterrupted vigilance.

ILLEGITIMATE CASE

The designation of an illegitimate case of a concept has a negative connotation. However, non-traditional use of a concept has a valid use in the construction of jargons for specific domains. In most domains the concept interruption implies performing an unexpected and unscheduled task. Conversely, interruption has a different meaning when used by musicians. The phrase 'cadence interrupted' is a term used in music to describe a **type** of cadence. An interrupted cadence, also called a false or deceptive cadence, refers to "any time that the music seems to lead up to a cadence, but then doesn't actually land on the expected tonic, and also often does not bring the expected pause in the music."[42] The expectation is that a dominant chord moves to a tonic chord, thus producing a perfect cadence. For this reason, if a dominant chord is followed by any other chord, the feeling is one of 'interruption'. The interrupted cadence is not a true cadence in syntactic terms because it serves only as an extension to the dynamic harmony of the closing section of the phrase.[42] Therefore, an interrupted cadence is a dominant chord followed by any chord except the tonic.

This example shows that a concept can have a different meaning when used within a specific domain or group. A discussion about an interruption between two musicians will have a different meaning than between two nurses. A break-down in communication occurs when the nurses and

musicians attempt to discuss an interruption. The lack of a shared definition of an interruption will result in miscommunication and frustration. Accurate communication is **only** possible when both groups make the definitions known.

ANTECEDENTS AND CONSEQUENCES

On examination, an interruption can be shown as a process. Antecedents that must occur before an interruption commences are:

1. intent to interrupt is formed by the initiator
2. physical signal passes threshold test of detection by the recipient
3. sensory system of the recipient is stimulated to respond to the initiator
4. interruption task is presented to recipient
5. interruption task is either accepted or rejected by the recipient

The antecedents can be more adequately depicted in a diagramatic model. The antecedents of interruption are depicted in Figure 3.

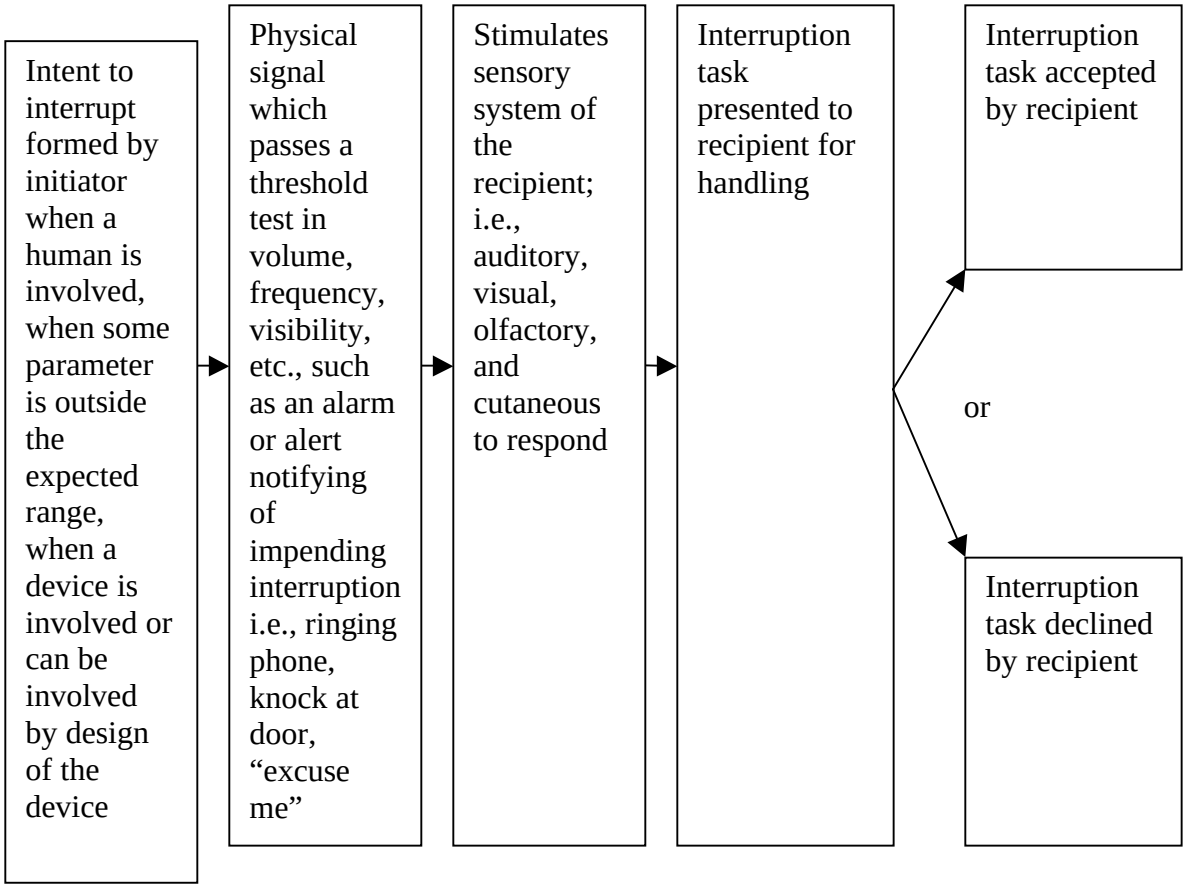

Figure 3. Antecedents of an interruption

The model shows that the antecedents of interruptions occur as an ordered sequence of steps. In order for an interruption to occur, there must an initiator, a recipient, a detectable signal that an interruption is about to occur, a medium through which the interruption is transmitted, and the management of the interruption. The interruption task is either accepted or rejected by the recipient. Therefore, a successful interruption depends on the detection and acceptance of the impending interruption task by the recipient.

CONSEQUENCES

The consequences of interruption have been studied extensively in the laboratory setting. Researchers have had an intense interest in how an interruption affects human task performance.

The preponderance of findings from research studies indicates that interruptions have a negative impact on performance. However, a few laboratory studies have found that interruptions can have a positive impact on performance.[43, 44]

The study of interruption in the workplace has focused on individuals working in high-risk industries such as nuclear power plants, aviation, and healthcare. For individuals working in these industries, interruptions can result in catastrophic events such as power plant shut downs,[2] plane accidents,[1] and medical errors.[8] Studies in other industries report that interruptions reduce the efficiency and productivity of employees. Interruption of software engineers result in time spent regaining flow of work following an interruption.[20] In the business field, recipients of interruption do not always discourage them.[45] Managers have been shown to perceive interruptions as an important part of their work in order to receive information.[45]

In healthcare, nurses, doctors, pharmacists, and other clinicians work in an interrupt-driven environment. Nurses are more likely to be interrupted because of the multi-tasking nature of their work as opposed to the single-tasking of physicians, particularly surgeons. The consequences of interruptions have been reported in terms of workplace satisfaction expressed by nurses[15] and doctors.[46] Other effects of interruptions include increases in communication tasks for nurses and doctors because of the preference for synchronous communication channels such as face-to-face conversation and the telephone. Healthcare agencies involved in patient safety are now compiling statistics on how distractions contribute to medical errors.[36, 38]

Moreover, the effects of interruptions are manifested in psychological effects such as increased annoyance, anxiety, and stress. In the workplace, interruptions have been found to increase stress levels for employees. Studies by Kirmeyer[47] of police dispatchers with Type A

personality suggest that they see interruptions as events which contribute to high workload levels while Type B personalities do not perceive interruptions in the same way.

Overall, studies of interruption provide extensive proof of the negative consequences of interruption. Empirical studies of interruption provide confirmation that interruptions negatively impact the human recipient, not only in task performance but in emotional responses as well. While most observational studies show the negative consequences of interruption in the workplace, some employees such as managers expect to be interrupted as part of the job.

Both the positive and negative consequences of interruptions indicate an interest in how to quantify the effects of an interruption. In the following section, we will discuss how to quantify an interruption through the identification of empirical referents.

EMPIRICAL REFERENTS

Empirical referents operationalize a concept using either quantitative or qualitative methods.[48] Quantitative methods rely on either directly or indirectly measuring the magnitude of variables associated with the concept. In contrast, qualitative methods use attributes or characteristics of the concept to assign the concept to a mutually exclusive category. Detection of an interruption relies on both qualitative and quantitative methods. An interruption can arise from a source internal or external to the recipient. Internal interruptions are difficult to observe and must rely on a self-report by the recipient. In contrast, external interruptions can be observed and recorded by:

1. identifying the intrusion of a secondary, unplanned, and unscheduled task
2. suspending the primary task before completion
3. switching to a different task

4. performing tasks in serial manner
5. returning to the primary task

The above empirical referents can be used to quantify an interruption by measuring:

1. the frequency of occurrence of an interruption
2. the number of times the primary task has been suspended to perform an interrupting task
3. the length of time the primary task has been suspended
4. the frequency of returning to the primary task or not returning to the primary task

Empirical referents could be used to classify an interruption. An interruption could be classified as to who received the interruption or the type of medium used to convey the interruption such as by the telephone or email.

Empirical referents assigned to an interruption show the concept can be measured either quantitatively or qualitatively. These findings will be useful for researchers when choosing a research design to study interruptions.

A DERIVED DEFINITION AND MODEL OF INTERRUPTION

The definition of an interruption has been derived from the literature. An interruption is defined as a break in the performance of a human activity initiated by a source internal or external to the recipient with occurrence situated within the context of a setting or location. This break results in the suspension of the initial task by initiating the performance of an unplanned task with the assumption that the initial task will be resumed. The definition is inclusive of all the

defining attributes of an interruption. This is a standard definition that can be used by the healthcare industry. The derived definition of interruption has been used to create a model of interruption shown in Figure 4.

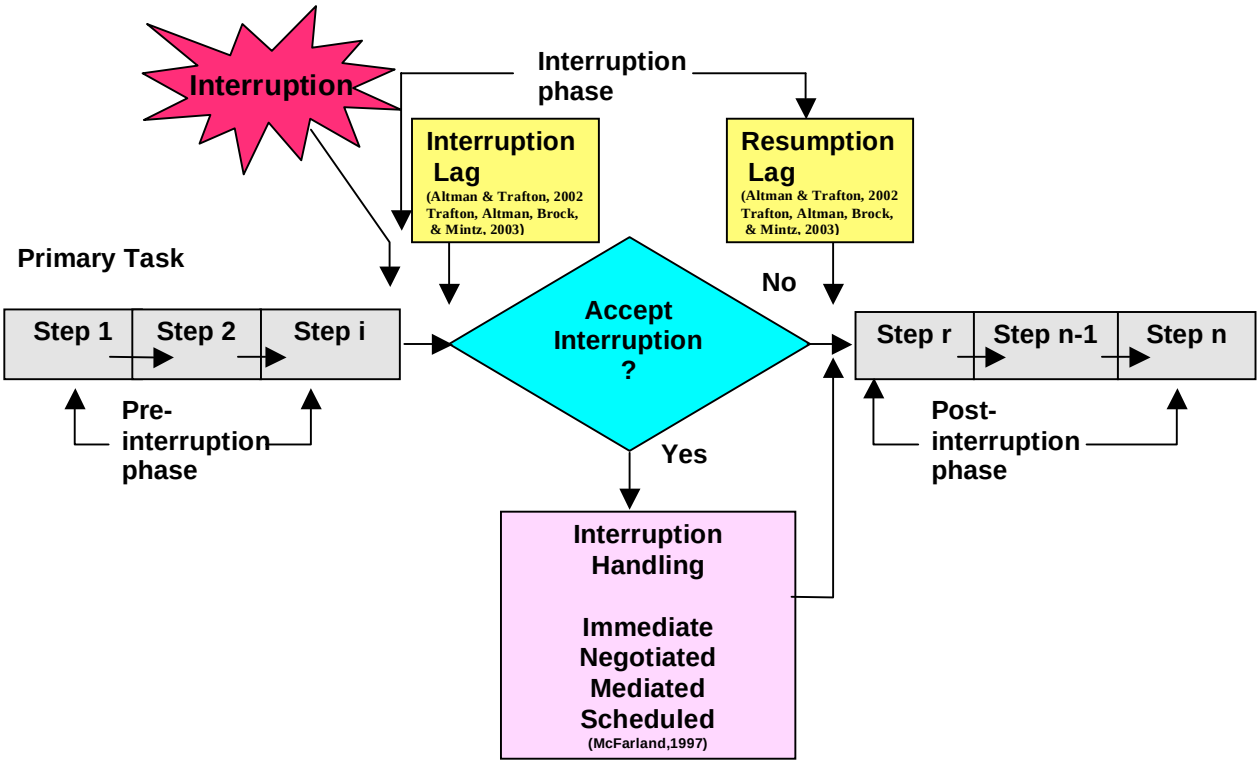

Figure 4. The Brixey Model of Interruption

The Brixey Model of Interruption is a diagrammatic representation of the derived definition. The model is a theoretical framework from which to study an interruption. The pre-interruption phase depicts a period of time during which no interruption is experienced. Step i is the step in which the interruption is perceived. This phase is followed by an Interruption Lag.[30] If the interruption is rejected, the primary task continues. If the interruption task is accepted, handling can occur using one of four methods:[49]

1. Immediate - to handle now
2. Negotiated - to handle at a better time

3. Mediated – to delegate to someone else
4. Schedule – to arrange for delivery at a specified time

After the interruption task has been performed there is a Resumption Lag in which the person prepares to resume the suspended primary task.[30] The point of resumption is designated at Step r in the model. Step n-1 indicates that additional steps in the task are needed to be performed. The final step in the task is designated Step n.

The diagram succinctly explains the interruption process in ways that words cannot. It effectively conveys the detail and complexity of an interruption within the context of performing a task.

DISCUSSION

The concept analysis of interruption has resulted in an extensive review of both healthcare and non-healthcare literature. Based on the review, five defining attributes of an interruption have been identified (1) a human experience (2) an intrusion of a secondary, unplanned, and unexpected task (3) discontinuity, (4) externally or internally initiated, and (5) situated within a context. Synthesis of the literature has resulted in both a definition and a model of interruption.

The concept analysis of an interruption illustrates the human experience of an interruption both in the laboratory and in the workplace. The human experience is closely tied to the context in which the interruption occurs. In either setting the person stops the performance of the primary task to perform the interrupting task. Results of the studies provide evidence of the negative effects of interruptions. The healthcare literature provides evidence that interruptions contribute to medical errors such as medication errors and wrong site surgeries. It is rare to see a report

where interruptions are perceived as positive. However, interruptions can provide useful and life-saving information in the form of alarms and alerts. The sounding of an alarm for a patient in cardiac arrest directs the nurse and doctor to initiate cardio-pulmonary resuscitation care in order to save the person's life. The alert from an infusion pump indicating that the rate or dosage just programmed into the pump is outside of expected ranges is an interruption of value by requiring the nurse to check the values, thus preventing a medical error. These alarms and alerts are of clinical relevance by providing information to the nurse. While these interruptions require immediate attention, other interruptions can be planned. An interruption in workflow is expected to be handled after timed laboratory tests are performed. The nurse expects a telephone call with the results. This example suggests that not all interruptions should be eliminated because some interruptions deliver useful and relevant clinical information to the clinician. The reduction or elimination of irrelevant interruptions is an important step in achieving the reduction of medical errors.

The role of technology as a source of interruption has been limited to the telephone. Healthcare organizations are providing nurses and doctors with mobile telephones and personal device assistance. The devices make the clinician more accessible and more likely to be interrupted. The roles of these devices as a source of interruption have not yet been studied extensively enough in order to determine how they affect workflow. A balance will need to be achieved between instant accessibility, an increasing number of interruptions requiring immediate handling, and the delivery of needed clinical information by new technologies.

CONCLUSION

A review of the literature has resulted in a clarification of the concept interruption. A definition and model of interruption have been derived from the literature. As this project is part of a larger study of interruption, the five defining attributes will serve as a framework from which to develop a category of interruption. The utility of the framework will be tested by categorizing interruptions for nurses working in an ED. It is anticipated that testing of the model will produce modifications that will ultimately produce a comprehensive category of interruption. The all-inclusive category will be used in future studies to consistently code and classify interruptions experienced by nurses working in healthcare. The category will be incorporated into a taxonomy of activity. The taxonomy will be used to categorize both uninterrupted and interrupted activities.

An ongoing end result should produce greatly improved methods with which to interpret and utilize data gained regarding the effects of interruptions, thus increasing efficiency, performance and production in the healthcare industry. It should also reduce the incidence of errors caused by these events.

ACKNOWLEDGEMENT

This project has been supported by a training fellowship from the Keck Center for Computational and Structural Biology of the Gulf Coast Consortia (NLM Grant No. 5 T15 LM07093) and Grant R01 LM07894 from the National Library of Medicine.

REFERENCES

1. Fitts PM, Jones RE. *Analysis of factors contributing to 460 "pilot error" experiences in operating aircraft controls.* Dayton, Ohio: Aero Medical Laboratories, Wright-Patterson Air Force Base; 1947. TSEAA-694-12.

2. Griffon-Fouco M, Ghertman F. *Recueil de donnees sur les facteurs humains a Electricite de France.* Vienna: International Atomic Energy Agency; 1984.

3. Kohn LT, Corrigan JM, Donaldson MS, eds. *To Err is Human: Building a Safer Health System*. Washington, DC: National Acedemy Press; 1999.

4. Chisholm CD, Collison EK, Nelson DR, Cordell WH. Emergency department workplace interruptions: Are emergency physicians "interrupt-driven" and "multitasking"? *Acad Emerg Med.* November 1, 2000 2000;7(11):Acad Emerg Med.

5. Chisholm C, Dornfeld A, Nelson D, Cordell W. Work interrupted: A comparison of workplace interruptions in emergency departments and primary care offices. *Annals of Emergency Medicine.* 2001/8// 2001;38(2):146-151.

6. Coiera E, Tombs V. Communication behaviours in a hospital setting: an observational study. *BMJ.* February 28, 1998 1998;316(7132):673-676.

7. Coiera EW, Jayasuriya RA, Hardy J, Bannan A, Thorpe MEC. Communication loads on clinical staff in the emergency department. *MJA.* 6 May 2002 2002;176(9):415-418.

8. Flynn EA, Barker KN, Gibson JT, Pearson RE, Berger BA, Leo A. Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. *American Journal of Health-System Pharmacy.* 1 July 1999 1999;56(13):1319-1325.

9. Shvartzman P, Antonvosky A. The interrupted consultation. *Family Practice.* 1992;9:210-221.

10. Alvarez G, Coiera E. Interruptive communication patterns in the intensive care unit ward round. *International Journal of Medical Informatics.* Jul 14 2005;74:791-796.

11. Walker LO, Avant KC. *Strategies for Theory Construction in Nursing*. 4th ed. Upper Saddle River, NY: Pearson Prentice Hall; 2005.

12. Wilson J. *Thinking With Concepts*. Cambridge: Cambridge University Press; 1963.

13. Webster's Revised Unabridged Dictionary (1913 + 1828); 1913.

14. "interruption". Oxford English Dictionary [computer file]: on compact disc.--2nd ed. *Oxford University Press* [CD-ROM].

15. Paxton F, Heaney DJ, Porter AM. A study of interruption rates for practice nurses and GPs. *Nursing Standard.* 1996;10(43):33-36.

16. Spencer R, Logan P. Role-based communication patterns within an emergency department setting. Paper presented at: Proceedings HIC 2002, 2002; Melbourne.

17. Spencer R, Coiera E, Logan P. Variation in communication loads on clinical staff in the emergency department. *Ann Emerg Med.* Sep 2004;44(3):268-273.

18. Realini T, Kalet A, Sparling J. Interruption in the medical interaction. *Arch Fam Med.* Dec 1995 1995;4:1028-1033.

19. CubeSmart I. Social interruption and the loss of productivity. Available at: http://www.cubedoor.com/docs/cs_productivity_wp1.pdf. Accessed March 6, 2006.

20. van Solingen R, Berghout E, Latum F. Interrupts: Just a minute never is. *IEEE.* September/October 1998 1998;15(5):97-103.

21. Yang L. Interruptions and intonation. Paper presented at: International Conference on Spoken Language Processing (ICSLP'96), 1996.

22. Kirsh D. Interruption in the workplace-Draft. Available at: http://adrenaline.ucsd.edu/edf/Position_paper.htm. Accessed March 8, 2006.

23. McFarlane DC. *Interruption of people in human-computer interaction* [Dissertation]. Washington, DC: The School of Engineering and Applied Science, The George Washington University; 1998.

24. Cooper R, Franks B. Interruptibility as a constraint on hybrid systems. *Mind and Machines.* 1 February 1993 1993;3:73-96.

25. Kincheloe JL, McLaren P. Rethinking critical theory and qualitative research. In: Denzen NK, Lincoln YS, eds. *Handbook of Qualitative Research*. Second ed. Thousand Oaks, CA: Sage Publication, Inc.; 2000:279-314.

26. Van Bergen A. *Task Interruption*. Amsterdam: North-Holland Publishing Company; 1968.

27. Norman DA. Cognitive Engineering. In: Norman DA, Draper SW, eds. *User Centered Design*. Hillsdale, New Jersey: Lawerence Erlbaum Associates; 1986:31-61.

28. Zhang J, Patel, V. M., Johnson, T. R., Shortliffe, E. H. A cognitive taxonomy of medical errors. *Journal of Biomedical Informatics.* 2004;37:193-204.

29. "discontinuity". The Oxford English dictionary: compact disc.--2nd ed.: Oxford University Press; 2002.

30. Trafton JG, Altmann EM, Brock DP, Minitz FE. Preparing to resume an interrupted task: Effects of prospective goal encoding and retrospective rehearsal. *International Journal of Human-Computer Studies.* 2003;58:583-603.

31. Hillel G, Vincente KJ. Nursing interruptions in a post-anesthetic care unit: A field study. Paper presented at: 47th Annual Meeting, 2003.

32. Wears RL. Caution interrupted [Online journal]. Available at: http://www.webmm.ahrqu.gov/case.aspx?caseID=73. Accessed March 8, 2006.

33. Bowers PJ, Maguire ML, Silva PA, Kitchen R. Everybody out! *Nursing Management.* 2004;35(4):50-54.

34. "distraction". Oxford English Dictionary [computer file]: on compact disc.--2nd ed. *Oxford University Press* [CD-ROM].

35. United States National Library of Medicine National Institutes of Health. Medical subject headings (MeSH). May 27, 2005. Available at: http://www.nlm.nih.gov/pubs/factsheets/mesh.html. Accessed March 8, 2006.

36. JCAHO. Preventing ventilator-related deaths and injuries. *Sentinel Event Alert*; 2002.

37. JCAHO. A follow-up review of wrong site surgery. December 5, 2001. Available at: http://jcipatientsafety.org. Accessed March 8, 2006.

38. Stevenson JG. Medication errors: Experience of the United States Pharmacopeia (USP). *Journal of Quality and Patient Safety.* 2005;31(2):114-119.

39. Bordon S. Medication errors in U. S. hospitals. Available at: http://www.medicalnewstoday.com/newssearch.php?newsid=4696. Accessed March 8, 2006.

40. "continuous". Oxford English Dictionary [computer file]: on compact disc.--2nd ed. *Oxford University Press* [CD-ROM].

41. Deming WE. *Out of Crisis.* Cambridge: Massachusetts Institute of Technology, Center for Advanced Engineering Study; 1986.

42. Schmidt-Jones. Cadence in music [PDF]. Accessed September 21, 2005.

43. Zijlstra FRH, Roe RA, Leonara AB, Krediet I. Temporal factors in mental work: Effects of interrupted activities. *Journal of Occupational and Organizational Psychology.* 1999;72:163-185.
44. Speier C, Valacich JS, Vessey I. The influence of task interruption on individual decision making: An information overload perspective. Paper presented at: Proceedings of the Eighteenth International Conference on Information Systems, 1997; New York, NY.
45. O'Connaill D, Frohlich D. Timespace in the workplace: Dealing with interruptions. Paper presented at: CHI'95 Mosaic of Creativity; May7-11, 1995, 1995.
46. Peleg R, Froimovici M, Peleg A, et al. Interruption to the physician-patient encounter: an intervention program. *Isr Med Assoc J.* July 2000 2000;2(7):520-522.
47. Kirmeyer SL. Coping with competing demands: Interruption and Type A pattern. *Journal of Applied Psychology.* 1988;73(4):621-629.
48. Waltz CF, Strickland OL, Lenz ER. *Measurement in Nursing Research*. Philadelphia: F. A. Davis Company; 1984.
49. McFarlane DC. *Interruption of People in Human-Computer Interaction: A General Unifying Definition of Human Interruption and Taxonomy.* Washington, DC: Naval Research Laboratory; December 31 1997. NRL/FR/5510-97-9870.

Towards a Hybrid Method to Categorize Interruptions and Activities in Healthcare

Juliana J. Brixey, MSN, MPH, RN[1]

David J. Robinson, MD[1,2]

Craig W. Johnson, PhD[1]

Todd R. Johnson, PhD[1]

James P. Turley, PhD, RN[1]

Vimla L. Patel, PhD[3]

Jiajie Zhang, PhD[1]

[1] School of Health Information Sciences, The University of Texas Health Science Center at Houston, Houston, TX
[2]Memorial Hermann Hospital Houston, TX
[3]Department of Biomedical Informatics, Columbia University Medical Center, NY, USA

Corresponding author
Juliana Brixey, MSN, MPH, RN
Juliana.J.Brixey@uth.tmc.edu
University of Texas Health Science Center at Houston
School of Health Information Sciences
7000 Fannin Suite 600
Houston, TX 77030
281.451.8206
713.500.3907 (FAX)

Abstract

In this paper we discuss the development a hybrid method of categorizing activities and interruptions. The method was developed using both a deductive *a priori* classification framework with the provision of adding new categories discovered inductively in the data. The inductive process utilized line-by-line coding and constant comparison as stated in Grounded Theory. The hybrid method was tested by analyzing data collected during an ethnographic study of doctors and registered nurses working in a Level One Trauma Center. This site was chosen because such a dynamic environment is intense, life critical, interruption-laden, and stressful. Understanding the effects of interruptions in such an environment is important for improving healthcare quality and patient safety. The categories of activities and interruptions were organized into a three-tiered hierarchy of activity based on Rosch's model for concepts. Validity and reliability of the categories was tested by categorizing a medical error external to the study. No new categories of interruptions were identified. The categories have been organized within a hierarchy of activities. Initial findings suggest that the hybrid model of categorization is more complete than either a deductive or inductive method alone.

Keywords: Interruption; Activity; Method; Categorize, Healthcare

Towards a Hybrid Method to Categorize Interruptions and Activities in Healthcare

1. Introduction

The systematic and unbiased review of non-numeric data such as field notes is a challenging process during the data analysis phase of qualitative research studies. Large volumes of notes are recorded during complex observations. The researcher is faced with the question of how to organize the data by developing a classification system *a priori* to the observation or allow the classification system to emerge from the recorded data [1]. The *a priori* method requires that recorded data fit a predetermined classification system. This deductive strategy may limit new categories from forming or force the data to be classified using an inappropriate category.

In contrast, an emerging classification scheme arises inductively in response to the data that has been recorded as recommended in Grounded Theory [2]. Grounded Theory was developed by Glaser and Strauss [2] to rigorously and systematically explore qualitative data. Grounded Theory encourages data analysis to begin as soon as data collection begins. Grounded Theory is based on two components:

- line-by-line coding
- constant comparison

Line-by-line coding involves the study of each individually recorded incident and constant comparison is a flexible strategy of creating and integrating categories during the analysis of qualitative data. Each new observation is compared with each previously coded observation for fit. If a new category is discovered it is easily added. The flexibility of the method is a positive attribute for a preliminary framework. The technique relies on the researcher's skill and ability to order the data through the identification of concepts, themes, and patterns found within the data.

In this paper, a third method was developed. The method is called the Hybrid Method to Categorize Interruptions and Activities (HyMCIA). The HyMCIA involves the hybridization of a deductive *a priori* classification framework with the provision of adding new categories discovered inductively in the data using Grounded Theory. The HyMCIA method uses both deductive and inductive processes to analyze qualitative data. HyMCIA was tested by analyzing data collected during an ethnographic study of healthcare professionals working in a Level One Trauma Center. The purpose of the ethnographic study was to observe healthcare professionals as they performed their usual duties in order to understand the tasks they performed as well as interruptions in workflow. A Level One Trauma Center was the chosen site because such a dynamic environment is intense, life critical, interruption-laden, and stressful. Understanding the effects interruptions have on such an environment is important for improving healthcare quality and patient safety. In this paper, we first begin with a review of the literature, examining how interruptions and activities occurring in the healthcare environment have been previously classified. Second, we describe our level of coding for activities and interruptions with an explanation of why this level is appropriate. Third, we provide a description of how to apply HyMCIA by analyzing the field notes of activities and interruptions collected in a Level One Trauma Center. Finally, we conclude by testing the validity and reliability of the categories by categorizing a medical error external to the study

2. Interruption in healthcare activities

An inductive approach based on Grounded Theory [2] was used to understand how interruptions have been defined in the healthcare literature. Researchers who have studied

interruptions occurring in the clinical setting have relied on operational definitions by which to classify an interruption. For example:

1. “anything that disturbed the continuity of the nurse’s work when already engaged on a task or caused a distraction during a consultation with a patient.” [3, p. 34]
2. “the ringing of the phone, any opening of the door to the surgery, or any action of the physician not directly related to the patient.” [4, p. 220]
3. “the cessation of productive activity before the current prescription-filling task was completed for any externally imposed, observable, or audible reason.” [5, p. 321]
4. “any event that briefly required the attention of the subject but did not result in switching to a new task.”[6, p. 1240]
5. “an event that diverted the physician’s attention from the task at hand.”[7, p. 148]
6. “a communication event that was not initiated by the observed party and occurred using a synchronous communication channel such as face-to-face conversation or the telephone.”[8, p. 2], [9, p. 270]
7. “a communication event in which the subject did not initiate the conversation, and which used a synchronous communication channel.”[10, p. 416]
8. “the usurpation of control.”[11, p. 1029]

Five specific attributes of interruption were identified through the analysis of these definitions. The five defining attributes are:

6. a human experience
7. the intrusion of an unplanned, unexpected, interrupting task

8. discontinuity in task performance

9. initiated external or internal to the recipient

10. situated within a context

First, an interruption is a human experience. The recipient of an interruption is a person such as a doctor, nurse, or pharmacist. Second, the healthcare professional encounters an interruption which occurs as the intrusion of a secondary, unplanned, and unexpected task into the primary task. The recipient of the interruption must suspend the current task in order to perform the interruption task. Third, there is discontinuity in performing the primary task. Fourth, an interruption may be initiated either externally or internally to the recipient. An externally-generated interruption is initiated by another person or device. In contrast, an internally-initiated interruption arises from intrusive thoughts or daydreams. Fifth, an interruption is situated within a context. The context provides information about the environment in which the interruption occurs, revealing some settings as more interrupt-driven than others. We use these five specific defining attributes to form a framework for categorizing and coding interruptions.

3. Activities performed in healthcare professionals

Grounded Theory [2] was used as an inductive strategy to analyze definitions and to identify specific activities performed by healthcare professionals. The state licensing agencies for various specific professional healthcare providers are the organizations which determine who meets the criteria to practice as a nurse or doctor and the activities that person can perform. For example, the Texas Board of Nurse Examiners (BNE) [12] state that a ‘Nurse’ means “a person required to be licensed under this chapter to engage in professional or vocational nursing”. The BNE further

defines professional nursing and the associated activity as: ‘Professional nursing’ means “the performance of an act that requires substantial specialized judgment and skill, the proper performance of which is based on knowledge and application of the principles of biological, physical, and social science as acquired by a completed course in an approved school of professional nursing. The term does not include acts of medical diagnosis or the prescription of therapeutic or corrective measures. Professional nursing involves:

a. the observation, assessment, intervention, evaluation, rehabilitation, care, and counsel, or health teachings of a person who is ill, injured, infirm, or experiencing a change in normal health processes;
b. the maintenance of health or prevention of illness;
c. the administration of a medication or treatment as ordered by a physician, podiatrist, or dentist;
d. the supervision or teaching of nursing;
e. the administration, supervision, and evaluation of nursing practices, policies, and procedures;
f. the requesting, receiving, signing for, and distribution of prescription drug samples to patients at sites in which a registered nurse is authorized to sign prescription drug orders as provided by Subchapter B, Chapter 157;
g. the performance of an act delegated by a physician under Section 157.052, 157.053, 157.054, 157.0541, 157. 0542, 157.058, or 157.058, or 157.059; and
h. the development of the nursing care plan.”

The Texas Medical Board [13] is explicit about who can perform the duties by stating a 'Physician' "means a person licensed to practice medicine in this state." The Board states the 'Practice of Medicine' occurs when:

i. "the person publicly professes to be a physician or surgeon and diagnoses, treats, or offers to treat any mental or physical disease or disorder, or any physical deformity or injury by any system or method or to effect cures thereof;
ii. the person diagnoses, treats or offers to treat any mental or physical disease or disorder, or any physical deformity or injury by any system or method and to effect cures thereof and charges therefore, directly or indirectly, money or other compensation;
iii. the person exercises medical judgment, renders an opinion, or gives advice concerning the diagnosis or treatment of a patient, or makes any determination regarding the appropriate or necessary medical response to a particular patient's medical condition that affects the medical care of the patient; or
iv. the person is physically located in another jurisdiction, other than the state of Texas, and through any medium performs an act that is part of patient care service initiated in this state that would affect the diagnosis or treatment of the patient."

Three specific attributes for activities were identified through the analysis of duties assigned by state boards to nurses and doctors. The three defining attributes are:

1. a human experience
2. initiated external or internal to the recipient
3. situated within a context

The defining attributes share three of five specific attributes with interruption identified in Section 2. First, an activity is a human experience. A person such as a doctor or nurse performs an activity. Second, an activity may be initiated either externally or internally to the person performing the activity. An externally-generated activity is one initiated by another person or device. In contrast, an internally-initiated activity arises from the person's own thoughts. Third, an activity is situated within a context. The context provides information about the environment and conditions in which the activity is performed. We use these three specific defining attributes to form a framework for categorizing and coding activities.

4. Activities performed in the Emergency Department

According to the American Heritage Dictionary of the English Language, Fourth Edition [14], an activity is defined as "a specific pursuit in which a person partakes". The healthcare literature was reviewed before beginning the study for activities performed by healthcare professionals working in the Emergency Department (ED). Hollingsworth, Chisholm, Giles, Cordell, and Nelson [15] compiled a list of activities performed in the ED as the result of a time-motion study. The activities were divided into those performed by faculty physicians, resident physicians, and emergency nurses. Categorization of the activity was also dependent on whether the activity was direct patient care, indirect care, or a personal activity. The list of activities is shown in Table 1.

Table 1. Activities performed by doctors and nurses working in an ED as identified by Hollingsworth, Chisholm, Giles, Cordell, and Nelson

Activities Performed by Faculty Physicians	Activities Performed by Emergency Nurses
Direct Patient Care	
Talking to patients	Talking to patients
Examining patients	Examining patients
Performing procedures	Performing procedures
Comforting patients	Comforting patients
Transporting patients	Transporting patients
Assisting with procedures (NA)	Assisting with patients
Indirect Patient Care	
Charting	Charting
Telephone calls (patient care)	Telephone calls (patient care)
Talking with physicians	Talking with physicians
Talking with nurses, EMTs	Talking with nurses, EMTs
Talking with ancillary staff	Talking with ancillary staff
Talking with patient's family	Talking with patient's family
Teaching residents, students	Teaching residents, students (NA)
Staffing cases with faculty (NA)	Staffing cases with faculty (NA)
Research	Research (NA)
Getting supplies, cleaning up	Getting supplies, cleaning up
Signing up for patients	Signing up for patients
Other paperwork	Other paperwork
Preparing for procedures	Preparing for procedures
Washing hands	Washing hands
Walking	Walking
Preparing medications (NA)	Preparing medications
Processing lab specimens (NA)	Processing lab specimens
Cleaning, stocking rooms (NA)	Cleaning, stocking rooms
Acquiring and interpreting test results	Acquiring and interpreting test results
Personal Activities	
Personal time	Personal time
Waiting	Waiting

NA, activity not applicable to this staff position.

To verify that similar activities were performed at the study site, a series of interviews were held with domain experts in Emergency Medicine to obtain a list of activities performed at the study site. A physician and two registered nurses (RNs) participated in developing an activity list for the Level One Trauma Center. The physician and RNs verified the list of duties for

completeness. The preliminary list of duties performed by healthcare workers is shown in Table 2.

Table 2. Activities performed by doctors and RNs in a Level One Trauma Center

Activities Performed by Doctors	Common Activities	Activities Performed by RNs
Dictating history and physical		
		Start IVs
		Draw blood
		Perform treatment
		Data entry
		Patient and family education
		Assist physicians
Physician-specific issues		
	Communication	
	Patient assessment	
	Documentation	
	Documentation	

In both Tables 1 and 2, specific activities performed by healthcare professionals are identified. The doctors' column contains duties performed only by doctors. The nurses' column lists those duties performed by RNs. In Table 2 the center column presents duties that both doctors and nurses perform. Tables 1 and 2 were used as a preliminary framework of activities from which to begin coding the field notes.

5. Category structure

The workflow in healthcare or other settings can be described and analyzed at various levels of granularity forming a hierarchy. For example, we can describe workflow at a very high level of goals: take care of patients, ensure quality of care, monitor medical errors, etc. Or we can describe workflow at a very low level of motor actions: move index finger to "u", then move the

mouse to the icon “print”, then click, and so on. Both of these levels are relevant to specific purposes. But for the study of interruptions and their impact on clinicians’ performance, they are not the right level. What we need is a level that has the basic properties relevant to meaningful performance in workflow. This is the level of activities. We call the abstract level “Superordinate Level”, the detailed level “Subordinate Level”, and the inclusive level “Basic Level”.

This hierarchy has been established in the cognitive studies of concepts and categories by deductive methods. The study of categories has focused primarily on tangible objects with physical attributes. An object denotes an entity such as person, place, or thing with specific characteristics. Rosch [16] maintains that categories are two-dimensional structures with a vertical and horizontal orientation. The vertical axis represents a three-tiered hierarchical structure:

- Superordinate
- Basic
- Subordinate

The highest level of abstraction is designated as the Superordinate Category. The category is the most exclusive, contains the most distinctive features of the concept, and has fewer attributes in common with other categories. In contrast, the Subordinate Category has the most typical attributes of an entity assigned to the category. The Basic Category is at mid-level in the hierarchy. It is the most inclusive level of classification, the level that is most useful, and the one most often used by people when designating a category. The Basic Level Category is a significant entity that is highly significant psychologically for various cognitive functions when dealing with concepts and categories. It is the level that is most informative, first learned, consistent across cultures, and which has a prototypical set of features and actions shared among members at this level [17]. For example we could categorize, “furniture” as an entity of the

Superordinate Category, “chair” as an object of the Basic Category, and “rocking chair” an instance of the Subordinate Category.

Conversely, the horizontal axis corresponds to the internal structure of the category. This axis is characterized by typicality of members represented in the category. For example, the five defining attributes cited in Section 2 were used to form the internal structure for the category of interruption.

First and foremost, to be classified as interruption, there must be the intrusion of a secondary, unplanned, and unexpected task into the primary task. The recipient of the interruption must suspend the current task in order to perform the interruption task, resulting in discontinuity while performing the primary task.

While the internal structure for the activity category shares three of the five attributes of an interruption, there is no intrusion of a secondary task or discontinuity. Therefore, this suggests continuity in the performance of an activity.

Rosch [16] asserts that prototypes are the most typical entities and are perceived as having more attributes in common with other objects in the category and less with things in another category. As such, membership in a category depends both on the degree of abstraction and prototypicality.

The study of categories has focused primarily on tangible objects with physical attributes. An object denotes an entity such as a person, place, or thing with specific characteristics. Rosch [16] and other researchers [18-20] have extended the study of categorization to non-concrete entities such as events. Rosch extended the three-tiered hierarchical category formation to form categories for events using a top-down configuration. An event is “a discrete bound temporal unit” [16, p. 43]. In our current study we consider an interruption an event based on operational

definitions of interruption published in the healthcare literature. From these definitions of interruptions, a three-tiered hierarchy as outlined by Rosch, begins to form. Definitions from the healthcare literature show that doctors and nurses perform activities within the context of a clinical setting. An activity is the most general and all-inclusive term used in the definitions and therefore belongs in the Superordinate Category. More specifically, the definition of interruptions either, implicitly or explicitly, states that the doctors or nurses were engaged in an activity prior to receiving an interruption. The activity in progress can be labeled the primary task and the interruption as the secondary task. Although we have previously labeled the primary task and the interruption as the secondary task, the definitions from the healthcare literature do not use the phrase secondary task but instead use the concept interruption. Interruption becomes the label for the Basic Category. The Subordinate Category of interruption is shown as specific instances in which healthcare workers become recipients of an interruption in the form of an unplanned, secondary task. Rosch's method is useful in the formation of categories but does not provide a specific strategy to analyze qualitative data such as field notes collected during observational studies. This requires an inductive approach such as methods found in Grounded Theory.

According to Glaser and Strauss [2], categories have properties or attributes as well as two levels of abstraction. At the lower level, categories emerge early in data analysis. In contrast, higher level categories tend to emerge later in the analysis. This indicates a bottom-up strategy for category formation. The two levels of abstraction suggest a two-tiered category hierarchy. The lower category level is similar to Rosch's Subordinate Category while the higher level is analogous to the Superordinate Category. In this arrangement, activities would be represented at the more abstract level while specific instances of activities would be represented at the lower

level. The two-level hierarchy does not accommodate Rosch's Basic Category, which is used to represent a mid-level of abstraction. Because Rosch's framework and Grounded Theory have a similar category structure and hierarchical arrangement, they significantly contributed to the formation of HyMCIA. HyMCIA is a more complete and flexible framework by which to study qualitative data.

6. Data acquisition

Data collection was accomplished using a convenience sample of five doctors and eight nurses who were shadowed during their scheduled shifts. Shadowing is a qualitative technique that involves following a person as they go about their activities. While following the target, the observer records the actions and interactions in which the target engages. In most cases there was no attempt to ask the target for clarification of the actions which were observed. This 'interruption' could lead to serious patient harm in a functioning ED. However, the target would sometimes spontaneously offer clarification of actions and interactions. In this specific study, we limited shadowing to routine sessions of doctors and nurses who gave written informed consent. Activities were recorded in one-minute intervals and began once the subject had completed the informed consent. The observers, using Tablet PCs, recorded all observations on a semi-structured field note form. This semi-structured form was developed in Microsoft Word®. The form was revised over six iterations using feedback from the observers and a domain expert in Emergency Medicine. The final iteration of the form was loaded onto Tablet PCs for use during data collection. An example of the form is shown in Fig. 1.

Observer:
Observation Date:
Start of Observation:
End of Observation:
Duration of Observation:

Subject Being Observed:
Role/Title:

Other ED personnel encountered during observation:

Start Time	End Time	Activity/ Event	Patient	Location	Other Participants	Details

Impressions from the observation

Fig1. Data collection form

The Tablet PCs were equipped with handwriting recognition software. This feature supported direct data entry into Microsoft® Word.

The researchers typically worked in teams of two and used direct observation with note-taking for activities performed by the study subject. Two observers were used in most observations to maximize the capture of interruptions in the fast-paced environment. The observers recorded their data independently and did not interact with each other for the purpose of clarifying observations just as they had, in general, refrained from interacting with the study subjects. This allowed for independent data capture which was used for inter-rater reliability at a later time.

The observers also typically worked in teams of two. Observer 1 is an RN with 26 years' experience in healthcare and is competent in human factors. Observer 2 is also a human factors expert with 6 years' experience but has had no training as a healthcare professional. Observer 3

is an RN faculty member with dual expertise in critical care and human factors. Observer 4 is a doctoral student in health information sciences and is competent in human factors but has no training as a healthcare professional. Each observer received 30 minutes training using the data collection tool prior to beginning data collection. The ED staff provided a 30-minute orientation to acquaint the observers with the ED.

7. Analyzing the data

Sixty hours fourteen minutes of field notes had been collected by shadowing eight RNs and five physicians working in a Level One Trauma Center. The field notes had been recorded by observers entering a beginning and ending time for each activity performed by the healthcare professionals during a scheduled shift. Analysis of the data occurred concurrent with data collection. The process of data analysis was supported by using NVivo© [21]. The software supports the analysis of non-numeric data or data that is not easily transformed into numbers. The software is useful in identifying themes, trends, and patterns in the data through the creation of categories and associated attributes. The data analysis protocol is described in the following section.

8. Data analysis protocol

The following protocol was used to analyze the field notes collected in the ED:

1. Each observation session that had been recorded as a Word® document was converted into a rich text format (RTF) document
2. The RTF document was imported into an NVivo© [21] project
3. An example of an imported observation in NVivo© [21] is depicted in Fig. 2

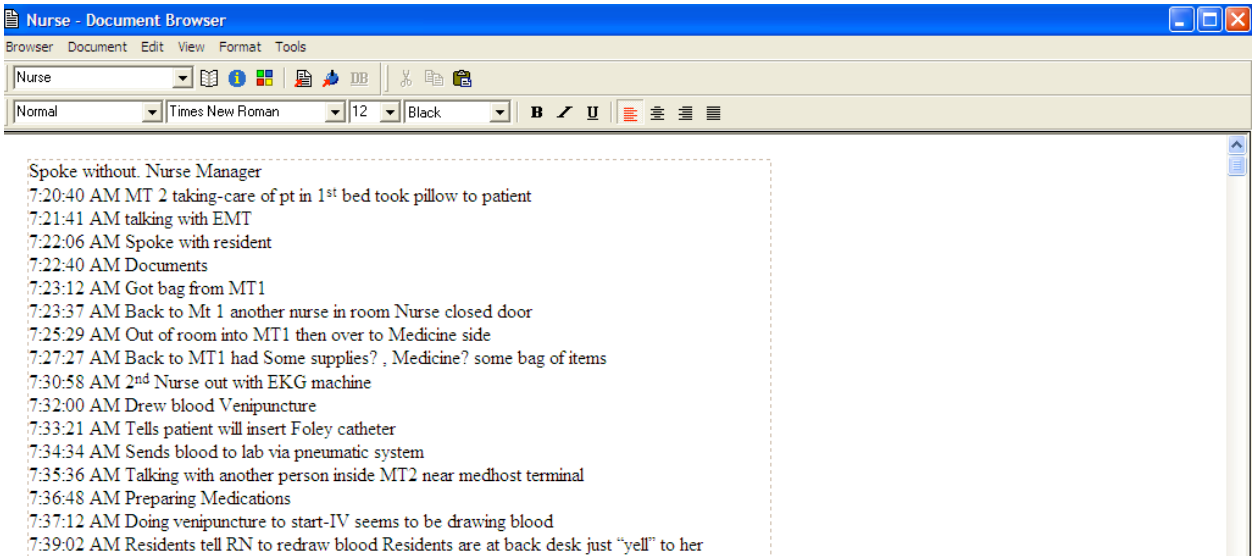

Fig. 2 An example of a field note for activities performed by an RN working in the ED

This entry shows the activities performed by an RN working in the ED. The observers recorded observations on an approximately minute-by-minute time interval.

4. Each time-stamped observation was reviewed for what activity had been performed, who performed the activity, if any other person(s) was involved and their role, the location where the activity was performed, and any other attributes that would make the category mutually exclusive from other categories
5. The activity was identified and color-coded using the coder feature available in NVivo© [21] which supports the use of 14 different colors.
6. Each attribute was identified and color-coded using the coder feature available in NVivo© [21]. This process occurred for each activity that had been recorded in the field notes.

7. Each activity that was identified was compared to all previous observations as well as the activity list to determine if that activity had occurred before or was a new activity. If it was discovered to be a new activity, it was added to the activity list.
8. Each time-stamped observation was analyzed to determine if the activity had been interrupted.

If the activity had been interrupted, it was categorized as an interruption. Each activity that was interrupted was color-coded. Upon completion of all observations, the categories were reviewed, refined, and structured using Rosch's three-tiered hierarchy.

9. Results

A three-tiered hierarchy of activities was formed through the systematic study of field notes collected during the observation of doctors and nurses working in a Level One Trauma Center. The categories had been developed using a bottom-up, which is an inductive approach found in Grounded Theory [2]. A partial list of activities is shown in Fig. 3.

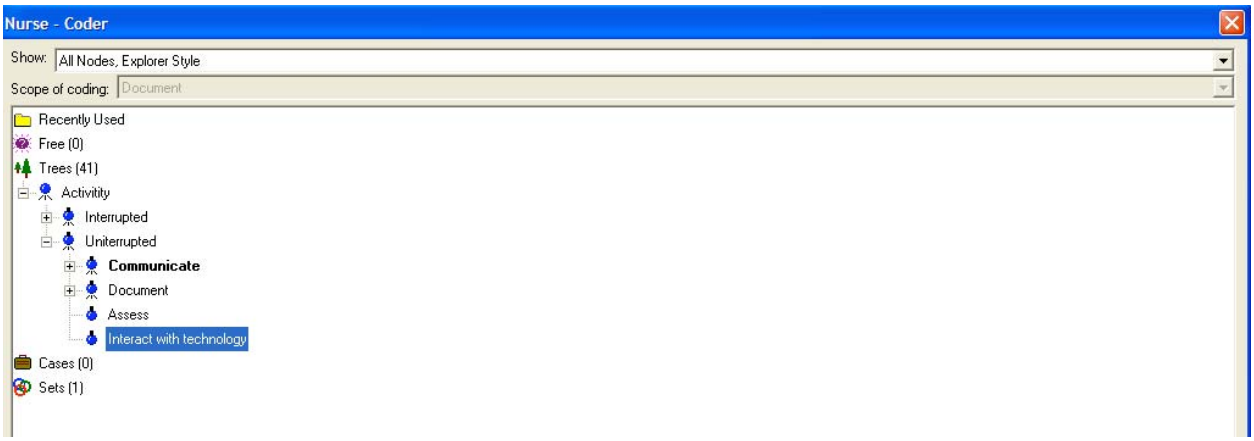

Fig. 3 A partial list of activities performed by doctors and nurses

The specific activities were assigned to the lowest position in the hierarchy. They were designated as “Subordinate Categories”. A complete list of the Subordinate Categories is presented in Table 3.

Table 3. Categories of activities performed by doctors and RNs in a Level One Trauma Center

Activities Performed by Doctors	**Common Activities**	**Activities Performed by RNs**
	***A priori* Categories**	
Dictating history and physical		
		Start IVs
		Draw blood
		Perform treatments
		Data entry
		Patient and family education
		Assist physicians
Physician-specific issues		
	Communication	
	Patient assessment	
	Documentation	
	Post Study Categories	
Activities Performed by Doctors	***Common Activities***	***Activities Performed by RNs***
Rounds		
Delayed Communication		
Blocked Communication		
Looks For		
Report		
Wait For		
Leaves Area		
Observe (i.e., present but not performing an activity)		
	Interact with Technology	
	Clerical Duty	
	Teach	
	Respond To (i.e., acknowledge)	
	Provide Information	
	Receive Information	
	Perform Procedure	
	Request Information	
	Personal Hygiene (i.e., handwashing)	
	Delegate Task	
	Leave Area	
	Request Assistance	
	Retrieve Supplies	
	Break Time	
		Transport
		Discharge Patient
		Set Up Room
		Safety
		Patient Need
		Housekeeping
		Medicate
		Retrieve Information
		Perform Treatment
		Assist

In this study we have identified an extensive list of activities performed by doctors and RNs. The activities identified in this study are similar to those reported by Hollingsworth, Chisholm, Giles, Cordell, and Nelson [15]. The list has been updated to include some new activities such as interacting with technology, addressing safety issues, delegating tasks, leaving the unit, and by delineating clinician communication patterns.

All activities were found to have a minimum of three defining attributes. First, an activity is a human experience. A person such as a nurse or doctor performs an activity. Second, an activity may be initiated either externally or internally to the person performing the activity. An externally-generated activity is one initiated by another person or device. In contrast, an internally-initiated activity arises from the person's own thoughts. Third, an activity is situated within a context. The context provides information about the environment and conditions in which the activity is performed. Other attributes that were identified added to the mutual exclusivity of the category. For example the following properties were assigned to the category of Interacts with Technology Category and properties are shown in Fig. 4.

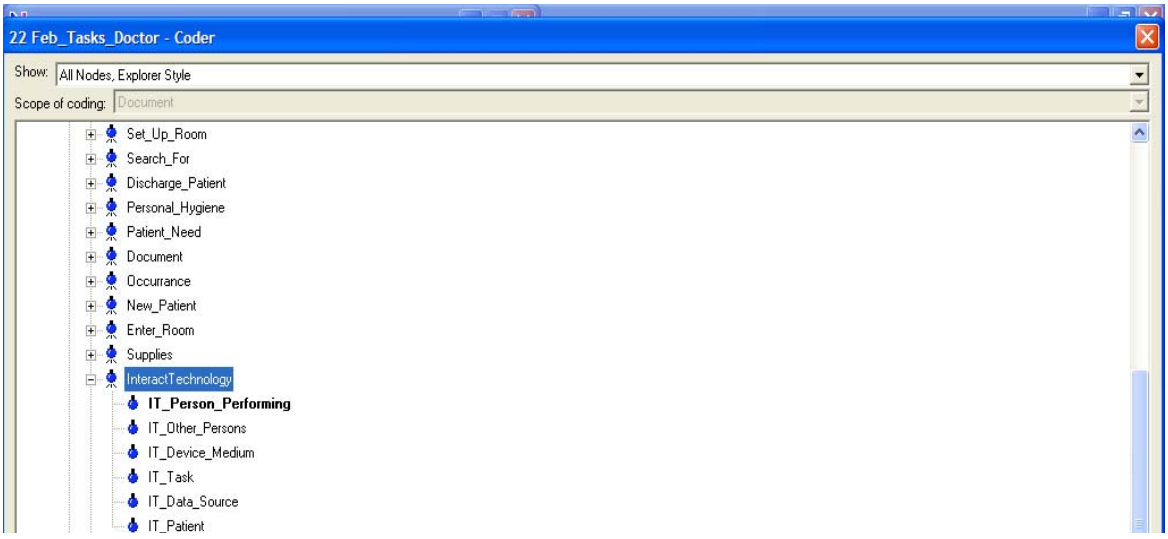

Fig. 4 Category of Interacts with Technology

For an activity to be categorized as Interacts with Technology, the subject would first have to be observed using a device such as an infusion. The activity may be initiated either externally or internally to the person performing the activity. Location provided the context in which the activity was performed.

Using a top-down approach, the Superordinate Category was formed by arranging the specific activities into a general category called Activity. This more inclusive category included any activity performed by a healthcare professional.

However, neither the Superordinate nor Subordinate differentiated as to whether an activity was performed with or without interruption. This separation is depicted in NVivo© [21] as illustrated in Fig. 5.

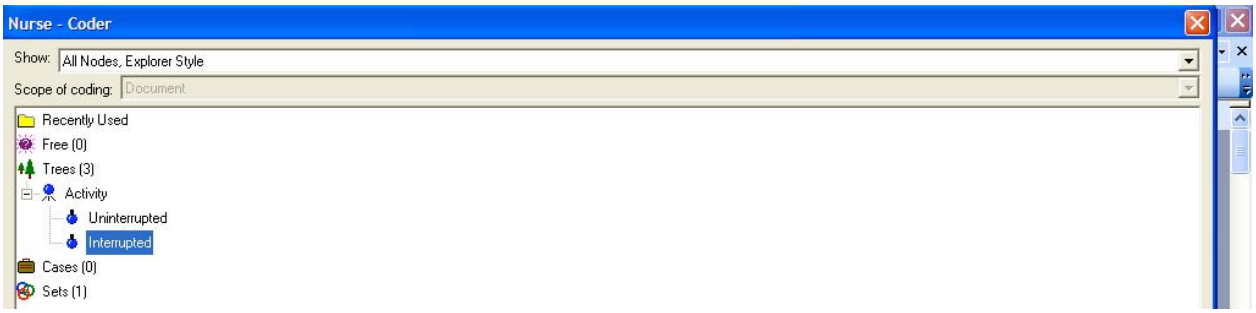

Fig. 5 Activities designated as interrupted and uninterrupted

The separation of activities into interrupted and uninterrupted led to the formation of the Basic Level Category. Specific instances of interruptions were organized into Subordinate Categories for interruptions. The Subordinate Categories for interruptions are found in Fig. 6.

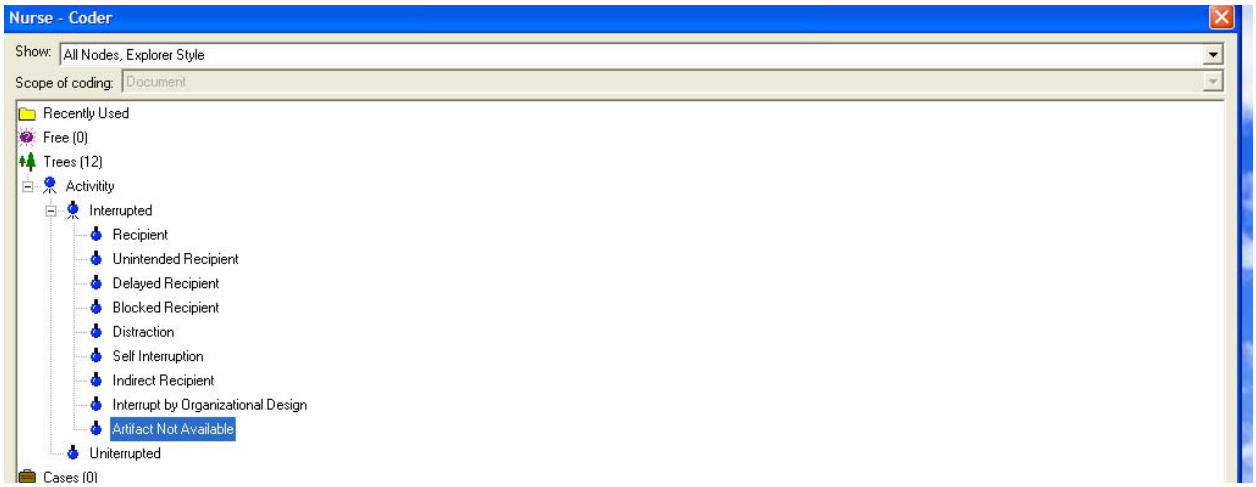

Fig. 6 Subordinate categories of interruption

The specific categories of interruption are:

2. Intended Recipient - the person to be interrupted
3. Unintended Recipient - not the intended recipient of an interruption; i.e., receiving a phone call that was incorrectly dialed
4. Indirect Recipient – the incidental recipient of an interruption; i.e., talking with a person who was interrupted that resulted in the suspension of the conversation
5. Self-interruption – a person independent of another person suspends an activity to perform another; i.e., while walking stops abruptly and talks to another person
6. Distraction – briefly disengaging from a task.
7. Organizational Design – disruption in workflow caused by flaws in the physical layout of the workspace

8. Artifacts Not Available – disruption in workflow caused by a need to procure supplies and equipment not available in the workspace, thereby causing a disruption in workflow
9. Initiator – the originator of an interruption

Naming of the categories for interruption differs from that used to designate an activity. Some categories of interruption are designated by the role assigned to the subject in the interruption event. These categories include the five basic attributes of an interruption. First, the recipient of an interruption is a person such as a doctor, nurse, or pharmacist. Second, the healthcare professional encounters an interruption, which occurs as the intrusion of a secondary, unplanned, and unexpected task into the primary task. The recipient of the interruption must suspend the current task in order to perform the interruption task. Third, there is discontinuity in performing the primary task. Fourth, an interruption may be initiated either externally or internally to the recipient. An externally-generated interruption is initiated by another person or device. In contrast, an internally-initiated interruption arises from intrusive thoughts or daydreams. Fifth, an interruption is situated within a context. For example the Category Recipient of an interruption has the attributes revealed in Fig. 7.

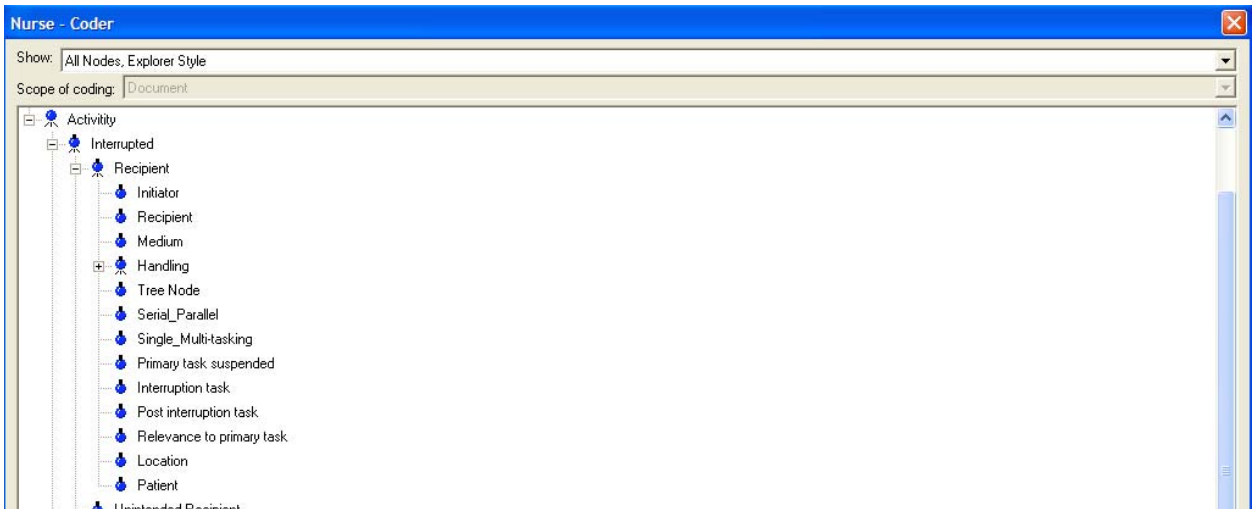

Fig. 7 The Subordinate Category of Recipient

The Subordinate Category of Recipient exemplifies the vertical and horizontal dimensions of a category. The term, Recipient, indicates the vertical dimension of the category and is assigned to the Subordinate Category in the Activity hierarchy. The properties of the category form the horizontal dimension. Both dimensions are required in order to categorize an interruption.

Two other types of interruption were identified while categorizing the data. First, there is Interruption by Organizational Design in which the physical layout of the workspace causes a break in workflow. An interruption of this type causes the nurse or doctor to leave their current workspace because completion of that activity must be carried out in another location. All other activities that they would perform are suspended until the person returns to their original workspace. A second type of interruption is known as Artifacts Not Available. Supplies or equipment are not available in the workspace. The recipient of this type of interruption must suspend the activity and retrieve the needed supply or equipment. These two new types of interruption finalize, up to this point, the categorization process for interruptions.

10. Discussion

In this project we have extended the use of Rosch's concept hierarchy to categorize activities and interruptions. Activity became the name for the Superordinate Category. This category made no distinction as to whether an activity was or was not interrupted. It was determined that additional specificity was needed to code and classify an activity. This resulted in the creation of a Basic Category. The Basic Category was used to classify whether or not an activity had been interrupted. This category was divided into those activities that were performed without interruption and those that had been interrupted. These categories were named uninterrupted and interrupted. To code an interruption for more detail, specific instances of interruptions were identified and formed the Subordinate Categories.

A criticism of qualitative studies is the lack of generalizability attributed to issues related to validity and reliability. Generalizability can be enhanced by increasing the "representativeness" of the sample entities (participants) with respect to their parent or target populations. Marshall and Rossman [22], argue that external validity can be achieved when the researcher uses the original framework to show how the data was collected and how concepts and models guided data collection and analysis. This process defines the theoretical parameters of the study. The theoretical parameters then become the criteria for determining generalizability to other studies.

Reliability in qualitative research differs from that of quantitative research. Marshall and Rossman [22] assert that reliability in qualitative research is achieved by keeping notes of the rationale that guided design decisions, review of procedures, protocols, decisions, and retrievable data. To test the validity and reliability of the method and the categories developed in this project, we coded the following medical error reported to AHRQ WebM&M [23]. *A 55-year-old man with acute myelogenous leukemia and several recent hospitalizations for fever and*

neutropenia presented to the emergency department (ED) with fever and hypotension. After assessment by the emergency physician, administration of intravenous crystalloid and empiric broad-spectrum antibiotics, the patient was assessed by his oncologist. Based on the patient's several recent admissions and the results of a blood culture drawn during the last admission, the oncologist added an order for Diflucan (fluconazole) 100 mg IV to cover a possible fungal infection. Because intravenous fluconazole was not kept in the ED, the nurse phoned the pharmacy to send the medication as soon as possible. A 50 ml bottle of Diprivan (propofol, an intravenous sedative-hypnotic commonly used in anesthesia) that had been mistakenly labeled in the pharmacy as "Diflucan 100 mg/50 mL" was sent to the emergency department. Because the nurse also worked in the medical intensive care unit, she was quite familiar with both intravenous Diflucan and Diprivan. When a glass bottle containing an opaque liquid arrived instead of the plastic bag containing a clear solution that she expected, she thought that something might be amiss. As she was about to telephone the pharmacy for clarification, a physician demanding her immediate assistance with another patient distracted her. Several minutes later, when she re-entered the room of the leukemia patient, she forgot what she had been planning to do before the interruption and simply hung the medication, connecting the bottle of Diprivan to the patient's subclavian line. The patient's IV pump alarmed less than one minute later due to air in the line. Fortunately, in removing the air from the line, the nurse again noted the unusual appearance of the "Diflucan" and realized that she had been distracted before she could pursue the matter with the pharmacy. She stopped the infusion immediately and sent the bottle back to the pharmacy, which confirmed that Diprivan had mistakenly been dispensed in place of Diflucan. The patient experienced no adverse effects presumably - he received none of the Diprivan, given the air in the line, the infusion time of less than a minute, and the absence

of clinical effect (Diprivan is a rapidly-acting agent). Nonetheless, the ED and pharmacy flagged this as a potentially fatal medication error and pursued a joint, interdisciplinary root cause analysis, which identified the following contributing factors: (i) Nearly 600 orders of medication labels are manually prepared and sorted daily; (ii) Labels are printed in "batch" by floor instead of by drug; (iii) The medications have "look-alike" brand names; (iv) A pharmacy technician trainee was working in IV medication preparation room at the time; and (v) The nurse had been "yelled at" the day before by another physician - she attributed her immediate and total diversion of attention in large part to her fear of a similar episode. (Reprinted with permission of AHRQ WebM&M)

In this example, the nurse performed a number of activities. The activities were color-coded following the previously determined rules. The activities categorized in this case were consistent with activities we have identified at the Subordinate Level such as communicating, assessing, observing, interacting with technology, and medicating. These activities contain the three defining attributes:

1. an activity is a human experience
2. an activity may be initiated either externally or internally to the person performing the activity
3. an activity is situated within a context

No new activities were identified in reviewing the error report. This shows the utility of the method that we have developed to categorize activities. It also shows that the level at which the activities are categorized is appropriate.

In this case, the nurse was the direct recipient of an interruption. This interruption was assigned to the recipient category and color-coded following the previously determined rules. The interruption of the nurse shows the five defining attributes of an interruption. The five defining attributes are:

1. a human experience
2. the intrusion of an unplanned, unexpected, interrupting task
3. discontinuity in task performance
4. initiated external or internal to the recipient
5. situated within a context

In this example, the human experience is that of the nurse as she works in the emergency ED. The nurse's plan to telephone the pharmacy to clarify a medication is superseded by a physician's need for assistance. The external source of the interruption arose from a physician. The interruption resulted in discontinuity in task performance when the nurse suspended making the telephone call to the pharmacy to assist the physician. The occurrence is within the context of the ED in which patients have complex medical conditions treated by multiple healthcare practitioners. The nurse is known to work other nursing units and the effects of this practice are not explained in the report. The context indicates a possible hostile work environment (e.g.; staff yelling). This was the second report of disruptive behavior in two days. The lack of continuity in the medication administration process resulted in a medication error. The method shows generalizability and utility in coding activities and interruptions occurring in another ED.

11. Conclusions

In this study we have developed a hybrid method to systematically categorize activities and interruptions. An *a priori* framework, a pre-determined classification method, was used to order recorded data for activities performed in the ED. The framework was developed deductively through a review of the literature and interviews with domain experts. Additional categories of activities were identified inductively through the analysis of field notes. Specific activities performed by the clinicians were assigned to the Subordinate Category in the Activity hierarchy. The specific category name indicated an action being performed. These specific duties could be grouped at the Superordinate Category level to indicate any duty performed by the clinician. The Basic Category was subdivided into Interrupted and Uninterrupted Activities. The labels assigned to designate interruptions indicated the role of the person involved in the interruption except for Interruptions by Organizational Design and Artifacts Not Available. All the categories were deemed to be mutually exclusive. The validity of the categories identified in the study was tested using a medical report in which a nurse was interrupted. All activities and interruptions could be classified using those that had been identified. No new categories for activities or interruptions were identified. Although HyMCIA was developed by analyzing activities performed in the ED, it is expected that it can and will be extensible to categorize activities and interruptions in other departments within a healthcare setting.

12. Acknowledgement

This project has been supported by a training fellowship from the Keck Center for Computational and Structural Biology of the Gulf Coast Consortia (NLM Grant No. 5 T15 LM07093) and Grant R01 LM07894 from the National Library of Medicine.

References

[1]. M.B. Miles, A.M. Huberman, *Qualitative Data Analysis: An Expanded Sourcebook.* 2nd ed. 1994, Thousand Oaks: SAGE Publications, Inc. 338.

[2]. B. Glaser, A. Strauss, *The Discovery of Grounded Theory*. 1967, New York: Aldine Publishing.

[3]. F. Paxton, D.J. Heaney, A.M. Porter, *A study of interruption rates for practice nurses and GPs.* Nursing Standard, 1996. **10**(43): p. 33-36.

[4]. P. Shvartzman, A. Antonvosky, *The interrupted consultation.* Family Practice, 1992. **9**: p. 210-221.

[5]. E.A. Flynn, K.N. Barker, J.T. Gibson, R.E. Pearson, B.A. Berger, A. Leo, *Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy.* American Journal of Health-System Pharmacy, 1999. **56**(13): p. 1319-1325.

[6]. C.D. Chisholm, E.K. Collison, D.R. Nelson, W.H. Cordell, *Emergency Department Workplace Interruptions: Are Emergency Physicians "Interrupt-driven" and "Multitasking"?* Acad Emerg Med, 2000. **7**(11): p. Acad Emerg Med.

[7]. C. Chisholm, A. Dornfeld, D. Nelson, W. Cordell, *Work interrupted: A comparison of workplace interruptions in emergency departments and primary care offices.* Annals of Emergency Medicine, 2001. **38**(2): p. 146-151.

[8]. R. Spencer, P. Logan. *Role-based communication patterns within an emergency department setting*. in *Proceedings HIC 2002*. 2002. Melbourne.

[9]. R. Spencer, E. Coiera, P. Logan, *Variation in communication loads on clinical staff in the emergency department.* Ann Emerg Med, 2004. **44**(3): p. 268-73.

[10]. E.W. Coiera, R.A. Jayasuriya, J. Hardy, A. Bannan, M.E.C. Thorpe, *Communication loads on clinical staff in the emergency department.* MJA, 2002. **176**(9): p. 415-418.

[11]. T. Realini, A. Kalet, J. Sparling, *Interruption in the medical interaction.* Arch Fam Med, 1995. **4**: p. 1028-1033.

[12]. Board of Nurse Examiners, Nursing Practice Act, Nursing Peer Review, & Nurse Licensure Compact. http://bne.state.tx.us/npa2005.pdf. http://bne.state.tx.us/npa2005.pdf. Retrieved January 13, 2006.

[13]. Texas Board of Medical Examiners, Rules, Regulations and Guidelines. http://www.tmb.state.tx.us/rules/rules/php. http://www.tmb.state.tx.us/rules/rules/php. January 13, 2006.

[14]. "activity", *The American Heritage® Dictionary of the English Language*. 2000, Houghton Mifflin Company.

[15]. J. Hollingsworth, C. Chisholm, B. Giles, W. Cordell, D. Nelson, *How Do Physicians and Nurses Spend Their Time in the Emergency Department?* Annals of Emergency Medicine, 1998. **31**(1): p. 87-91.

[16]. E. Rosch, *Principles of Categorization*, in *Cognition and Categorization*, E. Rosch and B.B. Lloyd, Editors. 1978, Erlbaum: Hillsdale, NJ. p. 27-48.

[17]. G.L. Murphy, *The Big Book of Concepts*. 2004, Cambridge: The MIT Press. 555.

[18]. M.W. Morris, G. Murphy, *Converging operations of a basic level in event taxonomies.* Memory and Cognition, 1990. **18**(4): p. 407-418.

[19]. A. Rifkin, *Evidence for a basic level in event taxonomies.* Memory and Cognition, 1985. **13**(6): p. 538-556.

[20]. R.R. Vallacher, D.M. Wegner, *What do people think they're doing? Action identification and human behavior.* Psychological Review, 1987. **94**(1): p. 3-15.
[21]. *QSR NVivo2*. 2002, QSR International Pty. Ltd.: Doncaster, Victoria, Australia.
[22]. C. Marshall, G.B. Rossman, *Designing Qualitative Research*. 3rd ed. 1999, Thousand Oaks: SAGE Publications, Inc. 224.
[23]. R.L. Wears, *Caution interrupted*. 2004.

An Instrumental Case Study of Interruptions in a Level One Trauma Center

Juliana J. Brixey, MSN, MPH, RN[1]

Zhihua Tang, PhD[1]

David J. Robinson, MD[1,2]

Craig W. Johnson, PhD[1]

Todd R. Johnson, PhD[1]

James P. Turley, PhD, RN[1]

Vimla L. Patel, PhD[3]

Jiajie Zhang, PhD[1]

[1] School of Health Information Sciences, The University of Texas Health Science Center at Houston, Houston, TX, USA
[2]Memorial Hermann Hospital, Houston, TX, USA
[3]Department of Biomedical Informatics, Columbia University Medical Center, NY, USA

Corresponding author
Juliana Brixey, MSN, MPH, RN
Juliana.J.Brixey@uth.tmc.edu
University of Texas Health Science Center at Houston
School of Health Information Sciences
7000 Fannin Suite 600
Houston, TX 77030
281.451.8206
713.500.3907 (FAX)

ABSTRACT

Background

Interruptions are events that unexpectedly fracture workflow which results in decreased productivity and efficiency, and increased errors. In 1999, the IOM report acknowledged that interruptions contributed to preventable medical errors. The purpose of this study was to observe, record, and contextualize activities and interruptions experienced by physicians and RNs working in a Level One Trauma Center.

Methods

Design: This is an instrumental case study that relied on an ethnographic study design by using the shadowing method.

Participants: A convenience sample of one female and four male physicians and six female and two male RNs, with at least six months' experience in the ED were asked to participate.

Ethical Approval: Both institutional and community consent was obtained. Approval was obtained from institutional ethic committees prior to initiating the study. Community consent was obtained from the ED staff through an inservice describing the study. Community consent is the terminology of consent that refers to gaining the community's permission or a leader's authorization for researchers to approach individuals in that group.

Setting: All observations were made in the trauma section of the ED of a large teaching hospital. The hospital is situated in a major medical center in the Gulf Coast region of the United States of America (USA).

Results

Five attending ED physicians were observed for a total of 29 hours, 31 minutes. Eight RNs were shadowed for a total of 40 hours 9 minutes. Interruptions and activities were categorized using the Hybrid Method to Categorize Interruptions and Activities. Interruptions and activities were visually represented on timelines. Registered Nurses received slightly more interruptions per hour when compared to physicians. People, pagers, and telephones were identified as mediums by which interruptions delivered. Interruptions most often involved the performance of one activity before returning to the original task.

Discussion

This study has provided an in-depth study of the interruptions that physicians and RNs experience while working in a Level One Trauma Center. However, several limitations have been identified in regards to the study. The sample size was small and was conducted in a sub-specialty of Emergency Medicine.

Conclusion

The instrumental case study supported the comprehensive study of interruptions within the context of an ED. Interruptions were best studied within the context of activities that physicians and RNs performed because interruptions are unplanned, unexpected secondary activities.

An Instrumental Case Study of Interruptions in a Level One Trauma Center

1.0 INTRODUCTION

Interruption, disruption, distraction, 'work-fragmenter', 'work-disrupter', and 'time-hacker' are a few of the names assigned to events that unexpectedly fracture workflow. Interruptions are so woven into today's workplace that employees not only expect to be interrupted but also often rely on interruptions to receive important information. Newspaper headlines announce that today's worker typically spends 2.1 hours per day handling interruptions which in turn costs companies an estimated $588 billion per year in unproductive time [1]. The financial impact on the companies is significant, but a more important concern is how interruptions contribute to decreased productivity and efficiency, and errors. In a communication driven environment such as healthcare, such observations should be of concern to health informatics specialists in the design and implementation of new technologies. New technologies such as mobile telephones not only change workflow but introduce new types of interruptions for physicians and RNs. Yet, in healthcare there is little evidence in the literature that these effects are being studied. It is imperative that research studies be conducted in healthcare to understand the impact of interruptions on workflow.

In 1999, the Institute of Medicine (IOM) report [2], brought attention to the fact that interruptions contributed to medical errors. During the last two years, governmental healthcare agencies such as the Agency for Healthcare Research and Quality (AHRQ) have also begun to suggest that interruptions and distraction in the workplace contribute to medical errors.

2.0 BACKGROUND

In healthcare, interruptions change workflow through the use of alerts and reminders emitted from medical devices such as infusion pumps, cardiac monitors, and ventilators. The device transmits a signal to a physician or the Registered Nurse (RN) that something is amiss and should be attended to immediately. Information is also delivered to physicians and RNs via pagers, land-line and mobile telephones. The information is delivered in real-time at the expense of interrupting the current activity. These examples show that while devices can be used to deliver useful information, they also increase interruptions. Conversely, interruptions can be reduced through the use of automation. An understanding of interruptions in healthcare is important for the design, implementation, and evaluation of health information systems, for the management of clinical workflow, and in order to reduce medical errors. Therefore, the purpose of this research is to conduct an instrumental case study using an ethnographic research design to observe, record, and contextualize activities and interruptions experienced by physicians and RNs working in a Level One Trauma Center. An instrumental case model is used to gain an in-depth understanding of a phenomenon as well as to broaden its generalizations [3].

The study of interruptions in healthcare has been primarily limited to intrinsic case studies. An intrinsic case study is primarily concerned with gaining an understanding of a particular case [3]. In each of the studies, the interest was to determine the frequency and sources of interruptions for physicians and RNs working in a particular setting such as an outpatient clinic or a hospital [4-20].

Of these intrinsic case studies, a limited number have specifically examined interruptions for physicians and RNs working in the Emergency Department (ED). The ED is characterized as intense, life-critical, stressful, and interruption-laden due to a fluctuating workload of critically

ill patients. Chisholm, Collison, Nelson, and Cordell [17] assert that physicians who simultaneously manage multiple patients are more likely to experience an increase in the number of interruptions than those who do not. They observed that ED physicians were interrupted approximately 20 times in a 180-minute observation period and the findings were positively correlated with the average number of patients simultaneously managed. In a similar study, Chisholm, Dornfeld, Nelson, and Cordell [16] compared the number of interruptions for ED physicians with those of primary care physicians (PCPs) working in ambulatory care settings. Results indicated that ED physicians were interrupted more often (9.7 times per hour) than PCPs (3.9 times per hour) because ED physicians were more likely to simultaneously care for multiple patients when compared to PCPs. However, these studies provide few explicit details about the interruptions.

In the ED, clinical care depends on communication among physicians, RNs, and other healthcare workers. Because of the need for vital and urgent information, clinicians do not consider making a phone call or stopping a colleague in the hall as an interruption. In a series studies, Coiera and others found that communication patterns, including the preference for real-time encounters in the ED, contributed to the interrupt-driven environment. Little regard was given for what consequences the interrupting telephone call had on the person receiving the call [13]. In an observational study of physicians and RNs working in ED, Spencer, Coiera, and Logan [19, 21] found that 35.5% of communication events were interruptions. This was equivalent to receiving 14.8 interruptions per person per hour. In a similar observational study, Coiera, Jayasuriya, Hardy, Bannan, and Thorpe [14] found that nearly one-third (30.6%) of the observed communication events were classified as interruptions for physicians and RNs working in two different EDs. This resulted in an average interruption rate of 11.15 interruptions per hour

for all subjects. These studies illustrate that while communication occurs among physicians, RNs, and other healthcare personnel, it can interrupt and disrupt workflow, reduce productivity and efficiency, and contribute to the occurrence of medical errors.

These intrinsic case studies indicate that physicians and RNs work in an interrupt-driven environment, and departments such as the ED are likely to be characterized in this way. However, these intrinsic case studies provide little information about the types of tasks the physicians and RNs were performing when receiving an interruption, the nature of the interrupting activities, and the impact of interruptions on workflow, efficiency, and productivity. This indicates there is a need for a more detailed study to observe, record, and contextualize activities and interruptions experienced by physicians and RNs working in the ED. A Level One Trauma Center was chosen to conduct this instrumental case study because this environment is characterized as intense, unpredictable, and interrupt-driven.

2.0 METHODS

In this section we will describe the methods used in an instrumental case study. The section will begin with a description of the study design and conclude with a description of the observers who participated in the data collection.

2.1 Study design

This is an instrumental case study that relied on an ethnographic study design by using the shadowing method. Shadowing is a qualitative technique that does not necessarily involve the use of statistical analysis of data. In shadowing, observers follow the subjects unobtrusively and take notes of what, why, and how the subjects perform their routine tasks in real-world settings.

2.2 Participants

A convenience sample of one female and four male physicians and six female and two male RNs, with at least six months' experience in the ED were asked to participate. Participation was voluntary and written consent was obtained prior to an observation session. Each session lasted a minimum of 2 hours but did not exceed 12 hours. The subjects had to be at least 21 years of age to participate.

2.3 Ethical Approval

Approval was obtained from institutional ethic committees prior to initiating the study.

2.4 Community Consent

Community consent was obtained from the ED staff through an inservice describing the study. Community consent is the terminology of consent that refers to gaining the community's permission or a leader's authorization for researchers to approach individuals in that group.

2.5 Setting

All observations were made in the trauma section of the ED of a large teaching hospital. The hospital is situated in a major medical center in the Gulf Coast region of the United States of America (USA). The organization is certified as a Level One Trauma Center, providing 24-hour emergency and trauma care to approximately 52,000 patients a year. Patients arrive at the ED via private car, ground and air ambulance. The ED occupies 51,000 square feet and contains major trauma and cardiac resuscitation rooms.

2.6 Data Collection

Observers typically worked in teams of two and recorded their observations using a semi-structured field note form implemented on Tablet PCs. Subjects were shadowed for a minimum

of 2 hours but did not exceed 12 hours. Recording of observations began when the subject had completed the informed consent. Observations were recorded in one-minute increments. Observers synchronized their stopwatches before the start of a session to assure accuracy in recording events.

2.7 Data Analysis

Each time-stamped observation was transcribed and entered into an Excel® spreadsheet for initial identification of interruptions experienced by the subject. Upon using NVivo© [22], more detailed analysis and categorization of the observations took place. During this phase of data analysis, observations were examined using constant comparison as a strategy to identify categories of interruptions [23]. Two coders analyzed the data for agreement of tasks and interruptions. A percent agreement score was calculated. The data in Excel® spreadsheet were entered into MacSHAPA© [24] for further analysis of the observational data. MacSHAPA© [24] is a Macintosh-based qualitative data analysis software application used for sequential data. It was designed to assist the researcher who is engaged in observing human operators interacting with complex systems, and with each other, in laboratory simulators or in the field. MacSHAPA© [24] supports both qualitative and quantitative statistical analyses of data and includes various visual tools such as a timeline report and tree outputs. It is easy to modify or change coding syntaxes and vocabulary using MacSHAPA© [24].

2.8 Observers

The observers typically worked in teams of two. Observer 1 is an RN with 28 years' experience in healthcare who is competent in human factors. Observer 2 is also a human factors expert with 6 years' experience but has had no training as a healthcare professional. Observer 3 is an RN faculty member with dual expertise in critical care and human factors. Observer 4 is a

doctoral student in health information sciences and is competent in human factors but has no training as a healthcare professional. Each observer received 30 minutes training using the data collection tool prior to beginning data collection. The ED staff provided a 30-minute orientation to acquaint the observers with the ED.

2.9 Those performing data analysis

Data analysis was performed by Observer 1 and Observer 2. Observer 1 was assigned the role of Coder 1 and Observer 2 assumed the role of Coder 2. It was determined that only 2 people would analyze the data for consistency in analysis.

3.0 RESULTS

In this section we present findings from analysis of the field notes. The results section begins with details of the demographics for the subjects who participated in the study. The section concludes with a discussion of whether an interrupted activity was resumed.

3.1 Demographics

Five attending ED physicians were observed for a total of 29 hours, 31 minutes. The physicians were pre-selected based on scheduling and a willingness to participate. Observations were made on either the 0700–1500 or the 1500-2300 shift. These shifts were selected because they were known to be periods of time characterized as high activity and recommendations from a domain expert in Emergency Medicine.

Eight RNs were shadowed for a total of 40 hours 9 minutes. Observations were made on either the 0700–1500 or the 1500-2300 shift. The charge nurse for the shift pre-selected which subject would participate in the observation and also elicited the willingness of the subject to participate.

3.2 Method to categorize activities and interruptions

The Hybrid Method to Categorize Interruptions and Activities (HyMCIA) was the product of data analysis [25]. HyMCIA was developed through the hybridization of a deductive *a priori* classification framework with the provision of adding new categories discovered inductively in the data using grounded theory [23].

3.3 Activities

Activities are performed by physicians and RNs to accomplish the task of providing care to ED patients. Physicians perform activities specific to their role and responsibilities. Other activities are exclusively performed by RNs. However, a number of activities are performed by both physicians and RNs. The taxonomy of activities was finalized after 5 iterations of data analysis. At the end of 5 iterations, no new categories of activities were identified. Table 1 shows the taxonomy of activities for physicians and RNs which evolved from a review of the healthcare literature and through data analysis of the field notes recorded for this study.

Table 1. A taxonomy of activities for physicians and RNs working in the ED

Activities Performed by Doctors	Common Activities	Activities Performed by RNs
	***A priori* Categories**	
Dictating history and physical		
		Start IVs
		Draw blood
		Perform treatments
		Data entry
		Patient and family education
		Assist physicians
Physician-specific issues		
	Communication	
	Patient assessment	
	Documentation	
	Post Study Categories	
Activities Performed by Doctors	***Common Activities***	***Activities Performed by RNs***
Rounds		
Delayed Communication		
Blocked Communication		
Looks For		
Report		
Wait For		
Leaves Area		
Observe (i.e., present but not performing an activity)		
	Interact with Technology	
	Clerical Duty	
	Teach	
	Respond To (i.e., acknowledge)	
	Provide Information	
	Receive Information	
	Perform Procedure	
	Request Information	
	Personal Hygiene (i.e., handwashing)	
	Delegate Task	
	Leave Area	
	Request Assistance	
	Retrieve Supplies	
	Break Time	
		Transport
		Discharge Patient
		Room setup
		Safety
		Patient Need
		Housekeeping
		Medicate
		Retrieve Information
		Perform Treatment
		Assist with procedure/treatment

Once the taxonomy of activities was finalized, the field notes for physicians and RNs was reanalyzed over 9 iterations to categorize the activities. After Iteration 9, no new activities were identified, indicating saturation had occurred. The percent agreement for categorizing activity using the taxonomy was found to be 90%. According to Miles and Huberman [26], a percent agreement in the range of 70% to greater than 90% is to be expected when coding qualitative data. The percent agreement calculated in this study is within the expected range.

Using the number of activities categorized in Iteration 9, physicians were found to perform slightly fewer activities per hour when compared to RNs. The difference is shown in Fig 1.

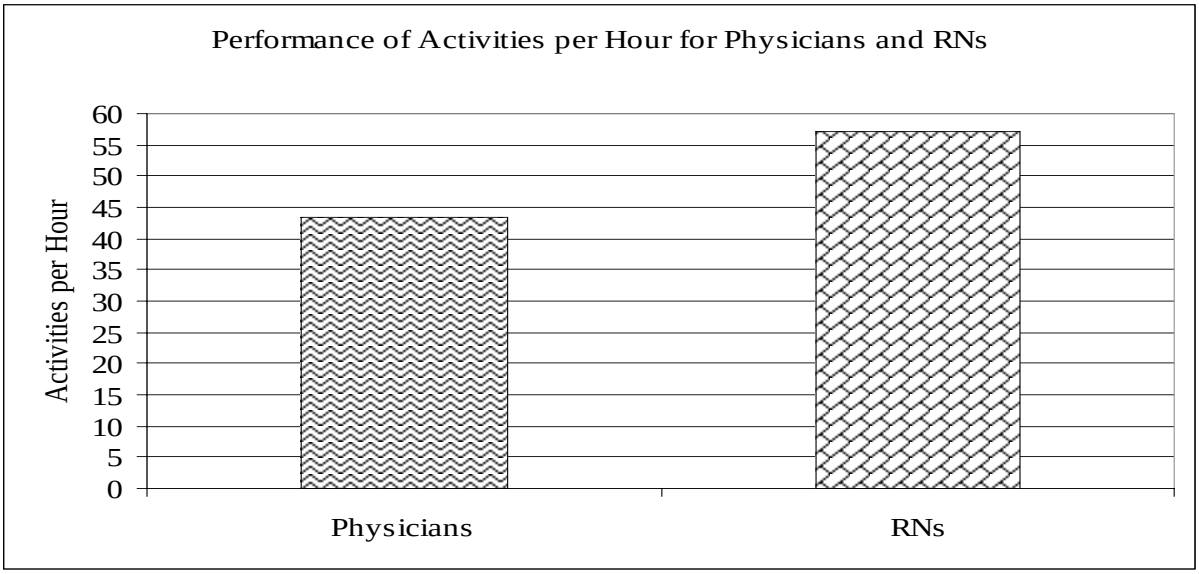

Fig. 1 Performance of activities per hour for physicians and RNs

This variance may be attributed to differing roles and responsibilities. Other factors, such as the number of patients in the ED, patient stability, and severity of the patient's injuries could have possibly contributed to the differences.

3.4 Interruptions

Interruptions do not occur in isolation but within the context of activity performance. Interruptions that occur in the workplace contribute to discontinuity of activity performance, can decrease efficiency and productivity, and sometimes contribute to the occurrence of errors. Fig. 2 shows the discontinuity using a timeline generated from analysis of the observation.

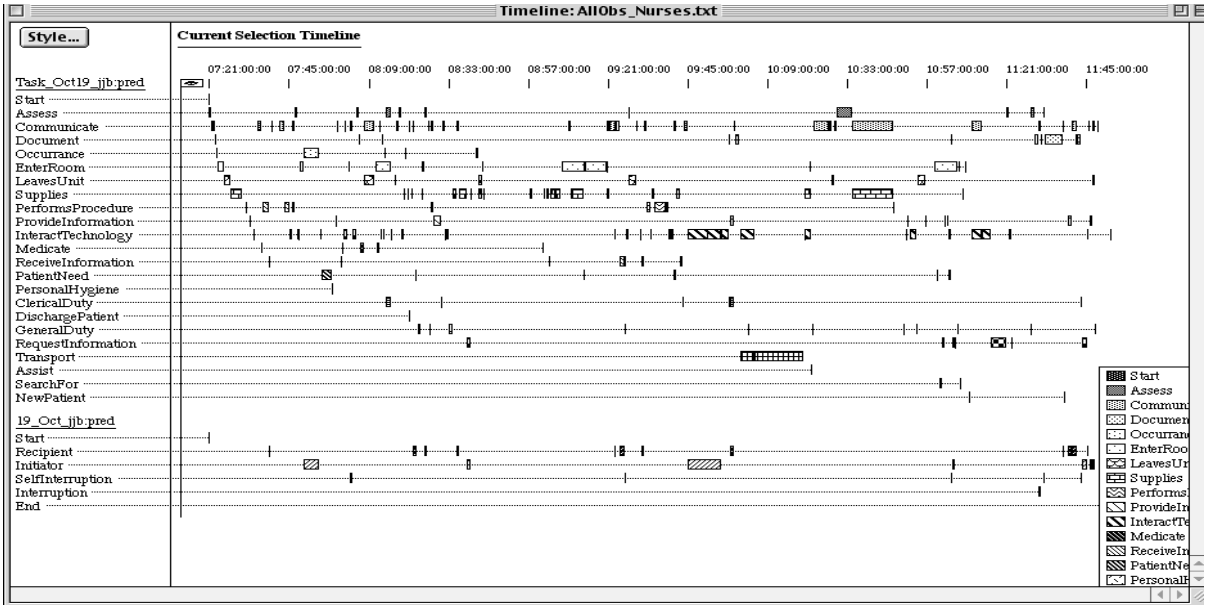

Fig. 2 A timeline of activities and interruptions

The time and duration of each activity the subject performed is shown across the top of the timeline. A list of activities is shown along the left margin of the timeline. The occurrence of interruptions is shown on a separate timeline directly beneath the activity timeline. The interruption can be mapped back to activities performed on the upper timeline. Timelines are useful in visually showing an interrupt-driven environment such as is found in the ED.

The percent of activities interrupted was calculated for ED physicians. The percent of tasks interrupted was calculated for the physicians. Analysis of the observations indicates that in Iteration 1, Observer 1 found that overall, 12.43% of activities were interrupted, whereas all Other Observers found that 16.87% of activities were interrupted. This could be attributed to the smaller number of activities observed by the Other Observers as well as the fact that all the Other Observers may have been more perceptive to interruptions than the actual tasks performed by the physicians. With continued analysis of the data, after 9 iterations, analysis of the physicians' data showed improvement in the identification of interruptions. Upon completion of 9 iterations of data analysis, no new categories or instances of interruptions were discovered. As the coders became more sensitive to subtle descriptions of interruptions, there was an overall increase in the number of interruptions. Analysis of the data indicates an overall agreement of 99.48% for observations in which an event was identified as an interruption by Observer 1.

Analysis of field notes recorded for the RNs followed the same protocol as that used for physicians. The percent of activities interrupted was calculated for RNs. Initial analysis of the observations indicate that Observer 1 found that overall, 4.11% activities were interrupted, whereas Observer 2 found 7.94%. This could be attributed to the smaller number of activities observed by Observer 2.

The low number of interruptions identified in Iteration 1 was due to conservative categorizing of the data as there was concern of over-inflation of the number of interruptions. At the end of Iteration 1 a percent agreement for categorizing interruption was calculated. As the coders of the data became more familiar with the descriptions and types of interruptions, the number of identified interruptions increased. After 9 iterations, no new categories of interruptions had been identified and no additional instances of interruptions were found

indicating that category saturation was achieved. For RNs, analysis of the data indicates an agreement of 93.56% for observations in which an event was identified as an interruption by Observer 1.

The data from Iteration 9 for both physicians and RNs is summarized in Fig. 3.

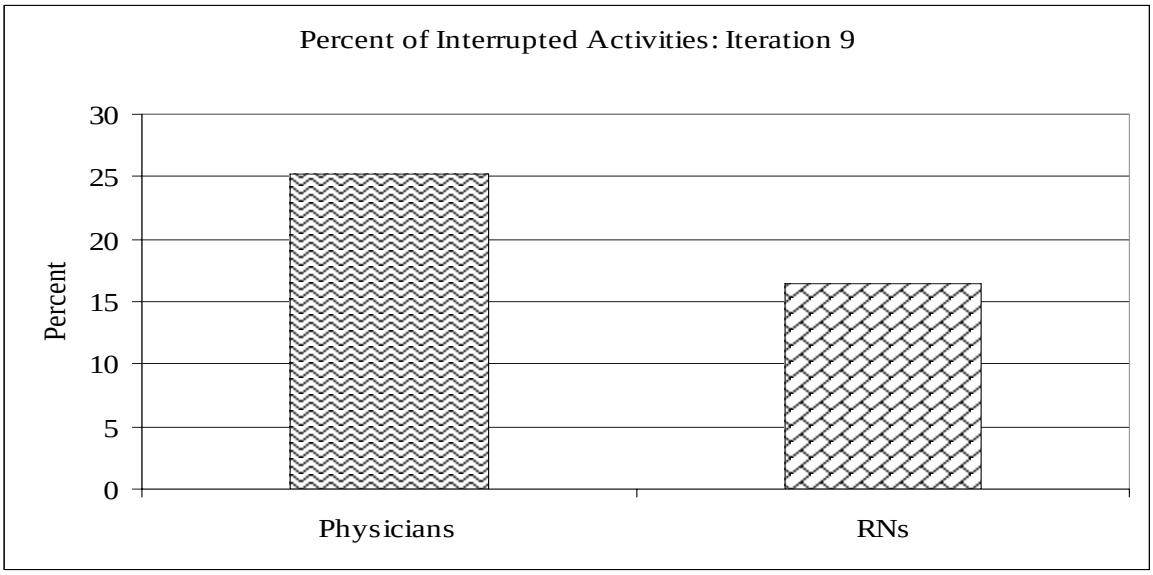

Fig. 3 Percent of interrupted activities for physicians and RNs

These findings provide additional insight into the frequency with which interruptions occurred. Iterative categorizing by those performing data analysis achieves a more comprehensive understanding of the observed phenomenon. The repetitive process suggests that the coders became more sensitive to the subtleties in the presentation of interruptions as they continued their analysis and were able to refine their categorization of the data.

A more accurate understanding of the impact of interruptions is gained by determining the frequency of interruptions per hour. This adjusts for the variation in time that each subject was observed. Fig.4 shows the overall of rate of interruptions for physicians and RNs.

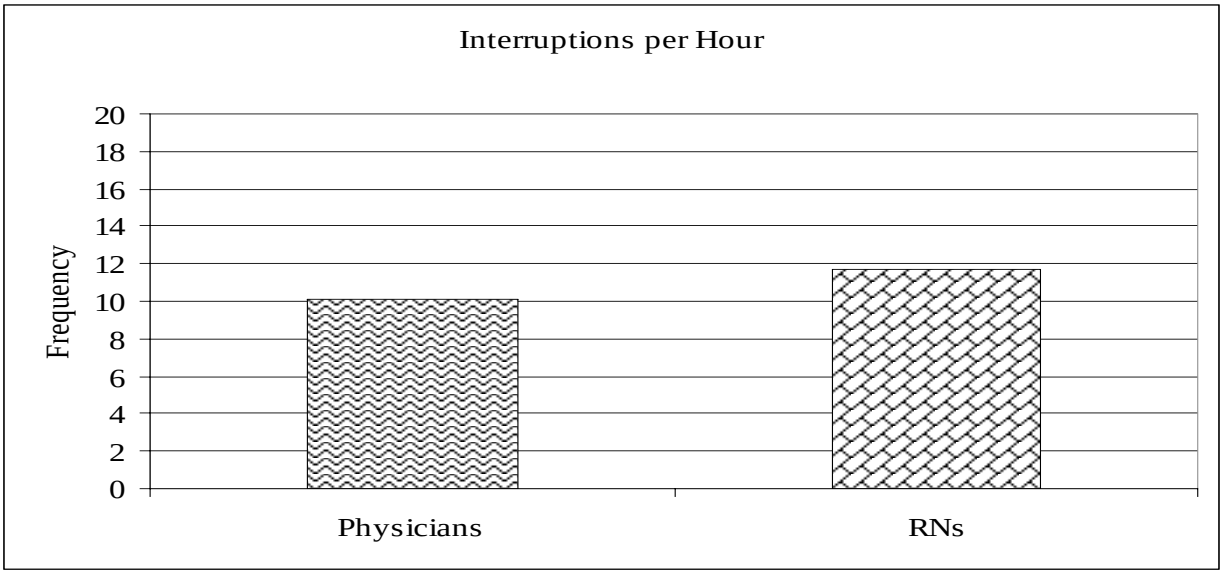

Fig. 4 Overall rates of interruptions for physicians and RNs

The variations in the number of interruptions per hour could be attributed to a number of factors each physician or RN such as:

1. the number of pages received
2. the number of telephone calls received
3. the design of the unit
4. the availability of supplies
5. the unplanned and unexpected encounters with other staff members, patients, and families

Although, the role and responsibilities are different for physicians and RNs, factors that contribute to interruptions may be similar for both groups. The two groups share a common workspace and workload in the ED.

3.4.1. Categories of Interruptions

Analysis of the data began with Observer 1 reviewing each time-stamped cell to determine if an interruption had occurred. Upon completion of the categorization of interruptions, the spreadsheet was sent to Observer 2 for verification and further identification of interruptions. The two coders met to resolve any disagreement in coding. If an agreement could be reached, the observation in question was resolved. If no resolution could be reached, the observation was left unresolved and so noted. A percent agreement was performed using data obtained by shadowing physicians. Analysis of the data indicates an agreement of 99.48 % for observations in which an event was identified as an interruption by Observer 1. According to Miles and Huberman [26], a percent agreement within the range of 70% to greater than 90% is to be expected when coding qualitative data. The percent agreement calculated in this study is within the expected range as stated by Miles and Huberman [26].

A percent agreement was calculated for RNs with analysis of the data showed indicate an agreement of 93.56% for observations in which an event was identified as an interruption by Observer 1. This value was within the expected range stated by Miles and Huberman [26].

For the analysis, a list of the different categories of interruptions was identified in the data. The following are the categories for interruptions that have been established:

1. Intended Recipient - the person to be interrupted
2. Unintended Recipient - not the intended recipient of an interruption; i.e., receiving a phone call that was incorrectly dialed
3. Indirect Recipient – the incidental recipient of an interruption; i.e., talking with another and which conversation suspends the original activity
4. Recipient Blocked – the intended recipient does not accept the interruption

5. Recipient Delayed – the intended recipient postpones an interruption
6. Self-interruption – a person, independent of another person, suspends an activity to perform another; i.e., while walking stops abruptly and talks to another person
7. Distraction – briefly disengaging from a task
8. Organizational Design – the physical layout of the workspace that causes a disruption in workflow
9. Artifacts Not Available – supplies and equipment that are not available in the workspace causing a disruption in workflow
10. Initiator – a person who initiates an interruption

New categories of interruptions emerged as sensitivity to the data increased. As noted in the list above, the new categories of Organizational Design and Artifacts Not Available were identified in the data. For example, the centralization of medication and supplies contribute to interruption in workflow. When the resources are not kept in the trauma cubicle, the RN must leave the workspace to retrieve the item. Medications are stored in a secured centralized location within the Trauma Department which means each time the RN medicates a patient the RN must suspend a task in order to retrieve the medication from this location. Each time a patient needs a warm blanket the RN must leave the bedside to retrieve the blanket. In order to take a patient's temperature, the RN must locate the thermometer because an individual device is not kept at the bedside, again causing the RN to leave the patient. In another type situation, workflow is interrupted as the RN leaves the immediate work area of the Trauma ED to deliver specimens to the Stat Laboratory which is located in the Medicine Section of the ED. The RN also leaves the Trauma Section for the Medicine Section to retrieve medications not stocked in Trauma. In order

to send a fax, the closest fax machine is also located in the Medicine Section. These examples show how the new categories give a more precise description of the interrupted workflow experienced by the RNs.

3.4.2 Mediums to Deliver an Interruption

Although an individual may state that they were interrupted by a telephone or pager, the device is only the *medium* through which the interruption was delivered. In the ED, the telephones, pagers, and other people were used as mediums by which to deliver an interruption. In Fig. 5 physicians were interrupted more often by other people. The physicians who were observed in this study were also in charge of the ED residents. It was observed that there were many interactions between the ED physician(s) and the residents. In contrast, RNs received more telephone calls. Registered Nurses are known to interact with many hospital departments outside the ED. This may have contributed to the increased percentage of interruption coming as telephone calls.

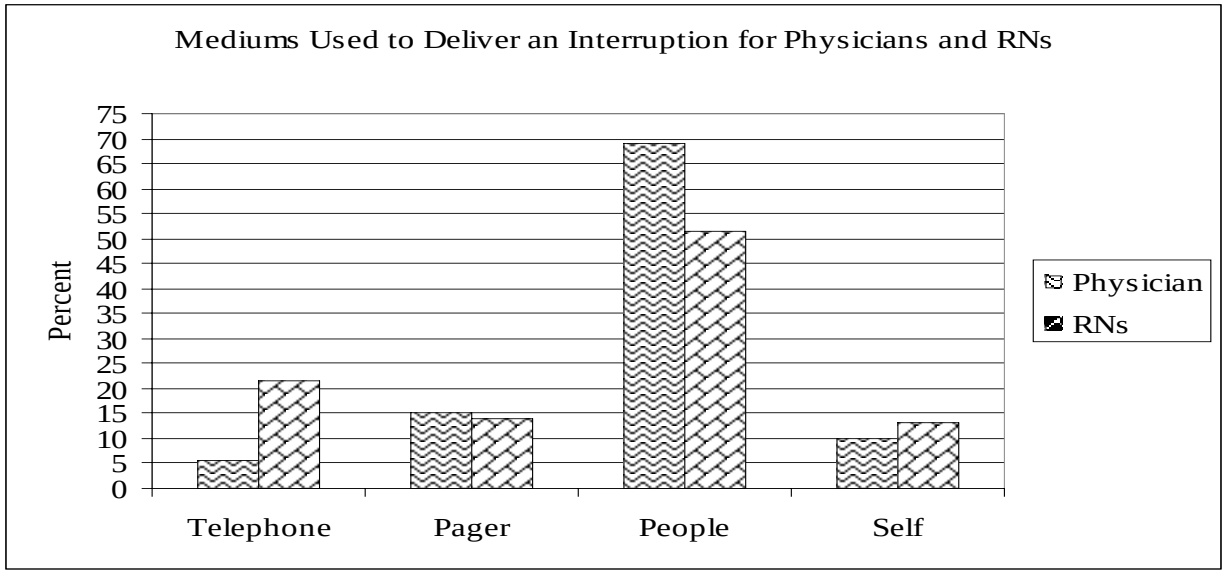

Fig. 5 Mediums of delivery for an interruption

Of particular interest was the use of telephones in the ED. It was observed that physicians used both landline and mobile telephones. Physicians received 31.58% interrupting telephone calls through landline telephones. The other 68.42% came via mobile telephones. Physicians were observed as immediately answering the mobile telephone. The mobile telephones are designed without a voice mail function. This feature forces the person receiving the telephone call to answer it immediately or miss the call with hopes that the caller would phone at a later time.

In contrast, the use of mobile telephones by RNs was limited to the charge nurse and that role was not part of this study. An exception was noted when the charge nurse delegated managing the mobile phone to a subject included in this study for a brief period of time.

Self interruptions were observed when the study subject stopped performing the initial task and performed an interrupting task without provocation from a source outside the subject. For instance, a physician was observed walking in the hallway. The physician suddenly stopped walking and began talking with another physician. In this instance the physician chose to use this chance meeting as a spur of the moment encounter.

Although a large number of medical devices used in the ED are equipped with alarms, no observer recorded an interruption occurring because of a medical device alarm. It could be inferred that through regular and consistent monitoring of the ED patients, changes in conditions were detected before an alarm sounded.

3.4.3 Resumption of Interruptions

Additional understanding of interruptions required the determination of whether a task was resumed or forgotten. Such information provides understanding of the possible effects of interruptions and how those delays can contribute to preventable medical errors. Data indicate

that physicians and RNs, indicates that after being interrupted, they did not resume the original, suspended activity until after they performed from 1 to 8 other activities. Fig. 6 shows a summary of the number of activities performed before returning to the original activity.

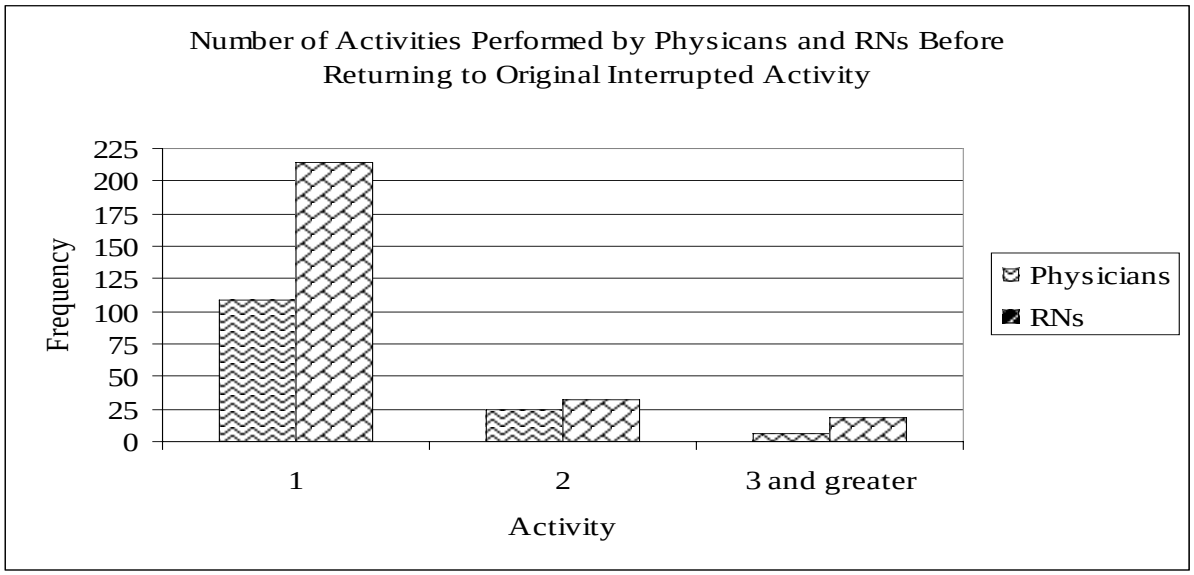

Fig. 6 Percent of activities performed by a physician or RN before returning to original task

The data indicates that in the majority of situations, physicians and RNs performed only one interrupting activity before returning to the interrupted activity. It could be inferred that the fewer interrupting tasks performed, the more likely the recipient of the interruption will return to the original task. However, returning to an interrupted activity does not eliminate the possibility that an error could occur after returning an interrupted task, possibly a result of said interruption.

Physicians resumed fewer interrupted activities than RNs as shown in Fig. 7. This may suggest that RNs used some memory aid or strategy to remember to return to the original activity. It was not observable as to what approach was used, or if any consistent method was taken advantage of to remind the person they need to resume the interrupted activity.

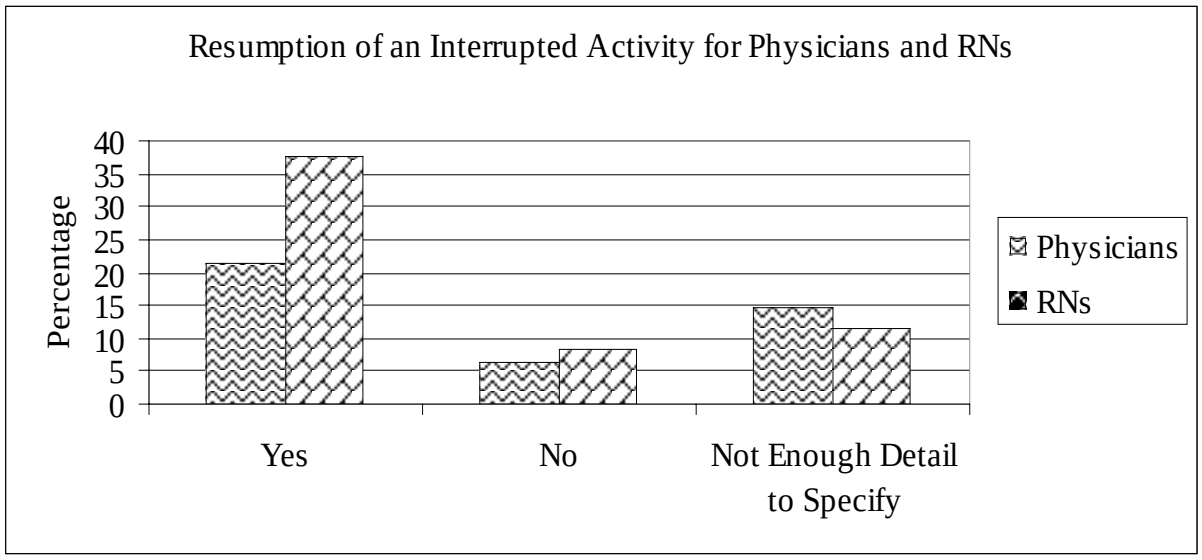

Fig 7. Resumption of an interrupted activity by physicians and RNs

The actual consequences of the activities that were not resumed in this observational study are not known. This would have required additional data collection such as retrospective chart reviews, videotaping of the observation, debriefing of the subject, or some combination of strategies that was not part of this study.

4.0 DISCUSSION

The purpose of this study was use a qualitative approach to study interruptions that physicians and RNs experience and to describe those interruptions within the context of a Level One Trauma Center. This study is the most comprehensive study of interruptions for physicians and RNs that has been conducted up to this time. By choosing a Level One Trauma Center as an instrumental case, the boundaries of whom, what, as well as the context in which interruptions would be studied, were defined. By using an instrumental case study, the focal point was on the phenomenon, interruptions that occurred in a Level One Trauma Center. According to Stake [3,

p.454] “Most case study is the empirical study of human activity”. Interruptions are a human experience. Interruptions influence human activity by causing the recipient to stop the performance of one task to perform another. Modeling activities and interruptions on a timeline shows how interruptions penetrate work as an unexpected, secondary activity. The timeline shows the overlap of the two activities resulting in changes in workflow. This is important in understanding if some activities are interrupted more often than others and in determining how they affect the overall smoothness and accuracy needed in the workplace.

During the process of categorizing the data, activities were given names conveying an action (i.e., interact with technology, retrieve supplies). In contrast, the interruption event was named according to the role that physicians or RNs assumed. The physicians or RNs were either the recipient or initiator of the interruption. Defining the role indicates whether the subject was more often in an active or passive role when receiving or initiating an interruption. This is important information in designing a technology to help reduce the number of interruptions.

We found that physicians and RNs were primarily interrupted by other people. This is consistent with other studies of interruptions [4, 5, 7, 12-14, 16, 17, 21, 27]. Previous studies of interruption have found that landline telephones have been used as a medium by which to deliver an interruption. Mobile telephones are becoming more common in healthcare organization as part of the communication systems. Moreover, in this study we identified mobile telephones as a medium by which to deliver interruptions. Physicians were observed promptly answering the mobile telephone. These mobile telephones did not have a voice mail feature. The lack of this feature can result in the interruption of another person when the call is rerouted to the hospital operators. Failing to answer the telephone meant that the caller might not call back and the physician would miss important information. In contrast, landline telephones can be answered by

anyone near the device, whereas mobile telephones are personal devices and are answered by the person assigned to them. In a recent study by Soto, Chu, Goldman, Rampil, and Ruskin [28], mobile telephones were designated as a technology that reduced medical errors by reducing delays in communication. The study did not discuss if the mobile telephone introduced any new interruptions and if workflow changed for the physicians. As with the introduction of other technologies into the clinical environment, the mobile telephone must be evaluated as to what new interruptions are introduced, how it changes workflow, and what errors occur.

Interruptions have been identified as an intrusion of a secondary, unplanned activity, into an activity that is in progress [29]. This intrusion results in the suspension of that activity. Other studies of interruption have not examined the number of activities that were performed between the occurrence of the interruption and the return to the primary activity. The number of additional activities that are performed provides information about the duration of interruptions. The duration of the interrupting activities are also a measure of efficiency and productivity. The additional activities may be important and necessary to perform but still this occurs at the expense of the interrupted activity. Currently, physicians and RNs have no technologies to manage interruptions but rely on physically delaying or blocking the interruptions. It is not possible to eliminate all interruptions but technologies should be developed and used to help physicians and RNs handle and manage interruptions.

Once the interruption is completed, it is assumed that the activity will be resumed. In this study we found that physicians and RNs do resume interrupted activities. The design of this study did not permit the discovery of what memory aids that the physicians and RNs were using to help them remember to resume the task. When an activity is not resumed, errors occur; for example there may be an error of complete repetition in which the primary activity is performed

in its entirety as starting over might be deemed to be the most efficient way to reduce making an error or it may be forgotten [29]. While re-reading a medical record following an interruption is not error that will likely result in patient harm, however the re-administration of a medication may result in serious injury to a patient. Assisting physicians and RNs to return to the interrupted activity is a function that health informatic specialist should consider when designing products used in the clinical setting. The suggestion of a memory aid could prove useful in resuming an interrupted activity.

This study has provided an in-depth study of the interruptions that physicians and RNs experience while working in a Level One Trauma Center. However, several limitations have been identified in regards to the study. The sample size was small and was conducted in a sub-specialty of Emergency Medicine. Level One Trauma Centers are dedicated to the care of trauma victims. Workflow changes with the arrival of each new trauma patient and must be interrupt-driven. The specificity of the Trauma ED should be considered when generalizing findings from this study to other EDs. However, the occurrence of interruptions occurs in all types of emergency departments as well as Intensive Care Units (ICUs) and in Operating Rooms (OR). Future studies should examine how new technologies introduce interruptions so that strategies can be developed to manage them.

5.0 CONCLUSION

An instrumental case study design was used to study interruptions for physicians and RNs working a Level One Trauma Center. The instrumental case study supported the comprehensive study of interruptions within the context of an ED. In this study activities were categorized by identifying if was performed the physicians, the RNs, or was an activity performed by both

physicians and RNs. We found that interruptions were best studied within the context of activities that physicians and RNs performed because interruptions are unplanned, unexpected secondary activities. Therefore interruptions must be considered as another activity. However, in categorizing an interruption was done so according to whether the subject was the recipient or the initiator of the interruptions. In addition, two other types of interruptions were identified. Interruption by organizational design and artifacts were not available were added to the categories of interruption. Together these findings led to the formation of a taxonomy of interruptions.

In this study, results indicate that physicians and RNs received about the same number of interruptions per hour. People, telephones, and pagers were the mediums used to deliver interruptions. It was observed that the physician on duty was assigned a mobile telephone but not the RNs. This study raises the concern regarding the impact of mobile telephones as a medium to deliver an interruption. Additional research will be required to fully understand if the use of mobile telephones contributes to an interrupt-driven environment.

When interrupted both physicians and RNs performed usually only 1 or 2 interrupting tasks before returning to the original task. This indicated that most tasks were resumed. It was not known if the original task was correctly resumed.

MacSHAPA [24] proved to be a useful qualitative software application to visually display both interruptions and activities. The visual display was used to show both the time and duration of the interrupted activities as well as when the interruptions occurred. A visualization of interruptions and activities gives a better understanding of what times are most interrupt-driven.

This study raises the issue that health informatics specialists should anticipate that new technologies can introduce interruptions. In addition, physicians and RNs need techniques to manage interruptions. This requires that interruptions be delivered as to minimize the negative impact on activity performance with consideration to the significance assigned to the interruption.

ACKNOWLEDGEMENT

This project has been supported by a training fellowship from the Keck Center for Computational and Structural Biology of the Gulf Coast Consortia (NLM Grant No. 5 T15 LM07093) and Grant R01 LM07894 from the National Library of Medicine.

REFERENCES

1. Lin-Fisher B. Discombobulated by distractions. Houston Chronicle 2006 February 27, 2006;Sect. D1,D4.
2. Kohn LT, Corrigan JM, Donaldson MS, editors. To err is human: Building a safer health system. Washington, DC: National Acedemy Press; 1999.
3. Stake RE. Qualitative case studies. In: Denzen NK, Lincoln YS, editors. The sage handbook of qualitative research. Third ed. Thousand Oaks, CA: Sage Publication, Inc.; 2005. p. 443-462.
4. Peleg R, Froimovici M, Peleg A, Milrad V, Ohana G, Fitoussi S, et al. Interruption to the physician-patient encounter: An intervention program. Isr Med Assoc J 2000;2(7):520-522.
5. Shvartzman P, Antonvosky A. The interrupted consultation. Family Practice 1992;9:210-221.
6. Paxton F, Heaney DJ, Porter AM. A study of interruption rates for practice nurses and gps. Nursing Standard 1996;10(43):33-36.
7. Dearden A, Smither M, Thapar A. Interruptions during general practice consultations - the patients's view. Family Practice 1996;13(2):166-169.
8. Realini T, Kalet A, Sparling J. Interruption in the medical interaction. Arch Fam Med 1995;4:1028-1033.
9. Rhoades DR, McFarland KF, Finch WH, Johnson AO. Speaking and interruptions during primary care office visits. Family Medicine 2001;33(7):528-532.
10. Blum NJ, Lieu TA. Interrupted care. The effects of paging on pediatric resident activities. Am J Dis Child 1992;146(7):806-808.
11. Harvey R, Jarrett PG, Peltekian KM. Patterns of paging medical interns during night calls at two teaching hospitals. Can Med Assoc J 1994;151(3):307-311.
12. Coiera E. Clinical communication - a new informatics paradigm. In; 1996; 1996. p. 17-21.
13. Coiera E, Tombs V. Communication behaviours in a hospital setting: An observational study. BMJ 1998;316(7132):673-676.
14. Coiera EW, Jayasuriya RA, Hardy J, Bannan A, Thorpe MEC. Communication loads on clinical staff in the emergency department. MJA 2002;176(9):415-418.
15. Parker JC, E. Improving clincial communication. Journal of the American Medical Informatics Association 2000;7(5):453-461.
16. Chisholm C, Dornfeld A, Nelson D, Cordell W. Work interrupted: A comparison of workplace interruptions in emergency departments and primary care offices. Annals of Emergency Medicine 2001;38(2):146-151.
17. Chisholm CD, Collison EK, Nelson DR, Cordell WH. Emergency department workplace interruptions: Are emergency physicians "Interrupt-driven" And "Multitasking"? Acad Emerg Med 2000;7(11):Acad Emerg Med.
18. Flynn EA, Barker KN, Gibson JT, Pearson RE, Berger BA, Leo A. Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. American Journal of Health-System Pharmacy 1999;56(13):1319-1325.
19. Spencer R, Logan P. Role-based communication patterns within an emergency department setting. In: Proceedings HIC 2002; 2002; Melbourne; 2002.

20. Burmistrov I, Leonova A. Do interrupted users work faster or slower? The micro-analysis of computerized text editing task. In: Stephanidis JJaC, editor. Human-Computer Interaction: Theory and Practice (Part I); 2003: Mahwah: Lawrence Erlbaum Associates; 2003. p. 621-625.
21. Spencer R, Coiera E, Logan P. Variation in communication loads on clinical staff in the emergency department. Ann Emerg Med 2004;44(3):268-73.
22. QRS. NVivo 2.0. In. Doncaster Victoria, Australia; 2002.
23. Glaser B, Strauss A. The discovery of grounded theory. New York: Aldine Publishing; 1967.
24. Sanderson PM. MacSHAPA. In. 1.0.3 ed; 1994.
25. Brixey JJ, Robinson, DJ, Johnson, CW., Johnson, TR, Turley, JP, Patel, V,Zhang, J. Towards a hybrid method to categorize interruptions and activities in healthcare International Journal of Medical Informatics 2006;In review.
26. Miles MB, Huberman AM. Qualitative data analysis: An expanded sourcebook. 2nd ed. Thousand Oaks: SAGE Publications, Inc.; 1994.
27. Alvarez G, Coiera E. Interruptive communication patterns in the intensive care unit ward round. International Journal of Medical Informatics 2005;74:791-796.
28. Soto RG, Chu LF, Goldman JM, Rampil IJ, Ruskin KJ. Communication in critical environments: Mobile telephones improve patient care. Anesth Analg 2006;102:535-541.
29. Brixey JJ, Robinson, D. J., Johnson, C. W., Johnson,T. R., Turley, J. P., Zhang, J. A concept analysis of the phenomenon interruption. Advances in Nursing Science 2006;30(1):In review.

CONCLUSION

This dissertation is comprised of three original manuscripts examining the various aspects of the concept of interruption. The first two papers took a theoretical approach to understanding the complexities of an interruption. In the first manuscript, a concept analysis was performed by examining how interruption had been defined in the literature. Definitions of interruptions were selected from healthcare, human factors, and cognitive science for analysis. Walker and Avant's method was used to guide the analysis. From analysis of the definitions, five defining attributes were identified for the concept interruption. Those attributes are: (1) a human experience, (2) an intrusion of a secondary, unplanned, and unexpected task (3) discontinuity, (4) externally or internally initiated, and (5) situated within a context. These attributes are essential components of the concept interruption at the cognitive level. If any of these attributes are absent, then an interruption has not occurred. This facilitates consistent classification to determine when an interruption has occurred.

A series of conditions were found to occur prior to an interruption. These conditions are known as the antecedents. In the case of an interruption, the following were identified as antecedents: (1) intent to interrupt is formed by the initiator, (2) physical signal passes threshold test of detection by the recipient, (3) sensory system of the recipient is stimulated to respond to the initiator, (4) interruption task is presented to recipient, and (5) the interruption task is either accepted or rejected by the recipient. A fully formed interruption has occurred once the above antecedents have been fulfilled and the interruption task is accepted. Therefore, an interruption has some rate of recurrence that can be measured as an empirical referent.

Empirical referents are used to measure a concept using either quantitative or qualitative methods. The following were identified as empirical referents by which to quantify an interruption: (1) identifying the intrusion of a secondary, unplanned, and unscheduled task, (2) suspending the primary task before completion, (3) switching to a different task, (4) performing tasks in serial manner, and (5) returning to the primary task. These empirical referents can be used to further quantify an interruption by measuring: (1) the frequency of occurrence of an interruption, (2) the number of times the primary task has been suspended to perform an interrupting task, (3) the length of time the primary task has been suspended, and (4) the frequency of **returning** to the primary task or of **not returning** to the primary task. The empirical referents that have been identified can be used by other researchers to quantify interruptions in other disciplines.

The final product of the concept analysis was the development of a standard definition of an interruption to use in healthcare. An interruption is defined as a break in the performance of a human activity initiated internal or external to the recipient and occurring within the context of a setting or location. This break results in the suspension of the initial task by initiating the performance of an unplanned task with the assumption that the initial task will be resumed. The definition is inclusive of all the defining attributes of an interruption. A standard definition of an interruption supports a shared understanding among healthcare professionals about what constitutes an interruption.

In the second manuscript, the Hybrid Method to Categorize Interruptions and Activities (HyMCIA) in healthcare is described. I formulated the HyMCIA as a flexible and reusable method by which to categorize interruptions and activities. The method was developed by using inductive and deductive methods as well as bottom-up and top-down strategies. An inductive

method was based on Grounded Theory used to categorize interruptions. The categories were grouped according to what role a person played in the interruption event. The person either received or initiated the interruption. However, in this paper, two types of interruptions were identified that are **not** role-based: Interruptions by Organizational Design and Artifacts not Available. Both show how the workplace design can contribute to types of interruptions not primarily people-oriented, but rather design-oriented. These categories of interruptions had not been previously discussed in the literature.

Grouping of the categories into a hierarchy of activity was guided by a method developed by Rosch. The categories of interruption and activities were arranged within a three-tiered hierarchy. The level of abstraction determined position in the hierarchy. Activity was the name assigned to the Superordinate Category in the hierarchy. This category made no distinction as to whether an activity was or was not interrupted. Subsequently, the category was divided into those activities that were performed without interruption and those that had performed with an interruption. These categories were named Uninterrupted and Interrupted. The Subordinate Category was used to classify specific instances of an interruption or activity.

An *a priori* framework was used to categorize activities. The framework was the product of a review of the literature and from solicited suggestions of domain experts in emergency medicine. The framework was further expanded when used to categorize activities recorded by observing physicians and RNs working in a Level One Trauma Center.

The categories of interruptions and activities identified using the HyMCIA will support the formation of a taxonomy of interruption and activities. The taxonomy has potential use as a means to categorize how interruptions can contribute to medical errors. This is a possible and positive step which could be taken and expanded upon at a time when healthcare is taking an

increasing interest in understanding how factors such as interruptions can, and most likely do, contribute to medical errors.

Finally, an instrumental case study, using an ethnographic design, investigated interruptions within the context of a Level One Trauma Center. By using qualitative methods, the physicians and RNs were observed in a naturalistic setting. In this manner, the fluctuation in interruptions and activities could be examined without the constraints found in quantitative study designs. Dynamic environments are best understood by recording observations in the form of field notes. The challenge and difficulty of analyzing the field notes is offset by the rich details that are revealed. Because of the design of this study and subsequent examination of the field notes, it was clearly shown that physicians and RNs were interrupted by the design of the workplace, and again when supplies were not readily available. When new categories emerge, such as those described above, it would indicate that studies should be implemented; in this case, specific consideration should be given to the design of the workplace and how it might be improved.

People, pagers, and the telephone were each identified as a medium by which to deliver an interruption. Physicians and RNs rarely delayed or blocked an interruption. More often the interruption was handled immediately. Mobile telephone technology is gaining acceptance in the healthcare environment. The physician or RN is immediately accessible. The consequence of instant accessibility and the impact on workflow will require further study. The receptiveness to interruptions continues to support an interrupt-driven environment. Continued study of interruption should consider how technology could be used to minimize or mitigate interruption but not at the sacrifice of losing access to time-critical patient information.

This dissertation is but a springboard to continued study of interruptions. For instance, the use of mobile technology is only one of many new technologies that will need to be studied

relative to the ways they interrupt workflow, the positive or negative consequences, and how to build creatively and productively using this knowledge. It is my desire not only to continue to study interruptions but to develop interventions with which to help manage them.

Juliana Brixey
March 27, 2006