Proposing a Taxonomy and Model of Interruption

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***Abstract* - Interruptions not only decrease performance but can also cause human errors that lead to catastrophic events. Interruptions in high-risk industries such as aviation and nuclear power plants have been studied extensively because of catastrophic events such as power plant shut downs and plane crashes. In contrast, healthcare has a limited understanding of interruption despite the frequent occurrence of medical errors; often leading to adverse events and mortality. We reviewed and integrated previously published literature in healthcare to propose a taxonomy and model of interruptions. This taxonomy will help us categorize and understand interruptions in healthcare. The model depicts interrupted task performance and possible error states when resuming an interrupted task.**

***Index Terms* - Interruption, medical error, patient safety, taxonomy, model.**

I. INTRODUCTION

A ringing telephone, the notification of an incoming email, or a stat lab signals an interruption in work performance. Acknowledging any of these comes at the cost of reducing efficiency, productivity, and the possibility of an error in performing a task. Conversely, ignoring an interruption could be harmful if the interruption is an alert or warning of impending danger, or information needed to complete a task [1].

Interruption is a known human factor that contributes to errors and catastrophic events in high-risk industries. For example in a study of nuclear power plants, Griffon-Fouco & Ghertman found that distractions accounted for 15% of the incidents leading to the shut down of processes [2].

The landmark Institute of Medicine (IOM) report, *To Err is Human*, brought attention to the significance of preventable errors in medicine [3]. The report identified a number of factors that contribute to human error. However the report did not address how interruptions may have contributed to preventable medical errors. Coiera, Jayasuiya, Hardy, Bannan, & Thrope suggest "the combination of interruptions and multiple concurrent tasks may produce clinical errors by disrupting memory processes" (p. 415) [4].

A review of the literature revealed a limited number of studies of interruptions in healthcare. Chisholm, Collison, Nelson, & Cordell contend that little is known about the effects of interruptions in the emergency department (ED) as compared to aviation and other work settings [5]. In another study, Coiera, Jayasuriya, Hardy, Bannan, Thorpe maintain "the combination of interruptions and multiple concurrent tasks may produce clinical errors by disrupting memory processes" (p. 415) [4]. A study of an ambulatory pharmacy by Flynn, Barker, Gibson, Pearson, Berger, Leo found that interruptions and distractions contributed to drug dispensing errors [6]. These arguments and findings support the need to study interruptions in healthcare.

We have chosen aviation, the most studied area for interruptions to learn about their effects. Fitts and Jones were among the first to report that interruptions contributed to pilot error. Interruptions continue to be a factor in pilot error [7]. In an analysis of 107 Aviation Safety Reporting System (ASRS) reports attributed to crew error, Dismukes, Young, & Sumwalt (1998) found that approximately 50% involved lapses of attention due to interruptions, distractions, and preoccupation related to competing tasks [8]. In another study of interruption in aviation, Loulopolous, Dismukes, and Barshi observed a flight crew during preflight preparation for departure. During this phase the pilot must be interrupted with information updates from crewmembers to ensure a safe departure and flight. During this time, the researchers observed many occurrences where the pilot had to divert attention to interruptions while engaged in a task such as completing a checklist. The interruptions caused pilots to blend the interruptions with the required task such as completion of checklists. Although interruptions are needed and expected the pilot has the potential to commit errors such as forgetting or becoming preoccupied with one task at the expense of another [9].

The purpose of this study was threefold. First, to conduct a retrospective review of previously published literature to understand interruptions in healthcare by identifying various dimensions of an interruption; such as initiators and recipients, frequency of interruption, what technologies were reported as sources of interruption, and what methods have been suggested to mitigate the effects of interruptions. Second, compile reported characteristics of an interruption to help us categorize and understand interruptions in healthcare. Finally, we provide evidence of the usefulness of the taxonomy by coding two examples of an interruption attributed to technology.

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II. METHODS

Several search strategies were used to maximize discovery of interruption studies in healthcare. PubMed was queried he using keywords "interruption and task performance", "interruption, primary care and task performance", and "interruption, hospital and task performance". Google, was used to search the World Wide Web (WWW) using the same search terms. Reference lists to all selected studies were reviewed to complete the search. Studies of interruptions for such events as interruption of drug treatment plans (i.e., drug holiday) or interruption of healthcare service due to loss of coverage were excluded.

To develop a taxonomy of interruptions, each research paper was analyzed and coded using Grounded Theory. This is a methodology developed by Glaser and Strauss that relies on an inductive process grounded in the systematic analysis of the data [10]. The primary purpose of the methodology is to develop middle-range theoretical frameworks that explain the collected data, which then can be used to build explanatory frameworks to identify relationships among concepts.

III. RESULTS

The search returned 14 research studies and one cognitive psychology paper for analysis. Analysis and coding began by identifying how each study defined an interruption. Although we found no standard definition of an interruption, the definitions fell into two broad categories. First, several research studies defined an interruption based on the recipient receiving a signal that an unexpected event was about to occur. For example, "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 "(p.200) [11]

Secondly, other definitions were task based where the intended recipient of an interruption was engaged in performing a task. For instance, "anything that disturbed the continuity of the nurse's work when already engaged in on a task or caused a distraction during a consultation with a patient" (p.34) [12]

"any event that briefly required the attention of the subject but did not result in switching to a new task" (p.1240) [5]

"an event that diverted the physician's attention from the task at hand" (p. 148) [13]

"an event that not only required the attention of the physician for more than 10 seconds, but subsequently resulted in changing task" (p.1240) [5]

" break-in-task is a specific type of interruption that preempted one task, resulting in a different task being performed" (p148) [13]

"the cessation of productive activity before the current prescription-filling task was completed for an externally imposed, observable, or audible reason" [6].

Line-by-line coding of the selected literature supported the identification of elements pertaining to an interruption. Ten major concepts were identified.

An impending interruption may be preceded by a visual or auditory stimulus. The following is an example of a signal, "the ringing of the phone, any opening of the door to the surgery" (p.200) [11].

Signals are associated with the technology from which the interruptions are generated. Communication devices such as pagers and the telephone [11], [12], [14], [15] have been identified as sources of interruptions. Blum and Lieu reported that during the study period, paging interrupted 45% of patient care activities [16]. In another study, researchers reported that 19% of received pages interrupted physicians while engaged in direct patient care [17].

Initiation of an interruption may originate from either a machine such as computer or a person. No study attributed initiation of interruption to a device or a machine but rather to a person. Several studies noted other clinicians, students, and clerical staff as initiators of interruption [4], [11], [12], [14], [18], [19]. Patients were also identified as initiators of interruptions [11], [14]. Both patients and physicians are initiators of interruption during the patient-physician interaction. Dearden et al. found that, during 20 audio taped interactions, 833 interruptions were identified. Patients initiated 55% of the interruptions [20]. Another study reported that residents interrupted the patient's conversation about 12 seconds after entering the room and one quarter of the time the resident interrupted before the patient had finished speaking [21].

Several studies reported that communication patterns among hospital workers contributed to an interrupt-driven environment [4], [18], [19], [22]. Findings from the studies suggest that clinicians prefer synchronous communication. Information seeking was the most common reason to interrupt another clinician even when the information was available in another medium. Clinicians generating the communication interruptions had little consideration for the impact on the person receiving the interruption.

The pervasiveness of interruptions was reported in several studies. For example, Shvartzman and Antonovsky reported an average of 1.36 interruptions per consultation in an Israeli primary clinic [11] and similar results were reported in another study [14]. Other studies reported interruption per 100 consultations. Paxton, Heaney, Howie and Porter reported nurses experienced nearly 50% of consultation were interrupted compared to about 5% for general practitioners [12]. Dearden, Smither, and Thaper reported an overall interruption rate at 10.2% [15].

The context and environment may be conducive to interruption. Hospital emergency departments are perceived as interrupt-driven. The unpredictable environment of the emergency department contributes to this impression. For example, Chisholm, Collison, Nelson, and Cordell reported the mean number of interruptions in the emergency department as 30.9 ± 9.7 per 180-minute study period [5]. In a second study, Chisholm, Dornfeld, Nelson, and Cordell compared interruption rates of emergency department (ED) physicians to primary care physicians (PCPs) finding that ED physicians were interrupted an average of 9.7 times per hour compared to 3.9 times per hour for PCPs [13].

Several studies reported the effects of interruptions as a measure of patient satisfaction. In one study, twenty percent of the patients reported the interruption had a negative effect and forty percent would have preferred not to be interrupted.

Of additional interest, patients expressed sympathy for the doctor if interrupted more than one time during consultation. More than half the patients in the study were satisfied with the clinical visit and the length of time they had to speak [15]. In another study, few patients reported dissatisfaction with an clinical encounter [12].

Only one study reported the outcome of an interruption as a preventable medical error. Flynn et al, examined if an association existed between interruptions and distractions and the occurrence of dispensing errors in an ambulatory care pharmacy [6]. A total of 2022 interruptions and 2458 distractions [needs to be defined] were detected. The error rate for set of prescriptions with one or more interruptions was 6.65% and for sets with one or more distractions, 6.55%. A prescription set was identified as all the prescriptions presented by a patient or the patient's agent.

While it is important to know the pervasiveness of interruption in healthcare, it crucial to know what has been developed to control and mitigate interruption in the clinical setting. Several studies offered suggestions or presented systems to manage interruptions. To manage the interruptions caused by paging, Blum and Lieu suggested that residents' schedules be posted and to encourage paging to be delayed during rounds and conferences or designate one physician to take all pages during these events [16]. Analysis of paging patterns would be useful to identify specific strategies to reduce disruption of patient care and increase residents' rest time [17]. Peleg et al, implemented strategies to manage interruptions in a primary care clinic such as by setting aside time slots in the computerized appointment system for patients requiring immediate attention, preventing other patients from entering occupied examination rooms, increased clinical responsibility for nurses, physicians returning telephone calls at specified times for non-urgent calls, discouraging patients from requesting house calls, and doctors could no longer leave the examination room during the appointment. One year after the implementation, the number of interruptions had not been significantly reduced but the staff reported an improved working environment.

In 1996, Coiera advocated a communication system that supported the mobile nature of clinicians, asynchronous messaging, role-based dialing and call forwarding, personal and organizational policy support, and informal data capture and sharing [18]. In a later study, Coiera and Tombs included the need for workers to consider the effects of their communication behaviors on others and supporting collaboration among team members through the use of mobile computers that would allow team members to work from a common list [19]. Other suggestions included the use of education to increase the awareness of the costs of interruptions [4].

Analysis of the studies resulted in the development of a taxonomy to classify interruptions. The concept identification was grounded in the data described in the interruption literature. The preliminary taxonomy is presented in Table 1.

TABLE I
A Taxonomy of Interruptions in Healthcare

Category	**Examples**
Signal	Auditory, visual
Technology	Telephone, pager
Initiator	Clinicians, patients
Recipient	Doctors, nurses
Reason to interrupt	Perform another task
	Provide information
	Control/power
Cognitive	Change in attention
	Distractibility
Frequency	Number during office visit
Context/Location	Emergency department, clinic
Environment	Interrupt-driven
	Multi-tasking, unpredictable
Outcome	Error
	Patient satisfaction
	Change in efficiency/productivity
Management Techniques	Asynchronous communication, physical barriers

The taxonomy could be used as a tool to identify how the introduction of a technology introduced new interruptions by contributing to a preventable medical error or changing the work of clinicians.

The following two examples involving the introduction of a technology show the usefulness of the taxonomy in understanding interruptions occurring in the workplace. The taxonomy facilitates teasing out the details of the interruption. For instance, doctors each received a personal digital assistant (PDA) by which to be notified of critical laboratory results. As a quality indicator, the doctor was to return a call to the laboratory within 10 minutes of receiving the alert. A medical error occurred when the doctor left the examination room to return the call and on return to the examination room forgot to order a medication for a patient. The example is coded using the taxonomy. An employee or device in the laboratory department is the initiator of the interruption. The physician is the recipient of the message. The PDA is the identified interrupting technology. A critical laboratory value was the reason to interrupt. A medical error occurred because the physician's attention was diverted to another task.

As another example, emergency room physicians and registered nurses had expressed dissatisfaction about being called to the telephone located at the nurses' station. In most cases the clinicians were called away from patient care to talk with other clinicians who had been paged and were returning the call. A communication vendor was contacted for a technology-based solution to address the concerns of the clinicians. The vendor recommended providing each clinician with a mobile phone so that the clinician could be contacted directly. Within a few weeks of receiving the phones, clinicians began expressing dissatisfaction because they were receiving more interruption calls than before. Also, the hospital communication operators had experienced an

increase in calls because the mobile phone calls were directed to the operators when the device was not answered after five rings. Patients complained that their providers were receiving too telephone calls during an examination. In this example, it is not clear who initiated the interruption. The recipient of the interruption is the clinician assigned to the mobile telephone. It is possible that patient care issues was be the reason to interrupt but other circumstances could be the reason to place a phone call. The interruptions are occurring within the context of the emergency room. The outcome in this example there was a decrease satisfaction for both patients and clinicians. An unexpected consequence of the mobile phones was an increase in the number of phone calls for the communication operators.

IV. DISCUSSION

When compared to aviation, healthcare has a limited understanding of how interruptions contribute to preventable errors or change in work. Airplane crashes are thoroughly investigated to determine the cause including how an interruption may have contributed. In comparison, only one healthcare study of interruption that specifically identified that interruptions contributed to preventable medical errors [6].

A small number of taxonomies for interruptions have been developed. McFarlane has developed a taxonomy of human interruption as a tool for describing instances of human interruption [23]. The taxonomy contains eight categories: (1) source of interruption, (2) individual characteristics of the person receiving interruption, (3) method of coordination, (4) meaning of interruption, (5) method of expression, (6) channel of conveyance, (7) human activity changed by interruption, and (8) effects of interruption. Rukab has developed a taxonomy based on activity theory for use in at team environment of biomedical engineers [24]. A review of the literature found no studies having tested the usefulness of either taxonomy to classify interruptions in healthcare.

The taxonomy developed in the project is grounded in the systematic analysis of previously published studies of interruption in healthcare. The examples provided in this study illustrate that the taxonomy can be used to classify interruptions associated with the introduction of technology into the clinical setting for such devices as mobile phones and PDAs.

While the taxonomy is helpful in analyzing an interruption event it does not provide information about the individual task that was interrupted. Tasks are performed as a series of steps. It is important to know at what point the primary task was interrupted and how the suspended task was resumed to better understand the effects of interruptions. We suggest the following model supports a deeper understanding of how an interruption affects task performance. The model is presented in Fig. 1.

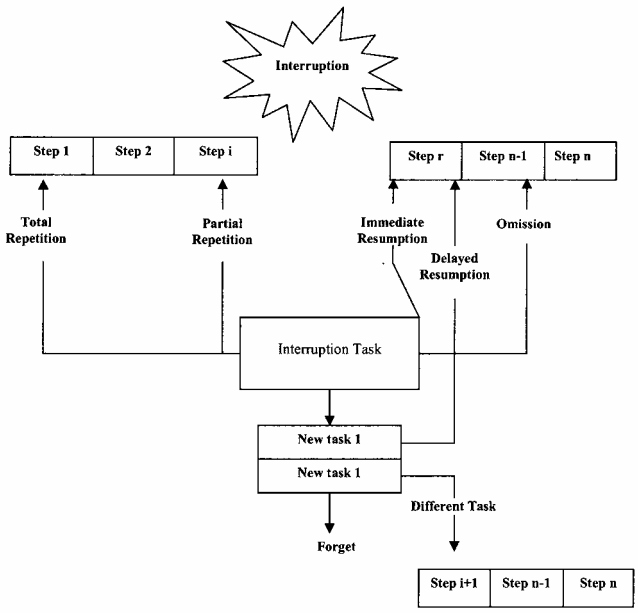

Fig.1 A general model of an interrupted task.

The model illustrates the execution of a task beginning in Step 1. Task execution continues until Step i, at which point an interruption is received. The primary task is suspended for the execution of the interrupting task. Completion of the interruption task does not guarantee that the suspended task will be immediately or correctly resumed. A task could be restarted at Step 1 resulting in an error of total repetition. The error could be of little or no consequence. For example, the nurse takes a patient's temperature twice because she was interrupted. Conversely, an error of total repetition could be catastrophic if a patient is given a repeated dose of the same medication. An error of partial repletion results when some but not all of the previously completed steps are repeated. An error of delayed resumption occurs when the primary task is correctly resumed but resumption had been delayed for some period of time. An error of omission occurs when one or more steps are omitted prior to resuming the primary task. The condition exists where the primary task is forgotten or a different task is initiated. In healthcare, all the errors have the potential to cause serious lifer-threatening medical errors.

We suggest the model will be helpful in finding steps in task performance that are vulnerable to the harmful effects of interruption. When used together, the taxonomy and model provide a unified and systematic mechanism to understand interruptions.

V. CONCLUSION

Although a limited number of interruption studies exist in the domain of healthcare, this retrospective study of the literature suggests that healthcare has an interest in understanding interruptions. The studies that we analyzed provided sufficient detail to develop a taxonomy of interruptions for use in healthcare. The general model of

interruption was developed to depict possible errors following completion of an interruption task. The taxonomy and model developed in this study can be used to explain how and why interruptions occur and predict potential errors following an interruption. The taxonomy and model is currently being used to code interruptions observed in an emergency department.

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