International Journal of Nursing Studies 52 (2015) 1573–1581

Contents lists available at ScienceDirect

International Journal of Nursing Studies

journal homepage: www.elsevier.com/ijns

The relationship between interruption content and interrupted task severity in intensive care nursing: an observational study

Farzan Sasangohar [a,b], Birsen Donmez [a,*], Anthony C. Easty [b,c], Patricia L. Trbovich [b,c]

[a] Department of Mechanical and Industrial Engineering, University of Toronto, 5 King's College Road, Toronto, ON, Canada M5S 3G8
[b] HumanEra, Techna, University Health Network, R. Fraser Elliott Building, 4th Floor, 190 Elizabeth Street, Toronto, ON, Canada M5G 2C4
[c] Institute of Biomaterials and Biomedical Engineering, University of Toronto, 164 College Street, Toronto, ON, Canada M5S 3G9

ARTICLE INFO

Article history:
Received 22 September 2014
Received in revised form 5 June 2015
Accepted 9 June 2015

Keywords:
Cardiovascular
Intensive care units
Interruptions
Nursing
Task severity

ABSTRACT

Background: In a previous study, we observed that the majority of interruptions experienced by nurses in a cardiovascular intensive care unit (CVICU) carried information directly related to their patient or other aspects of work affecting other patients or indirectly affecting their patient. Further, the proportion of interruptions with personal content was significantly higher during low-severity (in case of an error as defined by nurses) tasks compared to medium- and high-severity tasks suggesting that other personnel may have evaluated the criticality of the nurses' tasks before interrupting. However, this earlier study only collected data when an interruption happened and thus could not investigate interruption rate as a function of primary task type and severity while controlling for primary task duration as an exposure variable.
Objectives: We addressed this methodological limitation in a second observational study that was conducted to further study interruptions and also to evaluate an interruption mitigation tool. The data from the baseline condition (i.e., no tool) is analyzed in this paper to validate the results of our previous study and to report interruption rates observed during tasks of varying severities (low, medium, high), with a particular focus on comparing different interruption contents.
Design and setting: The study was conducted in a 24-bed closed CVICU at a Canadian hospital, during day shifts.
Participants: The baseline condition involved thirteen nurses.
Methods: Over a 3-week period, three researchers observed these nurses 46–120 min each, with an average of 89 min. Data were collected in real time, using a tablet computer and software designed for this purpose. The rate of interruptions with different content was compared across varying task severity levels as defined by CVICU nurses.
Results: Nurses spent about 50% of their time conducting medium-severity tasks (e.g., documentation), 35% conducting high-severity tasks (e.g., procedure), and 14% conducting low-severity tasks (e.g., general care). The rate of interruptions with personal content observed during low-severity tasks was 1.97 (95% confidence interval, CI: 1.04, 3.74) and 3.23 (95% CI: 1.51, 6.89) times the rate of interruptions with personal content observed during high- and medium-severity tasks, respectively.
Conclusions: Interrupters might have evaluated task severity before interrupting. Increasing the transparency of the nature and severity of the task being performed

* Corresponding author. Tel.: +1 416 978 7399; fax: +1 416 978 7753.
E-mail address: donmez@mie.utoronto.ca (B. Donmez).

http://dx.doi.org/10.1016/j.ijnurstu.2015.06.002
0020-7489/

may help others further modulate when and how they interrupt a nurse. Overall, rather than try to eliminate all interruptions, mitigation strategies should consider the relevance of interruptions to a task or patient as well as their urgency.

What is already known about the topic?

- Intensive care unit nurses get interrupted frequently; however, majority of the interruptions they receive may convey task- or patient-related information and thus have positive implications.
- There is some evidence suggesting that the proportion of interruptions with personal content is higher during low-severity (severity in case of an error) tasks compared to medium- and high-severity tasks. This indicates that other personnel may evaluate the criticality of the nurses' tasks before interrupting.

What this paper adds

- Not only are medium and high-severity tasks conducted frequently by ICU nurses, they also receive more interruptions than low-severity tasks. Thus, efforts should be made to minimize interruptions that could lead to errors, especially for high-severity tasks.
- Controlling for exposure (i.e., time spent performing different primary tasks), the rate of interruptions (per hour) with personal content is significantly higher during low-severity tasks compared to medium- and high-severity tasks. This finding provides support for the efficacy of tools or methods, which can improve the awareness of other personnel of the tasks performed by nurses.

1. Introduction

Interruptions experienced by intensive care unit (ICU) nurses are being studied widely due to their prevalence (Tucker and Spear, 2006) and their potentially negative effects on nurses' performance (Ballermann et al., 2010; Drews, 2007; Grundgeiger et al., 2010). However, not all interruptions are necessarily negative, and in certain contexts, ICU nurses may benefit from interruptions that communicate information related to patients, tasks, or decisions-at-hand (Coiera and Tombs, 1998; Grundgeiger and Sanderson, 2009; Rivera-Rodriguez and Karsh, 2010; Sasangohar et al., 2012; Walji et al., 2004). For example, ICU alarms (e.g., from intravenous pumps) can indicate an off-normal condition that needs immediate attention, or a nurse can interrupt another nurse to communicate an important event (e.g., patient arrival, hand-overs).

An earlier study we conducted in a Canadian Cardiovascular ICU (CVICU) revealed that the majority of the observed interruptions conveyed patient- or work-related content (Sasangohar et al., 2014). Therefore, mitigation strategies aimed at blocking interruptions with no consideration for interruption content may disrupt the communication of potentially important information. Overall, the interactions between the context in which interruptions happen (e.g., sources of interruption, tasks being interrupted), the interruption content (e.g., information conveyed, purpose of interruption), and the interruption characteristics (e.g., frequency and duration) can provide insights into developing more situation-specific mitigation approaches (Sasangohar et al., 2014). For example, non-urgent, non-task-relevant interruptions should be delayed or blocked during high-severity or highly critical tasks, whereas urgent or task-relevant interruptions might be allowed during low-severity tasks that are not as critical.

In our earlier CVICU study (Sasangohar et al., 2014), we observed that the staff's (e.g., nurses, MDs, other services) interruption behavior varied as a function of primary task severity (high, medium, or low) and interruption content (personal, patient-related, or work-related). To define the former variable, four experienced nurses were asked to categorize CVICU tasks as having high-, medium-, or low-severity outcomes in case of an error. The nurses responded individually, and the mode response was chosen for task severity. Overall, the proportion of interruptions with personal content was observed to be higher during low-severity tasks, compared to medium- and high-severity tasks. These results reveal a certain level of intuitive task-severity awareness among the interrupters, suggesting that a deliberate attempt at making task severity more transparent may help others modulate when and how they interrupt a nurse. However, this earlier study had a significant limitation in that the primary tasks were only recorded when an interruption happened and thus did not capture the prevalence of non-interrupted tasks. Previous studies have shown variation in the percentage of time nurses spend performing different ICU tasks. For example, Keohane et al. (2008) reported that about 10% of ICU tasks they observed were documentation, whereas Wong et al. (2003) reported documentation to be around 35%.

This methodological limitation was addressed in a second observational study conducted at the same CVICU. In this second study, we collected contextual information about the nurses' primary tasks in addition to the interruptions they experience in order to assess whether occurrence of interruptions varies as a function of primary task severity and interruption content. The overall objective of this second study was to further investigate interruptions and to also evaluate the effectiveness of an interruption mitigation tool, which was installed in one of the 24 rooms of this CVICU. The baseline data (i.e., data collected in 11 rooms without the tool) are used in this paper to validate the findings of the first observational study and also to report the make-up of different ICU tasks we observed. The findings on the effectiveness of the mitigation tool are presented in Sasangohar et al. (in press).

2. Methods

The CVICU of a Canadian hospital affiliated with the University of Toronto, Faculty of Medicine was observed weekdays over a 3-week period. The unit is a 24-bed closed CVICU that only accepts cardiovascular or vascular (both elective and emergent) surgery patients. The number of patients within the unit varies over the week, with about 12 patients cared for on Sunday, 16 on Monday, 20 on Tuesday, and 22 for the rest of the week. The study was approved by the Research Ethics Board of this hospital (Toronto, Canada, File #: 13-7147-AE) and as per ethics rules, all information obtained during the study is kept in strict confidence and no personal identifiers are attached to the data.

A convenience sampling methodology was employed. On a given day, the observers first identified the rooms which had patients and then asked the CVICU nurses (approximately 20) who cared for those patients to participate in the study. The first nurse to agree, who had not participated in the study before, was selected to participate. Overall, 13 nurses participated in baseline data collection. The observations were conducted in a specific ICU room that was under the care of the participant. The observer was stationed in this room and recorded interruptions experienced by the participant throughout the session. Other nurses were only observed if they interrupted the participant. Their consent was not required by the Research Ethics Board.

Observations were conducted on weekdays between 10:00 and 18:00 during day shifts (07:30–19:30) over a 3-week period. Three observers (1 Ph.D. and 2 undergraduate engineering students) trained in observational research methods and research ethics, who had experience conducting observations at the same CVICU, conducted thirteen observation sessions (1 observer per session) with one participant per session. Each participant was observed between 46 and 120 min, with an average of 89 min. The total observation time was 19 h. Each 2-h block from 10:00 to 18:00 was observed at least two times. Undergraduate students had been involved in the previous observational study conducted at the same CVICU (Sasangohar et al., 2014) and received further training before data collection. In addition, they performed two pilot studies (2 h each) along with the Ph.D. student. Furthermore, a codebook was developed to ensure standard adoption of terminology and to homogenize event coding (Table 1). This codebook was improved from the one used in our previous study (Sasangohar et al., 2014) based on lessons learned from this earlier study. The top three categories in Table 1 (i.e., interruption source, primary task, interruption content) were similar to our first observational study and were based on a review of the literature (Sasangohar et al., 2012) and interviews conducted with three experienced

Table 1
Description of data collection categories: Lists of sources of interruption, primary tasks, and interruption content; modified from Sasangohar et al. (in press).

Interruption source	Primary task	Interruption content
Anesthesiologist: CVICU medical anesthesia *Clerk:* CVICU staff in charge of documentation and communication *Equipment:* Any noise or alarm related to medical equipment *MD*: CVICU medical fellows *Nurse*: Other nurses in the unit *Patient*: Patient under care *PCA*: Patient-care assistants are in charge of helping the medical team in tasks such as moving the patient, bed setup, walking the patients. *PCC:* Patient-care coordinator works directly with CVICU manager and entire health care team facilitating flow of patients while ensuring all patients and family needs are met. *Pharmacist*: Hospital personnel in charge of supply of medications to CVICU staff *Phone*: Any phone that is answered *Physiologist*: Hospital personnel in charge of post-surgical patient rehabilitation *Psychologist*: Hospital personnel in charge of providing psychological consultation to patients and family members *Surgeon*: Hospital personnel who perform the surgery *Visitor*: Visitors or family members *X-ray technician*: Hospital personnel who perform in-room X-ray imaging *Other:* Any other personnel or source that the observer is not familiar with	*Connecting equipment*: Connecting medical equipment to patient (e.g., defibrillator, dialysis, ventilator) *Discussion*: Conversations with other health care providers about the status of the patient *Documentation*: Bedside clinical (paper) documentation of patient care such as vital signs, medications, and procedures *General care*: Routine ICU tasks such as feeding, bathing, and comforting the patient *Infusion setup*: Setting up the intravenous (IV) infusion such as priming, line insertion, and pump preparation *Medication administration*: Process of administering medication orally, through infusion, or injection (e.g., connecting syringe to the IV access device and injecting the medication directly into the vein) *Medication order*: Process of ordering medication for the patient using the medication electronic system *Medication preparation*: Preparing medication for injection, infusion, or oral administration (e.g., priming IV lines or syringe, preparing the medication cup, connecting IV lines to patients) *Procedure*: Medical procedures performed on the patient (e.g., taking blood sample, intubation) *Pump programming*: Setting the IV medication dosage and volume to be infused by the pump *Using the computer station*: Using the in-room computer station for any reason other than medication order (e.g., research, email) *Vitals monitoring*: Acquiring patient vital signs visually from the displays of the various monitoring devices to which the patient is connected *Other*: Any other task not categorized above	*Alarm*: Medical equipment or emergency alarms *Patient-related*: Interruptions that convey information about patient the observed nurse was treating (e.g., MD orders a new medication, phone call from the lab to discuss blood test) *Personal*: Personal communications that are not about the patient or CVICU tasks (e.g., greetings, personal conversations about vacations) *Work-related*: Interruptions that are related to CVICU tasks but not about the patient-in-care (e.g., PCC discusses a new transfer, other nurses request help for their patients) **Specific content** Asking help CCIS (Critical Care Info. System) Helping others Looking for colleague MD talking Missing tools Nurse talking Patient arrival Patient question Patient talking Patient transfer Patient-visitor conversation Shift hand-over/breaks Staff talking Visitor talking Visitor question

CVICU nurses before the first observational study was undertaken. The final category (i.e., specific content) was based on opportunistic notes taken during the previous study and was added to minimize the need for note-taking for some recurring events (e.g., asking for help).

An inter-rater reliability analysis was conducted for the coding of events observed in the pilot studies. Cohen's κ (Landis and Koch, 1977) was calculated to compare the coding of the three major data collection categories (i.e., interruption source, primary task, and interruption content) of the Ph.D. student (benchmark) with each undergraduate observer. Results showed perfect agreements between observer pairs for the interruption source ($\kappa = 1.00$), substantial to perfect for the primary task ($0.72 < \kappa < 1.00$), and almost perfect for the interruption content ($0.87 < \kappa < 1.00$).

2.1. Instrument

To facilitate data collection, a software tool inspired by Remote Analysis of Team Environments (RATE) (Guerlain et al., 2002) was developed and was used on Apple iPad tablets (with retina display). As shown in Fig. 1, the tool includes 4 clickable and scrollable lists: interruption source, primary task, interruption content, and specific content (described in Table 1). To code the start of an event (primary task or interruption) the observer interacted with the tool to select the proper categories from these four lists. Double-tapping anywhere on the screen meant that the event has started and this action created a time-stamped event in a database. The four most recent events were visible at the bottom of the screen to facilitate the recording of when an event ended. When the observer clicked an event, it was time-stamped and removed from the list. The timer on the top left of the display kept a running time of the entire observation which could be stopped by clicking on 'STOP'. There was also a 'NOTE' button, which was used by the observer to take opportunistic notes using iPad's digital keyboard. When the observer finished taking a note by clicking the 'ENTER' button, the note was time-stamped and saved in the database. The interface also allowed for indication of non-task times through the 'NTT' option whenever an observation was not possible (e.g., breaks, curtains on).

2.2. CVICU staff

The CVICU observed has approximately 20 registered nurses (RNs), who are rostered and are present during each day shift, including 1 clinical resource RN and 1 nurse manager. Overall, there are about 100 nurses working in this CVICU. Other personnel generally available during day shifts on weekdays are: 1 patient-care coordinator (PCC), 2 staff medical doctors (MDs), 2 vascular fellows, 2 unit clerks, 3 patient care assistants (PCAs), and 3–4 cardiovascular surgeons. Each day, there are two rounds (at 07:30

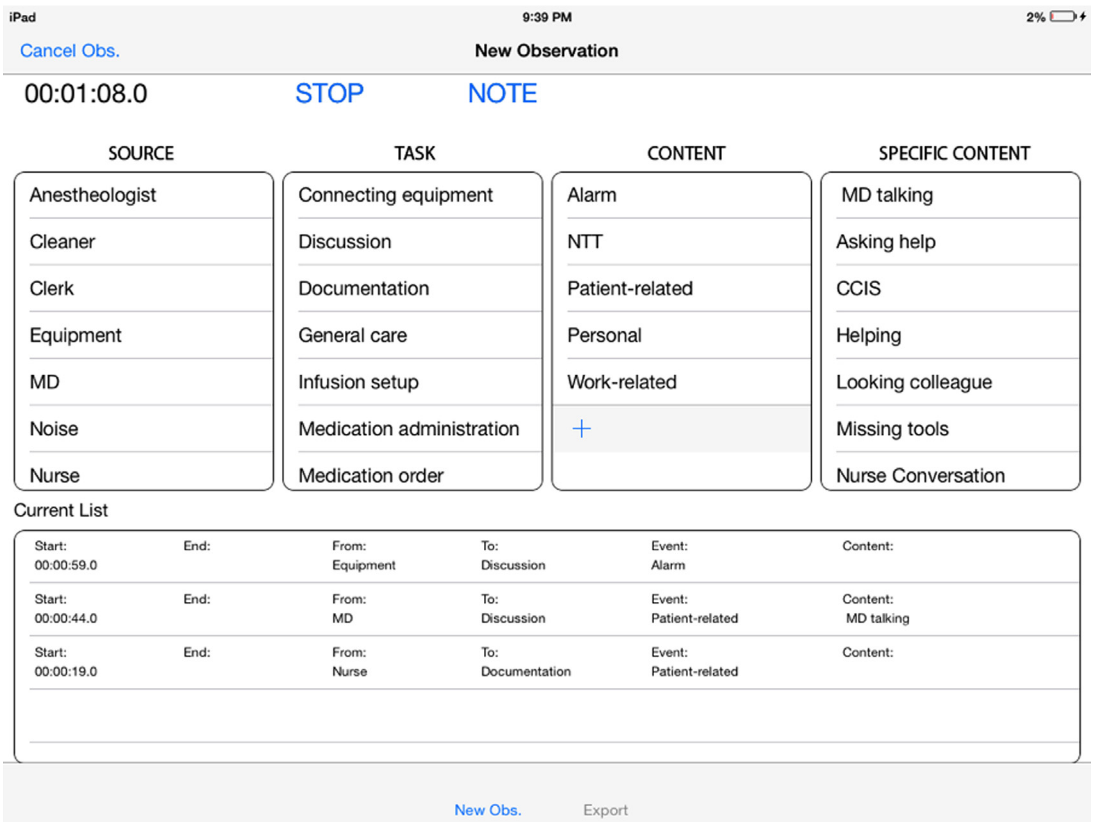

Fig. 1. The iPad data collection instrument.

and 15:00) in which the CVICU team participates. There are also vascular team rounds at 08:00. Due to the significant number of communication-related events involved and the presence of many clinicians (sometimes up to 10), rounds were treated as a special case and no observations were conducted during the rounds. In fact, there are previous studies dedicated specifically to investigating interruptions during ICU rounds (e.g., Alvarez and Coiera, 2005).

2.3. Procedure

At the beginning of the study, the observer explained the study procedures and told the participants that the focus of the study was not to collect data on their performance but to collect data on the events that resulted in an interruption to their tasks. After obtaining participant consent, one observer observed one nurse inside a specific ICU room that was under the care of the participant. The observer marked the start and end of each task conducted by the nurse (i.e., primary task). If the nurse went back and forth between two tasks, then for every switch, one task was ended and a new task was started. With this framing, there were no overlapping tasks. When an interruption occurred, the observer entered the relevant information on the tool. If time allowed, the observer also typed in additional comments (e.g., lab called to discuss results). The observer did not speak to the nurse and did not ask any questions during the observation period.

The definition of interruption adopted for this research is *an external intrusion of a secondary task, which leads to a discontinuity in primary task*. This definition is similar to the one used in previous research (Grundgeiger et al., 2010; Sasangohar et al., 2014). To operationalize this definition, the interruption data were collected only when it was possible to observe a break in the primary task due to an interruption (e.g., nurse stopping documentation while discussing the patient with an MD).

3. Results

3.1. Primary tasks

Overall, 827 primary task activities were observed. Of these activities, 256 (31%) involved discussion with other personnel, 166 (20%) were documentation, 81 (10%) involved general care, and 64 (8%) were procedures (Fig. 2a). Nurses spent almost half of their time communicating with other personnel (26%) and documenting (23%) (Fig. 2b). They spent 15% of their time conducting procedures and 10% providing general care. Both Fig. 2a and b categorize these different primary tasks in terms of having high-, medium-, or low-severity outcomes in case of an error. This categorization followed the methods used in our earlier studies (Sasangohar et al., 2014; Trbovich et al., 2010); as stated in the Methods section, four experienced CVICU nurses categorized their primary tasks as low-, medium-, or high-severity and the mode response was chosen. Based on this categorization, nurses spent about 50% of their time conducting medium-severity tasks, 35% performing high-severity tasks, and 14% on low-severity tasks (Fig. 2b).

3.2. Interruption characteristics

In 19 h of total observation time, 254 interruptions were observed. That is, on average, one interruption occurred per about 5 min of observation.

3.3. Interruption context

Of the 254 interruptions observed, other nurses were the most common source (51.57%), followed by MDs (12.99%), visitors (7.87%), equipment (6.69%), patients (4.72%), and phone (4.33%). The remaining interruption sources accounted for less than 15% of all interruptions.

The majority of interruptions happened during documentation (40.68%), general care (11.86%), discussion (10.17%), and procedures (9.32%). Overall, 52% of interruptions happened during medium-severity tasks, followed by high-severity (36%), and then low-severity (12%) tasks. Fig. 3 presents the average number of interruptions per task occurrence. High-severity tasks such as medication administration (0.26), medication preparation (0.26), medication order (0.23), and pump programming (0.2) were revealed in this figure to have high rates of interruptions per task occurrence following documentation (0.29) which had the highest rate.

3.4. Interruption content

The majority of interruptions were either work- (40%) or patient-related (29%). Interruptions with personal content and alarms constituted 24% and 7% of all interruptions, respectively.

Table 2 reports the average rate of interruptions per hour (and standard deviation, SD) from different sources and with different contents observed during the three primary task severities. To obtain this table, we first calculated the rates for each participant; the table presents the averages (and SDs) which were obtained across participants. Overall, nurses were the most prevalent source of interruption regardless of task severity, but their rate of interruptions was highest during low-severity tasks (high-severity: 8.66/h; medium-severity: 6.14/h; low-severity: 21.66/h). MDs were the second most frequent source of interruption during high (2.58/h) and low-severity tasks (6.17/h), whereas visitors were the second most frequent source observed during medium-severity tasks (2.09/h). There were a few observation sessions where the low-task severity periods were quite short (e.g., 48 s for one nurse). Interruptions happened during these periods, leading to large interruption rates calculated for these nurses. These extreme values, which are realistic, are reflected in the large standard deviations as well as the large averages reported in Table 2 for the low-severity tasks. However, the statistical models presented in the following sections adjust for such extreme values.

3.5. Statistical analysis

Generalized linear models were built to compare rate of interruptions with different contents observed during different levels of task severity. The models were fitted using PROC GENMOD in SAS 9.2, with the specifications of

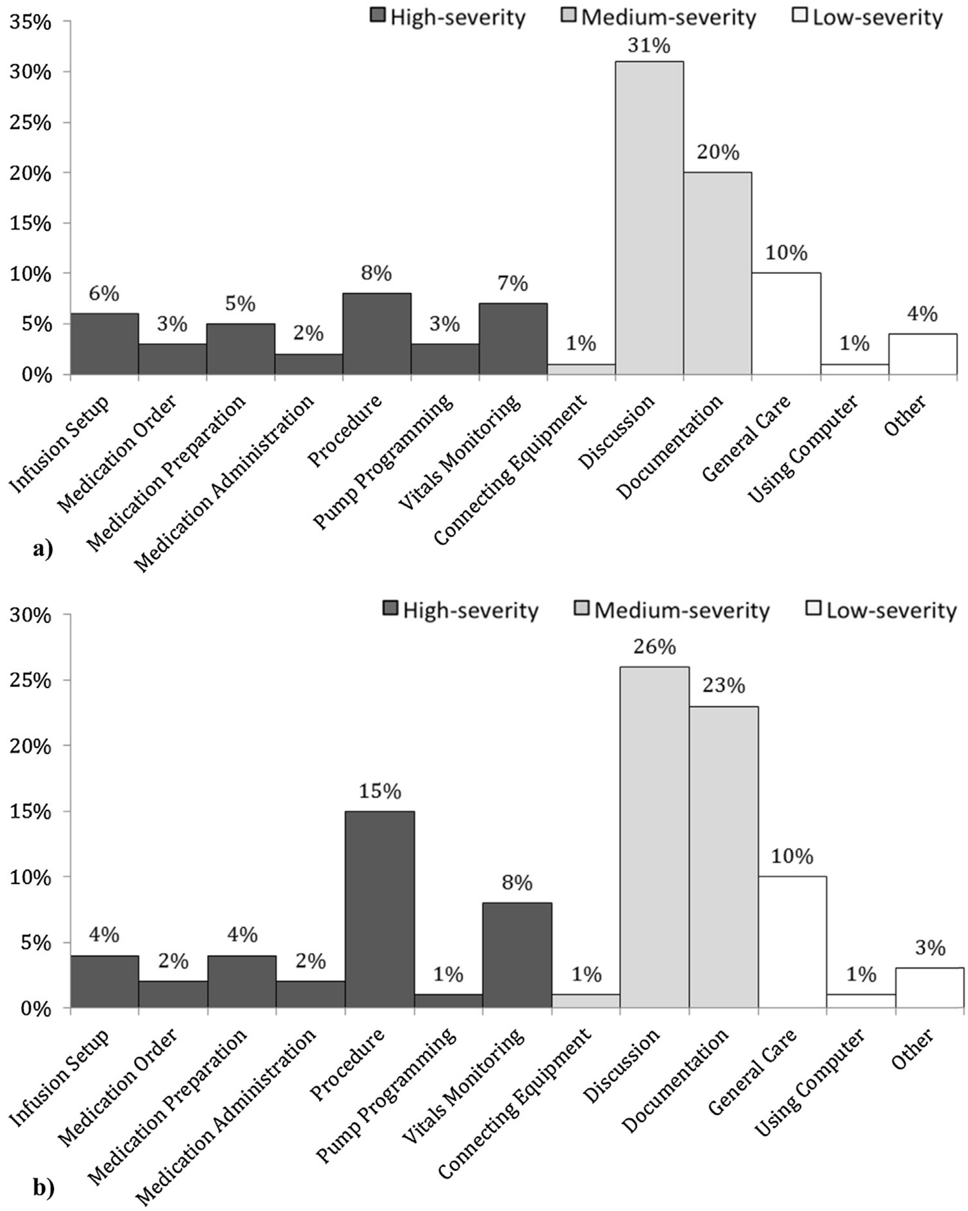

Fig. 2. Percentage of different primary tasks: (a) percent frequency ($n = 827$), (b) percent duration (total duration = 19 h).

a log link function and Poisson distribution. Repeated measures were accounted for by using Generalized Estimating Equations (GEE). The logarithm of the total duration of different task severities observed for each participant was used as an offset variable.

Two separate generalized linear models were built since no alarms were observed during medium-severity tasks. The first model was a 3 (task severity: high, medium, or low) $\times$ 3 (content: patient-related, work-related, or personal) and excluded alarms. The second model, which excluded the medium task-severity level, was a 2 (task severity: high or low) $\times$ 4 (content: patient-related, work-related, personal, or alarm) and informed the results about alarms.

Model 1 results revealed significant effects for content ($\chi^2(2) = 18.51$, $p < .0001$) and its interaction with task severity ($\chi^2(4) = 207.71$, $p < .0001$). Follow-up comparisons of content across different task severity levels revealed that the rate of interruptions with personal content observed during low-severity tasks was 1.97 (95% CI: 1.04, 3.74, $z = 2.08$, $p = .04$) and 3.23 (95% CI: 1.51, 6.89, $z = 3.03$, $p = .003$) times the rate of interruptions with personal content observed during high- and medium-severity tasks, respectively. Further, the rate of patient-related interruptions during high-severity tasks was 2.39 times that of low-severity tasks (95% CI: 1.03, 5.54, $z = 2.03$, $p = .04$). Other comparisons were not significant ($p > .05$), except there was a marginally significant difference between patient-related interruptions during high-severity tasks and during medium-severity tasks. More specifically, the rate of patient-related interruptions

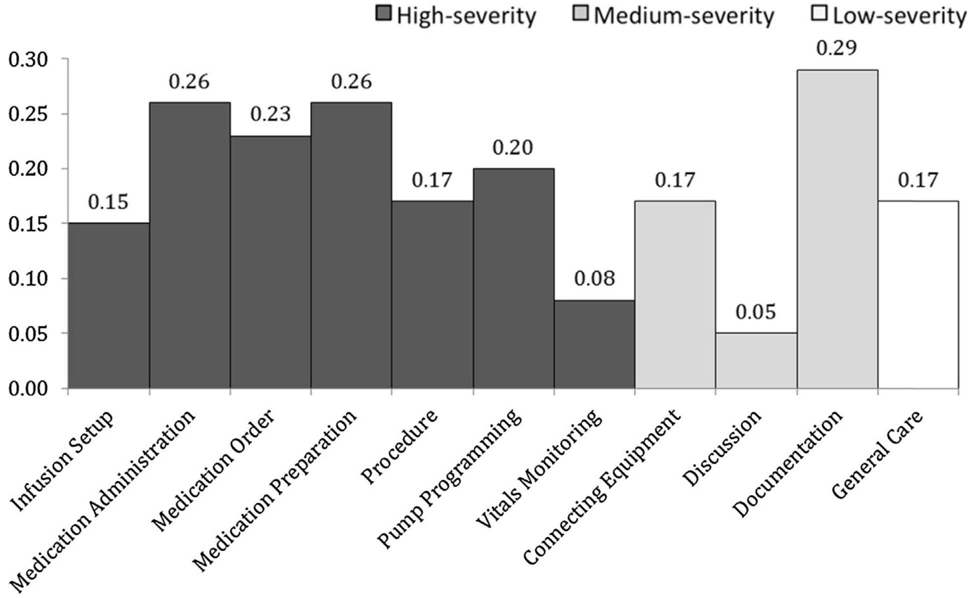

Fig. 3. Average number of interruptions per primary task occurrence (primary task categories during which no interruptions were observed are excluded).

during high-severity tasks was 1.3 times the rate of patient-related interruptions during medium-severity tasks (95% CI: 0.98, 1.88, $z = 1.86$, $p = .06$).

Follow-up comparisons of task-severity level across different contents were also conducted. During low-severity tasks, the rate of personal interruptions was 1.91 times the rate of work-related interruptions (95% CI: 1.43, 2.54, $z = 4.44$, $p < .0001$), 3 times the rate of patient-related interruptions (95% CI: 2.17, 4.15, $z = 6.66$, $p < .0001$), and 7 times the rate of alarms (95% CI: 2.78, 17.63, $z = 4.13$, $p < .0001$). In addition, during high-severity tasks, the rate of work-related interruptions was 1.9 times the rate of personal interruptions (95% CI: 1.34, 2.72, $z = 3.56$, $p < .0001$) and 2.5 times the rate of alarms (95% CI: 1.77, 3.53, $z = 5.21$, $p < .0001$). Similarly, again during high-severity tasks, the rate of patient-related interruptions was 1.57 times the rate of personal interruptions (95% CI: 1.16, 2.13, $z = 2.9$, $p < .0001$) and 2.06 times the rate of alarms (95% CI: 1.44, 2.98, $z = 3.98$, $p < .0001$). During medium-severity tasks, the rate of work-related interruptions was 1.47 times the rate of patient-related interruptions (95% CI: 1.02, 2.11, $z = 2.08$, $p = .037$) and 2.78 times the rate of personal interruptions (95% CI: 1.91, 4.03, $z = 5.37$, $p < .0001$). Furthermore, for medium-severity tasks, the rate of patient-related interruptions was 1.89 times the rate of personal interruptions (95% CI: 1.34, 2.67, $z = 3.61$, $p < .001$). Other comparisons were not significant ($p > .05$).

4. Discussion

As part of a larger observational study which also evaluated the effectiveness of an interruption mitigation tool in a CVICU setting, 13 nurses were observed in a baseline condition (i.e., in rooms with no tool). The total observation time for these nurses was 19 h during which the primary tasks performed by the nurses as well as

Table 2
Rate of interruptions (frequency per hour) by source and content during different interrupted-task severities.

Severity of interrupted task	Source Top 4 interruption sources: rate per hour (standard deviation)	Content Interruption content ranking: rate per hour (standard deviation)
High	(1) Nurse: 8.66 (4.01) (2) MD: 2.58 (2.33) (3) Equipment: 2.10 (1.73) (4) Visitor: 1.03 (3.73)	(1) Work-related: 6.21 (3.31) (2) Patient-related: 5.03 (2.45) (3) Personal: 3.29 (2.03) (4) Alarm: 3.26 (3.40)
Medium	(1) Nurse: 6.14 (2.16) (2) Visitor: 2.09 (2.09) (3) MD: 1.30 (1.66) (4) Patient: 0.54 (0.77)	(1) Work-related: 5.47 (3.37) (2) Patient-related: 4.02 (3.32) (3) Personal: 2.12 (1.64) (4) Alarm: 0 (0)
Low	(1) Nurse: 21.66 (42.86) (2) MD: 6.17 (19.40) (3) PCC: 5.77 (20.80) (4) Patient: 2.92 (9.75)	(1) Personal: 21.22 (43.04) (2) Patient-related: 9.70 (21.84) (3) Work-related: 5.16 (9.76) (4) Alarm: 3.20 (9.72)

the interruptions that they experienced were recorded. The results showed that nurses spent most of their time communicating with other staff (26%) and doing documentation (23%). These findings are in line with previous research; Keohane et al. (2008) reported 22.6% for the former and previous findings on the latter ranged between 12.84% and 35.1% (Keohane et al., 2008; Wong et al., 2003).

Similar to previous studies, we observed ICU nurses to get interrupted frequently. On average, 12 interruptions were recorded per hour, slightly smaller than our previous study (Sasangohar et al., 2014) but in line with other observational studies in ICU settings which reported 4.5–15.3 per hour (Ballermann et al., 2010; Drews, 2007; Grundgeiger et al., 2010). This reduction in rate from our previous study might be due to differences in the way the definition of interruption was operationalized. Other nurses (~52%) accounted for almost half of all interruptions, followed by MDs (~13%), and visitors (~8%). Previous research also found nurses to be the most frequent interruption source (Drews, 2007; McGillis Hall et al., 2010; Sasangohar et al., 2014).

Observation of nurses' tasks showed that nurses spent half of their time (50% of observation time) performing medium-severity tasks and almost one-third of their time (35%) conducting high-severity tasks. A very similar pattern was observed with respect to the percentage of interruptions, where most interruptions happened during medium- (52%) and high-severity tasks (36%). This evidence suggests that not only medium and high-risk tasks may be conducted frequently in ICUs, but they may also be interrupted as frequently as low-severity tasks. Thus, efforts should be made to minimize interruptions that could lead to errors, especially for high-severity tasks.

It should be noted that the percentage of different task severities observed in our study may not translate directly to other settings due to cultural and organizational differences across ICUs as well as due to variations in nurses' tasks and risk perceptions. A major contribution of our research is capturing the context in which interruptions happen, in particular the task criticality. No other interruption research we know of evaluated interruptions within this framing. However, as reported earlier, for common assessments (e.g., time spent on different primary tasks, frequency of interruptions, frequent sources of interruptions), our results are in line with other ICU studies, including ones from Canada (Ballermann et al., 2010), the United States (Drews, 2007; Keohane et al., 2008), and Australia (Grundgeiger et al., 2010), providing partial support to the generalizability of our findings.

Similar to our previous study (Sasangohar et al., 2014), a large percentage of interruptions were found to be either work- (40%) or patient-related (29%). These types of interruptions potentially have positive effects but might be delayed if they are non-urgent. Thus, future research should investigate the urgency of interruptions. There were also potentially negative interruptions observed in our study. For example, personal interruptions were observed at a rate of 3.29/h during high-severity tasks. Arguably, these interruptions should be blocked during high-severity tasks but can help relieve boredom and have a positive effect during low-severity tasks. The majority of previous interruption mitigation approaches in healthcare such as no interruption-zones (Anthony et al., 2010) or 'Do Not Disturb' vests (Craig et al., 2013) try to block interruptions without considering potentially important contextual information. Overall, developing situation-specific mitigation approaches by considering the relevance of an interruption (to patient and/or task) as well as its urgency remains a research gap.

In line with our previous findings (Sasangohar et al., 2014), it was found that the rate of interruptions with personal content was significantly higher during low-severity tasks compared to medium- and high-severity tasks. This finding provides support for the efficacy of tools or methods which can improve the awareness of other personnel of the tasks performed by nurses. Given that such awareness displays have been shown to be effective in other domains (e.g., Dabbish and Kraut, 2008; Fogarty et al., 2004), we developed a task-severity awareness tool through which the nurses can communicate to people who are approaching a room that they are conducting a high-severity task. When engaged by the nurse through different controls (e.g., buttons) within a room, a display presents a 'Do Not Disturb Please!' message outside the room. As reported in Sasangohar et al. (in press), this tool was observed to eliminate interruptions with personal content during high-severity tasks. It should be noted that the tool was installed in the CVICU unit we observed, 2 weeks prior to the start of data collection, including the baseline condition reported in this paper. Although the tool was installed in only one out of the 24 rooms of this CVICU, it is possible that the existence of the tool in another room while the baseline data reported in the current paper were being collected may have influenced the general interruption behavior within the unit. However, even when there was an observer present, the nurses had to be prompted to use the tool 69% of the time (Sasangohar et al., in press). Thus, it is reasonable to assume that the use rate was much lower in general, relieving concerns about the effects of the tool on the data reported in the current paper.

In general, the participants were aware of the study's objective of investigating interruptions and some had participated in our previous study, which might have also influenced their behavior. However, if there were an influence, one would expect the frequency of interruptions to decrease, leading to an underestimation. Further, clinical errors were not documented in this study. Future research is needed to understand the effects of different types of interruptions on task performance.

A general limitation of observational studies is the possibility of deviation from natural behavior due to the presence of an observer (also known as the Hawthorne effect). Future work is needed to replicate this study using less intrusive observational techniques such as video recording. In general, recording observations in a complex environment such as an ICU is challenging and requires domain expertise. Although our analysis revealed a high degree of inter-rater reliability, utilizing healthcare personnel as a benchmark in future studies can help improve the quality of data collection. In addition, in this study, we did not collect participants' demographic information in order to prevent privacy concerns and encourage natural behavior. Arguably, characteristics such as age, experience, and organizational ranking may result in different interruption behaviors. For example, interruptions to and from nurse managers may differ significantly compared to interruptions experienced or initiated by junior nurses. Future studies should investigate the effect of these characteristics on the occurrence of interruptions.

Another limitation of our study was that only the day shifts were observed. Interruptions may in fact have different characteristics during night shifts where no admissions or rounds happen and communication is reduced. In addition, other ICU environments (e.g., pediatric) may generate different patterns due to variations in workflow, culture, and policies. Moreover, although we captured exposure through task durations, some tasks may require more personnel to be present (e.g., procedures) and therefore might be more likely to be interrupted. This variation might explain the higher rate of MD interruptions observed during high-severity tasks compared to medium-severity tasks.

In conclusion, the results reported in this paper support the findings of our previous study (Sasangohar et al., 2014). CVICU personnel appear to take context into account before interrupting nurses. This finding provides support for the efficacy of tools or methods which can improve other personnel's awareness of the tasks performed by nurses.

Acknowledgments

We gratefully acknowledge Helen Storey for providing domain expertise and her help in facilitating data collection. We also would like to thank Dr. Mark Chignell and Dr. Linda McGillis Hall for their insightful feedback, and Parya Noban, Sahar Ameri, and Areeba Zakir for their help in data collection and analysis. The study sponsors were not involved in the conduct of this research.

Conflict of interest. The authors have no conflicts of interest regarding this research.

Funding. This research was funded by a Natural Sciences and Engineering Research Council of Canada (NSERC) Postgraduate Scholarship and a Canadian Institute of Health Research (CIHR) Strategic Training Initiative in Health Research in Health Care, Technology, and Place Doctoral Scholarship awarded to Farzan Sasangohar, as well as an NSERC Discovery Grant awarded to Birsen Donmez.

Ethical approval. The study was approved by the Research Ethics Board of this hospital (Toronto, Canada, File #: 13-7147-AE) and as per ethics rules, all information obtained during the study is kept in strict confidence and no personal identifiers are attached to the data.

References

Alvarez, G., Coiera, E., 2005. Interruptive communication patterns in the intensive care unit ward round. Int. J. Med. Inf. 74 (10), 791–796, http://dx.doi.org/10.1016/j.ijmedinf.2005.03.017.

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 (3), 21–29, http://dx.doi.org/10.4037/ccn2010473.

Ballermann, M.A., Shaw, N.T., Arbeau, K.J., Mayes, D.C., Noel Gibney, R.T., 2010. Impact of a critical care clinical information system on interruption rates during intensive care nurse and physician documentation tasks. Stud. Health Technol. Inform. 160 (Pt 1), 274–278.

Coiera, E., Tombs, V., 1998. Communication behaviours in a hospital setting: an observational study. Br. Med. J. 316 (7132), 673–676, http://dx.doi.org/10.1136/bmj.316.7132.673.

Craig, J., Clanton, F., Demeter, M., 2013. Reducing interruptions during medication administration: the White Vest Study. J. Res. Nurs. 19 (3), 248–261, http://dx.doi.org/10.1177/1744987113484737.

Dabbish, L., Kraut, R., 2008. Research note—awareness displays and social motivation for coordinating communication. Inf. Syst. Res. 19 (2), 221–238, http://dx.doi.org/10.1287/isre.1080.0175.

Drews, F.A., 2007. The frequency and impact of task interruptions in the ICU. In: Proceedings of the 51st Human Factors and Ergonomics Society Annual Meeting. pp. 683–686, http://dx.doi.org/10.1177/154193120705101117.

Fogarty, J., Lai, J., Christensen, J., 2004. Presence versus availability: the design and evaluation of a context-aware communication client. Int. J. Hum.-Comput. Stud. 61 (3), 299–317, http://dx.doi.org/10.1016/j.ijhcs.2003.12.016.

Grundgeiger, T., Sanderson, P., 2009. Interruptions in healthcare: theoretical views. Int. J. Med. Inf. 78 (5), 293–307, http://dx.doi.org/10.1016/j.ijmedinf.2008.10.001.

Grundgeiger, T., Sanderson, P., MacDougall, H.G., Venkatesh, B., 2010. Interruption management in the intensive care unit: predicting resumption times and assessing distributed support. J. Exp. Psychol.: Appl. 16 (4), 317–334, http://dx.doi.org/10.1037/a0021912.

Guerlain, S., Shin, T., Guo, H., Adams, R., Calland, J.F., 2002. A team performance data collection and analysis system. In: Proceedings of the 46th Human Factors and Ergonomics Society Annual Meeting. pp. 1443–1447, http://dx.doi.org/10.1177/154193120204601608.

Keohane, C.A., Bane, A.D., Featherstone, E., Hayes, J., Woolf, S., Hurley, A., Poon, E.G., 2008. Quantifying nursing workflow in medication administration. J. Nurs. Adm. 38 (1), 19–26, http://dx.doi.org/10.1097/01.NNA.0000295628.87968.bc.

Landis, J.R., Koch, G.G., 1977. The measurement of observer agreement for categorical data. Biometrics 33 (1), 159–174, http://dx.doi.org/10.2307/2529310.

McGillis Hall, L., Pedersen, C., Fairley, L., 2010. Losing the moment: understanding interruptions to nurses' work. J. Nurs. Adm. 40 (4), 169–176, http://dx.doi.org/10.1097/NNA.0b013e3181d41162.

Rivera-Rodriguez, A.J., Karsh, B.-T., 2010. Interruptions and distractions in healthcare: review and reappraisal. Qual. Saf. Health Care 19 (4), 304–312, http://dx.doi.org/10.1136/qshc.2009.033282.

Sasangohar, F., Donmez, B., Easty, A., Storey, H., Trbovich, P., 2014. Interruptions experienced by cardiovascular intensive care unit nurses: an observational study. J. Crit. Care 29 (5), 848–853, http://dx.doi.org/10.1016/j.jcrc.2014.05.007.

Sasangohar, F., Donmez, B., Easty, A.C., Trbovich, P.L., in press. Mitigating non-urgent interruptions during high-severity ICU tasks using a task-severity awareness tool: a quasi-controlled observational study. J. Crit. Care, http://dx.doi.org/10.1016/j.jcrc.2015.05.001 (in press).

Sasangohar, F., Donmez, B., Trbovich, P., Easty, A.C., 2012. Not all interruptions are created equal: positive interruptions in healthcare. In: Proceedings of the 56th Human Factors and Ergonomics Society Annual Meeting. pp. 824–828, http://dx.doi.org/10.1177/1071181312561172.

Trbovich, P., Prakash, V., Stewart, J., Trip, K., Savage, P., 2010. Interruptions during the delivery of high-risk medications. J. Nurs. Adm. 40 (5), 211–218, http://dx.doi.org/10.1097/NNA.0b013e3181da4047.

Tucker, A.L., Spear, S.J., 2006. Operational failures and interruptions in hospital nursing. Health Serv. Res. 41 (3 Pt 1), 643–662, http://dx.doi.org/10.1111/j.1475-6773.2006.00502.x.

Walji, M., Brixey, J., Johnson-Throop, K., Zhang, J., 2004. A theoretical framework to understand and engineer persuasive interruptions. In: Proceedings of the 26th Annual Conference of the Cognitive Science Society. pp. 1417–1422.

Wong, D.H., Gallegos, Y., Weinger, M.B., Clack, S., Slagle, J., Anderson, C.T., 2003. Changes in intensive care unit nurse task activity after installation of a third-generation intensive care unit information system. Crit. Care Med. 31 (10), 2488–2494, http://dx.doi.org/10.1097/01.CCM.0000089637.53301.EF.