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A socio-technical systems approach to studying interruptions: Understanding the interrupter's perspective

A. Joy Rivera*

Clemson University, Industrial Engineering Department, 130-C Freeman Hall, Clemson, SC 29634, USA

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ABSTRACT

The purpose of this study was to understand the cognitive processes underlying nurses' decision to interrupt other nurses. The Institute of Medicine (2000) reported that interruptions are likely contributors to medical errors. Unfortunately, the research to date has been quite homogenous, focusing only on the healthcare provider being interrupted, ignoring the true complexities of interruptions. This study took a socio-technical approach being the first to examine interruptions from the viewpoint of the interrupting nurse. Over 15 h of observations and 10 open-ended interviews with expert nurses in a Neuroscience Surgical Intensive Care Unit were conducted. It was found that nurses conduct a quick cost-benefit assessment to determine the interruptibility of other nurses and whether an interruption is value-added vs. non-value added. To complete the assessment, nurses consider several conditional factors related to the interruptee, the interrupter, and the nature of the interruption content, and different potential consequences of the interruption.

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1. Introduction

The study of interruptions in the domain of healthcare is relatively new, as compared to other domains such as aviation and driving. However, recently, the topic of interruptions has been heavily pursued by healthcare researchers (Coiera, 2012). This new interest is in part due to the Institute of Medicine's (2000) report which highlighted interruptions as likely contributors to medical errors. Unfortunately, the healthcare research to date has been quite homogenous in nature (Coiera, 2012; Rivera-Rodriguez and Karsh, 2010). The main focus has only been on the healthcare provider (HCP) being interrupted (i.e. the interruptee) and their experiences with and reactions to interruptions (Biron et al., 2009). This one-sided perspective on interruptions is a concern for several reasons. First, it does not capture the dual (interrupter–interruptee) complexities that Rivera-Rodriguez and Karsh (2010) identified when they depicted the varying outcomes (positive–positive, positive–negative, neutral–negative, etc) that the interruptee and interrupter can experience from any given interruption. Second, it tends to highlight the micro-cognitive elements related to interruptions (i.e., effects on the interruptee), while ignoring the socio-technical system implications that interruptions can have on the system (e.g., interruptions emerging from teamwork) (Rivera-Rodriguez and Karsh, 2010). Third, this approach only studies interruptions after they have already occurred. All of these limitations have cultivated insufficient interruption interventions which have focused on eliminating or reducing all interruptions (Anthony et al., 2010; Pape, 2003; Pape et al., 2005; Peleg et al., 2000; Relihan et al., 2009). These intervention strategies (e.g. orange vests to signify "interruption-free" zones) are troublesome because they do not fit with the workflow of the system (Karsh et al., 2006), many times resulting in non-value added interruptions themselves (e.g., putting on and taking off the vests). However, many interruptions are actually necessary (e.g. nurses calling another HCP when they need immediate help with their patient, patient monitors and intravenous pumps alarming to indicate a change in the patient's status). Researchers studying interruptions and developing interruption interventions in healthcare need to better understand the nuances that exist with interruptions in such complex systems (Rivera-Rodriguez and Karsh, 2010).

1.1. Socio-technical systems approach to studying interruptions

From a complex socio-technical systems perspective, interruptions can be thought of as one way in which two systems (made of inputs, transformations, and outputs) interact with one another (see Fig. 1) (Donabedian, 1979). With interruptions, one system (i.e. the interrupter) produces the interruption as an output and the other system (i.e. the interruptee) receives the interruption as an input (Rivera and Karsh, 2008). Past research has extensively

* Tel.: +1 864 656 3114.
E-mail address: Rodrig7@clemson.edu.

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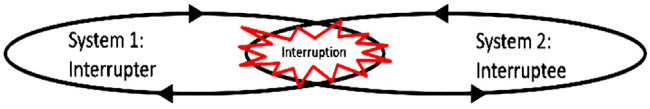

Fig. 1. Dual complexities of interruptions.

examined the latter system, only providing us with ex post facto information on interruptions. Little is known about the former system, the system that triggers the interruption process. Therefore, this study takes a first-of-its-kind look at interruptions by studying interruptions from the interrupter's point-of-view.

Studying this system (i.e. the interrupting agent) will allow us to understand interruptions from a completely different perspective—one that tries to understand the situation prior to an interruption occurring by understanding the cognitive processes (e.g., perceiving and assessing) underlying the decision to interrupt. This approach will facilitate our understanding of the dual-complexities and socio-technical influences of interruptions. This new understanding can help researchers develop interventions that are more compatible with HCPs' workflow and more beneficial to patient safety because they will be able to target non-value added interruptions for elimination while still facilitating value-added interruptions.

1.2. Purpose of study

In this study, an interruption was defined as an unplanned break in workflow caused by an external source (i.e. the interrupter). This definition is deliberately broad to encompass many of the definitions other researchers have used for interruptions (e.g., Coiera and Tombs, 1998; Flynn et al., 1999; Pape, 2003) and distractions (e.g., Healey et al., 2007), disruptions (e.g., Wiegmann et al., 2007), breaks-in-task (e.g., Chisholm et al., 2000), etc. Interruptibility (see research questions below) can be thought of as a combination of 1) how interruptible someone is based on the interruption's potential impact on their task performance, which takes into consideration their cognitive and social state; and 2) how interruptible someone is based on a conscious choice of their willingness to be interrupted (Grandhi and Jones, 2009).

This study, being the first to examine interruptions in this way, took an exploratory approach, to answer the following research questions (RQs):

- RQ 1: *How do nurses determine the interruptibility of other nurses?*
- RQ 2: *Which interruptions are perceived as warranted even if a nurse's interruptibility is determined to be low?*
- RQ 3: *How do nurses interrupt other nurses?*

Table 1
Study setting and population demographics.

Neuroscience Surgical Intensive Care Unit (NSICU)	
Number of beds	8
Typical patient occupancy	88%
Number of RNs	28
Typical shift schedule of nurses	Mix of 8 & 12 h shifts. Days = 7am-7pm, 7am-3pm, 3am-3pm PMs = 3pm-3am, 3pm-11pm Nights = 7pm-7am, 11pm-7am
Spread of RNs per shift	Day = 46% (n = 13) PM = 32% (n = 9) Night = 21% (n = 6) Note: These may not be exact numbers as some shifts overlap each other and nurses may vary in the shifts they work.
How many nurses with 3 or more years of experience on the unit?	19 (68%)
How many bedside nurses also play the role of Charge nurse?	21 (75%)
What type of health information technology did RNs interact with on unit?	Electronic health records (EHRs) including computer provider order entry (CPOE), and bar coding medication administration (BCMA)
Sample	
Experience of observed nurses (N = 5):	Average years as nurse = 24.6 (range 11–32) Average years as nurse on unit = 4.3 (range 4–4.5)[a]
Experience of interviewed nurses (N = 10):	Average years as nurse = 18.6 (range 4.5–40) Average years as nurse on unit = 4.3 (range 4–4.5)[a]

[a] NSICU became its own unit in January of 2007; previously it was combined with the Cardiovascular Intensive Care Unit.

2. Method

All procedures were approved by the Hospital's and University's Institutional Review Boards.

2.1. Study setting

This study was conducted in a Neuroscience Surgical Intensive Care Unit (NSICU) at a non-profit, 440-bed tertiary care hospital in the Midwest of the United States. With 1100 staff nurses, this hospital offers both inpatient and outpatient treatment and diagnostic services. An ICU within a hospital setting was purposively sampled over other healthcare settings (e.g., primary care, pharmacy) because interruptions occur more often in hospitals (Chisholm et al., 2001) and in ICUs (Alvarez and Coiera, 2005; Anthony et al., 2010). Table 1 shows the demographical statistics of the study unit and population.

2.2. Participants

Nurses within a critical care setting were purposefully selected as the healthcare provider of interest for this study. The focus was on the nurse-to-nurse dyad, concentrating on the interrupting nurse. Past research has highlighted that not only are nurses frequently interrupted (e.g., 16.7 interruptions per hour (Alvarez and Coiera, 2005)), but they are also cited as sources of interruptions (e.g., Friedman et al., 2005; Hedberg and Larsson, 2004; Kreckler et al., 2008). Furthermore, Brixey et al. (2008) and Edwards et al. (2009) revealed what a *significant role* nurses in hospital settings play as contributors of interruptions over other healthcare providers. They found that nurses initiated 36.16% (Brixey et al., 2008) and 41.50% (Edwards et al., 2009) of the observed interruptions.

Although interruptions are events that typically occur in hospital settings, they are not considered a part of the typical nursing work taught in school and nurse training. Therefore, the knowledge that is required to deal with interruptions is not covered in formalized procedures, but rather it is tacit knowledge that is developed over time and with experience (Klein et al., 1989). To target the tacit knowledge used to interrupt, and to reduce variability and increase methodological control, expert nurses were purposively sampled. This also means that all the results of this study are framed from the expert nurse's perspective. According to how Benner's (1982) study applied the Dreyfus Model of proficiency to nursing work, expert nurses for this study were defined as nurses with more than 3 years of experience on the NSICU.

Table 2
Strategies to ensure research rigor.

Criteria (Devers, 1999)	Strategies used in this study
Credibility/internal validity	• Researcher has extensive experience with observations and interviews in healthcare (Patton, 1999) • Researcher is knowledgeable on the topic of interruptions in healthcare (Patton, 1999) • Coding structure was checked by 5 other researchers whom are experts in healthcare research, but were not a part of this study (See acknowledgments: B-TK, PC, JD, BK, TW): *Analyst triangulation* (Creswell and Miller, 2000; Devers, 1999; Patton, 1999)[a] • Results were reviewed by participants: *Member checking* (Devers, 1999)
Dependability/reliability	• Researcher journaled to report her thoughts, assumptions, biases, and actions (Devers, 1999; Malterud, 2001; Mays and Pope, 2000) • Researcher kept careful documentation of each step in the research process: *Audit trail* (Devers, 1999) • Researcher ensured the accuracy of the transcripts by double-checking (Devers, 1999) • Coding structure and data was checked by 5 other researchers (see above) (Devers, 1999)[a] • Observations and interviews followed a written protocol (Devers, 1999; Neuman, 2000)
Confirmability/objectivity	• Coding structure and data was checked by 5 other researchers (see above): *Analyst triangulation* (Creswell and Miller, 2000; Devers, 1999; Patton, 1999)[a] • Researcher journaled to report her thoughts, assumptions, biases, and actions (Devers, 1999; Malterud, 2001; Mays and Pope, 2000)

[a] 5 other researchers reviewed the author's coding structure in NVivo9©. Based on their reviews, they gave written feedback to the author which consisted of comments/questions regarding the codes. The author reviewed the feedback and modified the codes if necessary. For example, some chunks of data were split into different codes or were double coded based on the external feedback obtained.

2.3. Data collection

The author conducted 15 h and 47 min of observations shadowing five unique nurses sampled randomly throughout both day and night shifts. The author followed nurses while they worked and recorded the tasks they completed by hand in a notebook. An observation lasted between 2 and 4 h. Observations helped the author become familiar with this particular ICU, its layout, the nurses' workflow, the nurses' vocabulary, and the way nurses interrupted other nurses. Observations also helped the author better understand references nurses' made about their work during the interviews.

Using what was learned from observations, the author conducted 10 interviews with nurses, ranging between 20 and 45 min. Interviews began with an open-ended question (How do you decide whether you should interrupt another nurse?) allowing participants to describe their experiences with interruptions, their work environment with regards to interruptions, and the decisions they make about interrupting. Multiple probes (some modified from Klein et al.'s (1989) Critical Decision Method to elicit tacit knowledge) were used to uncover: 1) the context surrounding interruptions, 2) contributing factors to interrupting, 3) the different ways nurses interrupt one another, and 4) the potential consequences of interrupting. Each interview was audio-recorded and then transcribed by an external transcriptionist.

2.4. Data analysis

Dimensional analysis was used to guide the analysis of the interview data. Dimensional analysis is an analytic method derived from grounded theory (Schatzman, 1991). It is an inductive analytical method that builds on natural analysis (i.e. a normative cognitive process used to interpret meaning from the data) and symbolic interactionism (i.e. the notion that reality is socially constructed and people behave according to their understanding of the situation) to understand and describe human experiences or phenomena that have not been well studied within its social

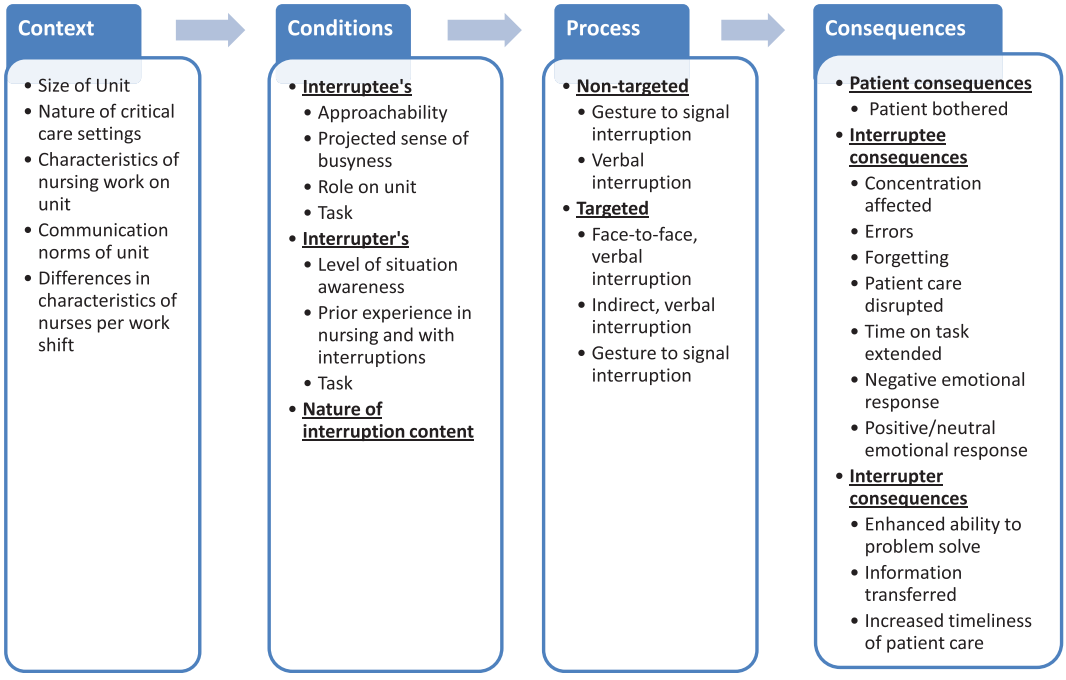

Fig. 2. Explanatory matrix of NSICU nurses' experiences with and decisions about interrupting one another.

context (Caron and Bowers, 2000; Kools et al., 1996; Schatzman, 1991). The data analysis was conducted by the author using NVivo9© (QSR International Pty Ltd., Melbourne Australia).

The data analysis process started by highlighting chunks of data (dimensionalizing) that could be labeled using one descriptive phrase or code (designating) (Kools et al., 1996; Kramer et al., 2006). This process was repeated until the major aspects of nurses' experiences with interruptions appeared to be covered, representing a "critical mass" of dimensions. Once a "critical mass" was obtained the dimensions were categorized into higher-level dimensions (Kools et al., 1996; Kramer et al., 2006). Then these high-level dimensions were coded into the conceptual categories of dimensional analysis that result in an explanatory matrix of the results: *Context*: the situation or environment in which the phenomenon is studied; *Conditions*: dimensions that facilitate or block actions or processes related to the phenomenon; *Processes*: intended or unintended actions shaped by the conditions; and *Consequences*: outcomes of the processes of the phenomenon (Kools et al., 1996). Table 2 highlights the strategies that were used to ensure data collection and analytical rigor.

2.4.1. Interpreting the explanatory matrix

Within the explanatory matrix (Fig. 2), the conceptual category of context provides a description of the study unit characteristics that affect the way nurses communicate and work together, which influences when and how nurses interrupt each other. All the other conceptual categories are bounded by this context. The conceptual category of conditions and consequences provides the answer to RQ 1 and 2; and the conceptual category of processes answers RQ 3.

3. Results

Prior to discussing the main results (i.e., answers to RQ 1–3), it is first necessary to highlight how the uniqueness of the NSICU and critical care nursing work influences nurses' experiences with interruptions. The context or environment in which nurses work provides a structure for the inputs that feed the interrupting system (i.e., the interrupting nurse). During the interviews, nurses discussed five general themes that exemplified their context of work; each will be discussed below.

3.1. NSICU context

3.1.1. Size of unit

The NSICU is a relatively small unit. As shown in Table 1, it consists of 28 nurses and only eight patient beds which run on average at an 88% occupancy rate. The patient rooms are geographically collocated and arranged in a "U" shape with the nursing station and medication room in the center of the "U". Nurses feel that this arrangement affords them the opportunity to have frequent face-to-face communication with all hospital staff.

3.1.2. Nature of critical care settings

According to the nurse participants and validated by the literature, critical care settings tend to be much more dynamic and fast-paced than acute care units. Critical care units also have patient populations that are very ill and have complex conditions. These two factors create a unique pattern of communication where nurses must interrupt each other to solve clinical issues related to patient care. For example, one nurse said: *"I think a lot of times I dismiss the interruptions as just part of being in like a critical care setting where things are changing so rapidly, we have very sick patients that, you know, it's for the patient's benefit I think that we're often interrupting each other that, um, I think I just kind of assume that that's why we do what we do is because of the setting that we're in."*

3.1.3. Characteristics of nursing work on unit

NSICU nurses all follow a general nursing practice pattern. Nurses try to block off chunks of time to spend in their patient's room to complete all their direct patient care tasks, then most nurses perform indirect patient care tasks and their documentation responsibilities at the nursing station.

Working in teams is another important part of nursing work in the NSICU. Nurses rely on each other to help them with both routine tasks such as lifting a patient and non-routine tasks such as helping with a patient emergency. Depending on the nurses' training, they may have different practicing styles which can lead some nurses to need more help than others. Although working in teams helps nurses complete their daily tasks, it also creates an environment rich with interruptions.

3.1.4. Communication norms of unit

The NSICU nurses do not use phones or other locating devices to communicate with one another. Most of their communication is conducted synchronously (i.e. face-to-face), which they prefer over asynchronous communication (e.g., pagers).

3.1.5. Differences in characteristics of nurses per work shift

As seen in Table 1, the NSICU has three different working shifts; however due to staffing assignments, the three shifts can be dichotomized into two shifts: Day and Night, where the Night shift also includes the PM shift. There are some clear differences between nurses working the day and night shift. Less experienced, younger nurses generally work the night shift rather than the day shift because the night shift positions tend to open up more often and are filled by new hires. Due to this less experienced, younger set of nurses all working together on the night shift, nurses tend to be more comfortable with interrupting one another to ask each other questions. One nurse explained it like this: *"I work, well, the evening through night shift and a lot of the nurses are younger so I think it's kind of raised an atmosphere of it's okay to ask questions and it's encouraged to ask questions if you're not 100% sure about something or you need some backup…But, you know, I have worked…on other shifts when there's people there that I would not prefer to seek help from or interrupt something that they're doing. But I would say on the shift that I work, I feel comfortable asking just about anybody."* This comfort level is also influenced by differences in relationships that nurses have with one another on each shift. Night shift nurses share a different camaraderie than day shift nurses. As this quote illustrates night shift nurses tend to have relationships with each other outside of work, while day shift nurses tend to only have professional relationships with each other: *"Nights and PM seem like there's more of a, I don't want to say friends, but they seem a little bit more close, closer…. Like days, I think, the older people, the people who have been here for a while, they have their own families. They [the day shift nurses] don't do stuff together outside of work."* Due to both these factors (i.e., similar age group and closer relationships), night shift nurses tend to be more comfortable with interrupting one another to ask each other questions.

3.2. How do nurses determine the interruptibility of other nurses? (RQ1)

Although interruptions are but a moment in time, this study found that prior to that moment, nurses most often conduct a quick, but extensive cost-benefit assessment to determine the interruptibility of another nurse and decide whether to interrupt, delay interrupting, or not interrupt at all. To complete such an assessment, nurses consider: 1) several conditional factors related to the interruptee, 2) conditional factors related to the interrupter, 3) the nature of the interruption content, and 4) potential

Table 3
Tasks less or more acceptable to interrupt.

Tasks less acceptable to interrupt:	Tasks more acceptable to interrupt:
• Nurse is charting	• Nurse is charting
• Nurse is completing patient assessments	• Nurse is checking e-mail
• Nurse is completing medication pass	• Nurse is completing a task they can leave
• Nurse is having a conversation with: Doctor, Family, Patient	• Nurse is completing routine patient assessments
• Nurse is involved in a task that took concentration	• Nurse is conversing with another nurse (as opposed to doctor)
• Nurse is involved in nurse-to-nurse report	• Nurse is having non-work related conversation
• Nurse is involved in a sterile procedure	• Nurse is performing procedure
• Nurse is involved with doctor, patient, family	• Nurse is performing indirect patient care
• Nurse is on phone	
• Nurse is participating in multidisciplinary rounds	
• Nurse is performing tasks that cannot be left	
• Nurse is performing direct patient care tasks	

consequences of the interruption. Nurses take these factors into account in combination with each other or apart from each other. Additionally, these factors seem to be weighted differently depending on the interrupter, the interrupter's role, the interrupter's work shift, etc.

3.2.1. Interruptee's approachability

Perceptions of approachability are determined by: 1) How comfortable the interrupter feels with the interruptee, where comfort was described as being based on the personality of the interruptee and how well the nurses got along with each other; and 2) The interruptee's previous reactions to being interrupted. Nurses are less likely to interrupt another nurse if they do not feel comfortable with that nurse or if that nurse had reacted negatively to previous interruptions.

3.2.2. Interruptee's projected sense of "busyness"

Nurses get to know each other and the way they practice care, which helps them judge whether it is an acceptable time to interrupt. They use cues such as the interruptee's movement around the unit, their body language, facial expressions, demeanor, and listen to their tone of voice to determine if that nurse is too busy and should not be interrupted. One nurse explained it like this: *"Their demeanor, basically their body language. Some nurses, you can tell by how they're scurrying around the unit, that's not a person I'm going to interrupt, because they are extremely busy. Maybe they have a heavy patient load."*

3.2.3. Interruptee's role on unit

Nurses' perception of interruptibility is influenced by the interruptee's role on the unit. The charge nurse is seen as more interruptible than bedside nurses because in the NSICU the charge nurse is not responsible for patients. Instead, the charge nurse manages the dynamics of the unit and is responsible for helping bedside nurses manage their workload. The charge nurse's role is to help others and to be a constant resource for other nurses on the unit. Nurses will often look to interrupt a charge nurse first, prior to another bedside nurse, or if they can, they will wait to interrupt until the charge nurse is available. One nurse who also rotates as a charge nurse put it like this: *"I think that, um, the majority of the time, the charge nurse is there as a resource, especially if there's less experienced nurses, somebody that is there to offer help, someone that is there because they have more experience that they should be able to, you know, be interrupted depending on what they're doing. They don't have the specific tasks that a bedside nurse would do, to ask them to do something for you or to help you with something, I think that that's kind of primarily, the way that I act as a charge nurse is being helpful to others, being a resource for others, there as an option if people need to seek someone to help them with something."*

3.2.4. Interruptee's task

Nurses use the interruptee's actions and location as cues to determine what the interruptee is doing and if he/she is interruptible. Table 3 lists certain tasks nurses consider more or less acceptable to interrupt. Note, these tasks are not mutually exclusive—depending on the nurse or the nature of the interruption content, some tasks are considered as both more and less acceptable to interrupt. However, in general direct patient care tasks are seen as less interruptible than indirect patient care tasks. For that reason, nurses tend to interrupt each other more often at the nursing desk where charting is the main task, rather than at the bedside where nurses interact with patients and their families and administer medications. The following quotes describe nurses' decisions about interrupting other nurses at the nursing station versus the patient's room (or bedside): Nurse A: *"I think that a lot of times at the desk people are just charting or are just watching the monitors and kind of, you know, a little bit more of a downtime kind of feeling sometimes. So I think that I'd have an easier time interrupting someone at the desk saying, hey, I, can you help me with this. And it's right there when you come out of a room, you know, you can just open the door and say, hey, can someone help me with something versus seeking someone specific out in a room, going in there, and like I said you're, they are in front of a patient for sure whether or not they [the patient] can understand what's going on, but there may be family in the room, that kind of thing. So try to avoid that, you know, if there's someone at the desk that you can [get] help from."* Nurse B: *"So if they're involved in specific patient care that's, if I would see it as non-interruptible, then I wouldn't interrupt. Um, then I would go to the next person that looked like they were interruptible, not busy, not at the bedside, um, pretty much trying not to get somebody that's at the bedside."*

Lastly, besides visual cues, nurses will use auditory cues to interrupt conversations. If necessary, nurses will briefly listen into conversations to determine whether they are work-related or non-work related discussions, and interrupt the non-work related conversations. Regardless of conversation topic, nurses tend to interrupt nurse-to-nurse conversations more often than nurse-to-doctor conversations, for two reasons: 1) Nurses interrupt nurse-to-nurse conversations (even if it is work-related) to offer their expert advice or opinion; and 2) Nurses know doctors are busy so when they are on the unit the conversation is likely about a patient and important.

3.2.5. Interrupter's level of situation awareness

Nurse's level of situation awareness (SA) about their environment, the unit dynamics, and other nurse's patient load or workload, can facilitate or hinder their ability to determine a nurse's interuptibility. Nurses use proactive or "in-the-moment" techniques to increase their SA. Proactively, nurses increase their SA by taking notes at the beginning of their shift about patient-nurse assignments, patient criticality, patient transfers, or by using prior knowledge, knowing that during certain times throughout a shift, nurses tend to complete certain tasks. In-the-moment, nurses increase their SA by peeking behind a closed curtain to see what the nurse is doing before interrupting rather than interrupting through the closed curtain. The former methods are most preferred to reduce non-value added interruptions.

3.2.6. Interrupter's prior experience in nursing and with interruptions

Experience influences nurses interrupting patterns. Experienced nurses tend to need less help, reducing the need to interrupt to ask questions, however, they may be more likely to interrupt to offer their opinion or to give a suggestion to more novice nurses. Based on the nurses descriptions of how they interrupted as novice nurses versus how they interrupt now, it appears that experienced nurses tend to interrupt at more appropriate times because they are able to shift their work and complete other tasks until they see it is a better time to interrupt. While novice nurses interrupt more frequently and more immediately to ask questions because they are less confident and less flexible in their workflow. Lastly, expert nurses use their own experiences (e.g., likes and dislikes) with being interrupted to determine when and how to interrupt others. One nurse described the evolution of her interrupting pattern like this: *"I think I am more confident at this point that I would probably only interrupt someone if I knew that I needed help with something versus when I first started, I was probably a lot more insecure about the decisions that I was making and I needed a lot more confirmation from other people."*

3.2.7. Interrupter's task

The tasks that nurses need to complete sometimes increase the probability of them interrupting other nurses. For example, there are certain tasks that per protocol require two people to complete—co-signing certain medication orders, witnessing wasting of certain medications, and repositioning the patient. Other tasks that increase the likelihood of interruptions are: fielding phone calls and medications delivered to the unit, and helping nurses with their patient load.

3.2.8. Nature of interruption content

The nature of the interruption content plays a major role in the cost-benefit assessment nurses conduct to determine interruptibility. Nurses interrupt based on the importance, the time-sensitivity, and the urgency of the interruption content, where urgency is a combination of importance and time-sensitivity.

3.2.9. Patient consequences

In critical care, specifically in the NSICU many patients are either unconscious or sleeping the majority of the time. However, depending on patients' conditions or statuses some can be more alert than others. Nurses feel that patients who are more alert, can become bothered by interruptions if their nurse keeps getting interrupted while in the patient's room. One nurse explained it like this: *"If [interrupting is] done frequently with patient care, I know the patients get frustrated. And sometimes it just can't be helped, your other patient is really sick."*

3.2.10. Interruptee consequences

Nurses discussed several negative outcomes that interruptee nurses can experience when they are interrupted. Interruptions can affect an interruptee's concentration on the primary task, they can contribute to an interruptee forgetting what they were doing when interrupted, and they can increase the likelihood of an interruptee making a general error, a medication error, or a documentation error. One nurse discussed her experiences with interruptions that highlighted some of the negative consequences: *"I don't like to interrupt giving meds, because then you lose all track and then it's hard and you're more prone to make a mistake."*

Beyond the impact on attentional resources, the nurses discussed how interruptions can increase nurses' workload by extending the time required to complete tasks or by adding new tasks to their work plan. This elicits negative emotional responses from some nurses. Occasionally some nurses feel frustrated, annoyed, or bothered by being interrupted. One nurse explained like this: *"I know there's days where, just the other day, it seemed like I, I get done at 3:30, and it was 4:00 o'clock and I was just trying to write a note and I had one person try to talk to me here, one person trying to talk to me here, the phone ringing for me, it just gets frustrating."*

That being said, not all interruptions from the interruptee's perspective are negative. There are times when interruptions can elicit positive/neutral emotional responses from an interruptee nurse. Some nurses are even enthusiastic to attend to an interruption if it means helping a fellow nurse. For example, one nurse explained interruptees' reactions to interruptions like this: *"I mean, there are some people who are like super enthusiastic to help out"* while another nurse explained interruptees' reactions to interruptions like this: *"Most of the nurses on this floor do very well with being interrupted. They don't get, I guess you'd say, bent out of shape."*

3.2.11. Interrupter consequences

Nurses identified three important positive outcomes of interruptions related to the interrupter. Nurses feel that interruptions allow them to transfer needed information to one another in a timely manner. Nurses feel that because they communicate most often through interruptions, that interruptions often increase the timeliness of patient care. Also, along those same lines, nurses feel that overall, interruptions enhance their ability to problem solve. In general, interruptions facilitate teamwork by improving the interrupters' ability to provide safe and quality care to their patients. In fact, when asked if they could complete their job without interrupting other nurses, nurses said it would be impossible or nearly impossible.

3.3. Which interruptions are perceived as warranted even if a nurse's interruptibility is determined to be low? (RQ 2)

Although most interruptions are contingent on a multitude of factors, there were only two types that were always seen as warranted even if a nurse's interruptibility was judged as low. Not surprising, an interruption due to a patient-related emergency supersedes any primary task, conditional factor, or potential consequence. Regarding patient-related emergency interruptions, two nurses said this: Nurse A: *"It depends on the situation, you know. If I had someone that, you know, was obviously dying or coding, I wouldn't care what the next person was doing. I would interrupt because I needed help."* Nurse B*: "If I had an emergency with a patient, I wouldn't, I would just yell. I wouldn't care who I interrupted."*

More surprising, was the fact that all the nurses stated they would always interrupt to notify other nurses that the doctor is on the phone, no matter what the doctor is calling for and no matter what the nurse is doing. One nurse said it simply: *"If a physician needs to talk to you, that, you know, pretty much regardless of what, uh, how important that phone call is, you just get the nurse."* Nurses stated two main reasons for this warranted interruption: 1) doctors are busy and time with them is valuable, and 2) if a doctor is calling the unit, it likely means that he/she is returning a call or page from the nurse, therefore the interrupter sees this as the nurse "requesting" the interruption.

3.4. How do nurses interrupt other nurses? (RQ 3)

After the nurse decides to interrupt, they generally interrupt in one of five ways. These methods were discussed in the interview and validated by the observations conducted. Table 4 describes the different methods nurses use to interrupt one another.

Table 4
Processes of interrupting.

Method of interrupting	Description/example	Nurses' quotes
Non-targeted gesture to signal interruption	A non-targeted gesture to signal an interruption is used when a nurse uses non-verbal actions to interrupt anyone on unit. Example: Nurses turn on a patient's call light to signal that they need help in their patient's room. The call light turns on outside the patient's room and a general alarm beeps in the nursing station. Anyone that notices the light or hears the alarm may potentially be interrupted.	*"If you're stuck in a room and you can't leave, if you're holding pressure on bleeding or something, you know, someone will hit the call light just to get some backup help. Because then you could be, very much could be interrupting whatever they're doing. You don't even know."*
Non-targeted verbal interruption.	Non-targeted verbal interruptions occur when nurses use verbal communication to interrupt anyone on the unit. Nurses tend to use this method most often when they need help with their patient and quickly. Nurses' tone of voice or the statement they use (e.g., "code blue") when interrupting may provide the potential interruptee with needed information of how important, time-sensitive, or urgent the interruption is. Example: Nurses will yell out for help from their patient's room because their patient falls.	*"If I had someone that, you know, was obviously dying or coding, I wouldn't care what the next person was doing. I would interrupt because I needed help… I would just shout, I need help, and hopefully, someone would decide they could leave what they were doing."* *"Sometimes you'll just yell out I need a turn, and then that's usually whenever anybody's available. So you're interrupting, but you're just kind of yelling it out there so anybody can come… [but] you don't know what you're interrupting"*
Targeted, face-to-face, verbal interruption.	Targeted, face-to-face, verbal interruptions are completed when nurses target a specific nurse to interrupt and then interrupt via a face-to-face, verbal interaction. This is the most common method used for interrupting. Example: Nurses seek out a particular nurse and interrupt them by providing them information or asking them a question.	*"Oh, my heavens, it's pretty much everything. Every communication is based on that….95% of our conversations are based on interruption."*
Targeted, indirect, verbal interruption.	Targeted, indirect, verbal interruptions are conducted when nurses target a specific nurse to interrupt and then interrupt using verbal communication that is not face-to-face. With this type of interruption, nurses have lower SA and are unable to accurately assess the interruptibility of the interruptee prior to interruption. Example: Nurse interrupts and starts talking to another nurse through the curtain of the patient's room.	*"[You] just call their name out, and say…hey, are you in here [patient's room]. Doing okay?"*
Targeted gesture to signal interruption	A targeted gesture to signal an interruption is a method used when a nurse targets a specific nurse to interrupt and then signals an interruption through a non-verbal action. Example: Nurse knocks on door to get the interruptee's attention and then proceeds with the interruption, or a nurse stands and waits near a nurse or at the patient's room doorway until the interruptee notices.	"*Sometimes I'll just wait, come up by somebody if they're like on the computer, and I'll just, you know, wait, and wait for them to acknowledge me. And, you know, kind of interrupt by not interrupting."*

4. Discussion

This study aimed to understand the system that generates the interruption process (i.e., the interrupting nurse). This study's perspective is innovative, yielding new information about interruptions and nurses' decision making processes about interrupting. By taking a socio-technical systems approach, the results complement the dual-complexity paradigm presented in Rivera-Rodriguez and Karsh (2010) and provides evidence that although interruptions are just an instant in time, they are much more complex than what previous literature has been depicting them as.

4.1. Attributes of critical care that foster interruptions

Researchers studying interruptions in hospitals and specifically ICUs have shown that interruptions occur frequently in critical care **environments** (Alvarez and Coiera, 2005; Anthony et al., 2010; Drews, 2007). One of the reasons why interruptions may occur so often in critical care is because of the dynamic, fast-paced nature of the environment. However, beyond this hectic environment there are other attributes that may increase the likelihood of interruptions.

The structure of the NSICU, the characteristics of critical nursing work, and the criticality of ICU patients all foster an atmosphere of frequent interruptions, so much so, that nurses consider interruptions as part of their job. First, whether intentional or not, the NSICU's layout is designed to promote collaboration and teamwork between nurses—the NSICU is small, the layout of the patient rooms is condense, and the nursing station is centrally located. It is much easier for nurses to talk to one another face-to-face (creating interruptions) on a unit structured like the NSICU than on a larger unit where patient rooms are located further away from one another and the nursing station is not in the center. Second, critical care nurses in the NSICU and in general complete lots of task switching between patients. Although nurses prefer to "chunk" their work by patient and direct versus indirect care tasks, many times, due to the criticality of their patients, nurses must switch between patients mid-assessment or mid-task especially if one of their patients is deteriorating. This working pattern may require nurses to travel into the halls and near the nursing station much more often than nurses in acute care settings. Wolf et al. (2006) found that nurses who ventured out into the halls, as opposed to those who stayed in their patient's room, incurred many more interruptions. This is probably due to the fact that nurses seem more available when in the hall than when in a patient's room. Additionally, while nurses venture out into the halls it is much more likely that they may interrupt nurses at the nursing station due to their proximity to those nurses. It seems that the travel patterns of critical care nurses affords them the opportunity to interrupt more easily than nurses on other units who may stay in their patient's room for longer periods of time; however, more research is needed to confirm this. Lastly, nurses emphasized that critical care patients, tend to have much more complex and fast changing conditions than patients on other units; therefore, nurses rely on each other for clinical problem solving and for emergency help when needed. The way nurses solve problems and help each other with emergencies is through communication. Some problems, along with emergencies, need to be dealt with quickly; therefore, nurses do not have the luxury of waiting for when other nurses are not busy, rather they must interrupt to get help. Related, expert nurses can recognize problems as they begin and they will interrupt other nurses to proactively help problem solve and offer suggestions or their opinion.

Table 5
Limitations.

Limitation:	Explanation:
1. Small sample size and study conducted in only one hospital unit.	Although this sample size and methodological control is appropriate for qualitative research it limits the generalizability of this study. That said, the focus was on transferability which means readers must judge for themselves if the findings fit their settings and experiences (Malterud, 2001). To help with transferability, the author sought to provide a complete and detailed description of the study setting and context, and a comprehensive explanation of the findings.
2. Data collection and analysis was conducted by one researcher.	This may have increased the consistency between interviews but reduced the validity of the coding process. To increase internal validity, a member checking focus group with nurses ($N = 5$) was conducted and the coding structure was critically reviewed multiple times ($N = 6$) by different researchers ($N = 5$).
3. Interviewing is a retrospective method	This means that recall biases may have influenced the data collected. That said, interviews were conducted during nurse's shift to reduce the time between the event in question (interrupting) and the questioning.

4.2. Complexities of interruptions

Within the context of critical care, this study examined the cognitive processes underlying nurses' decisions to interrupt other nurses. It is quite apparent that very often, prior to interrupting, nurses complete quick cost-benefit assessments to determine whether another nurse is interruptible and the interruption is value-added versus non-value added. Nurses weigh cues they obtain from the environment, including information derived from assessing the interruptee's circumstances, with their needs (i.e., their task and interruption content), and the potential consequences (positive or negative) to the patient, interruptee or themselves. Although there are exceptions (i.e., doctor phone calls), it seems that if the cost of not interrupting is high (e.g. patient crashing), nurses only consider the benefits for themselves (and crashing patient) and not the conditions of or potential consequences to the interruptee or other patients. However, if that same cost is judge**d** as bearable to the interrupter, but high for the nurse being interrupted, they may not interrupt, or they may try to interrupt in a "less" intrusive manner. More research is needed to test these observations. However, the fact that nurses use different methods of interrupting is a new facet to interruptions, not covered in the current literature. Although past research has categorized the source of the interruption (pager, phone, person) (e.g., Friedman et al., 2005; Potter et al., 2004), it has not examined the method in which HCPs choose to interrupt each other. Nurses choose their method based on the task they are doing or need to do, the task the interruptee is doing, and the potential consequences. Most interesting is when nurses consider the interruptee's tasks and potential consequences, as they are unknowingly taking into account the interruptee's need to manage the interruption. For example, nurses sometimes choose to interrupt using a targeted gesture to signal an interruption over a targeted, face-to-face verbal or targeted, indirect verbal interruption to allow the interruptee time to mark their place so they are able to safely return to what they were doing after the interruption. Marking one's place or having the opportunity to rehearse the primary task, reduces the chances of committing an error of omission or commission (Altmann and Trafton, 2004; Gillie and Broadbent, 1989). When possible, this method of interrupting needs to be encouraged to provide interruptee's the opportunity for interruption management which should indirectly increase patient safety.

4.3. Interrupting to maintain safety and organizational resilience

Nurses' roles are multidimensional (Tucker and Spear, 2006). In hospital settings, the most common aspect of their role is providing direct care to patients. However, they are also responsible for care coordination between different healthcare providers and they must consistently deal with and recover from system failures in order to keep patients safe and the system functioning properly (Gurses and Carayon, 2007; Rivera-Rodriguez et al., 2012; Tucker, 2004; Tucker and Spear, 2006).

At the individual level, nurses adapt to different situations and changes in patients' conditions; and through this process, interruptions emerge as a strategy to redeploy resources where needed to enhance organizational resilience (Hollnagel et al., 2006). This study, and others (e.g., Holden et al., 2012; Potter et al., 2004; Tucker and Spear, 2006; Wolf et al., 2006), provide evidence that nurses use interruptions to manage and recover from system failures such as inadequate training, unavailable resources, and technology breakdowns. Additionally, as stated above, nurses use interruptions to facilitate teamwork which helps support competing healthcare quality goals set by the Institute of Medicine (Institute of Medicine, 2001). For example, nurses must balance the goal of providing patient-centered care which focuses on the patient's needs and preferences, while simultaneously increasing efficiency by avoiding waste of equipment, supplies, energy, etc. (Hollnagel et al., 2006; Institute of Medicine, 2001).

Unlike other methods of adapting and problem solving where clinical judgment, taught in an academic or training environment, is used, the process of interrupting always involves another person and is a self-taught skill developed through on-the-job, hands-on experiences. Therefore, similar to the concept of workarounds (Halbesleben et al., 2010), interrupting can be both necessary and an inherent system vulnerability. Performing the interrupting process at appropriate times (i.e. when the interruptee's interruptibility is high) facilitates the joint optimization of system safety and resilience. However, when the timing of the interruption is not ideal, which is often the case during emergency situations, one or more parts of the system move towards the system's boundary of acceptable limits, reducing the margin of error, and increasing the system's brittleness and the risk to patient safety (Cook and Rasmussen, 2005; Hollnagel et al., 2006). This only raises the importance of examining interruptions from a socio-technical perspective, to understand all of the system factors that influence how and why nurses interrupt each other, in order to design more compatible interruption interventions and better interruption management training for nurses.

5. Limitations

Table 5 lists the main limitations of this study, many of which can be attended to with an expanded, follow-up, study.

6. Conclusion

This study highlighted four new phenomena related to nurses' decision making about interruptions. First, nurses' decisions about interruptions are bounded and constrained by the context in which they work. The NSICU is structured in a way that facilitates teamwork and face-to-face communication; additionally, nurses do not have cell phones or a paging system both of which would influence how they interrupt one another. Second, to determine

interruptibility, nurses conduct a cost-benefit assessment to distinguish value-added interruptions from non-valued added interruptions when deciding whether to interrupt. This underscores two important points for future research and interventions: 1) nurses need to be provided the necessary tools and training so they are able to appropriately assess the costs and benefits prior to interrupting; and 2) in order to design interventions that eliminate non-value added interruptions and facilitate value-added ones, it must be understood that the definition of value-added and non-value added interruptions is, in part, context (and person) dependent. This means that not all interventions are created equal across units, hospitals, and healthcare settings, and researcher must be careful of contextual fallacies. Third, when discussing consequences it must be noted that nurses provided evidence for the assertions made in Rivera-Rodriguez and Karsh (2010), that not all interruptions are bad. Nurses reported many positive consequences that can result from interruptions. Lastly, this study reported that nurses use five different methods for interrupting, one of which facilitates interruption management by the interruptee. Due to the difficulty of defining value-added and non-value added interruptions, providing this interruption management opportunity, along with training interrupters to properly assess the situation prior to interrupting might be more advantageous than inappropriately designed interventions.

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References

Altmann, E.M., Trafton, J.G., 2004. Task interruption: resumption lag and the role of cues. In: Proceedings of the 26th Annual Conference of the Cognitive Science Society, pp. 42–47.
Alvarez, G., Coiera, E., 2005. Interruptive communication patterns in the intensive care unit ward round. Int. J. Med. Inf. 74, 791–796.
Anthony, K., Wiencek, C., Bauer, C., Daly, B., Anthony, M.K., 2010. No interruptions Please: Impact of a No interruption zone on medication safety in intensive care units. Crit. Care Nurse 30, 21–29.
Benner, P., 1982. From novice to expert. Am. J. Nurs. 82, 402–407.
Biron, A.D., Loiselle, C.G., Lavoie-Tremblay, M., 2009. Work interruptions and their contribution to medication administration errors: an evidence review. Worldviews Evid.-Based Nurs. 6, 70–86.
Brixey, J.J., Robinson, D.J., Turley, J.P., Zhang, J., 2008. The roles of MDs and RNs as initiators and recipients of interruptions in workflow. Int. J. Med. Inf..
Caron, C.D., Bowers, B.J., 2000. Methods and application of dimensional analysis: a contribution to concept and knowledge development in nursing. In: Rodgers, B.L., Knafl, K.A. (Eds.), Concept Development in Nursing: Foundations, Techniques, and Applications, second ed. Saunders, Philadelphia, pp. 285–319.
Chisholm, C.D., Collison, E.K., Nelson, D.R., Cordell, W.H., 2000. Emergency department workplace interruptions: are emergency physicians "interrupt-driven" and "multitasking". Acad. Emerg. Med. 7, 1239–1243.
Chisholm, C.D., Dornfeld, A.M., Nelson, D.R., Cordell, W.H., 2001. Work interrupted: a comparison of workplace interruptions in emergency departments and primary care offices. Ann. Emerg. Med. 38, 146–151.
Coiera, E., 2012. The science of interruption. BMJ Qual. Saf. 21, 357–360.
Coiera, E.W., Tombs, V., 1998. Communication behaviours in a hospital setting: an observational study. Br. Med. J. 316, 673–676.
Cook, R., Rasmussen, J., 2005. "Going solid": a model of system dynamics and consequences for patient safety. Qual. Saf. Health Care 14, 130–134.
Creswell, J.W., Miller, D.L., 2000. Determining validity in qualitative inquiry. Theory into pract 39, 124–130.
Devers, K.J., 1999. How will we know "good" qualitative research when we see it? Beginning the dialogue in health services research. Health Serv. Res. 34, 1153–1188.
Donabedian, A., 1979. The quality of medical care: a concept in search of a definition. J. Fam. Pract. 9, 277–284.
Drews, F.A., 2007. The frequency and impact of task interruptions on patient safety in the ICU. In: Human Factors and Ergonomics Society 51st Annual Meeting. Human Factors and Ergonomics Society, Baltimore, MD, pp. 683–686.
Edwards, A., Fitzpatrick, L.A., Augustine, S., Trzebucki, A., Cheng, S.L., Presseau, C., Mersmann, C., Heckman, B., Kachnowski, S., 2009. Synchronous communication facilitates interruptive workflow for attending physicians and nurses in clinical settings. Int. J. Med. Inf. 78, 629–637.
Flynn, E.A., Barker, K.N., Gibson, J.T., Pearson, R.E., Berger, B.A., Smith, L.A., 1999. Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. Am J Health Syst. Pharm. 56, 1319–1325.
Friedman, S., Elinson, R., Arenovich, T., 2005. A study of emergency physician work and communication: a human factors approach. Isr. J. Emerge. Med. 5, 35–42.
Gillie, T., Broadbent, D., 1989. What makes interruptions disruptive - a study of length, similarity, and complexity. Psychol. Res.-psychol. Forsch. 50, 243–250.
Grandhi, S.A., Jones, Q., 2009. Conceptualizing interpersonal interruption management: a theoretical framework and research program. In: System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on. IEEE, pp. 1–10.
Gurses, A.P., Carayon, P., 2007. Performance obstacles of intensive care nurses. Nurse. Res. 56, 185.
Halbesleben, J.R., Savage, G.T., Wakefield, D.S., Wakefield, B.J., 2010. Rework and workarounds in nurse medication administration process: implications for work processes and patient safety. Health Care Manage. Rev. 35, 124–133.
Healey, A.N., Primus, C.P., Koutantji, M., 2007. Quantifying distraction and interruption in urological surgery. Qual. Saf. Health Care 16, 135–139.
Hedberg, B., Larsson, U.S., 2004. Environmental elements affecting the decision-making process in nursing practice. J Clin. Nurs. 13, 316–324.
Holden, R.J., Rivera-Rodriguez, A., Faye, H., Scanlon, M., Karsh, B., 2012. Automation and adaptation: nurses' problem-solving behavior following the implementation of bar-coded medication administration technology. Cogn. Technol. Work, 1–14.
Hollnagel, E., Woods, D.D., Leveson, N., 2006. Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd., Burlington.
Institute of Medicine, 2000. To Err is Human: Building a Safer Health System. National Academy Press, Washington, DC.
Institute of Medicine, 2001. Crossing the Quality Chasm: a New Health System for the 21st Century. National Academy Press, Washington DC.
Karsh, B., Holden, R.J., Alper, S.J., Or, K.L., 2006. A human factors engineering paradigm for patient safety – designing to support the performance of the health care professional. Qual. Saf. Healthcare 15, i59–i65.
Klein, G.A., Calderwood, R., Macgregor, D., 1989. Critical decision method for eliciting knowledge. IEEE Trans. Syst. Man Cybern. 19, 462–472.
Kools, S., McCarthy, M., Durham, R., Robrecht, L., 1996. Dimensional analysis: broadening the conception of grounded theory. Qual. Health Res. 6, 312–330.
Kramer, B., Boelk, A., Auer, C., 2006. Family conflict at the end of life: lessons learned in a model program for vulnerable older adults. J. Palliat. Med. 9, 791–801.
Kreckler, S., Catchpole, K., Bottomley, M., Handa, A., McCulloch, P., 2008. Interruptions during drug rounds: an observational study. Br. J. Nurs. 17, 1326–1330.
Malterud, K., 2001. Qualitative research: standards, challenges, and guidelines. Lancet 358, 483–488.
Mays, N., Pope, C., 2000. Qualitative research in health care – assessing quality in qualitative research. Br. Med. J 320, 50–52.
Neuman, W.L., 2000. Social Research Methods: Quantitative and Qualitative Approaches, fourth ed. Allyn & Bacon, Needham Heights, MA.
Pape, T.M., 2003. Applying airline safety practices to medication administration. Medsurg. Nurs. 12, 77–94.
Pape, T.M., Guerra, D.M., Muzquiz, M., Bryant, J.B., Ingram, M., Schranner, B., Alcala, A., Sharp, J., Bishop, D., Carreno, E., Welker, J., 2005. Innovative approaches to reducing nurses' distractions during medication administration. J. Contin. Educ. Nurs. 36, 108–116 quiz 141–102.
Patton, M.Q., 1999. Enhancing the quality and credibility of qualitative analysis. Health Serv. Res. 34, 1189–1208.
Peleg, R., Froimovici, M., Peleg, A., Milrad, V., Ohana, G., Fitoussi, S., Dryfuss, E., Sharf, M., Shvartzman, P., 2000. Interruptions to the physician-patient encounter: an intervention program. Isr. Med. Assoc. J. 2, 520–522.
Potter, P., Boxerman, S., Wolf, L., Marshall, J., Grayson, D., Sledge, J., Evanoff, B., 2004. Mapping the nursing process: a new approach for understanding the work of nursing. J Nurs. Adm. 34, 101–109.
Relihan, E., O'Brien, V., O'Hara, S., Silke, B., 2009. The impact of a set of interventions to reduce interruptions and distractions to nurses during medication administration. Qual. Saf. Health Care.
Rivera-Rodriguez, A.J., Faye, H., Karsh, B., Carayon, P., Baker, C., Scanlon, M., 2012. A survey study of nursing contributions to medication management with special attention to health information technology. IIE Trans. Healthcare Syst. Eng. 2, 202–210.
Rivera-Rodriguez, A.J., Karsh, B.T., 2010. Interruptions and distractions in healthcare: review and reappraisal. Qual. Saf. Health Care 19, 304.
Rivera, A.J., Karsh, B.T., 2008. Human factors and systems engineering approach to patient safety for radiotherapy. Int. J. Radiat. Oncol. Biol. Phys. 71, S174–S177.
Schatzman, L., 1991. Dimensional analysis: notes on an alternative approach to the grounding of theory in qualitative research. In: Maines, D.R. (Ed.), Social

Organization and Social Process: Essays in Honor of Anselm Strauss. Aldine De Gruyter, New York, pp. 303–314.
Tucker, A.L., 2004. The impact of operational failures on hospital nurses and their patients. J. Oper. Manage. 22, 151–169.
Tucker, A.L., Spear, S.J., 2006. Operational failures and interruptions in hospital nursing. Health Serv. Res. 41, 643–662.
Wiegmann, D.A., ElBardissi, A.W., Dearani, J.A., Daly, R.C., Sundt, T.M., 2007. Disruptions in surgical flow and their relationship to surgical errors: an exploratory investigation. Surgery 142, 658–665.
Wolf, L.D., Potter, P., Sledge, J.A., Boxerman, S.B., Grayson, D., Evanoff, B., 2006. Describing nurses' work: combining quantitative and qualitative analysis. Hum. Factors 48, 5–14.