Distractions and Interruptions in the Intensive Care Unit: A Field Observation and a Simulator Experiment

T. Grundgeiger[1], P.M. Sanderson[1], C. Beltran Orihuela[2], A. Thompson[2], H.G. MacDougall[3], L. Nunnink[2], & B. Venkatesh[1,2,4]

[1]The University of Queensland, Brisbane, Australia; [2]Princess Alexandra Hospital, Brisbane, Australia; [3]The University of Sydney, Sydney, Australia; [4]Wesley Hospital, Brisbane, Australia

Distractions and interruptions are frequently mentioned as sources of errors in healthcare research, and laboratory research has shown that they can disrupt cognition. However, the current evidence that distractions and interruptions cause patient harm is mixed. In two studies in an intensive care unit, we investigated whether and when distractions and interruptions might lead nurses to forget critical care tasks. Study 1 was an observational study using a mobile eye tracker. It investigated which properties of an interruption influence resumption times and how nurses manage distractions and interruptions. Study 2 was a controlled experiment in a full-scale patient simulator. It investigated whether reminders improve nurses' ability to remember routine tasks when multitasking and resume interrupted routine tasks. We discuss theoretical and practical implications of the studies.

INTRODUCTION

Intensive Care Units (ICU) are characterized by (1) seriously ill patients, (2) the use of sophisticated equipment to give advanced life support, such as mechanical ventilators and vital sign monitors, and (3) a care team made up of different specialties such as medical, nursing, and allied health staff (Torpy, Lynm, & Glass, 2009). As a result, distractions and interruptions are very common in critical care settings, possibly causing patient harm (Parker & Coiera, 2000).

Recently, Liu et al. (2009) showed that anaesthesiologists who engaged with an interruption were significantly less likely to notice an omitted blood transfusion patient check. Furthermore, Westbrook et al. (2010) showed that interruptions increase the likelihood of medication errors. Finally, Westbrook et al. (in press) observed in an emergency department that interrupted tasks were more likely to be left unfinished than uninterrupted tasks. Although it is unknown whether the interrupted tasks became irrelevant due to the course of the events or were executed by someone else, the study suggests that interruptions can lead to unfinished tasks.

However, a recent study did not find a relation between interruptions and errors (Kalisch & Aebersold, 2010) and three recent reviews on the issue only provide weak evidence for such a relation (Biron, Loiselle, & Lavoie-Tremblay, 2009; Grundgeiger & Sanderson, 2009; Rivera & Karsh, in press).

Overall, interruptions may lead to unfinished tasks and errors in some situations but not others. Theoretically motivated studies can give insights into when interruptions lead to forgetting but they are rare in healthcare (for an example see Grundgeiger, Liu, Sanderson, Jenkins, & Leane, 2008). Furthermore, we know little about the behaviour and strategies that nurses adopt to manage interruptions. Since preventing all interruptions is impossible, interruption management is considered an important strategy to minimise negative effects of interruptions (Biron, Loiselle, & Lavoie-Tremblay, 2009).

In the current paper, we summarize two ICU-based studies in which we attempted theory-driven investigations of when distractions and interruptions might lead to forgetting of tasks. Furthermore, we observed how nurses manage memory demands caused by distractions and interruptions. Study 1 is a theory-driven observational field study using a custom-build mobile eye tracker (Grundgeiger, Sanderson, MacDougall, & Venkatesh, under review): we present a high-level summary of some of its results. Study 2 presents findings that form part of a larger theory-driven experimental study using a full-scale patient simulator and a representative scenario (Grundgeiger et al., in preparation).

STUDY 1

The aims of Study 1 were (1) to apply laboratory based theories to investigate interruptions in the ICU and (2) to understand how nurses manage to resume interrupted tasks.

First, if we have a theoretical account of interruptions, the theory might lead to more specific recommendations for how we can prevent people from forgetting to resume interrupted tasks. Furthermore, it is useful to know if theory generalizes to the field. The *memory for goals* theory (Altmann & Trafton, 2002; Trafton, Altmann, Brock, & Mintz, 2003) and a theory of *prospective memory* – the memory for future tasks - (Dismukes & Nowinski, 2007) were used to model resumption times of interrupted tasks.

Second, the disruptive effects of interruptions on cognition are well known (e.g., Trafton & Monk, 2007). However, the low error rates in relation to interruptions despite heavily-interrupted healthcare settings suggest that nurses somehow manage the disruptive effects of interruptions. Therefore, we investigate how nurses react to prospective memory demands caused by interruptions.

Method

Ethical approval was granted by the local hospital and university committees. Ten senior registered nurses participated in this study. Each nurse wore a mobile eye tracker from the start of their shift (7 am) for approximately 3 hours while taking care of a patient. A total of 27 hours of eye tracking video was recorded and analyzed.

In a first pass, all distractions (audio or visual events that capture the nurses' attention) were identified and classified in three distraction handling strategies:

- acknowledging: brief acceptance of distraction, no hands-off task at hand
- multitasking: dealing with distraction and task at hand concurrently, no hands-off task at hand
- interrupting: turning to distracting task and discontinuing task at hand, hands-off task at hand

Second, all interruptions were further analyzed to model the resumption lag (Trafton, et al., 2003) – here defined as time from end of interruption to the first fixation on the object associated with the to-be resumed task. A multiple regression was calculated to test the model with six predictors distilled from the literature: (1) length of interruption in seconds, (2) context change (defined as a change in location of at least 1 meter because of the interruption), (3) mid-task step interruption, (4) time before attending interruption (*interruption lag*), (5) further distractions during interruption, (6) fixation on task during interruption. Finally, concepts from distributed cognition (Hutchins, 1995) were used to describe how actions of the nurses change the cognitive demands of resuming interrupted tasks. Statistical analysis was done with SPSS17® ($p = 0.05$).

Results

A total of 570 distractions were identified (20.8/hr). Nurses' responded to distractions with acknowledging and multitasking in approximately 2/3 of the cases and interrupted an ongoing task only in approximately 1/3 of the cases.

The interruptions with a computable resumption lag were included in the regression model. The overall model was significant and explained about one third of the variance in the resumption lag. The result of the multiple regression model showed that the predictors *context change* and *interruption length* had a significant effect on the resumption lag.

However, not all interruptions could be included in the model because nurses applied different behavioral strategies that prevented any memory demands and therefore resulting in a resumption lag of zero. First, nurses finished the task at hand before attending the interruption. Second, nurses held artifacts such as syringes in the hand while dealing with the interruption. Finally, sometimes nurses placed reminders in the environment that represented the to-be resumed task.

Discussion

The field study showed that laboratory-based theories on interruptions can be applied to study interruptions in the field. However, the model only explained a third of the variance, indicating that current theories are missing components to account for all variance in field settings.

Nurses showed different behaviors that removed all memory demands (finishing the interrupted task) or lowered demands to dramatically (holding artifact while dealing with the interruption). In the latter case, the artifact is acting as an external reminder that reminds the nurse at the end of the interruption immediately to resume the interrupted task.

The field study has several shortcomings. First, the analysis is based on creating contrasts through post-hoc classification of events rather than through prospective design. Second, all interruptions were unique and distinct. Although this indicates that the theory is "robust", confounding factors cannot fully be ruled out. Third, the resumption lag is only a proxy for forgetting. Accordingly, Study 2 was designed as a follow up study to address prospective memory in general and to overcome limitations of the field study.

STUDY 2

The aim of Study 2 was to investigate the effect of reminders on prospective memory in the context of critical care nursing. The experiment was conducted using a full-scale ICU patient simulator with a representative patient care scenario that included eight prospective memory events. The use of a scripted scenario lets researchers expose all participants to the same initial situation, but lets participants use their expertise and react flexibly to this situation.

From the total of eight events used in the full study, here we only report results for a subset of four events: two involving multitasking and two involving an interruption (defined as in Study 1).

The two events that involved multitasking were used to investigate the effect of multitasking during the execution of *habitual prospective memory tasks* (Dismukes, 2008). Habitual prospective memory tasks have multiple task steps that are frequently done in the same order, such as safety checks. In Study 1, we observed that multitasking during routine tasks, such as checking whether emergency equipment is available and functioning, can challenge remembering of all steps. Based on the concept of distributed cognition (Hutchins, 1995) and findings on prospective memory (Vedhara et al., 2004), we predicted that providing external visual reminders during a distracted safety check would increase remembering of task steps.

For the two events that involved *interruptions*, the prospective memory task was to remember to resume the interrupted task (Dodhia & Dismukes, 2009). It was expected that providing external reminders would increase task resumption (Dodhia & Dismukes, 2009; Hutchins, 1995).

Method

Ethical approval was granted by the local hospital and university committees. A total of 24 registered nurses participated. The study took place in an actual isolation room in the ICU bed space. Equipment included a Laerdal SimMan® manikin with a patient history, paper record, mock-up electronic patient record, mechanical ventilator, patient monitor, syringe drivers, and so on. Each nurse participated in a scenario lasting about 40 minutes representing a morning shift start. The scenario was scripted based on observations and local subject matter experts input. The factor *reminder* (reminder, no-reminder) was manipulated between subjects.

Multitasking during habitual task. As part of their safety checks, nurses in the ICU must check the content of the emergency drawer at their bedside to ensure that a portable

oxygen cylinder is available. During these checks, the night nurse (actor; pretending to write patient notes) engaged the participants in a social conversation (Figure 1, panel A). We recorded whether the participants realized that the 14 Gauge cannula for emergency treatment of tension pneumothorax (long needle to relieve trapped air that is putting pressure on the lung) and the oxygen cylinder were missing.

Depending on the reminder condition, a reminder was either present (i.e., drawer divider with picture of cannula or an empty oxygen cylinder holder) or absent (i.e., no divider or no oxygen cylinder holder). The divider had been introduced 2 months before the study to every bedside to standardize item locations and remind nurses of missing items by providing yellow labels. Before the dividers were introduced, items were loosely placed in the empty drawers. Figure 1 panels B and C show the reminder and no-reminder condition for cannula event.

Interruption of routine task. As part of the bedside safety check, nurses are required to check the patient monitor and the mechanical ventilator settings and alarm limits. In the alarm limits event, the night nurse indicated that she was ready for handover just as the participant was about to finish the check of the vital sign alarm limits on the monitor. The participant therefore needed to remember to resume the safety check of the ventilator settings and alarm limits. The alarm limits tab on the ventilator interface screen was either open (reminder condition) or closed (no-reminder condition).

As part of the patient assessment, nurses must feel the pulse on all four limbs of the patient. The check starts with the radial pulses at the wrist or the dorsalis pedis pulses at the feet. Participants were interrupted by a phone call of a patient relative when at least one pulse was still unchecked. Concurrently, the night duty senior registrar (actor) entered the room and did a quick assessment of the patient. The registrar either covered the limbs (no-reminder condition) or left the limbs uncovered (reminder condition) (see Figure 2).

Recording and Analysis. The scenarios were recorded with two cameras in the room and a mobile eye tracker worn by the participant (eye tracking results not reported here). At the end of the scenario a semi-structured interview was conducted with each participant. Significance testing was done with Barnard's exact test for contingency tables using StatXact8 ® ($p = 0.05$).

Results

Events in which the scenario did not work out as planned were excluded from the analysis (e.g., multitasking or interruption was not initiated). Amongst the n = 24 cases for each event, three cases for the 14 Gauge cannula event failed, four cases of the oxygen cylinder event failed, six cases of alarm limits event failed, and three cases of the pulse event failed.

Multitasking during habitual task. Nurses in the reminder condition realized significantly more often that the 14 Gauge cannula was missing than did nurses in the no-reminder condition. However, there was no significant difference between conditions for realizing that the cylinder was missing.

Interruption of routine task. There was no significant difference in task resumption frequency between the reminder and no-reminder conditions for the alarm limits or the pulse event. However, in the alarm limits event, some nurses did not let themselves be interrupted and finished the check before attending the handover. A post hoc test showed that significantly more nurses in the reminder condition prevented the interruption from occurring compared to the no-reminder condition (no difference in work experience between groups).

For the interruption events, the nine instances in which participants were not interrupted due to failures to initiate the interruption enabled us to observe uninterrupted performance. These instances confirm that uninterrupted nurses always remember to do the alarm limits check or assess the missing pulse as a next step. Despite a numerical difference, a post hoc test between interrupted and uninterrupted tasks showed a non significant result.

Discussion

Results for habitual tasks were mixed. For the 14 G cannula event, nurses were more likely to remember to check for its presence if a reminder was present compared to no-reminder. Providing a reminder for the oxygen cylinder did not increase the likelihood that nurses checked for the cylinder compared to no reminder. The lack of reminder effect for the oxygen cylinder might be because the cylinder is not always at exactly the same location at each ICU bed or because the reminder was not a specific artifact designed for this purpose, as was the case for the cannula.

Figure 1. Missing 14 g cannula event. Panel A shows the participant (right) checking the emergency equipment and talking to the night nurse (actor, far left at computer terminal) concurrently who is finishing writing patient notes (view room camera 1). Panel B shows one possible layout of items in the emergency drawer with no pictorial divider (no-reminder condition). Panel C shows the drawer with pictorial divider (reminder condition). The label in the bottom left corner shows the cannula (arrow).

Figure 2. Interrupted pulse assessment event (view from room camera 2). Doctor (left) and nurse (right) review adrenaline settings on the electronic patient record. The nurse had been interrupted while assessing the patient's pulses on all four limbs. At the point of the interruption, the check on at least one limb was still outstanding. Panel A shows the no-reminder condition (all patient's limbs are covered). Panel B shows the reminder condition (patient's left foot is uncovered).

Neither of the interruption events showed the predicted reminder effect. Similarly to the oxygen cylinder event, neither event included reminders specifically produced for the situation, which might explain the absence of an effect. For the alarm limits event, the results show that nurses in the reminder condition were significantly more likely to finish the alarm limits check before attending the interruption. This suggests that the open alarm limits tab encouraged nurses to finish the check, thereby eliminating any prospective memory demands.

Furthermore, there is an apparent difference between nurses' overall forgetting when interrupted vs. when they could work uninterruptedly (i.e., events in which the interruption was accidentally not initiated). For both the oxygen cylinder and alarm limits events, there was no forgetting if nurses could work without being interrupted, but there was some forgetting if they were interrupted. This is also supported by observations from Study 1 on the corresponding tasks. The effect is non-significant, but this is likely to be due to missing power. It might be that the interruptions led to forgetting of tasks. This interpretation is consistent with a recent finding by Westbrook et al. (2010).

DISCUSSION AND CONCLUSION

The two studies reported explored the specific conditions surrounding nurses' ability to remember to return to interrupted tasks and to remember distracted habitual tasks, as well as what strategies nurses use to manage interruptions.

Study 1, the field study, indicated when task resumption might be more challenging. When interruptions require a change in context and are long they might challenge task resumption. Furthermore, nurses showed various behaviours that diminished or prevented any prospective memory demands.

Study 2, the simulator study, showed that a reminder increases nurses' remembering of habitual tasks while multitasking. Furthermore, in the alarm limit event the availability of a prompting cue such as the open alarm limit tab encouraged nurses to finish the task at hand before attending an interruption.

The results of the studies have implications for theory. The field study showed that theories about task resumption only accounted for at third of the variance. In the field, further factors such as interference between the interrupting and ongoing tasks may be affecting resumption time. Furthermore, current theories do not incorporate how actions by an individual affect the individual's cognitive demands. For example, holding a task artifact while attending an interruption prevents the need to remember to resume which task as the artifact acts as a timely and specific reminder.

The simulator study contributes to our understanding of the effectiveness of reminders. When nurses are multitasking, only an additional artifact, such as the label in the missing cannula event, seems to remind nurses. The reminders for both the interrupted events were not artifacts specifically produced for that situation, which is probably why they showed no effect. Reminders that are not specifically associated with a specific action seem not to prompt memory. This interpretation is consistent with previous healthcare research that showed that only a very specific cue prompted remembering of a habitual task (Grundgeiger et al., 2008) and with general research on prospective memory (Nowinski & Dismukes, 2005). Subsequent analyses with the eye tracking data (not reported here) indicate that reminders can attract attention but in some instances they fail to cue memory, possibly because the cue is not sufficiently specific.

In practice, it might be beneficial for nurses to try to solve interruptions on the spot and to keep interruptions short. Strategies more likely to lead to remembering include holding task artifacts while attending the interruption. Finishing the task at hand before attending the interruption will prevent any memory demands from occurring. The results provide information for distraction and interruption management training (Fox-Robichaud & Nimmo, 2007).

Methodologically, the simulator offered several advantages. With the simulator it was possible to (1) distract and interrupt nurses without possible patient harm, (2) introduce experimental contrasts, (3) repeat situations between nurses,

and (4) provide nurses with all required tools in their usual work environment. In addition, the use of the mobile eye tracker enabled a detailed analysis of retrieval processes.

Limitations include possible undetected confounds and limited generality in Study 1 (e.g., time of day or local ICU layout). Furthermore, Study 2 was conducted in a simulator rather than in the field. However, great care was taken to represent the patient case and the environment as realistically and in as much detail as possible to trigger habitual behavior. Finally, parts of the analysis have been conducted post hoc.

Future research should examine the effects of the environment on behavior and cognition. Specifically, studies should address what triggers behavior such as finishing a task before attending to an interruption or holding artifacts during the interruption. Furthermore, the actions of individuals change the cognitive demands of tasks. Future research on interruptions and prospective memory needs to address theses interactions as they are pervasive in our everyday life. These future studies might indicate how we can design healthcare environments that provide support for remembering distracted or interrupted tasks.

ACKNOWLEDGEMENTS

This paper was written while Tobias Grundgeiger was holding an Endeavour IPRS at The University of Queensland. This project is supported by the National Health and Medical Research Council (NHMRC) Center of Research Excellence in Patient Safety. The Center is funded by the Australian Council for Safety and Quality in Health Care (the Safety and Quality Council) and is designated as a NHMRC Center of Research Excellence. The Safety and Quality Council is a joint initiative of the Australian, State and Territory Governments. We thank Princess Alexandra Hospital ICU staff for support and Matthew B. Thompson for taking photos.

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