A Concept Analysis of the Phenomenon Interruption

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An interruption was found to have no consistent definition in either healthcare or nonhealthcare literature. Walker and Avant's 8-step method of concept analysis was used to clarify, define, and develop a conceptual model of interruption. The analysis led to the identification of 5 defining attributes that 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:** *concept analysis*, *healthcare*, *interruption*, *nursing*

*I*NTERRUPTIONS 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 that 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 where registered nurses 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, interrupting conversation. A nurse informatist could experience both a reduction in efficiency in productivity by receiving a large number of unexpected telephone calls while trying to resolve a system failure. The unexpected increase in telephone calls contributes to interruptions in workflow. The change can cause the nurse to forget to reset a critical function, resulting in an error by interruption. For registered nurses to communicate the negative effects of an interruption, it is necessary that all attributes of the interruption be described using consistent terms. This uniform use of terminology is most important when recording 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 contribute to medical errors.

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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.

A 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[12] suggests that the process of concept formation begins during childhood when we begin to form mental representations of objects. 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 that can subsequently result in communication errors. For that reason, a collective meaning and understanding of a concept is essential for successful communication. For example, the term "interruption" is commonly used when indicating that an unex-

pected 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[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 used to define an interruption. In a study examining interruptions occurring during conversation, Alvarez and Coiera[10] identified 2 specific types of interruptions. These are conversation-initiating interruption and turn-taking interruption. A *conversation-initiating interruption* 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 *turn-taking interruption* was defined as occurring "within an individual communication event, when one individual begins speaking before the other finishes."[10(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 an 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 nonhealthcare studies of interruption have defined it as:

1. "an interruption is nothing more than an 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. They also 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 was 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 the identification of a shift in power.[25] There will be those who will experience an increase in power while there will be those who 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

the 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 his or her 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, 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 in order to eliminate studies that were outside the interest of this study, and to 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[12] introduced an 11-step process to guide concept analysis. 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 situations that are not the concept
5. *Related cases* have 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* are imaginary examples of the concept
8. *Social context* is the setting and situation of use
9. *Underlying anxiety* exemplifies the mood or feeling of the person using the concept, the connotation of the concept
10. *Practical results* indicate 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

Wilson's *process* is a useful tool in understanding not only the denotation but also 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 support the aim of this analysis to explore the concept of interruption. Their process was used exclusively for this concept analysis.

RESULTS

Results of literature search

One hundred twenty journal articles were reviewed and examined to identify whether the concept was explicitly defined in the study and how the researcher defined interruption. Definitions were entered into an Ex-cel 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 are 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] Commencing 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. 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 was 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
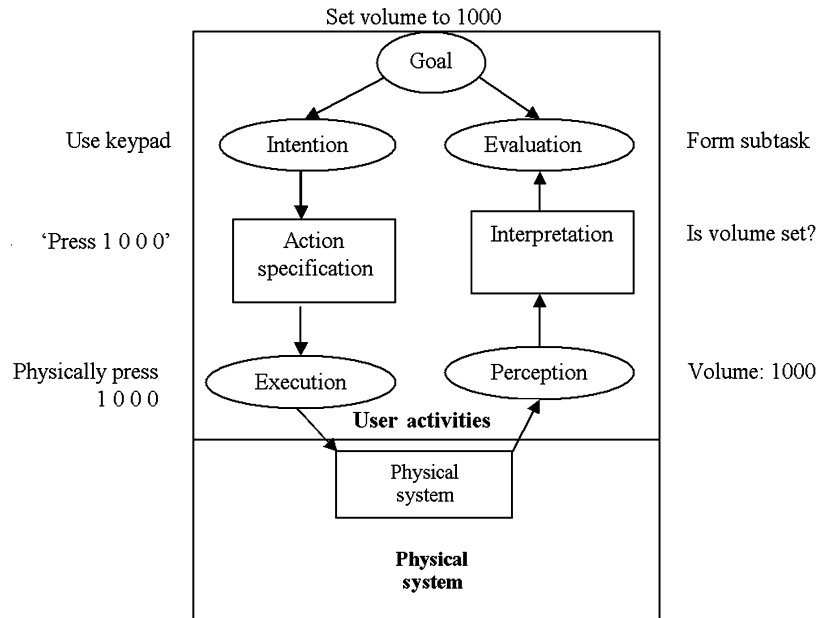
Figure 1. Norman's[27] Seven Stage Action Cycle model depicting programming of an infusion pump as depicted by Zhang et al.[28] Used with permission from Dr Zhang.

into the primary task. The intrusion of the interrupting 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 et al[28] show how the model can be used to depict the actions involved in programming an infusion pump. This is shown in Figure 1.

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 nonobservable stages of the Action Cycle, the recipient of the interruption may be performing an internal task such as forming a goal.

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 nonvisible 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 nonobservable states are more difficult to link to a specific step in the Action Cycle.
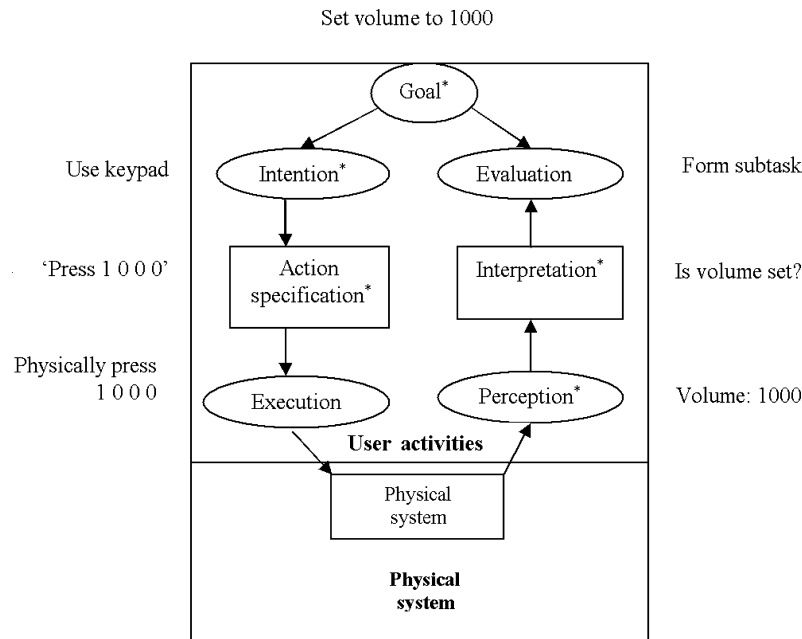
Figure 2. Nonobservable stages in the Action Cycle during programming of an infusion pump as depicted by Zhang et al.[28] Used with permission from Dr Zhang.

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 begins 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 also 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 because this type of interruption most often occurs within the thought process. For example, an internally generated interruption can occur as a daydream or an intrusive thought unrelated to the primary task. Internal interruptions are experienced privately within the mind or body of the individual. It is interesting to note that those who teach meditation techniques such as those taught by Zen and Chen who 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. In the healthcare field, there are no studies that indicate utilizing this method of decreasing internal interruptions.

Interruption: Situated in a context

An interruption occurs within the context of a setting or a 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 of the employees. Studies of interruptions experienced by nurses have been conducted within the context of 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.[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 to illustrate the 5 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 Agency for Healthcare Research and Quality WebM&M)[32]

The interruption of a nurse in the model case shows the 5 defining attributes of an interruption. These 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; and
5. situated within a context.

In this example, the human experience is that of the nurse working in the 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 that 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 because of 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 backup power, generators, and switchgear), and heating, ventilation, and air conditioning equipment. Many facilities lost both primary and backup power. These conditions resulted in the evacuation of 1000 patients from the 9 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.

This 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 also the use of distraction as a synonym for an interruption. According to the Oxford English Dictionary,[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 Pharmacopeia (USP) and Joint Commission on Accreditation of Healthcare Organizations (JCAHO) use 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, the JCAHO reported distraction in the form of environmental noise as a contributing factor in 22% 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%. Staffing issues accounted for 36%, whereas workload contributed 22%.[39]

The statistics cited above indicate that distractions are environmental causes that can and do 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, whereas agencies such as the USP and the 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* to identify the process. Healthcare organizations' use of CQI indicates it is used not only to improve clinical quality but also to improve patient satisfaction, reduce error rates, reduce cost, as well as to improve productivity.

CQI relies on a constant vigilance of processes that are designed to detect and reduce errors and defects. The sole purpose of Total Quality Management is to meet customer expectations and specifications. These 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,[41] as a student of Shewhart, used the same model in his teaching of Total Quality Management.

The PDCA model relies on 4 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 whether 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, nontraditional 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(p18)] 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 2 musicians will have a different meaning than between 2 nurses. A breakdown 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; and
5. interruption task is either accepted or rejected by the recipient.

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

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
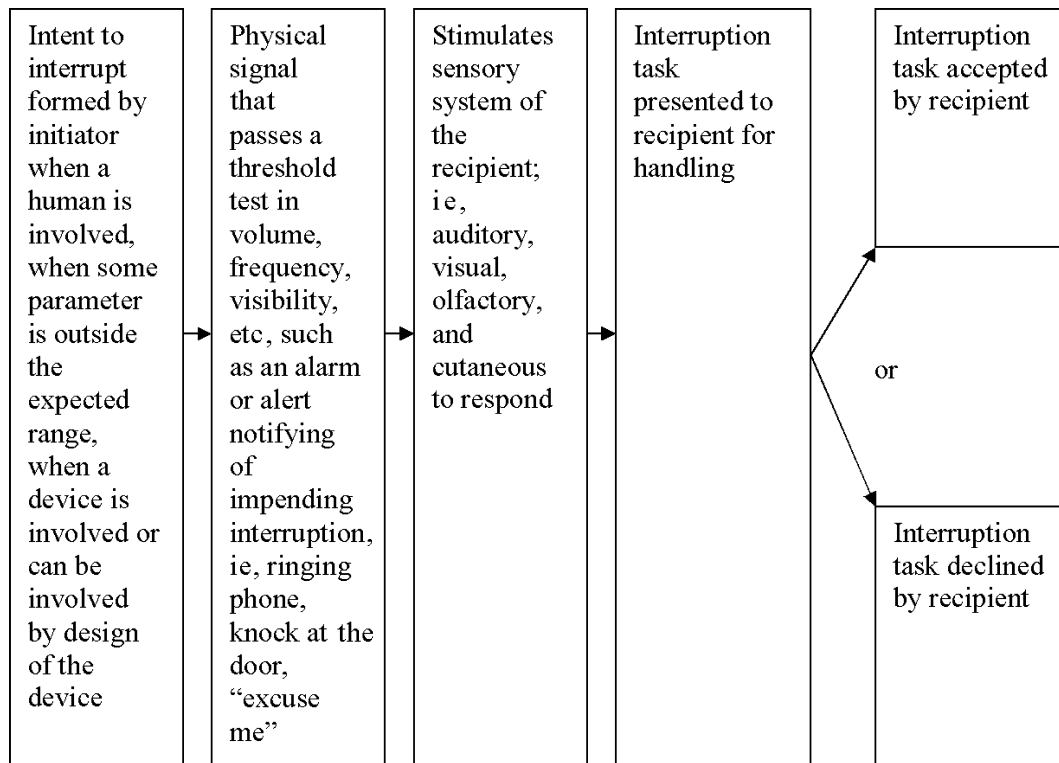
Intent to interrupt formed by initiator when a human is involved, when some parameter is outside the expected range, when a device is involved or can be involved by design of the device	Physical signal that passes a threshold test in volume, frequency, visibility, etc, such as an alarm or alert notifying of impending interruption, ie, ringing phone, knock at the door, "excuse me"	Stimulates sensory system of the recipient; ie, auditory, visual, olfactory, and cutaneous to respond	Interruption task presented to recipient for handling	Interruption task accepted by recipient

or

Interruption task declined by recipient

Figure 3. Antecedents of an interruption.

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 interruptions 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 shutdowns,[2] plane accidents,[1] and medical errors.[8] It has been shown that 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 interruptions do not always discourage them.[45] Managers have been seen to perceive interruptions as an im-

portant 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 multitasking 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 conversations 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 that contribute to high workload levels, whereas 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 in both task performances and 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 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; and/or
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; and/or
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 e-mail.

Empirical referents assigned to an interruption show that 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 a 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 the model of interruption shown in Figure 4.
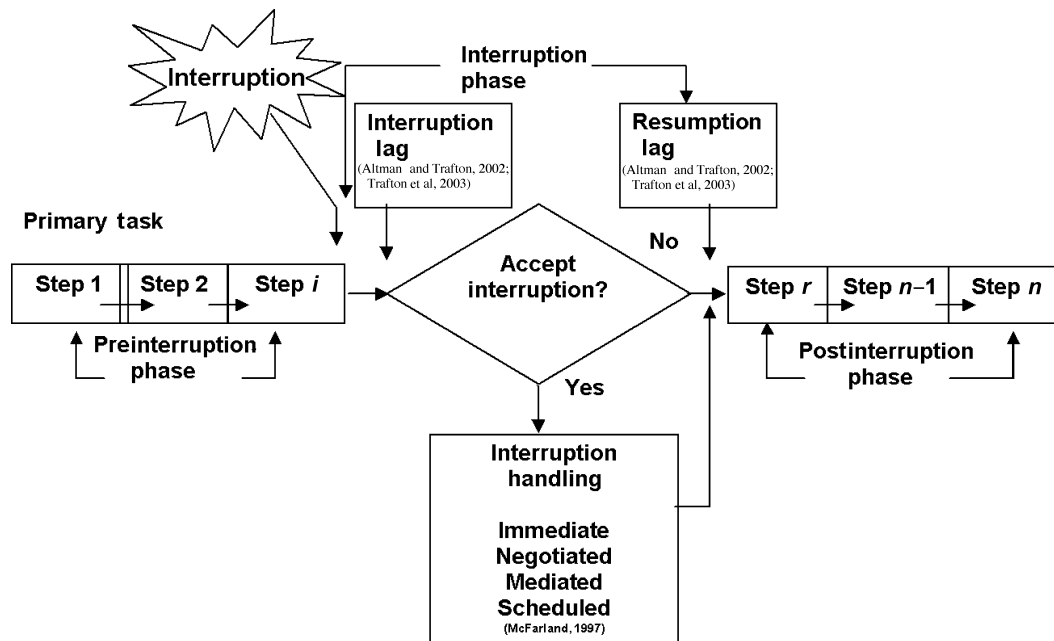
Figure 4. The Brixey Model of Interruption.[30,49,50]

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 preinterruption 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 1 of 4 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 nonhealthcare literature. On the basis of the review, 5 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 cardiopulmonary 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 that requires 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. Consequently, this example suggests that not all interruptions should be eliminated because some interruptions deliver useful and relevant clinical information to the nurse. Consequently, the reduction or elimination of irrelevant interruptions is an important step in achieving a decrease in 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 assistants. 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 the new technologies.

CONCLUSION

A review of the literature has resulted in a clarification of the concept of interruption. A definition and a model of interruption have been derived from the literature. As this project is part of a larger study of interruption, the 5 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.

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