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Impact of Interruptions, Distractions, and Cognitive Load on Procedure Failures and Medication Administration Errors

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Medication administration errors are difficult to intercept since they occur at the end of the process. The study describes interruptions, distractions, and cognitive load experienced by registered nurses during medication administration and explores their impact on procedure failures and medication administration errors. The focus of this study was unique as it investigated how known individual and environmental factors interacted and culminated in errors. **Key words:** *cognitive load*, *distractions*, *errors*, *interruptions*, *medication errors*, *nurses*

MEDICATION ADMINISTRATION is a high-volume as well as high-risk nursing activity. Nurses have a pivotal role in optimizing individual performance and controlling environmental factors to reduce error. The purpose of this article is to present the results of a national study under the auspices of the Improvement Science Research Network (ISRN) to examine the impact of interruptions, distractions, and cognitive load on procedure failures (PFs) and medication administration errors (MAEs). The ISRN is a National Institutes of Health–supported network of clinical and academic scholars focusing on transforming health care through quality improvement.[1]

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Medication errors are among the most common medical errors occurring in hospitals, harming at least 1.5 million people yearly.[2] A hospitalized patient can expect to be subjected to more than 1 medication error a day when all types of errors are considered,[2] and 96% of these errors are preventable.[3] Administration errors are difficult to intercept[4] as they occur at the end of the process where nurses are "the last link in the safety net."[5]

FACTORS CONTRIBUTING TO MAEs

Multiple causes of MAEs can be grouped under categories such as inadequate knowledge, failure to follow policy and procedures, communication failures, and individual and systems issues.[6] Variations from standards of practice, preoccupation and attention slips, interruptions, distractions, and inadequate staffing[7,8] are also frequently cited. Nurses perceive medication errors to be caused by several factors such as heavy workload, distractions, interruptions, and inexperience.[4] Several studies have validated these perceptions, particularly linking interruptions, distractions, and medication errors.[9,10]

Complexity of nurses' work

The error-provoking properties[11] of interruptions, distractions, and cognitive load in medication administration can be examined within the complexity of nurses' work. Medication administration is embedded in numerous nursing actions.[12] This is further complicated by the constantly changing patient conditions and environment requiring critical thinking and constant reprioritization. Nurses are required to integrate their cognitive work with psychomotor and affective skills for delivering effective care.[13] According to Ebright et al,[14] nurses' care delivery involves 3 patterns: work complexity, complex cognition, and care management strategies. Work complexity includes disjointed supply sources, missing equipment, difficulty accessing resources to complete care, and inconsistencies in care communication. Cognitive factors include maintaining patient safety, staying timely in completing patient care tasks, appearing competent to coworkers, maintaining patient satisfaction, and knowing patient profiles and unit routines. Care management strategies include stacking of activities (anticipating and organizing numerous tasks), proactively monitoring patient status, and strategically delegating and making handoff decisions.

Interruptions and distractions

Interruptions and distractions are ubiquitous in nursing work,[15] and the examination of disruptions as the source of medication errors remains a contemporary nursing safety issue.[16] Yet, standardized descriptions of interruptions had not been found in the nursing literature until the concept analysis by Brixey and colleagues.[17] These investigators describe interruptions as a human experience of intrusion of a secondary, unplanned, and unexpected task, leading to discontinuity, either internally or externally initiated. Distractions include anything that draws away, diverts, or disturbs attention from achieving a goal.[18] Distractions have been characterized as internally driven processes.[19]

Studies support the relationship between interruptions and medication errors.[20,21] Nurses were found at risk of an interruption or distraction with *every* medication pass.[22] Potter and colleagues[23] analyzed the nature of nurses' cognitive work using human factors engineering techniques and observation of clinical activities. This study revealed 3.4 to 5.9 interruptions an hour. Despite the number of interruptions, no errors were observed among the nurses. However, a total of 21 omissions in care delivery was observed. The analysis of the cognitive pathways revealed that nursing work is complex and nonlinear.

Reports of interruption frequencies and their effects vary.[24,25] A study[20] observing 98 nurses administering 4271 medications to 720 patients over 505 hours found that each interruption was associated with 12.1% increase in PFs and 12.7% increase in clinical errors. Error severity was found to increase with the interruption frequency. Specific actions contribute to interruptions[26] such as obtaining missing medications, managing requests, and attending to call bells and phones.

Cognitive load demands

Potter et al[23] calculated a measure termed "cognitive stacking" to determine nurses' cognitive demands. This measure quantifies tasks and priorities that nurses need to complete at any given time for their patients. Nurses in their study were observed to have high cognitive loads, holding 11 activities in their mind at a time. Cognitive load is critical to the nurses' ability to shift attention at any given time. The frequency of cognitive shifts creates a risk for loss of attention that could potentiate errors.

In light of cognitive demands, the cognitive processing of interruptions and distractions is of note. The need to respond to interruptions places greater demands on cognitive-processing resources. This can result in loss of memory or confusion among information cues.[27] Human memory impacts cognitive processing. The functional component of memory, long-term memory, includes retrospective and prospective memory.[28] Retrospective memory is retaining the factual knowledge, and prospective memory is planning for future action. There is a critical interval between the formation of an intention to act and the execution of that act.[11] The intention has to be held in prospective memory, a vulnerable part of memory system. Prospective memory may fail, allowing for the danger of error in the medication administration setting. These dynamics of a complex nursing environment, coupled with interruptions, distractions, and high cognitive loads, led us to the formation of a conceptual model delineating the origin of MAEs (see Supplemental Digital Content Figure, available at: http://links.lww.com/JNCQ/A329).

Specific aims

The specific aims of this multisite study were as follows: (1) Describe interruptions, distractions, and cognitive load experienced by registered nurses (RNs) during administration of medications; (2) Examine the relationship of interruptions and distractions on cognitive load; and (3) Investigate the impact of cognitive load on PFs and MAEs. Supplemental Digital Content Table, available at: http://links.lww.com/JNCQ/A330, provides definitions of variables.

METHODS

The structure of this design is hierarchical. The unit of analysis was an episode of medication administration to 1 patient by an RN working in a medical surgical unit. One episode of medication administration included either single or multiple medications.

Study sample

The ISRN recruited hospitals meeting eligibility criteria to participate in the study from their virtual network of hospitals. The inclusion criteria were (*a*) hospitals with 200 or more beds and a defined medical surgical unit, (*b*) unit size of 30 beds or greater, with average length of stay of 2 to 7 days, and (*c*) RNs working part time/full time providing direct patient care and having worked at least 6 months on the unit. The study received institutional review board approval at the principal investigator's institution as well as the participating sites.

Instruments

Demographics

Information collected regarding the participating RNs included their gender, education, experience, employment status, RN-to-patient ratios, shift worked, and sequence of the shift during the work week for the medication administration episode observed.

Structured observation sheet

A structured observation sheet was used for documenting the number and type of medications given, PFs (deviation from the listed steps of the medication administration procedure), and the frequency and sources of observed interruptions. The sheet also had a list of MAEs that could be selected after reviewing the medication administration record to reconcile the medications administered with medications ordered.

Self-report: Distraction experienced during medication administration

A numerical visual analog scale score from 0 to 100 was used for this self-report; 0 represented no distractions and 100 represented the highest rate of distraction. The 9 items were modified from TeamSTEPPS curriculum I M SAFE Checklist; this checklist is specifically recommended for individual health care team members to use for self-assessment as part of situation monitoring. The checklist includes scanning oneself for anything that would distract from optimal engagement with the task at hand.[19] The participants select the numeric value representing their current source of distraction and enter it in the corresponding space provided in the column titled "Rate of Distraction."

NASA Task Load Index

The NASA Task Load Index (NASA-TLX) was used to measure cognitive load. Cognitive load is a multidimensional construct representing the load that performing a particular task imposes on the learner's cognitive system.[29] Mental load is the aspect of cognitive load that originates from the interaction between task and subject characteristics. According to the authors, mental load provides an indication of the cognitive capacity demands and can be considered an a priori estimate of the cognitive load.

The NASA-TLX is a subjective workload assessment developed by the Human Performance Group at NASA Ames Research Center. Originally developed in the aviation industry, the NASA-TLX has been shown to be a reliable (Cronbach $\alpha = 0.72$) and valid (face and discriminant) tool to measure workload. A widely used index to measure mental workload, the NASA-TLX,[30] uses 6 dimensions to assess mental workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. This combination of variables is considered likely to represent the experience of "workload" when most people perform most tasks.[31] A score from 0 to 100 is obtained on each of the five 7-point scales. Increments of low, medium, and high estimates for each point result in 21 gradations on the scale.

Data collection

Data collection procedures were managed by the ISRN Coordinating Center and were identical across all study sites. Each of the participating 9 hospitals was asked to collect data from 96 episodes of medication administration from the study unit, equally divided between RNs participating in the study; 79 RNs participated. Two RNs from each participating site were trained in direct observation and data collection. The RN observers were from other units of the hospital and did not have supervisory authority over the RNs participating in the study.

Data were collected by direct observation of medication administration episodes using a structured observation sheet. The observation method is an efficient and accurate process of collecting error data.[32] Interrater reliability was established prior to data collection. Observers were trained to be unobtrusive and not to interrupt the work of RNs.

As the observers arrived on the unit, each observer was directed to observe the next available episode of medication administration by participating RNs and complete the structured observation sheet. The observers did not have prior knowledge of the medications being given. The participants (RNs giving the medications) were instructed to provide the labels or wrappers to the observer after completing the medication administration. Observers were able to note the form and type of medications given such as tablets, liquids, and oral or parenteral medications.

The participants in each observed medication administration episode were asked to complete the Demographics Form, Self-Report: Distractions Experienced During Medication Administration, and NASA-TLX, after completing each medication administration episode. After completing the observation, the observers reviewed the medication administration record and reconciled the medication administered with the medication ordered to estimate errors.

Statistical analysis

The primary unit of analysis was the episode, a discrete interval of time during which a nurse administers 1 or more medications to a single patient. The 2 primary outcome variables were (1) presence of at least 1 PF in an episode and (2) presence of at least 1 MAE in an episode. Secondary variables included the scores on each of the 5 constructs measured via the NASA-TLX Index. The sixth construct, Performance, was eliminated from analysis because of a technical difficulty in its measurement. Each raw NASA-TLX Index construct score was transformed using arcsine square root transformation to meet normality assumptions.

Descriptive statistics (frequencies and percentages for categorical variables; means and standard deviations for continuous variables) were computed for all variables. As the study included a hierarchical design whereby episodes are nested within nurses and nurses nested within hospitals, generalized linear mixed models were used to analyze the data for the presence of MAEs and PFs, separately, and linear mixed models were used for each cognitive load score. Generalized linear mixed models and linear mixed models were used because they account for the correlation among episodes within a nurse and among nurses within a hospital. Specifically, the significance of variation in each outcome was assessed in terms of both fixed and random effects. Episode-level fixed-effect covariates included presence of a distraction or an interruption, number of interruptions, and number of medications administered. Nurse-level fixed effects included number of shifts worked in a row, education level, gender, age, employment status (full- vs. part-time), and years of experience. For MAE and PF outcomes, the raw cognitive load scores also were each assessed as fixed effects. Hospital and nurse nested within hospital were entered as random effects in each model. All statistical tests were 2-sided, with a significance level of 5% and performed using SAS Version 9.3 (SAS Institute, Cary, North Carolina).

RESULTS

The majority (93.67%) of the 79 RN participants were female. The mean age of the participants was 38.14 (SD = 12.1) years; the means for RN experience and experience in the study unit were 9.59 years and 6.28 years, respectively. Most of the RNs (87.34%) were employed full time. Educational preparation of the participating RNs was as follows: 5.06% masters, 62.03% bachelors, 31.65% associate, and diploma 1.27%. The highest number (56.96%) of medication administration observations was completed during first shift, followed by second (31.65%) and third (8.86%) shifts. Registered nurse-to-patient ratios ranged from 1:2 to 1:8.

Interruptions occurred in 478 of the 857 (67.1%) medication administration episodes, and nurses experienced at least 1 distraction in 575 of the 857 (76.1%) of the episodes. The top 4 self-reported distractions experienced by RNs were (1) unresolved issues regarding other patients, followed by (2) fatigue, (3) hunger, and (4) noise level in the unit (Table 1).

At least 1 PF occurred in 81.3% of the 857 medication administration episodes; however, of the 854 episodes that could be analyzed for MAE, only 8.31% of the episodes had at least 1 MAE observed. The proportion of PFs and MAEs varied from hospital to hospital; for PFs, the proportion ranged from 36.5% to 97.7%, and MAEs ranged from 0 to 36.1%.

There was a significant independent relationship between a nurse having a distraction, a nurse having an interruption, the number of interruptions experienced during a medication administration episode, and each cognitive load measurement (mental demand, temporal demand, physical demand, effort, and frustration). All results yielded $P < .05$ (Table 2). When interruptions were assessed using frequency of interruptions, results

Table 1. Type and Frequency of Distractions by RNs During 857 Medication Administration Episodes

Type of Distractions	n (%) of Episodes With RN Reporting Distractions
Unresolved issues regarding other patients	421 (49.12)
Fatigue	310 (36.17)
Hunger	305 (35.59)
Distracted by noise level	266 (31.04)
Personal factors	261 (30.46)
Bathroom need	180 (21.00)
Worry (RNs worry about own family)	126 (14.70)
Illness	107 (12.49)
Pain (experienced by RNs)	96 (11.20)

Abbreviation: RN, registered nurse.

showed that as the number of interruptions increased, so did the perceived cognitive load construct being measured ($P < .0001$).

Nurses with any distraction had a greater perceived mental, temporal, and physical demand, as well as effort and frustration levels for the medication administration task, compared with nurses who did not have any distractions. The effect of having a distraction was similar to having an interruption on its effect on cognitive load.

A statistically significant relationship was not found between having a distraction, having an interruption or the number of interruptions, and any of the 5 cognitive load measurements with the occurrence of PF or MAEs in an episode. However, there were significant relationships between a nurse's age and risk of MAE ($P = .03$) and between the number of medications being administered within an episode and MAE ($P = .015$). Number of medications was also significantly associated with PF ($P = .0008$). The results suggested that the older the nurse, the greater the risk of an MAE, and as the number of medications being

Table 2. Association of Distractions and Interruptions With NASA TLX Outcomes

	Mental Demand		Temporal Demand		Physical Demand		Effort		Frustration	
Experienced	***M* (95% CI)[a]**	***P***	***M* (95% CI)**	***P***	***M* (95% CI)**	***P***	***M* (95% CI)**	***P***	***M* (95% CI)[a]**	***P***
Distraction		.0024		.0013		.0027		.0044		.0010
Yes	25 (19-31)		24 (19-30)		16 (12-20)		28 (21-34)		23 (16-30)	
No	16 (11-22)		14 (9-19)		10 (6-14)		19 (12-25)		12 (6-18)	
Interruption		.0021		.0040		.0517		.0031		.0025
Yes	25 (18-31)		24 (17-30)		15 (10-20)		28 (21-35)		23 (14-31)	
No	19 (13-25)		18 (12-24)		13 (8-17)		21 (14-28)		16 (8-23)	

Abbreviation: CI, confidence interval.

[a]Means and CIs are reported in the original units for each outcome (score out of 100); analyses were performed using the transformed outcome variables. M is estimated mean score (95% CI). *P* is *P*-value.

administered in an episode increases, so does the risk of MAE or PF.

DISCUSSION

The study findings support the occurrence of interruptions and distractions during medication administration and found a relationship between interruptions and distractions with cognitive load. However, the relationship between cognitive load and PF and MAEs was not supported. This study did not find relationships between interruptions, distractions, and PFs and MAEs reported in other studies.[27,33] This may be due to mitigating factors that prevented PFs and MAEs, failure to detect the relationship, or because this study did not group the definitions of interruptions and distractions together and tested the relationships individually.

The study showed a significant relationship between interruptions, distractions, and cognitive load, not unlike previous research[27] but did not find a significant relationship between cognitive load and PFs and MAEs. There are 3 possible explanations: (1) there may not be any relationship, (2) other variables not measured in the study mitigated the occurrence of PFs and MAEs, and/or (3) the study failed to detect the relationship due to lack of sufficient power. The sample size in this study, estimated to detect 20% of MAEs, was based on previous studies. However, this study sample had only 8.3% MAEs. Detecting the relationships between the multiple variables for a smaller percentage of errors requires a larger sample.

The unit of analysis in this study was medication administration episodes instead of medication doses. This was done to reproduce standard practices of administering multiple medications in 1 episode and capture the complexity of medication administrations. Furthermore, our data collection method did not lend itself to analysis between the variables using individual doses of medications.

The significant relationship between the number of doses in a medication administration episode to PFs or MAEs should not be of surprise.[27] However, a surprising finding was the significant relationship between a nurse's age and MAEs. Although this finding evokes concern, further exploration is warranted prior to drawing conclusions. After adjusting for the number of medications, the significant effect of nurse's age on MAE risk lessened ($P = .043$). The most frequent error was related to inaccurate documentation, followed by wrong time of medication administration. The inaccurate documentation may be a reflection of the change in the documentation process from paper to electronic medical record. The electronic medical record captures actual time of documentation and records medications documented prior to the specific time indicated in the medication administration record. All of the nurses in the study had multiple patients, and routine medications have to be administered within the hour. It is not possible to administer medications to all the patients at the exact time—a few patients will need to receive the medications before the specific time and a few after. However, the medications documented before the time indicated in the medication administration record can be picked up as errors. Also, there are multiple situations in practice that could exceed the 1-hour window for medication administration such as unpredictable patient responses, needs of other patients, and nurses' organizational skills, to name a few.

IMPLICATIONS

Although nurses view interruptions as part of their day,[15] multiple strategies have been suggested that consider not only safe medication calculation and administration but also the personal and professional factors of the individual administering the medication and the complex environment in which medications are distributed. Helpful interruption and distraction strategies already proposed should be followed. These include the use of standardized scripts to handle interruptions,[33] identification and elimination of disjointed travel flow,[13] and reduction in the use of personal mobile devices.[34] Nursing leadership and multidisciplinary teamwork were credited for a reduction in interruptions when specific safety measures were bundled together for maximum effect.[35]

We also suggest the incorporation of mindfulness strategies, memory management devices such as checklists, and visual cues such as warning signs for silence in the medication areas, with frontline nurses having the responsibility of choosing what works best for them to attain safety goals. A just culture where debriefing and analysis of errors and near misses, without fear of blame, is essential for advancing nursing knowledge in this area.

Nurses reported unresolved issues about other patients as their primary source of distraction. This professional distraction needs to be addressed through organizational and leadership strategies. Nurses have to be aware of their own personal needs acting as distractions and how they relate to medication errors. Our study gives evidence to the distracting role of both hunger and fatigue in the daily workflow of the nurse. Hospitality areas on each floor would prevent nurses from experiencing hunger when breaks and lunches are delayed.

The teaching of medication administration in prelicensure programs should be radically transformed to encompass an awareness of organizational systems as well as personal and professional responsibility. The long-held emphasis on medication knowledge competence for students and new graduates must widen to include interruption and distraction management skills. More nursing research is necessary into what cognitive process occurs at the moment of interruption, and how the nurse can respond to the interruption with insight and resume seamless care. To maximize effectiveness, strategies should be directed simultaneously to the individual and the environment. Leadership is critical as medication safety will not evolve without a strong nursing administration emphasis on patient safety, focusing on the quality of the medication administration process.

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