November 2016

The Effect of Interruptions on Primary Task Performance in Safety-Critical Environments

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THE EFFECT OF INTERRUPTIONS ON PRIMARY TASK PERFORMANCE IN SAFETY-CRITICAL ENVIRONMENTS

A Dissertation Presented

By

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Submitted to the Graduate School of the

University of Massachusetts Amherst in partial fulfillment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY

September 2016

Industrial Engineering and Operations Research

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DEDICATION

To my husband and my sons and their families

Thank you for your love, your patience, and your support.

ACKNOWLEDGMENTS

My sincere appreciation is given to the many people at the University of Massachusetts, Amherst, who have supported me on this journey. I would like to thank my advisors: Dr. Donald L. Fisher, Dr. Elizabeth A. Henneman, and Dr. Jenna L. Marquard for providing input and guiding my research. Special gratitude is given to Dr. Fisher. Thank you for the many meetings, discussions, and suggestions on how to move my research forward. In sharing your research in Human Factors, you have inspired me to continue the study of human performance in safety-critical environments.

I want to thank Dr. Michael and Theresa Hluchyj. I am honored to have been a Hluchyj Fellow. Thank you for the financial support of my collaborative research in engineering and nursing. This research has added to the body of knowledge that addresses the impact of interruptions in the healthcare environment. I want to continue this research to bring the medical community solutions to prevent errors and improve the quality of healthcare.

I want to thank Dr. Andrew Cohen, Professor at the Department of Psychological and Brain Sciences for inviting me to be part of the Perception and Cognition Laboratory. I sincerely appreciate your support and participating in your lab.

My experiments were conducted in Dr. Henneman's nursing simulation laboratory at the College of Nursing. The faculty and staff at the College of Nursing were wonderful, welcoming, and supportive. Thank you Dr. Henneman and the many individuals at the College of Nursing who made this experience a memorable one.

Finally, I want to acknowledge the staff and faculty at the Mechanical and Industrial Engineering Department. Your helpfulness, support, and cheerful greetings made each day on campus enjoyable and contributed to a wonderful learning experience.

ABSTRACT

THE EFFECT OF INTERRUPTIONS ON PRIMARY TASK PERFORMANCE IN SAFETY-CRITICAL ENVIRONMENTS

SEPTEMBER 2016

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Safety critical systems in medicine utilize alarms to signal potentially life threatening situations to professionals and patients. In particular, in the medical field multiple alarms from equipment are activated daily and often simultaneously. There are a number of alarms which require caregivers to take breaks in complex, primary tasks to attend to the interruption task which is signaled by the alarm. The motivation for this research is the knowledge that, in general, interrupting tasks can have a potentially negative impact on performance and outcomes of the primary task.

The focus of this research is on the effect of an interrupting task on the cognitive behavior of nurses on a primary task: administering medication to a simulated patient. Fifty-eight student nurses were monitored with eye-tracking technology as they perform direct patient care and a medication administration task. There are four hypotheses. First, it is hypothesized that an interruption generated by an alarm during medication administration significantly increases errors because it causes caregivers to forget

components of the original task. These errors result when the primary task is suspended in memory, as a result of the intervening task, and because of this suspension, memory for the original task can decay. Second, it is hypothesized that interrupting tasks result in time delays on the primary task (the time during which the caregiver is performing the interrupting task is not included in the time to perform the original task). Third, it is hypothesized that metacognition training will mitigate the negative effects of the interrupting task on the primary task. The metacognition training is based on knowledge of how memory processes are affected by interruptions and how modifying these processes can potentially result in a reduction of errors. Fourth, it is hypothesized that the intervention strategy will lead to improvements in the memory for the material that is required to resume and complete the primary task. This improvement will be measured by increases in the number of eye fixations to the primary task before attending to the secondary task. Furthermore, this measurement will correlate with a reduction in errors.

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CHAPTER 1

EXECUTIVE SUMMARY

Healthcare workers depend on many electronic health devices to inform them of a patient's health status. This equipment is considered a crucial and important instrument for helping healthcare workers make medical decisions in an environment characterized as demanding, stressful, and with changing goals (Elstein, 2001; Kalisch & Aebersold, 2010). These health devices, whether they are bedside monitors, infusion pumps, or other clinical equipment, are designed to redirect the caregiver's attention to another event by the sound of an alarm. This alarm-based equipment has also caused concern as to it's impact on human performance resulting from the momentary or extended interruptions generated by these electronic health devices (Varpio, Kuziemsky, Macdonald, & King, 2011). A momentary interruption could be as simple as a caregiver recognizing that an alarm requires that something be checked, but the action can be postponed while the primary task is completed. An extended interruption could be as complex as a caregiver recognizing that he or she needes to abandon temporarily and immediately the primary task in which he or she is engaged and undertake some secondary task, only later to return to the primary task. In either case, the alarm, originally viewed by healthcare professionals only as benefiting patient safety, (Phansalkar et al., 2010), has now been identified as a patient hazard itself or as signaling something that could lead to risks to patients (ECRI, 2012, 2013,2014) In particular, both types of task interruptions (momentary or extended) have been reported to increase the caregiver's stress, result in time delays, and importantly, potentially impact the safety of the patient (Antoniadis, Passauer-Baierl, Baschnegger, & Weigl, 2014; Drews, 2007).

This study is motivated by findings from an observational study in the medical literature that has identified a relationship between interruptions and medication administration errors (Westbrook, Woods, Rob, Dunsmuir, & Day, 2010). Additionally, research in the field of psychology has, for the most part, identified interruptions as being disruptive (Altmann & Trafton, 2004; Altmann & Trafton, 2007; Altmann, Trafton, & Hambrick, 2013; Cades, Trafton, Boehm-Davis, & Monk, 2007; Gillie & Broadbent, 1989; Li, Blandford, Cairns, & Young, 2008; Monk, Trafton, & Boehm-Davis, 2008; Ratwani & Trafton, 2008; Trafton & Monk, 2008; Trafton, Altmann, Brock, & Mintz, 2003) and resulting in errors (Altmann et al., 2013; Trafton, Altmann, & Ratwani, 2011; Boehm-Davis & Remington, 2009; Li, Blandford, Cairns, & Young, 2008; Speier, Valacich, & Vessey, 1999; Speier, Vessey, & Valacich, 2003). Finally, despite the extended interruptions being the likely cause of medical errors, there are no training programs designed to reduce such errors.

1.1 Objectives

Given the above as background, the two objectives of this research are: (1) *to evaluate the effect of an extended interruption on a medication administration task and* (2) *to determine whether an intervention reduces the effect of interruptions*. In this Executive Summary, the literature relevant to the design of an experiment to evaluate each of the above objectives is first described. Then the experiment itself is briefly discussed.

1.2 Extended Interruptions and Medical Errors

It is true that these interruptions generated by the alarm are not viewed as unecessary events (Hillel & Vicente, 2003). In fact, the alarm is what directs the

caregiver's attention to a more pressing matter. However, as noted above studies have reported on the negative effects of interrupting on-going critical tasks generated by alarmed-based equipment (Block, Nuutinen, & Ballast, 1999; Borowski, et al., 2011), or discussed what has been called the alarm burden issue (ECRI, 2012, 2013, 2014). Moreover, extended interruptions, the focus of my dissertation, many of which are generated by an alarm, have been identified as resulting in medical errors (Biron, Loiselle, & Lavoie-Tremblay, 2009; Liu, Grundgeiger, Sanderson, & Jenkins, 2009; Magrabi, Li, Day, & Coiera, 2010; Westbrook et al., 2010), frustration and stress (Antoniadis et al., 2014), increasing the cognitive load on caregivers (Rivera-Rodrigues & Karsh, 2010), and leading to delays in performing the original task (Antoniadis et al., 2014), all which could lead to patient safety issues (Drews, 2007).

Yet, empirical evidence linking extended interruptions to negative outcomes, in particular to medication errors, is still not conclusive. For example, many studies in the medical field that study interruptions have been prospective or retrospective observational studies or surveys (Biron, Lavoie-Tremblay, et al., 2009; Biron, Loiselle, et al., 2009; Brixey et al., 2008; Grundgeiger, Liu, Sanderson, Jenkins, & Leane, 2008; Grundgeiger & Sanderson, 2009; Grundgeiger, Sanderson, MacDougall, & Venkatesh, 2010; Kalisch & Aebersold, 2010; Westbrook et al., 2010) or literature reviews linking interruptions to adverse affects (Li, Magrabi, & Coiera, 2012; Rivera-Rodrigues & Karsh, 2010).

It is generally accepted that interruptions have negative consequences and result in medical errors but there is little scientific evidence to support this assertion. Experts contend that a lack of a theoretical framework to support interruptions in healthcare,

particularly related to the cognitive processes affected by interruptions, have limited an understanding of the causal relationship between interruptions and adverse events (Grundgeiger et al., 2009). They suggest that future research informed by cognitive theory, could provide guidance for the study of interruptions and in particular, for the evaluation of interventions to mitigate negative consequences.

In summary, no study in a healthcare setting has designed a controlled experiment to analyze an extended interruption generated by the alarm addressing both medication administration errors and time delays.

My study uses a psychological memory-based theory to explain the error and time outcomes recorded from this study. Thus, I now want to focus in more detail on those studies in psychology that have measured the cost of interruptions in terms of errors (Altmann et al., 2013; Li et al., 2008; Trafton et al, 2011). Studies in the field of pyschology have found the interruption to be disruptive in terms of time delays (Altmann & Trafton, 2004; Altmann & Trafton, 2007; Monk et al, 2008), sequence errors (Altmann et al., 2013; Trafton et al., 2011), procedural errors (Li et al., 2008), and imparied human performance (Dodhia & Dismukes, 2009). In particular, two interruption theories, Memory for Goals theory (Altmann & Trafton, 2002) and prospective memory theory (Dismukes, 2010; Dodhia & Dismukes, 2009), have defined frameworks to describe how interruptions influence individuals. These theories suggest that the delays in the return to the original task, interference from residual memory goals, and the method by which environmental cues are used to recover from the interruption can explain the process by which interruptions influence behavior. Understanding this process can potentially provide insight into strategies that can lessen the negative effects of interruptions. My

research will incorporate the Memory for Goals theory because it gives me a distinct cognitive timeline to measure the influence of interruptions, something not as easily provided by prospective memory theory. From this point on, this theory will just be referred to as Memory for Goals.

1.3 Mitigating Errors

There are currently no training programs in healthcare designed specifically to address the effect of extended interruptions on the performance of a primary task. However, the broad literature on theory and practice suggests how one might construct a successful training program, one that reduced errors on a primary task when it was interrupted for an extended period of time by a secondary task. Briefly, medical researchers (Croskerry, 2000, 2003) advocate the the need for medical personnel to have simple cognitive strategies that can be used to reduce errors and to assist caregivers in acquiring these strategies. But what simple cognitive strategies migth be helfpul in this context? Well, in this regard the memory-based theory that stress the importance of mentally encoding a placemark on the primary task before disengaging from that task could be used as a starting point. As noted above, this memory-based theory is Memory for Goals (Altmann & Trafton, 2002). In particular, Memory for Goals maintains that the seconds right after the individual is made aware of the interruption – but before attention is directed to the intervening task – is an opportunity for the to-be-suspending-task to be strengthened in memory for later activation.

The next question one needs to ask is how best to emphasize to participants the need to mark their place in the primary task before moving on to the extended interruption. In the domain of driving, it is clear that error management programs work

best. Given that safety is the key component in the domain of driving, it could well be the case that error management training works best in the healthcare field as well in this particular context. This training is based on the 3M (mistakes, mentoring, and mastery) method (Romoser & Fisher, 2009). For this type of training to work, first and foremost the participants must make an error in the context of the training environment which they believe would represent their behavior in the real world. Second, the participants must be told, when it is not obvious, why they made a mistake and how to mitigate the mistake (mentoring). Third, the participants must be given the opportunity to use the knowledge that they aquired and practice the faulty behavior until they master their errors. The training program I developed for my dissertation is designed to apply the 3M training method to the types of errors that healthcare workers make when transitioning from the primary to the secondary task (i.e., to the extended interruption) before returning to the primary task.

1.4 Dissertation Experiment

As noted above in my statement of objectives, because studies in the healthcare field have looked at the correlation between errors and extended interruptions, first and foremost I wanted to design an experiment which would make it possible to determine whether there was a causal relationship (as opposed to a correlational one) between extended interruptions and errors on a medication administration task. Then, second, assuming that it was possible to establish that extended interruptions were the cause of medication administration errors, I was also interested in determining whether it was possible to design a training program that mitigated the negative effects of the extended interruptions.

1.4.1 Evaluation of Performance on Medication Administration Task During Interruptions

First, I needed to determine what task to study in the healthcare field and what general category of participants to use in the experiment. The experiment was designed to introduce an abrupt and extended interruption to a primary task which requires the caregiver to remove her or his visual attention from the primary task. This would replicate the real-life environment of a clincal setting where the medical alarm is considered an abrupt and non-negotiable event (i.e., an event which requires an extended interruption). A medication administration task was selected for this study as the primary task based on research that cites this task is one that is frequently interrupted (Biron et al., 2009; Kalisch & Aebersold, 2010; Westbrook et al., 2010). A nursing environment was choosen for this experiment since studies have reported nursing tasks are interruption intensive work settings (Brixey, et al., 2005).

Second, I needed to identify a scenario which would provide the evidence I required that a causal relation could be identified between an extended interruption and errors on the primary task. The extended interruption in my experiment is both a manual and cognitive disengagement from the on-going primary task that is required in order to respond to an intervening task presented by the bedside monitor alarm. The on-going primary task as noted above is a medication administration task, delivered to an elderly simulated patient. The patient was situated in a laboratory that duplicated a fully functional clinical single patient room. The medication administration task consisted of an initial verbal assessment by the student-nurse, verification of the patient's identification and medical documentation records, and delivery of an antibiotic via a pre-connected interlink injection system into the patient's intravenous site.

Third, I needed to determine who would best serve as participants in the study. The participants in this study were senior nursing students at the College of Nursing, University of Massachusetts on the Amherst campus. These students had been academically trained to perform the primary task in this study and thus any effect of the extended interruption generated by the alarm is associated with the impact of the interruption and not a lack of knowing the sequence of tasks that need to be performed, either with the primary on-going task or the secondary interrupting task.

Fourth, I needed to decide on a setting in which to run the medication administration task. Given the participant population, this research took place in a patient simulator nursing laboratory at the College of Nursing at the University of Massachusetts Amherst. This simulator is utilized as part of student nursing education in the third and fourth year of academic training and is designed to replicate a single patient room. The patient simulator is controlled by the Laerdral SimMan system that was programmed with vital parameters associated with the health status of the patient.

Fifth, I needed to decide on the experimental design that was required to evaluate the two objectives of my dissertation. With the above as background, the initial focus of my study was on the comparison of the errors made by participants who were subjected to an interruption (experimental groups) with those who did not experience an interruption while performing a medication administration task (control group). Errors made during this medication administration task were identified as the absence of a procedure based on standard medical administration nursing procedures. During this first segment of the experiment, the control group performed the same medication

administration task as the experimental group, but did not experience an interruption during the task.

Finally, for this part of the study I needed to decide what information to collect in order to measure the effect of extended interruptions on nurses' behavior. The error rates of the experimental group were compared with the same measures of the performance of the control group on the first evaluation. The groups who received an interruption were further classified into three different categories as a function of the type of training (active, passive, no-training) they received to mitigate the effects of the interruption generated by the alarm. The no-training group served as the control to the other training groups. The second evaluation then compared the effects of the training to mitigate errors. Additionally, the time period in Memory for Goals, termed the Interruption Lag, is measured in my study to determine if the process taught to participants in the training, to remember their place in the primary task reduces future errors in the medication administration task.

Medical studies report that caregivers experience delays in the performance of tasks if an interruption causes a break in the primary task (Antoniadis et al, 2014). These delays are believed to be the result of the disruption caused by the extended interruption in the performance of the primary task or a delay in the return to the primary task after completing the secondary task. Therefore, in my study I also measured the time to perform the primary medication administration task, when that task is interrupted by a secondary task generated by the alarm alert. The purpose of this test was to substantiate the observations, by medical caregivers, that interruptions result in a delay in the performance of the primary task.

1.4.1.1 Eye Behavior Data Analysis

During my experiment, the student-nurse participant was wearing a mobile eye-tracker to collect audio and video files. These files were recorded by an Applied Science Laboratory eye-tracking recording device. The experimenter analyzed these files and documented time, error, and eye-fixation data.

1.4.2 Design and Evaluation of Training Program

The subsequent focus of my study was on the effect of training on errors during the medication administration task. The training took place after the initial assessment of the performance of nurses who did experience an interruption during the medication administration tasks. With respect to the evaluation of training, I needed to determine what different types of training might be consistent with previous programs which proved successful. One training method is called Active Training. This training is based on the 3M (mistakes, mentoring, mastery) method described above (Romoser & Fisher, 2009) which stresses that actively engaging individuals in the tasks where they are known to make errors (mistakes), providing them with feedback on their errors (mentoring), and given them the opportunity to master their behaviors in scenarios which lead to errors (mastery) will greatly reduce their chance of making errors. The second training method is called Passive Training. This method involved some components of the Active Training method, but did not provide the participants with the opportunity to review their errors, or to master the behaviors which had led to their errors. The Passive Training group was provided information on how interruptions could lead to errors. Finally, the performance of the experimental (trained) and no-training group (untrained) participants was compared on the medication administration task. The participants experienced an interruption generated from the alarm, as in the first experimental trial, a second time.

After the training period, the medication administration task was repeated for these three group and the errors observed and recorded. The same dependent variables were measured here as were measured in the original evaluation of the effect of extended interruptions on the performance of a medication administration task.

CHAPTER 2

LITERATURE REVIEW

2.1 Psychology - Origins of Interruption Theory

The study of interruptions have their origin in psychology, with early studies demonstrating that interrupted tasks were easier recalled than completed tasks (Zeigarnik, 1927/1938). Consequently, the interruption was not considered a deterrent although later research would refute that theory. The ability to recall an interrupted task was based on a self-generating force called 'memory-tension' that directed one to complete an unfinished task. These special memory structures were available and ready whenever the subject needed to recall past information.

This memory tension system did not presume a need for an external stimulus or cue to support remembering since this system was based on both a recall and resumption mechanism (Butterfield, 1984). The memory tension concept was based on Gestalt theory that asserts the mind's tendency to connect objects as a whole (Lewin, 1938) and was developed by early 20th century German philosophers (Johnson, 2014). Gestalt is a German word that loosely translates to pattern or form, and refers to one's perceptual mental organization. Zeignarik (1927/1938) set out to prove that it was the gestalt memory structures that enabled her subjects to remember which tasks were uncompleted and presented her subjects with multiple tasks, where half of the tasks were interrupted and the other half not. These tasks ranged from drawing pictures, multiplication problems, counting backwards, and so forth (Van Bergen, 1968). After all the tasks were completed, Zeignarik asked her subjects which tasks they recalled. The experimental results from her first study showed that "interruption of a task greatly improves its

chances of being remember (Zeigarnik, 1927/1938)". Zeignarik's studies focused on retrospective memory asking subjects to recall past intentions of the uncompleted task. Her studies did not explore how well those intentions could be successfully carried out to completion (Einstein, McDaniel, Williford, & Dismukes, 2003). That focus on prospective memory, or the ability to remember where to resume after an interruption, would not come until many years later.

Interruption studies that followed Zeignarik's work, between 1927 and 1968, incorporated many human characteristics such age, fatigue, personality, among others to measure the effect of the interruption (Van Bergen, 1968). These studies helped to further the understanding of interruptions, but no consistent pattern of how interruptions influenced human behavior developed (Van Bergen, 1968). Van Bergen notes that many of these studies did not consider any theory to support their outcomes. The lack of a unifying theory in the early interruption studies was also echoed as a concern in other interruption research during this period (Prentice, 1944). Even today, interruption research has a strong applied focus and the lack of theory driving the research, especially in the medical domain is noted as a concern (Grundgeiger & Sanderson, 2009). Researchers have highlighted the importance of using memory theory to support findings on interruption studies (Monk et al., 2008). A theoretical and quantitative approach could continue to build on research that examines the behavorial and cognitive impact when an individual breaks their train of thought.

2.1.1 From Tension Theory to Current Interruption Models

Few studies in the decades from 1920 to 1980 pursued the question of interruption effects (Monk et al., 2008). However, in 1981 Kreifeldt & McCarthy set out to study individuals' performance on calculators and computers when subjected to interruptions.

These researchers wanted to understand if different calculator interface designs resulted in different performance when subjects were interrupted during the task. They found that interruptions increased the time to perform calculations on one particular type of interface and recommended that the device be "performance resistant" since interruptions were to be considered a common occurrence. Interestingly, this theme of making situations resistant to interruptions is still discussed today and is now referred to as interruption tolerance (Oulasvirta & Saariluoma, 2006).

In 1989 Gillie and Broadbent measured the interruption's disruptiveness on a problem solving task. Gillie and Broadbent determined that the complexity of the interrupting task and the similarity of the interrupting task to the primary task resulted in a disruptive effect as measured by a time delay to complete the primary task. This focus on time, as a dependent measure, is still a principal focus of interruption studies.

After the Kreifeldt & McCarthy (1981) and Gillie and Broadbent (1989) studies, interruption research became more common and started to examine interruption effects on human performance and errors, among other variables. New theories and models were developed to explain outcome effects as a result of being interrupted. One theory that incorporates interruptions into a cognitive architectural model was the goal-activiation memory theory called Memory for Goals. This theory offers a cognitive framework and timeline to measure the disruptiveness of an interruption and is utilized in the current research.

2.2 Memory for Goals – A Goal Activation Model

Memory for Goals (Altmann & Trafton, 2002) is a memory-based theory that establishes how individuals suspend current tasks into memory and then retrieve these

tasks. Tasks in this theory are also called goals. A goal in this context refers to a previous intention that has been suspended to accommodate a new assignment. Memory for Goals is based on the cognitive architecture theory, Adaptive Control of Thought (ACT-R) (Anderson, 1996; Altmann & Trafton, 2002). In this cognitive architecture theory when an individual needs to suspend one task to attend to another, the memory system pushes the to-be-suspended information into an allegorical stack-like device in the mind. A stack in this context is similar to how computers store information in holding places while performing operations. When an individual requires that suspended information, the memory system simply retrieves that information off the stack. In this cognitive model, the memory system needs no special device to recall the last task since information in memory is ready and available when the mental system requires it.

Altmann and Trafton (2002) suggest that this goal stack concept cannot fully explain how individuals suspend and remember past intentions since some individuals exhibit difficulty in retrieving suspended goals. Altmann and Trafton (2002) believe mental effort is required to retrieve past intentions and that multiple cognitive and temporal factors need to be considered for the goal recovery process.

Altmann and Trafton (2002) developed the Memory for Goals theory, which is based on goal-directed cognition, much like ACT-R, but supports the need for cognitive effort to recover past intentions. Memory for Goals (Altmann & Trafton, 2002) explains the cognitive and temporal factors that transpire when an interruption forces an individual to suspend a current task and the process to retrieve that task back into “active” memory.

In this theory when one is interrupted, the current task is pushed below an “activation level” in memory to make room for the new task to be performed. This

activation level represents a figurative memory dividing line where past information is no longer active but is in a suspended state until needed again. The new task now moves into the primary memory position and directs behavior. A key element in this theory is the length of time the old task is suspended below the memory activation line. Memory decay can result from the task being suspended for too long. Memory decay is rapid and if the task is suspended over 30 seconds, support for a recovery process is required (Cane, Cauchard, & Weger, 2012). This recovery process depends on how many times in the past the current task was performed and if environmental cues are available at the time of task suspension and recovery.

Due to these suspended memory tasks, time delays, and interference possibilities, memory needs to be strengthen during segments of the interruption process to keep those past goals more active in memory. These refresh opportunities take place both during the the seconds before engaging in the new task, and in the time immediately after the interrupting event (Trafton et al., 2003).

The time period following an interruption, where the interrupting event is known but the secondary task has not started is called the Interruption Lag. The Interruption Lag is a period of time when the individual can mentally strengthen the to-be-suspended goal, thereby increasing its activation level in memory before fully engaging the intervening task (Altmann & Trafton, 2002; Altmann & Trafton, 2004; Hodgetts & Jones, 2006; Trafton et al, 2003). This strengthening process is also called ‘encoding’ (Altmann & Trafton, 2002; Trafton et al., 2003).

An example of this encoding process was presented to me in relationship to the clinical nursing task of medication administration (E. Henneman, personal

communication, 2014). Interruptions during procedures such as administering medications to patients are known to result in errors (Biron, Loiselle, et al., 2009; Westbrook et al., 2010). These medication errors can be serious or even fatal if, for example, the wrong medication is given to the wrong patient. In a discussion with a nurse about the need to mentally encode information prior to engage an interrupting task, she indicated that she places her hand on the current medication container before disengaging the medication task to respond to an interrupting event. This placement of her hand is the encoding process Memory for Goals proposes to accurately resume a suspended task. While in this case it is a manual process, it can also be a mental representation, a mental placement of sorts to return to the original task.

Figure 1 describes the major components of the interruption timeline as defined by Memory for Goals. For example, as mentioned, T1 is the time when the interruption is known but action to the secondary task has not started and is defined as the Interruption Lag. The action on the interrupting task is T2 in Figure 1. This is the period where attention has shifted to the secondary task and the primary task is now in a suspended state.

After the interruption event has ended and the secondary task has been completed, the cognitive system retrieves the suspended goal as a function of its activation level in memory. This retrieval process takes place during the time period called the Resumption Lag. The Resumption Lag is the time to resume a suspended task (Altmann et al., 2013; Monk et al., 2008; Trafton et al., 2003) and is denoted as T3 in Figure 1.

The availability of cues during the interrupting event, that were also visible during the time period T1, can additionally support memory during the Resumption Lag (T3).

For example, if an individual is in the middle of writing a document and the phone rings; the visual cue of the document helps to strengthen memory before that task is suspended and also, during the interrupting event, and during recovery of the goal after the phone call has been completed.

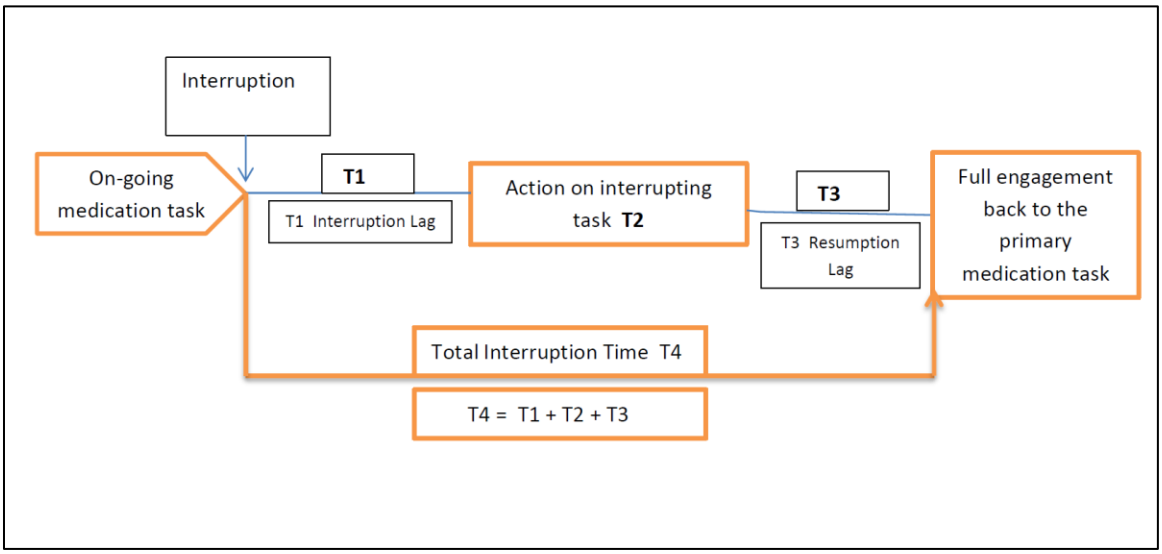


Figure 1 Interruption Timeline and Major Components

Some authors have called attention to the inability of Memory for Goals to explain learning effects seen over time (Trafton et al., 2003). For example, some studies have found interruption effects to lessen over multiple sessions (Altmann & Trafton, 2007; Trafton et al., 2003). Memory for Goals does not provide an explantion for this adaptivity effect but suggest that training to use the Interruption Lag to strengthen memory for recovery could lessen the disruptive effects from the interruption (Altmann & Trafton, 2002).

Memory for Goals research has reported interruptions to be disruptive, mainly in terms of the delay the individual experiences to resume the original task. However, other factors and interruption characteristics, such as the complexity of the interrupting task

and the position of the interruption in the task, among others, have been studied as to their effect on outcome and performance.

2.3 Interruption Definition and Characteristics

The term, interruption, for this research project, is defined as disengagement from a primary task to attend to a secondary task. This definition is in line with many well-defined constructs used in the literature today. For example, Li, Blandford, Cairns, and Young (2008) define interruption as an "abrupt onset of a different task activity during the execution of a primary task" and Brixey, Johnson, and Turley (2007) derived the concept of interruption as a "break in the performance of a human activity initiated by a source internal or external to the recipient."

Researchers have tended to use one or two characteristics as factors in interruption studies. Not all characteristics are defined uniformly in the literature. My research does not study the characteristics of the interruption, such as duration of the interrupting task or the complexity of the interrupting task. However, I do discuss some aspects of these characteristics as they relate to the outcomes in my study.

2.3.1 Length of Interruption Duration

Researchers have found that length of time of the interruption, also called duration, is a factor that contributes to disruptiveness (Trafton & Monk, 2008). The interruption duration is the time period from when the individual has taken action to engage the secondary task until the time that the secondary task has concluded. Interruptions durations, have ranged from 2.8 seconds up to 75 seconds in research studies. Research has identified that interruption durations, over 30 seconds, typically result in disruption effects (Cane, Cauchard, & Weger, 2012; Monk et al., 2008; Oulasvirta & Saariluoma, 2006)

There is general support for the relationship that longer interruption durations result in resumption delays, increase error rates, and sequence errors. (Altmann & Trafton, 2004; Brumby, Cox, Back, & Gould, 2013; Hodgetts & Jones, 2006; Li et al., 2008; Monk et al., 2008; Monk, Boehm-Davis, Mason, & Trafton, 2004; Ratwani & Trafton, 2010; Trafton et al. 2003; Trafton et al., 2011).

2.3.2 Interruption and errors

Researchers have identified the effects of interruption duration on errors. Altmann, Trafton, and Hambrick (2013) report that even very short (4 seconds) interruptions can have significant impact to certain types of errors, called sequence errors. Sequence errors are missteps in returning to the original task. These authors noted that interruptions of 4 seconds can triple the rate of sequence errors in returning to the correct step and interruptions as short as 2 seonds can also significantly affect resumption accuracy.

2.3.3 Complexity of Interrupting Task

Complexity of the interrupting task is a factor contributing to the disruptiveness of an interruption (Cades, Trafton, Boehm-Davis, & Monk, 2007; Gillie & Broadbent, 1989; Monk et al., 2008; Speier et al., 1999; Trafton, & Monk, 2011). Byrne and Bovair (1997) have defined complexity as, "number of actions to be performed, number of subgoals to be completed, amount of information to be assimilated and acted on." However, the majority of interruption studies do not report on the complexity of the interruption task. Additionally, the term, complexity, has not been strictly defined (Monk et al., 2008). Some researchers have used a processing requirement to define the complexity of the interrupting task. For example Gillie & Broadbent (1989) had subjects memorize different items on a list and this reflected a processing demand for working

memory. Monk, Trafton and Boehm-Davis (2008) use the term processing demand instead of interruption complexity in their research to measure the disruptiveness of the interruption due to increased cognitive demands. They suggest that equating complexity to demands of working memory more adequately models the restriction imposed by the memory system to process two tasks concurrently. However, few interruption researchers have elaborated on the factors which contribute to the complexity of the interrupting task.

2.3.4 Suspension and recovery cues

The Memory for Goals theory (Altmann & Trafton, 2002) proposes that cues, available at the suspension and recovery of the primary task are paramount to task recovery. These cues allow for a stronger activation of the suspended goal and enables memory to overcome any interference effects or decay (Altmann & Trafton, 2004; Boehm-Davis & Remington, 2009; Cane, Cauchard, & Weger, 2012).

2.3.5 Interruption control, position, and recovery

The point at which the individual is interrupted in the task has been found to have significant effects on resumption (Li et al., 2008; McFarlane, 1999; Monk et al., 2004). Memory for Goals states that when a person performing a task is cognitively engaged, the activation level in memory for that task is at its peak. When the interruption occurs during this high activation period, more mental effort needs to be expended to push that current task below the activation level in memory.

2.3.6 Interruption effect on time

One measure of interruption disruptiveness is the delay – measured in time - to recover from the interruption. This delay is most noticeably demonstrated in the time period called the Resumption Lag (Monk et al., 2008; Trafton et al., 2003), the time after

the interrupting task is completed to the first action back to the primary task. This time, denoted as T3 in Figure 1, typically measured in milliseconds, is a sensitive measure of the impact of the interruption.

Delays in performing the primary task, called global delays, have also been observed (Bailey & Konstan, 2006; Gillie & Broadbent, 1989; Speier et al., 1999; Speier et al., 2003). Bailey and Konstan (2006) demonstrated that when their subjects were interrupted during reading, adding, counting tasks, and among other similar tasks, they performed the task more slowly. They hypothesized that this slow-down was due to mental resources being used to reorient to the original task. Gillie and Broadbent (1989) demonstrated that the time spent on the second part of problem, after returing from the interrupting task, took a longer time than the time spent on the problem prior to the interruption, although this effect was not always significant. Magrabi, Li, Day, and Coiera's (2010) study of error rates and completion times on complex and simple tasks on a computerized order entry system determined that the interrupted task's completion time was shorter for simple tasks, but longer for complex tasks. However, these times did not reach significance in this study. One production management control study, looking at interruption effects, identified that interruptions resulted in a speed-up effect on simple tasks, but resulted in a longer completion time on complex tasks (Speier et al., 1999). Simple tasks in this research consisted of the subject assembling information from visual cues for a decision task.

Speier, Valachch, and Vessey (1999) commented that the speed-up effect they observed was contrary to many previous interruption studies, which demonstrated a slow-down effect. They suggest that interruptions have been known to cause attention

narrowing due to stress or anxiety. One outcome from attention narrowing is that the individual uses fewer cues to make decisions and the task is completed faster (Baron, 1986; Speier et al., 1999).

On the other hand, the healthcare literature has associated interruptions and distractions with delays in the time to complete a task (Antoniadis et al., 2014).

2.4 Interruption in Healthcare

Today's work environments are fragmented, often involving tasks of short durations (Trafton & Monk, 2008). One reason for this fragmentation in the healthcare environment is the frequency of interruptions. Several healthcare studies have reported on the frequency of these interruptions, in particular to the nursing care process (Kalisch & Aebersold, 2010;. Potter, et al., 2005; Westbrook et al., 2010). These interruptions, whether extended or momentary, come with a potential cost in terms of frustration, errors, and delays (Bailey & Iqbal, 2008; Hillel & Vicente, 2003) especially when they disrupt safety-critical tasks such as medication administration (Westbrook, et al.,2010).

There are many sources of interruptions cited in the healthcare literature and the source of these interruptions will vary as a function of medical environment. For example, in hospitals, healthcare workers can experience numerous work interruptions per shift. Potter (2005) cites that nurses can be interrupted up to 30 times in one shift and Biron, Lavoie-Tremblay et al., (2009) report that nurses are interrupted 6.3 times an hour. Many of these interruptions involve healthcare workers interrupting each other (Biron, Lavoie-Tremblay et al., 2009). Interruptions are also associated with technical equipment and, in particular, alarms. Researchers have reported that technical equipment alarms can constitute between 4.5% to 13% of interruptions (Biron, Loiselle, et al., 2009), and

Drews (2007) reported that the second largest category of interruptions were from alarms. Westbrook et al., (2010) reported that 37% of interruptions are from monitor alarms. Finally, Grundgeiger et al. (2010) reported that alarms represented 94% of interruptions in an Intensive Care Unit (ICU).

It is generally accepted that interruptions have negative consequences and result in medical errors, but there is little scientific evidence to support this assertion. The Institute of Medicine report (1999) raised awareness that interruptions contribute to medical errors. Collins et al. (2007) reports that distractions and interruptions are frequently viewed as negative and can impact patient safethy. One primary task often interrupted is the medication administation task. This task has been reported as the most interrupted nursing task with 29% of all work interruptions (Biron, Loiselle, et al., 2009) occurring during the medication administration process. These authors state that this task is especially vulnerable to cause patient harm. Westbrook et al. (2010) reported that each interruption is associated with a 12.1% increase in procedural failures, such as a failure to read medication labels and failure to check patient identification and a 12.7 % increase in clinical errors, such as a wrong drug, or a wrong dose.

Memory failures due to interruptions have been studied as a cause of error in medical tasks (Dieckmann, Reddersen, Wehner, & Rall, 2006; Grundgeiger et al., 2008), yet memory theories have only recently been used as a theoretical basis for studying interruptions in healthcare (Grundgeiger et al., 2010).

Healthcare workers frequently cite that interruptions contribute to medical errors, result in disruptions to primary task, increase cognitive load, and are perceived in causing delays to perform safety-critical fucntions (Antoniadis et al., 2014; Biron, Lavoie-

Tremblay, et al., 2009; Biron, Loiselle, et al., 2009; Brixey et al., 2007; Colligan & Bass, 2012; Collins, Currie, Patel, Bakken, & Cimino, 2007; Cornell, Riordan, Townsend-Gervis, & Mobley, 2011; Drews, 2007; Grundgeiger & Sanderson, 2009; Grundgeiger et al., 2010; Kalisch & Aebersold, 2010; Li et al., 2012; Magrabi, Li, Day, & Coiera, 2010; Potter, et al., 2005; Rivera-Rodrigues & Karsh, 2010; Westbrook et al., 2010). The effects of interruptions in healthcare have been a major concern for both caregivers and patients for many years as cited in many of the references above. What has yet to be determined is how interruptions increase medical errors, what type of errors result from interruptions and what error mitigation strategies are most effective in minimizing the negative consequences of an interruption.

2.5 Error-based Training

There are many ways to train participants to develop skills that reduce safety-critical errors, roughly categorized into active and passive strategies. Passive strategies include those that do not require actual responses of the participants during the training itself, e.g.. lectures. Active strategies include those that require the engagement of the participant. Active strategies are more effective in general than passive strategies (Ivancic & Hesketh, 2000; Romoser and Fisher, 2009).

Error-based training is one type of active strategy that has shown to be effective in both healthcare (Henneman et al., 2014) and non-healthcare settings (Pradhan, Pollatsek, Knodler, & Fisher, 2009; Pradhan et al, 2011) when visual scanning is a critical skill. For example, in the transportation arena an older driver-training program that takes the 45 minutes to administer has effects that last up to two years (Romoser, 2011).

These error-based training programs include scenarios where the participants are likely to make errors that they believe are predictive of the errors that they would make in the real world. In a healthcare setting they might include a simulated scenario where patient identification information contained on a patient identification wristband differed from the patient information on the medication record (Henneman et al., 2014). Healthcare workers' eye movements and responses would be recorded and then played back to them pointing out where they had neglected to inspect key pieces of information. In transportation, they might include scenarios (on a simulator or in the field) where potential (latent) threats were hidden. Again, participants' eye movements would be recorded. Failures to glance towards a potential threat would easily be visible on the record of eye movements.

Regardless of how the errors are recorded, the participants' errors are then shown to the participants. Those conducting the training program then provide the participants with strategies for mitigating these errors. The participant is then provided an opportunity to repeat the scenario in which the error occurred, thereby mastering the skill and hence reducing errors to a minimum. Because the training programs has three components – mistakes, mentoring and mastery – it is sometime referred to as a 3M training program (D. Fisher, personal communication, 2014; Romoser & Fisher, 2009).

CHAPTER 3

EXPERIMENT

The objective of the Experiment is to examine the influence of the extended interruption as a result of the alarm on the medication administration task. The objective of repeating the experiment, after different training scenarios, is to evaluate intervention strategies, enabling caregivers to understand the interruption error process, thereby, lessening the negative impact of the interruption.

3.1 Experiment Description

To repeat, the goal of the experiment is to determine the role that extended interruptions play in medication administration errors. This study involves an on-going clinical care evaluation with one medication administration task. The extended interruption, generated by the alarm, is introduced during the initial phase of the medication task. This is a single experiment with two components.

The first component measures the impact of the interruption, in terms of error generation, on the medication administration. The goal of this component was to determine whether there is a causal relationship between the extended interruption, generated by a bedside monitor alarm, and errors on a medication task.

The goal of the second component is to conduct an intervention that would give nurses the skills and tools to mitigate the negative effects of the task being interrupted. The intervention strategy is based on the concept of metacognition and uses the 3M training methods that are described shortly. The cognitive technique that is provided as part of this training is based on memory theory that describes how memory processes are

affected by interruptions. Understanding these processes can strengthen memory for the primary task that is interrupted.

As noted previously, the theory motivating the design of cognitive training in the experiment is Memory for Goals (Altmann & Trafton, 2002). In Memory for Goals, it is projected that during the Interruption Lag, a period where the subject is made aware of the interruption but has not yet engaged in the secondary task, individuals have the opportunity to encode information on the primary task for task recovery. This encoding process strengthens the suspending task before the individual needs to switch attention to attend to the intervening task. Researchers have identified that the Interruption Lag is one such time period for this strengthening process to take place (Cane et al., 2012; Grundgeiger et al., 2010; Trafton et al., 2003). The assumption is that the strengthening process helps to make that suspended task more accessible for recovery when the individuals has to recover past task information. It is assumed that the individual will form an intention to resume the primary task after the interrupting task has been completed.

My research utilizes eye-tracking technology to capture eye movements during the direct patient care process. As such, I am able to collect eye fixation data during the Interruption Lag. The number of fixations measured in this time period is counted. I assume that the larger the number of fixations, the more likely is an individual to be encoding information for recovery of the primary task. A pictorial representation of the interruption event during the experiment is represented in Figure 2. This representation is based on the Memory for goals (Altmann & Trafton, 2002). The encoding process takes place in the time segment called T1 in Figure 2. Encoding time is relatively quick and a

short span of a few seconds is sufficient to encode a goal into memory (Altmann & Trafton, 2002; Trafton et al., 2003). This cognitive encoding represents a mental placemark of sorts to enable one to return to the original task. The duration of the Interruption Lag, T1, is recorded in this study to evaluate the encoding process.

As mentioned, Memory for Goals also defines a return measure from the interruption. This is called the Resumption Lag and is labeled T3 in Figure 2. This return measure is not a measure of interest for this study as the focus is on the encoding process that takes place during the Interruption Lag.

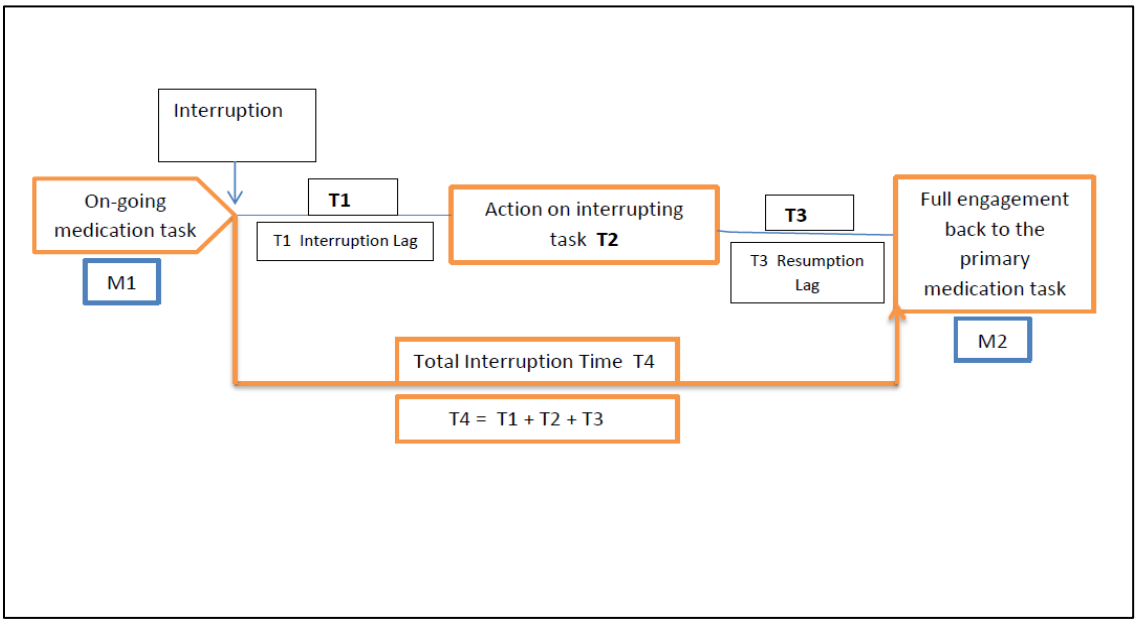


Figure 2 Interruption Timeline for Experiment

Finally, I need to define the total time to perform the medication administration task. This is simply the sum of M1 plus M2. Note that the time to perform the total extended interrupting task is not included in this computation.

3.2 Experimental Design

The experiment involved an on-going clinical care evaluation with one medication adminstration task. Participants were assigned to different groups as they arrived at the simulation laboratory. All particpants performed the medication administration task, however, only one group, the control group did not experienced an extended interruption. The control group consisted of 17 student nurses.

The individuals who experienced an extended interruption during the medication administration were randomzied into one of three categories which consisted of two different training methods and the no-training category which served as the control for the training groups. These training methods will be discussed momentarily. This group consisted, in total, of 41 student nures.

The first evaluation of the experiment consisted of measuring the effect of the interruption in terms of time and error. This evaluation was performed with both groups performing the experiment once. The control group (no interruption) did not continue with the experiment after this first evaluation.

After this first evaluation, the group who experienced the interruption during the medication administration task continued to participate in the second evaluation. The second evaluation consisted of measuring the effect of the intervention training to mitigate errors. The student-nurses were assigned to one of three possible categories to assess the intervention.

One group received the active training method and will be called, hereafter, the Active training group. The invididuals in this group received the extended interruption during the medication task and then received an active training module which consisted

of a video playback of their behavior in the presence of the interruption, metacognition training on how to manage interruptions, and up to 4 mastery exercises which provided practice on metacognition skills. After the training, these individuals immediately performed the same medication interruption task with an extended interruption. There were 14 participants in this group.

Another group received the passive training method and will be called, hereafter, the Passive training group. The individuals in this group received the extended interruption and a passive training module. This passive training consisted of the metacognition training on how to manage interruptions and a three item questionnaire that solicited their view of how interruptions could affect their nursing tasks. The Passive training group immediately performed the same medication administration task, after the training, with an extended interruption. There were 13 participants in this group.

The final group, called No-training, performed the medication administration task with the extended interruption, but did not receive intervention training on how to manage interruptions. This group acted as the control group to assess the active and passive training method. This group immediately performed the same medication administration task with an extended interruption as the Active and Passive training groups. This group will now be referred to as the No- training group. There were 14 participants in this group.

All groups followed the same process upon arriving at the simulation laboratory. This process included signing the consent form as the first step. Then I provided them with an introduction to the simulation room and equipment. They received a briefing on the eye-tracking equipment and operation before they are asked to place the eye-tracker

on their head. Once the eye-tracker was calibrated, the participants were instructed to begin the medication administration task.

3.3 Experimental Hypotheses

Four major hypotheses are evaluated.

Hypothesis 1: Nurses who experience an extended alarm interruption during the medication administration process will commit significantly more medication errors than those who do not experience an interruption.

Hypothesis 2: Nurses who experience an extended alarm interruption during the medication administration process will take significantly more time to perform the primary medication administration task (M1 + M2, Figure 2) than those who do not experience an interruption.

Hypothesis 3: Nurses who are given 3M training, which includes a metacognitive component, will make significantly fewer errors when interrupted during a medication administration task. Additionally, participants who are provided active training will perform better than those who are given passive training and both training groups will perform significantly better than the No-training group.

Hypothesis 4: Metacognition training significantly increases attention to the primary task just prior to that task being suspended by an alarm indicating the nurse needs to focus on the interrupting task. The effectiveness of the training in this regard will be measured by the increase in the number of eye fixations in and duration of the Interruption Lag. Furthermore, these two measurements correlate with reductions in errors.

The motivation for the hypotheses is discussed in more detail here. Hypothesis 1 is that an extended interruption results in a significant increase in the likelihood that nurses make an error during the medication administration process. The motivation for this hypothesis is supported by the medical literature previously cited that makes the case for interruptions to lead to errors in medical procedural tasks. In an observational study the rate of medication procedural failures was demonstrated to increase appreciably with interruptions (Westbrook et al., 2010). However, there have been no randomized controlled studies which have compared the performance of one group who has been interrupted with another another that has not been interrupted on the primary task (Grundgeiger & Sanderson, 2009).

Hypothesis 2 is that an extended interruption results in a significant increase in time to complete the primary task (exclusive of the time to complete the secondary task, i.e., M1 + M2). In other studies, the principle dependent variables in measuring the disruptivenss of an interruption is the time to resume an interrupted task (Monk et al., 2008) and an increase in overall task processing time resulting from an interruption for complex tasks (Speier et al., 1999; Speier et al., 2003). In my study, I evaluate this hypothesis using the total time to complete the medication administration task. Again, this is the time the particpant spends on the medication task minus the time to perform the interrupting task.

Hypothesis 3 is motivated by research that has been referred to above and now needs to be discussed in more detail. This research indicates than an understanding of the the error process when a nurse is interrupted is vital to incorporating strategies appropriate to remediating these errors in a clinical situation. In order to better motivate

the hypotheses, I need to discuss in more detail the interventions the Active training and the Passive training group received. First consider the Active training group. The goal of the intervention and the training is for nurses to see for themselves that interruptions cause them to make errors. The training method is based on the 3M (mistakes, mentoring, mastery) technique to teach individuals how to respond to hazard identification and mitigation training. 3M training has been proven effective over and over again in the world of driving and should prove equally effective here (Romoser and Fisher, 2009). Briefly, nurses are shown the video of them performing the medication administration during the interrupting event and see for themselves that interrupting the primary task can cause them to make errors on the primary task. They are then given metacognition training which provided them with the tools that they need to innoculate themselves against future interruption errors. The metacognition aspect of this training is discussed shortly. Finally, the Active training group is given a chance to practice these new tools.

The Passive training group is given the passive training (mentoring only). In particular, the Active and Passive groups are given training in the mentoring component on the cognitive root causes of the error and understanding the error process as noted above. People can learn to manage the cognitive processes involved in the interruption timeline and learn the technique of mentally placemarking their current position to increase memory activation for a successful recovery process (Altmann & Trafton, 2002; Cades et al., 2011; Dodhia & Dismukes, 2009). However, no research has incorporated a metacognition decision tool as part of the training process for interruption research. The metacognition component of the training stresses a conscious interruption strategy to

encode a placemarker for a return position, upon an interruption, if the nature of the alarm permits this opportunity. While this training approach has been previously advocated, this is the first study to implement a metacognition focus as part of the training program in a controlled experiment.

Hypothesis 4 is movitated by research that demonstrates a causal link between the eye movements of the subject during an interruption in the primary task and the resulting resumption accuracy (Ratwani & Trafton, 2010; Ratwani, McCurry, & Trafton, 2008). The underlying theory of Hypothesis 4 is based on the associative theory of Memory for Goals (Altmann & Trafton, 2002) which predicts if a strengthening process can take place on the primary task before that task is suspended in memory, a quicker and more accurate recovery back to the primary task is possible. This strengthening process is also referred to as encoding and for this study, is measured during a time period called the Interruption Lag and is denoted at T1 in Figure 2.

3.4 Training Concept, Method, and Cognitive Strategy

The goal of the training is for nurses to see for themselves that interruptions cause them to make errors. My hypothesis on the interruption caused by the alarm is that healthcare workers do not have the time, nor the training, to sufficiently mentally placemark information in the primary task prior to attending to the resultant alarm information. Researchers discuss that due to the fast-paced and regularly shifting goals in the healthcare domain, wokers seldom have the time to refect on the current task before redirecting their attention to another event (Biron, Loiselle, et al., 2009; Grundgeiger et al., 2010).

Again, alarm interruptions are meant to serve as a notification signal for a potentially harmful situation. In this sense, they are important. However, the impact of these alarm interruptions on the individual cognitive process needs to be clearly understood. Moreover, cognitive strategies need to be developed that will assist the healthcare professional to manage any negative impact from alarm interruptions.

The concept to teach cogntive strategies is based on the reflective approach of Metacognition (Flavell, 1992; Nelson, 1992). Metacognition is the self-awareness of one's action and involves a conscious effort to redirect behavior based on knowledge of one's goals. Metacognition is aslo defined as an iterative learning process that incorporates a task activity (Salas, Fiore, & Letsky, 2012). In other words, it is a self-directed and feedback-based system that can be taught. The training method is based on the 3M approach as previously described. This training method stresses that showing individuals the error process and giving them the opportunity to practice these skills to mitigate errors results in improved performance. Finally, the cogntive technique that is taught is based on Memory for Goals that supports the hypothesis that an individual can learn how to placemark their current position on a task before switching attention (Altmann & Trafton, 2002; Cades et al., 2007).

Studies have looked at cognitive strategies to overcome the negative effects of interruptions. However, many of these strategies are not realistic in the event-driven, fast-paced environment of the medical world where frequent extended interruptions are generated by an alarm. For example, one solution for the cognitive system to manage interruptions is to have the interruption occur at a "sub-task boundary" (Boehm-Davis & Remington, 2009). A sub-task boundary in reading a book would be the mental pause

one takes between reading chapters. This boundary signals an end to one thought before the next thought begins. The problem with this solution is that medical alarms do not and cannot wait for a convenient sub-task boundary if an urgent situation is at hand.

Boehm-Davis and Remington (2009) highlight that in fast-paced, complex environments, such as healthcare, the cognitive system is not well adapted to handling and assimilating multiple pieces of information imposed by the interruption. In this regard, cognitive strategies that can assist the healthcare worker to manage the sequence and processing of information could prove beneficial.

Memory for Goals supports the hypothesis that people can learn to manage the interruption process and learn the technique of placemarking goals in memory (Altmann & Trafton, 2002; Cades et al., 2011). The nursing literature has suggested that training caregivers about the interruption process, and in particular the encoding process, could mitigate negative effects from interruptions (Colligan & Bass, 2012). Researchers (Trafton & Monk, 2008) have suggested that individuals can be taught how to develop strategies to minimize effects of interruption and these strategies could be incorporated into healthcare programs.

The goal of the metacognition training is for the participants to consider using a cognitive strategy before responding to an alarm interruption. Of course, it is stressed that this may not be possible in all situations given the gravity of a patient's condition.

3.4.1 Metacognition Training

The metacognition training in this study consisted of seven powerpoint slides that were viewed on a computer screen by the participant. The metacognition training encouraged nurses to select an interruption strategy which requires them to reflect, however briefly, on the fact that they are moving from one task to another. For example,

the training suggested that they could make a mental note before disengaging from the primary task. It was stressed that this action only required one to two seconds of attention to cognitively placemark their current sequence in the task. Moreover, if time permits, they might consider spending one to two seconds to glance back at the primary task after engaging the secondary task. Alternatively, if the task is critical and time permits, they could decide to finish the primary task. However, once finishing the primary task they should engage in the same reflective (note to self) and behaviorial (eye glance) activities vis a vis the interrruption. The goal of the training was to teach a cognitive process to strengthen memory on the current task. While this training approach has been previously advocated, (Altmann & Trafton, 2002; Croskerry, 2000, 2002, 2003; Sherbino, Dore, Siu, & Norman, 2011; Trafton et al., 2003; Trafton & Monk, 2008) this is the first study to implement metacognition training in a controlled experiment with a medication administration task.

The training also suggested the use of artifacts to support memory for the recovery function (Grundgeiger et al., 2010). For example, the training stressed that placing their hands on the object, that is a component of the task to be suspended, could provide an additional aid for memory.

Eye tracking terminology, such as the word ‘fixation’, was not incorporated as part of the training material. Instead, technical phrases were avoided and plain langauge was used.

3.4.2 Active Training Method Process

The active training method process consisted of the following specific steps. After the participant completed the first medication administration task, I asked them to watch their reaction to the alarm by reviewing the video tape with me. During this

activity, I asked them to describe what they were thinking when they heard the alarm. There were 14 participants in this active training category. After this discussion, I asked them to review the training slides titled, Managing Interruptions. The mastery exercises followed this training.

The mastery exercises are listed in Appendix A. The participant was asked to perform three to four tasks to practice the metacognition training. Not every task will be reviewed here but I will discuss the sequence of the Mastery Task #1. Task 1 asked them to read the patient's vital sign flow sheet information out-loud. This document was located on a tilt table at the end of the patient's bed and listed the patient's vital signs. When the participant read the respiratory information on the flow sheet, the alarm alerted. I asked them to walk over to the patient's right side and read the patient's ID band information out-loud to me. This required a context change to move to another location. After the participant read the information on the patient's ID band, I then asked them to give me information about what they were doing or reading at the time of the alarm. The purpose of these exercises was to practice the mental encoding technique stressed in the metacognition training.

Two to three exercises followed after this first exercise. After the participant completed these mastery exercises, the experiment was restarted. In some cases, the eye calibration had to be repeated due to the eye-tracker monocle shifting from its original position.

The time to perform the metacognition training and the mastery exercises ranged from 15 to 20 minutes. Additional time to recalibrate the eye-tracker averaged 5 minutes before starting the experiment again.

3.4.3 Passive Training Method Process

The passive training method process consisted of the same metacognition training slides. However, the participants did not view their behavior to the alarm or practice any mastery exercises. Rather, after reviewing the training slides, they were asked to complete a three point survey. The survey asked them to describe, in their own words, how interruptions could affect their work. The survey also asked them to consider how they could use the metacognition training in their work. These comments are listed in Appendix D. After the participant completed the survey, the experiment was repeated.

The time to perform the metacognition training and complete the three point survey ranged from 15 to 20 minutes. Many of the participants took off the eye-tracker while they completed this exercise so they would be comfortable writing their input to the survey. Consequently, eye calibration had to be performed again before starting the experiment.

3.4.4 No-training Process

This group performed the medication administration task twice. No training, survey, or video playback were provided. If the particpant had any questions about the alarm alert, I referred them back to the nursing report (Appendix A) which indicated the patient had a difficult time keeping the 02Sat probe attached to her finger and consequently the O2Sat probe had a tendency to fall off and trigger the bedside monitor 02Sat alarm.

3.5 Method

3.5.1 Participants

Participants are student nurses in their senior year of a four-year baccalaureate program. The student nurses had been previously academically trained in the task(s)

planned for the experiment and had prior experience administering medications in both simulated and actual hospital settings. This ensured that any performance issues with the medication administration task was not the result of a lack of theoretical knowledge or experience on the part of the student nurses, but rather, the result of the effects of the extended interruption. There were no exclusion criteria for participating in the study such as age, types of prior clinical experience, or the wearing of glasses or contact lenses (due to the eye-tracker).

3.5.2 Setting

3.5.2.1 Simulated Nursing Environment

The nursing environment for this experiment is located in Room 214 at the College of Nursing. This room is a fully functional, clinical, single patient room. In many hospital environments, the medication room is a separate room from the patient's quarters. For this experiment, however, the medication room is isolated off to one side of the patient's room. A clearly marked sign, titled, Medication Room, identified the area as the simulated medication room. Studies have identified the medication room as the location of frequent interruptions (Biron, Lavoie-Tremblay et al., 2009; Potter, et al., 2005), and thus this experiment presents an opportunity to study the influence of interruptions during a medication administration task in a location identified as a common interruption setting.

3.5.3 Equipment

3.5.3.1 Eye Tracker

An Applied Science Laboratories (ASL) Eye-tracking recording device was used to measure and record eye movements during the experiment (Bedford, Massachusetts). The ASL system uses the pupil to corneal reflection technique to determine the relationship between the pupil and the cornea to compute the location of the gaze in the

scene environment. The system consists of the Data Transmit Unit (DTU), the Scene Mounted Unit (SMU), the eye camera, and the external computer laptop with the Mobile-Eye XG and ASL Results+GM File Analysis Tool. The Mobile-Eye XG unit has an update rate (frequency) of 60 hertz. The exact update rate reported by the unit is 59.975 cycles per second. The scene camera had a resolution of 640 x 480 pixels and a search window of 590 x 430 pixels.

The ASL software resided on a Dell E5520 computer running Windows 7 operating system. The SMU model is SMU-XG-0054; the DTU processing unit is model XG12-0050.

Eye movement data is collected automatically by the ASL unit data throughout each trial. A fixation is defined as a successive sample of points within one degree of visual angle for a period of at least 100 ms. A fixation is terminated when 3 successive samples are outside the 1 degree of visual angle.

The eye data measures, such as the fixation number and time of the fixation, are contained in either a .csv or .txt file. Eye measures such as fixations are a function of various characteristics, such as color of the iris or the ability of the individual's eye to maintain fixation stability. For example, fixation data can be influenced by the amount of blinking the eye performs and the rapid head movements observed with some participants.

The fact the an individual is fixating on a given location does not indicate directly that the individual is attending to this location, but often this is the case (Just & Carpenter, 1976), often enough that in my experiment the fixation location is assumed to be the locus of attention.

3.5.3.2 Calibration of Eye Tracker

The eye tracker calibration was made with the participant sitting a distance of approximately 2 feet from the 9-point poster. This calibration focal length was to ensure eye fixation capture for viewing and reading the medication documentation used in this experiment.

This calibration procedure took, on average, 5 to 10 minutes to complete.

3.5.3.3 Patient Simulator Laerdral SimMan

The Laerdal SimMan patient simulator is a realistic patient model used in learning environments. The Laerdral simulator generates patient's vital signs, such as blood pressure, heart rate, respiratory rate, and other physiological vitals and displays them on the patient's bedside monitor. The model used for this experiment is Laerdral version 3.5.0 release date of February 22, 2011. The Laerdral operating system was running on a Latitude E5510 15" screen running Windows version 7.

The simulated patient for this experiment was an 85 year-old woman recently admitted to the hospital from a nursing home with a diagnosis of dehydration and pneumonia. The nursing report, given to the student participant, provided a comprehensive overview of the medical history and current status of the simulated patient. The nursing report is included in Appendix A.

3.5.3.4 Other Equipment

A Baxter Flo-Guard Model 6201 infusion pump controlled the flow of normal saline solution into the patient's IV site. The infusion rate was preset to 75ml/hour as per the nursing report. Therefore, the participant did not have to program or adjust any

information on the infusion pump. The infusion pump was present only to provide a realistic simulation of the medication administration task.

3.5.4 Procedure

3.5.4.1 Subject Recruitment and Induction

Internal Review Board (IRB) approval at the University of Massachusetts Amherst for this experiment was obtained including the method of subject recruitment and induction. Subject recruitment was achieved through postings and visiting classes to hand out the postings. Interested subjects called or emailed the study's principle investigator or her designee to schedule times for the experiment.

3.5.4.2 Simulator Scenario

Each participant was greeted as they entered the room. I asked the participant to sit at a desk located inside the simulation room. This was a desk against the wall with the appropriate paperwork for the subject. I asked the participant to sign the consent form (Appendix C). Consent forms had been previously emailed to the participant when they had agreed to take part of the study. The participant was given ample time to read the consent form again and I answered any questions they had on the study at this time.

I then asked each participant to join me for an orientation to the simulated laboratory and equipment. We stood together at the end of the patient's bed and I discussed the layout of the room and the equipment in the room. I indicated that they would not have to program or manipulate the infusion pump settings for this experiment. I then asked them to return to the desk to read the nursing report (Appendix A). If they had any questions on the nursing report, I answered the questions. We reviewed the purpose of the simulation which was to administer a medication to the simulated patient. I stressed that this study was not time-based and that they should work at a normal pace.

I asked them to sit on a chair to start the eye-tracking calibration procedure. After the calibration, each participant returned to the foot of the patient's bed to perform a scan of the room wearing the eye-tracker. This scan was a validation that the eye-tracker was working and I could capture their field of view. At this point, I asked them to begin the process of administering the medication as per the nursing report instructions.

3.5.5 Tasks

3.5.5.1 Medication Task

A standard medication administration task is performed by the student-nurse. This medication task consists of administering either a dose of Ampicillin (500 mg in 100 ml 0.9 NS IV) or Cefotetan (1 gram in 100 ml 0.9 NS IV) to the simulated patient. Each unit is preconnected to a Baxter Interlink System. The Baxter interlink system is a 76" injection site, lever lock cannula with a luer lock adpater. The medication bag and Baxter Interlink system is pre-connected and placed in a 11" x 7" container placed on the medication table. Therefore, the subject had to pick up the medication bag and Interlink system, verify the correct information on the medication documentation, verify that the medication is for the patient currently in the room, and insert the medication into the patient's intravenous site.

3.5.5.2 On-going Clinical Care Task

The simulated scenario used in the research involves direct patient care of an elderly woman admitted to the hospital from a nursing home. Physiological parameters, associated with the patient's case, e.g. heart rate, blood pressure, respiratory rate, oxygen saturation and temperature, were displayed on a bedside monitor. Time-based parameters

are programmed into the Laerdral system and displayed on the on a Spacelab 19" XPrezzon ™ Touch Bedside Monitor.

The physiological parameters were steady-state throughout the experiment and were programmed into the unit.

Heart Rate	Blood Pressure	RR	02Sat %	Temperature
90	120/70	20	95%	98.5 °F

Table 1 Patient's Vital Signs

The simulation scenario involved the student nurse performing a variety of routine procedures typical of those required in the clinical settings (Henneman, et al., 2014). For example, the student nurse would monitor the vital signs, review the patient's medication chart, and verify the patient identifcation prior to delivering the medication treatment.

The nurse-subject is instructed, per the medication administration record, that the patient requires the medication to be administered as soon as the initial assessment period has been completed. This is documented on the medication administration as "now." To reflect standard medication retrieval practices, the medication is located in a box and had to be properly identified and compared with the identifcation information on the patient's ID band and medication chart.

During this medication administration, the participants in interruption groups are interrupted from an alarm signal from the patient's bedside monitor.

3.5.5.3 Interruption Stimulus

The interruption in this study is triggered via a bedside alarm generated from a Spacelab 19" Xprezzon bedside monitor alarm. The alarm was activated by the experimenter. The experimenter observes when the participant starts the medication administration task. This is noted as when the participant is directly in front of the medication table and either a manual or visual contact with the medication is detected. The interruption occurs approximately 5 to 10 seconds into the medication administration task. This delay is inserted in order to give the particpant sufficient time to read enough information so as to not feel like they have to start the process over when they have completed the interrupting task.

The alarm produces an audible signal and the out-of-limit physiological parameter, Sp02, is displayed as a flashing yellow number on the bedside monitor. The alarm only stays active until the particpant acknowledges it or the experimenter brings attention to the situation by assuming the voice of the patient and saying that the oxygen saturation finger probe did not feel right. The experimenter is the voice of the patient during the experiment. At this point the alarm is cancelled by the experimenter. The physiological parameter, Sp02, displayed on the bedside monitor returns to a normal state and the alarm is silenced. *The intent of the interruption is to force a break in the medication administration task.* Only one interruption occurs in this study.

Support for the timing of this interruption is based on research that has initiated the interruption concurrent with another task, as in Grundgeiger, et al., (2008) or was introduced when a participant began a medication task (Magrabi et al., 2010). Additionally, the experimenter is monitoring the participant's eye data during the

interruption event to ensure at least two to three eye fixations or gaze crosshairs have been directed at the medication container before initiating the alarm.

3.5.6 Data Collection

Data for the experiment is collected by the Applied Science Laboratory Eye-Tracking system. At the start of the experiment, the record function is activated on both the Data Transmit Unit (DTU) and the Mobile-Eye laptop software to monitor, collect, and store data both as an .avi and .csv file. The .avi is a standard video and audio file. The .csv is a comma-separated value tabular file in plain-text format. Both files are analyzed in addition to any notes taken by the experimenter during the trials.

Each subject is assigned a random four alpha string. These alpha strings were generated from an on-line random string generator at RANDOM.org. Additionally, the participants were randomly assigned to one of the four groups as they entered the simulation laboratory.

As mentioned above, 58 particpants took part in this experiment. Each experiment had one to three video files associated with the trial. The control group had one video file. There were 17 participants in the control group. The Active training group had three video files; they were, the pre-training file, the mastery file, and the post-training file. There were 14 participants in the Active training group. The Passive training group had two video files; they were, the pre-training file and the post-training file. There were 13 participants in the passive training group. The No-training group had two video files associated with the trial; they were, the first trial (evaluation) file and the second trial file. There were 14 participants in the No-training group.

There are a total of 113 video files.

3.5.6.1 Fixation Data

A total of 34.15% eye fixation data were lost on the video files from the three groups who experienced an interruption. This was due to either the eye tracking losing the eye reflections or the quick pace (and head movement) of the participants in this environment. Since the test for Hypothesis 4 required both pre-and post-fixation data, some additional fixation data needed to be excluded for the final analysis.

3.5.7 Dependent Variables: Time, Errors, and Fixations

There are four dependent variables in this experiment: time to perform the medication administration task, errors, number of fixations during the Interruption Lag, and the duration of the Interruption Lag.

Medication administration errors are identified as the failure to perform the medication administration procedue as intended based on standard nursing practices. This definition is consisent with the Institute of Medicine (IOM) definition of medical error (1999). The errors will be defined in a following section.

These variables are described in detail below. The first set are associated with time spent performing the medication administration task, including a description of typical events during the extended interruption. The second set is associated with eye-tracking measures. I then discuss the medication administration errors defined for this study.

3.5.7.1 Total Time Spent on Primary Task

A medication administration task is the primary task in this experiment. The total time spent working on the primary task is calculated as follows: Total Time = total time to perform the medication task minus interruption duration.

The medication task consists of the delivery of either the Ampicillin or the Cefotetan into the IV catheter. This primary task should include the following specific steps:

- Verification of the patient's information on the ID band to the medication order.
    - The medication order can be either the Medication Administration Record (MAR) or the medication bag label.
- Verification of the medication bag label to the MAR
- Verification of the correct patient by verbally asking the patient for their name, date of birth, and asking the patient if they have any allergies.
- Insertion of the medication into the patient's catheter. The catheter is located in the left arm of the patient.

The medication start time is defined as the first gaze/fixation detected directed to the medication table, or when the participant is facing the medication table if no fixation data is available. The medication administration end time is the time the Intravenous (IV) canula, connected to the medication bag (Ampicillin or Cefotetan) is inserted into the injection site on the patient's left arm.

Some student-nurses had difficulty inserting the canula. Although, this situation did not occur frequently, if this case was observed, the end of the medication task was defined as the first attempt at inserting the canula into the IV site. The total time on the medication task, then, is from the start of the task, specified to the point where attention is directed to the medication table to when medication is administered.

The interruption time is subtracted from the medication administration task time. The following description is further provided to define the interrupting event.

3.5.7.2 The Interruption

The time duration of the interruption is not included in the medication administration time. Typical activities during this time could involve the nurse comparing the patient's vital sign information displayed on the bedside monitor, based on the alarmed physiological parameter, with the procedural knowledge obtained from their professional training. In this experiment, the alarm was generated when the 02Sat parameter reached 90%. Some typical nursing actions involved the participant reading the value of the 02Sat parameter on bedside monitor and incorporating this information with procedural knowledge to initiate action. A typical action, performed by the participant, was to check the patient's nasal cannula or raising the height of the bed. Typically, these actions were accompanied by asking the patient how she is feeling. The interrupting event duration varied depending on the numbers and types of actions performed by the participants.

3.5.7.3 Fixations and the Interruption Lag

The ASL eye-tracking software, throughout the experiment, collected fixation data automatically. Fixation data is then calculated in the time duration called the Interruption Lag.

The Interruption Lag duration is defined, for this experiment, as the time between the alarm alert, which signified the start of the secondary task, to the first eye fixation or the first detected gaze/crosshair on the secondary task.

3.5.7.4 Errors on Medication Administration Task

Medication administration errors are categorized into procedural and clinical errors (Westbrook et al., 2010). Clinical errors include: wrong drug, wrong dose, or wrong

timing to deliver the medication. Clinical errors are not part of this experiment. Procedural errors include: failure to read the medication label, failure to check patient identification, and failure to check the medication administration information on the medication administration record among other responsibilities. Only procedural errors are included in this study.

Procedural errors are classified into two categories for this experiment. Active errors are defined as error types that could result in harm, whereas, latent error are due to systems or routines that may not result in immediate harm but may at some point result in harm. Unlike active errors, latent errors are difficult to identify and measure (E. Henneman, personal communication, 2015).

Additionally, medication administration tasks are classified into two phases; preparation and administration (Potter et al., 2005). While the extended interruption generated by the alarm occurs during the preparation phase of the medication administration task, errors could be made in either one of these phases in this study. The description of the active and latent errors types are listed next.

3.5.7.5 Active Error Types

There are six potential active error types defined in this study. The error types define actions that must be performed before the medication is administered to the patient.

ACTIVE ERRORS	Active Error Descriptions
A	Not checking patient's ID band to medication bag label or to the MAR
B	Not checking MAR to the medication bag label
C	Not checking the patient's identification on the ID band (on the patient's wrist)
D	Not asking patient's name
E	Not asking patient to state DOB
F	Not asking patient about allergies

Figure 3 Active Error Types

- **Active error A**

Active error A is defined as a failure to compare the patient identification information on the ID band to the medication bag label or to the MAR

- **Active error B**

Active error B is defined as a failure to compare the information on the MAR to the medication label before administering the medication to the simulated patient.

- **Active error C**

Active error C is defined as a failure to verify the patient's verbal statement of their name and DOB information with the information on the patient's wristband. Usually, the participant is holding the patient's wrist and reads-out-loud the information.

- **Active error D,E,F**

These error types are defined as the failure of the participant not verbally asking the patient for their name, date of birth, and if they have any allergies. The patient responds with their name, DOB, etc. to complete this step. The experimenter is the voice of the patient for this activity.

3.5.7.6 Latent Error Types

There are four latent error types. Latent errors are error types that should be part of routine care in a real clinical setting, but are not directly related to the medication administration process per se. However, due to the simulated environment, these actions may not be considered by the participant to be of importance. All these actions must be performed before the medication is given to the patient.

LATENT ERRORS	Latent Error Descriptions
J	No self introduction
K	Not checking medication to drug book
L	Not scanning monitor when alarm alerts
M	Not washing hands
N	Self-introduction does not include full name (for informational purposes only)

Figure 4 Latent Error Types

- **Latent Error J**

This error is defined as the failure of the student to introduce themselves to the patient during the experiment.

- **Latent Error K**

This error is defined as the failure of the participant to check the nursing Davis's Drug Guide for Nurses (14th Edition) for any nursing implications (for the medication). Note that this book was not available during the first week of the experiment. Consequently, this error type was not recorded until the book was part of the experiment.

- **Latent Error L**

This error is defined if the participant fails to perform a visual scan of the bedside monitor when the alarm alert is recognized. Note: due to the ASL scene camera vertical

field of view limitation, the participant's direct gaze on the monitor panel is not always possible to detect. However, if the participant turns to face the monitor, it is assumed that this event occurred.

- **Latent Error M**

This error is defined as the failure of the student to wash their hands during the experiment. Again, due to the ASL scene camera limited field of view, the hand-wash unit was not always visible in the eye-tracking scene. If I heard the participant pressing on the hand-wash pump, I marked this action as completed. If they never approached the hand-wash unit, I marked this error as occurring.

- **Latent Error N**

For information purposes only, not included in the analysis.

3.5.7.7 Descriptive Statistics - Errors and error rates

Active and latent errors are summed and compared between the group who received an interruption to the group who did not receive an interruption for the first evaluation of this experiment. For the second evaluation of this experiment, these errors are then compared pre-and post-training only for the group(s) who experienced an interruption.

Errors are normalized by defining the opportunity for each error in the trial. For example, if six opportunities for active errors are possible and 14 subjects performed the task, a total of 84 error opportunities are calculated. If 22 of these error types are observed in one group, an error rate of 26.19% [22/84] is calculated . The motivation for this approach is supported from literature examining errors resulting from interruption on a healthcare electronic order entry system (Magrabi et al., 2010).

3.5.8 Predictor Variables

Predictor or explanatory variables are the interruption and the training intervention.

3.5.9 Hypotheses Outcome Measures

Hypothesis 1 measures the active and latent errors made during the first trial of the experiment. Error counts are normalized and then compared between the interruption and control (no interruption) groups. Hypothesis 2 measures the time duration of the medication administration task and compares this time between the group who experienced the extended interruption to the control (no interruption) group. Hypothesis 3 measures the effect of training intervention pre- and post-training to the group(s) who experienced the interruption. Hypothesis 4 measures the fixation count during the Interruption Lag and the duration of the Interruption Lag pre- and post- training. A linear regression tests if these measures are correlated to a reduction in errors.

Statistical significance was defined a priori at alpha = 0.10. Therefore if the p-value is as small or smaller at level alpha = 0.10, the data are statistically significant.

3.5.9.1 Duration of Extended Interruption

The time spent on the interrupting task has been associated as a disruption factor in interruption studies (Altmann et al., 2013; Grundgeiger et al., 2010; Monk, Trafton, & Boehm-Davis, 2008).

The length of the interrupting event is variable due to each participant performing a variety of activities during this time period. For example, some participants might only adjust the nasal cannula, while other participant performed a more lengthy assessment.

This time period is denoted as T4 in Figure 2. The time is measured in seconds. There is overall support, that as a function of the interruption duration, that the primary

task can decay in memory, resumption times are longer, and errors increase (Altmann & Trafton, 2002; Li et al., 2008; Monk et al., 2008). This variable is not a principal focus of my study. However, I report on this measure and perform a statistical regression to test a relationship between the interruption duration to errors.

3.5.10 Statistical Software Analysis

All analysis was completed with open source R software, Version 3.1.3 Smooth Sidewalk (R Core Team, 2016).

3.5.11 Data Verification Procedure

I reviewed each video file and documented the number of errors from watching the .avi file. I calculated the time to perform the medication primary task and subtracted the intervening task time. A student performed an independent verification of the video tapes and calculated the error and time measures separately. The agreement on these measures is as follows:

3.5.11.1 Control Group

There were a total of 17 subjects. Verification was done on six of the files or 35.29% of the recordings. Each file had thirteen pieces of data. Therefore, a total of 13 x 6 for a total of 78 data points. We had an agreement on 77 out of the 78 data points, or a 98.71% agreement.

3.5.11.2 Passive Training Group

There were a total of 13 subjects with two recordings per file resulting in a total of 26 video files. Verification was done on 12 of the 26 files for a total verification of 46.15% of the files. There were fifteen pieces of data per file for a total of 15 data points x 12 files for 180 individual data points. We had an agreement on 176 out of the 180 data points, or an agreement of 97.78%.

3.5.11.3 Active Training Group

There were a total of 14 subjects with three recordings per file. However, only the first and last recording involved the actual experiment for a total of 28 data files.. Verification was done on 14 out of the 28 files for a total verification of 50.00% of the files. There were fifteen pieces of data per file, for a total of 15 data points x 14 files for 210 individual pieces of data. We initially had an agreement of 192 out of 210, or an agreement of 91.42%. However, one major discrepancy involved active error type B. This error type involved not checking the medication administration record to the medication bag label. The verifier and I disagree on this error 7 times. I had to ask for clarification on this error to Dr. Elizabeth Henneman who clarified the error type. My initial results agreed with the clarification from Dr. Henneman. After eliminating these discrepancies from the results, we had an agreement of 199 out of 210 data points, or an agreement of 94.76%.

3.5.11.4 No-training Group

There were a total of 14 subjects with two recordings per file, for a total of 28 video files. Verification was done on 12 out of the 28 files for a total verification of 42.86% of the files. There were fifteen pieces of data per file for a total of 15 x 12 files for a total of 180 data points. We had an agreement on 174 out of 180, or an agreement of 96.67%.

CHAPTER 4

ANALYSES

Analyses are presented for error, medication administration time, and intervention training effects. Each hypothesis is analyzed separately and briefly discussed. The discussion section further reviews and provides support for each test.

4.1 Hypothesis 1

H1: Student nurses who experience an extended interruption during the medication administration process will commit significantly more medication administration errors than those who do not experience an interruption.

Outcome analysis is based on a normalized error rate: Error rate $=E_j/E_n$, where E_j is the number of errors made, in either the active or latent error condition, and E_n are the total number of error opportunities based on the number of possible errors for the error type and the number of participants in the group. The active error analysis is performed first followed by the latent error analysis.

4.1.1 Proportion Test on Active Error Rates

The active error rates made by the group who experienced an extended interruption are analyzed against the control group (no interruption) error rates. A Pearson's chi-square test of proportions is conducted. Where the interruption active error rates are defined as p_1 and the control error rates are defined as p_2. The null (H_o) and the alternative (H_a) hypotheses are:

$$Ho: p_1 = p_2$$
$$versus$$
$$Ha: p_1 \neq p_2$$

The proportion of the active errors are listed in Table 2.

p_1 Proportion of Active Errors in Interruption Group	p_2 Proportion of Active Errors in Control (no interruption group)
0.276	0.196

Table 2 Interruption and Control Active Error Rates

Based on the Pearson's chi-square test of proportion, I computed the following:

$$\chi 2 = 2.057,\ df = 1,\ p = 0.076$$

At the $\alpha = 0.10$ significance level, I can reject the null hypothesis that the two proportions are identical. Thus, the results are consistent with the alternative hypothesis: the proportion of errors in the interruption group is different than that in the control group, and, in particular, is larger in this case

The group who received an interruption had, on average, a 40.82% increase in error rates. This did achieve significance at the α = 0.10 level with a p-value of 0.076. Based on this test, there is evidence that extended interruptions contribute to increases in active error rates.

Recall that the group who received an interruption was further randomized into one of three training categories. This group had not received any training in the first evaluation. Thus, any differences in error rates among these three groups are due purely to the random assignment. For informational purposes, however, I will present the error rates with each group in the Table 3.

ACTIVE ERRORS	Error types	# of subjects	Error opportunities	Total Errors observed	Error rate
Control No interruption	6	17	102	20	19.61%
Interruption Pre-training Active	6	14	84	22	26.19%
Interruption Pre-training Passive	6	13	78	25	32.05%
Interruption No-Training	6	14	84	21	25.00%

Table 3 Active Errors for First Evaluation

At a quick glance, the interruption pre-training passive group seems to have been more influenced by the interruption than the other two interruption groups. Again, this is due to purely to random assignment.

4.1.2 Proportion Test on Latent Error Rates

The latent error rates made by the group who experienced an interruption are analyzed against the control group (no interruption) error rates. A Pearson's chi-square test of proportions is conducted. Where the interruption latent error rates are defined as p_1 and the control error rates are defined as p_2. The null (H_o) and the alternative (H_a) hypotheses are:

$$Ho: \ p_1 = p_2$$
$$versus$$
$$Ha: \ p_1 \neq p_2$$

The proportion of the latent errors is listed in Table 4.

p_1 Proportion of Latent Errors in the Interruption Group	p_2 Proportion of Latent Errors in the Control (no interruption group)
0.457	0.397

Table 4 Interruption and Control Latent Error Rates

Based on the Pearson's chi-square test of proportion, I computed the following:

$$\chi 2 = 0.485,\ df = 1,\ p = 0.243$$

At the $\alpha = 0.10$ significance level, the null hypothesis that the portions are identical can not be rejected. Although the proportion of errors in the interruption group is 15.11% higher than the control group, the difference is not large enough to conclude that there is an effect of interruptions on latent errors. Recall that the group who received an interruption was further randomized into one of three training categories. This group had not received any training in the first evaluation. Thus, any differences in error rates among these three groups is due purely to the random assignment The information on the latent errors for each group is presented in Table 5.

LATENT ERRORS	**Error types**	**N (number of participants)**	**Error opportunities**	**Total Errors observed**	**Error rate**
Control No interruption	4	17	68	27	39.71%
Interruption Pre-training Active	4	14	56	29	51.76%
Interruption Pre-training Passive	4	13	52	22	42.31%
Interruption No-training	4	14	56	24	42.86%

Table 5 Latent Errors for First Evaluation

4.1.3 Summary for Hypothesis 1

Error rates were significantly higher for the individuals who experienced an extended interruption for the active error types. The interruption error rate for the active errors was 0.276 for the interruption group and the error rate was 0.196 for the control group (no interruption). A Pearson's chi-square test was significant at the $\alpha = 0.10$ level with a p-value of 0.075. No statistical significance was found on the Pearson's chi-square tests between the latent error types and the extended interruption.

In summary, the data suggests that the extended interruption relates to higher active error rates but not to higher latent error rates.

4.2 Hypothesis 2

4.2.1 Medication Time Analysis

H2: Student nurses who experience an interruption during the medication administration process will take significantly more time to perform the primary task than those who do not experience an interruption. The primary task is the medication administration.

The medication administration time for the interruption group is analyzed against the control group (no interruption). A one-sided, two-sample, t-test is performed. Where μ_1 represents the population mean of the medication administration time for the interruption group and μ_2 represents the population mean of the medication administration time for the control group. The null (H_o) and the alternative (H_a) hypotheses are:

$$Ho: \mu_1 \leq \mu_2$$
$$versus$$
$$Ha: \mu_1 > \mu_2$$

Table 6 displays the average time taken to perform the medication administration primary task for the interruption group compared to the control (no interruption) group. The time during which the caregiver is performing the interrupting task is not included in the time to perform the primary task. Table 7 lists other metrics of performance.

Mean Medication Administration Time for Interruption Group	Mean Medication Administration Time for Control Group
$\bar{x}_1$ = 97.846 seconds	$\bar{x}_2$ = 162.176 seconds

Table 6 Medication Administration Time

The test statistic is t= 2.933 with a p-value of 0.996, df = 19. The medication administration time for the two of the initial participants could not be computed and hence were not included in the analysis. At the $\alpha = 0.10$ level, I can not reject the null hypothesis of the interruption group's average medication administration time of being less than or no different than the control group's average medication administration time. The data does not support the hypothesis that the average medication time for the interruption group is greater than the average medication time for the control group. In fact, the result is opposite of the original hypothesis.

Group's Med Time	n	Min	Q1	Median	Q3	Max	$\bar{x}$ seconds	Standard Deviation
Control	17	71	105	140	218	389	162.176	85.442
Interruption	39	33	68	81	120	219	97.846	44.826

Table 7 Medication Time Summary Statistics

4.2.2 Summary for Hypothesis 2

On average, the interruption group's mean medication administration time is 64.33 seconds *less* than the no-interruption (control) group. This represents a 39.67%

decrease in the time, for the group who experienced an extended interruption, to perform the medication administration task. This direction is the opposite from the anticipated direction. However, as I will review in the discussion section of this document other non-healthcare research has found a similar, speed-up effect associated with the interruption. A boxplot of the data is presented in Figure 5.

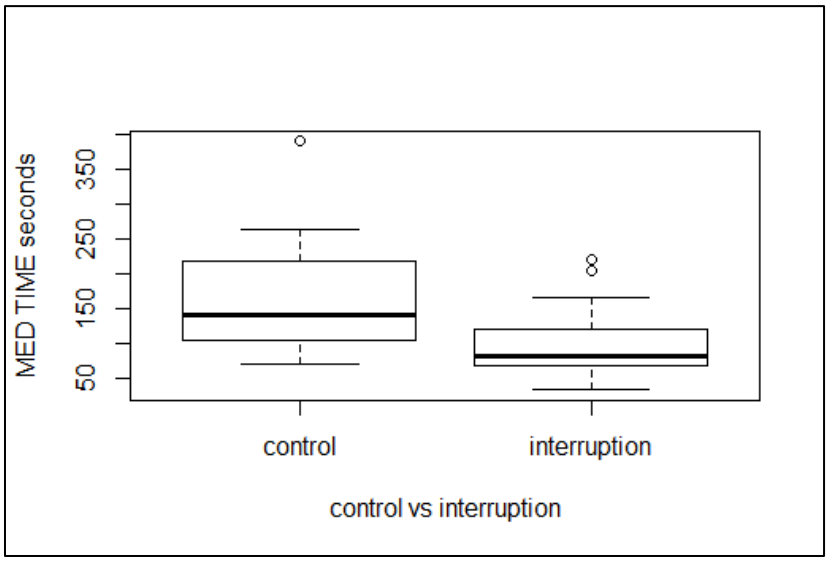


Figure 5 Boxplot of Medication Times

4.3 Hypothesis 3

H3: Nurses who are given 3M training, which includes a metacognitive component, will make significantly fewer errors when interrupted during a medication administration task. Additionally, participants who are provided active training will perform better than those who are given passive training and both training groups will perform significantly better than the no-training group.

4.3.1 Active Error Analysis

The active errors are discussed first and the latent errors discussed next. Hypothesis 3 tests the pre- and post-training intervention effects with the groups who received an extended interruption during the medication administration test.

A Pearson's chi-square test of proportions is conducted. The null hypothesis states there exists no difference between the pre- and post-training active error rates. The alternative hypothesis is that the error rates in the post-training condition and the pre-training conditions differ from one another, where p_1 is the proportion of error rates in the post-training and p_2 is the proportion of error rates in the pre-training. Table 8 displays the pre-and post-training error rates. As stated above, the null (H_o) and the alternative (H_a) hypotheses are:

$$Ho: p_1 = p_2$$
versus
$$Ha: p_1 \neq p_2$$

GROUP ACTIVE ERRORS	Error types	N (number of participants)	Error opportunities	Errors observed	Error rate
Active p_2 **Pre-training**	6	14	84	22	26.19%
Active p_1 **Post-training**	6	14	84	14	16.67%
Passive p_2 **Pre-training**	6	13	78	25	32.05%
Passive p_1 **Post-training**	6	13	78	22	28.21%
Trial 1 p_2 **(No-training)**	6	14	84	21	25.00%
Trial 2 p_1 **(No- training)**	6	14	84	23	27.38%

Table 8 Active Error Rates Pre- and Post-Training

The Pearson's chi-square proportion test reached statistically significance at p = 0.066, df = 1, based on a significance level of $\alpha = 0.10$ for the pre-post active training error rate. Table 9 displays the p-value for each of the training groups. Although the effect of training with the passive training group did not achieve statistical significance, this group did show an average error rate decrease of 11.98% between the pre- and post-training in the direction predicated (Table 8).

It is important to note the results in the no-training group (Table 8). A 9.52% increase is observed for the no-training group, while the active and passive training groups demonstrated a decrease error rate after the training. In effect, training, either with the active or passive method, demonstrated a reduced error rate compared to the no training group.

Group category	χ_2 test statistic	Df	p-value
Active training	2.263	1	0.066
Passive training	0.274	1	0.300
No- training	0.123	1	0.673

Table 9 Active Errors Pre-and Post-Training Summary

This hypothesis also states that participants who are provided active training will perform better than those who are given passive training and both training groups will perform significantly better than the No-training group. This hypothesis measures the effect of the post-training effects only. A Pearson's chi-square test of proportions is conducted. Where p_1 is the active post-training proportion error rate and p_2 is the passive post-training proportion error rate. The null

(H_o) and the alternative (H_a) hypotheses are:

$$Ho: p_1 = p_2$$
$$versus$$
$$Ha: p_1 \neq p_2$$

The active post-training proportion error rate is 0.167 and the passive post-training proportion error rate is 0.282 (Table 8). The Pearson's chi-square test statistic is 2.844, with a df=1, and p-value of 0.058. At a significance level of $\alpha =$ 0.10, the null hypothesis of no difference is rejected. The results suggest that the active training method for the active error types is more effective at reducing error rates compared to the passive training method.

Additionally, the hypothesis states that the training groups (active or passive) will perform better than the No-training group. A Pearson's chi-square test of proportions is conducted, where p_1 is the active (passive) post-training error rate in the second test and p_2 is the no-training error rate in both tests. The null (H_o) and the alternative (H_a) hypothesis are:

$$Ho: p_1 = p_2$$
$$versus$$
$$Ha: p_1 \neq p_2$$

The active post-training error rate is 0.1667 and the no-training post-training error rate is 0.274. The Pearson's chi-square test is 2.2 with a df = 1, and a p-value of 0.068. At a significance level of $\alpha = 0.10$, the null hypothesis of no difference is rejected. The data suggest that the active training method for the active error types is more effective at reducing error rates compared to the no-training method.

The passive post-training proportion error rate is 0.282 and the no-training post-training error rate proportion is 0.274. The chi-square test is 0 with a df = 1, and a p-

value of 0.5. At a significance level of $\alpha = 0.10$, the null hypothesis of no difference cannot be rejected. The data suggest that the passive training method for the active error types is not more effective at reducing the error rate compared to the no-training method.

4.3.2 Latent Error Analysis

H3: Nurses who are given 3M training, which includes a metacognitive component, will make significantly fewer errors when interrupted during a medication administration task. Additionally, participants who are provided active training will perform better than those who are given passive training and both training groups will perform significantly better than the No-training group This analysis is for the latent errors.

A Pearson's chi-square test of proportions is conducted. The null hypothesis is that there is no difference between the pre- and post-training latent error rate. The alternative hypothesis is that the error rate in the post-training condition is not equal to the error rate in the pre-training condition, where p_1 is the proportion of latent error rates in the post-training and p_2 is the proportion of latent error rates in the pre-training. The null (H_o) and the alternative (H_a) are:

$$Ho: p_1 = p_2$$
$$versus$$
$$Ha: p_1 \neq p_2$$

Table 10 displays the pre-and post-training latent error rates and Table 11 displays the p-value pre-and post-training latent error rates for each training group.

GROUP LATENT ERRORS	Error types	N (number of participants)	Error opportunities	Errors observed	Error rate
Active p_2 ***Pre-training***	4	14	56	29	51.79%
Active p_1 ***Post-training***	4	14	56	26	46.43%
Passive p_2 ***Pre - training***	4	13	52	22	42.31%
Passive p_1 ***Post-training***	4	13	52	24	46.15%
Trial 1 p_2 ***(No-training)***	4	14	56	24	42.85%
Trial 2 p_1 ***(No-training)***	4	14	56	25	44.64%

Table 10 Latent Error Rates Pre- and Post-Training

Group Category	χ_2 Test Statistic	Df	P-value
Active Training	0.322	1	0.2853
Passive Training	0.156	1	0.6535
No-Training	0.036	1	0.5755

Table 11 Latent Errors Pre- and Post-Training Summary

The data suggest that the training did not reduce the latent error rates in either of the training groups between the pre-test and post-test and, not surprisingly, there was no difference in the latent error rates in Trial 1 and Trial 2 of the no training condition.

4.3.3 Summary for Hypothesis 3

Nurses who are given training, which included a metacognitive component, made significantly fewer errors based on the active training method for the active errors only. This reduction in active errors among nurses using the passive training method was not statistically significant, although the training did result in an 11.98% decrease in active error rates. The error rate, for the No-training group, increased by 9.52% for the second

trial. These findings are consistent with other training studies in healthcare that have identified a positive effect of training and will be reviewed further in the discussion section.

The active training method was superior to the passive training method and the no-training method for the active error rates. The passive training did not result in improved performance compared to the No-training group for the active error rates.

For the latent errors, no training method, either from the active training compared to the passive training ($p = 0.5$), or active training compared to no-training method ($p = 0.5$) and the passive training method to the no-training ($p = 0.5$), led to a significant reduction.

4.4 Hypothesis 4

H4: Metacognition training significantly increases attention to the primary task just prior to that task being suspended by an alarm indicating the nurse needs to focus on the interrupting task. The effectiveness of the training in this regard will be measured by the increase in the number of eye fixations in the interruption lag and in the duration of the Interruption Lag. Furthermore, it is hypothesized that these two measurements will correlate with reductions in errors.

4.4.1 Eye Measure and Interruption Lag Duration

The average number of eye fixations pre-training is compared with the average number of eye fixations post-training for the groups who received an interruption. The mean number of eye fixations in the post-training Interruption Lag is represented by μ_1 and the mean number of eye fixations in the pre-training Interruption Lag is represented

by μ_2. A one-sided, paired, two-sample t-test is performed. The p-values for the pre-and post-training tests are presented in Table 12. The null (H_o) and the alternative (H_a) hypotheses are:

$$Ho: \mu_1 \leq \mu_2$$
$$versus$$
$$Ha: \mu_1 > \mu_2$$

The null hypothesis that the mean number of eye fixations in the post-training Interruption Lag is less than or equal to this number in the pre-training Interruption Lag can be rejected with the active and passive training group based on a significance level of $\alpha = 0.10$. The data suggest (Table 12) that training did result in increases in the number of eye fixations for the Active and Passive training groups.

While the No-training group also increased the average number of fixations in the Interruption Lag, the result did not reach statistical significance.

In summary, metacognition training resulted in a significant number of additional eye fixations in the post-training Interruption Lag for the Active and Passive training groups.

Average Number of Fixations in Interruption Lag	N (number of participants)	Average Number of fixations	p-value
Active- Pre-training μ_2	6	5.000	
Active – Post-training μ_1	6	11.833	p = 0.098
Passive – Pre-training μ_2	6	5.500	
Passive - Post-training μ_1	6	8.833	p = 0.010
No-Training – Trial 1 μ_2	10	3.200	
No-Training – Trial 2 μ_1	10	4.700	p = 0.204

Table 12 Fixation Count Pre-and Post-Training

4.4.1.1 Interruption Lag Time

Fixation data were derived from an interval of time which I have referred to throughout as the Interruption Lag. This variable is also of interest to determine if a longer time period was spent focusing (encoding) on the primary task before disengaging from the primary task and moving on to the intervening task. Table 13 lists the Interruption Lag time pre- and post-training. Data are recorded in seconds.

The average duration of the Interruption Lag pre-training is compared with the average duration of the Interruption Lag post-training. The data are presented in Table 13. A one-sided, paired, two-sample, t-test is performed, where μ_1 represents the duration of the Interruption Lag in the post-training condition and μ_2 represents the duration of the Interruption Lag in the pre-training condition. The null (H_o) and the alternative (H_a) hypotheses are:

$$Ho: \mu_1 \leq \mu_2$$
$$versus$$
$$Ha: \mu_1 > \mu_2$$

Using a significance level of $\alpha = 0.10$, I can reject the null hypothesis that the duration of the post-training Interruption Lag for the passive training group is less than or equal to the duration of the pre-training interruption lag for this group. The data suggest (Table 13) that training did result in an increased duration of the Interruption Lag. The difference in the duration of the Interruption Lag for the passive training group was significant with a p-value of 0.010. The difference in the durations of the post-training and pre-training Interruption Lags for the Active and the No-training group did not achieve significance. There was one individual in the Active training group who spent an inordinate amount of time fixating before attention was redirected to the

secondary task. This could have influenced the test and while the percentage increase in Interruption Lag duration for the Active training group time was 42.37%, the difference did not achieve statistical significance.

It is of interest to note that the duration of the Interruption Lag decreased during Trial 2 by 6.62% for the No-training group. This result would suggest that training, either with the active or passive method, did influence the amount of time the participant spent focusing on the primary task before turning their attention to the secondary task.

Average Time Encoding Interruption Lag	# participants	Seconds	p-value
Active – Pre-training μ_2	11	2.36	
Active – Post-training μ_1	11	3.36	p = 0.140
Passive – Pre-training μ_2	9	1.89	
Passive - Post-training μ_1	9	3.33	p = 0.010
No-training – Trial 1 μ_2	11	1.36	
No-training – Trial 2 μ_1	11	1.27	p = 0.602

Table 13 Total Encoding Time in Interruption Lag

Hypothesis 4 additionally states that the number of fixations in the Interruption Lag and the duration of the Interruption Lag will correlate with reductions in errors.

To test this statement, a linear regression was conducted to determine if a relationship exists between the number of eye fixations and the Interruption Lag duration to errors made in the Active or Passive training groups.

We first present the simple linear regression model: Let Y_i =1 if the ith individual makes an error, 0 otherwise. Then,

$$Y_i = \beta_0 + \beta_1 X_{i,1} + \beta_2 X_{1,2} + e_i$$

where $X_{i,1}$ *and* $X_{i,2}$ represent the independent variables: interruption lag for the ith participant and number of fixations for the ith individual count.

The hypothesis for this model is:

$$H_o : \beta i = 0, where \text{ i} = 0,1,2$$
versus
$$H_a\text{: not all } \beta i = 0$$

The resulting regression model for the active errors to the explanatory variables of the number of eye fixations and the Interruption Lag is the following:

$$\hat{y}_i = 1.567 - 0.508X_{i,1} + 0.1226X_{i,2}$$
where $X_{i,1} =$ Interruption Lag for the ith participant
and $X_{i,2} =$ Number of Eye Fixations i^{th} participant

Regressing the active errors on the number of eye fixations and the duration of the Interruption Lag resulted in a test statistic of F(2,21) = 2.918 with a p-value of 0.076. The null hypothesis is rejected at the $\alpha = 0.10$ significance level. The interpretation of this result is explained by the following statement: Holding the number of eye fixations constant, a decrease in the Interruption Lag of about half a second results in one fewer errors. On average, a unit increase in eye fixation counts, results in a higher chance of making an error. This model that includes the number of eye fixations and Interruption Lag explains 21.75% (the coefficient of multiple correlations) of the variation in the number of active errors.

Regressing the latent errors on the number of eye fixations and the duration of the Interruption Lag resulted in a test statistic of F(2,18) = 1.257 with a p-value of 0.305. The null hypothesis cannot be rejected. Knowledge of the fixation counts and the Interruption Lag duration gives no knowledge about the dependent variable latent errors.

4.4.2 Summary for Hypothesis 4

The number of eye fixations and the duration of the Interruption Lag were larger in the post-training than in the pre-training for both the active and passive training method. The difference in the number of eye fixations was statistically significant for both the passive and active training methods. However, the difference in the duration of the Interruption Lag was significant only for the passive training method. This hypothesis, furthermore, stated that these two independent measures would predict the active and latent errors. Regressing the active errors on these two explanatory variables did achieve significance, however not in the manner projected. The data suggest that decreasing the Interruption Lag duration reduces the number of active errors and a unit increase in eye fixations results in a 12% increase in the number of active errors. No significance was achieved for the latent errors

4.5 Ad Hoc Analysis – Interruption Duration

I discussed in Chapter 3 that the duration of the interruption has been found to increase errors (Altmann et al., 2013) due to memory decay. This decay results when the secondary task is of a long duration and memory for the primary task can decay. The mean interruption durations for this experiment ranged from 20.86 seconds to 25.42 seconds for the groups who experienced an extended interruption. These ranges are very consistent given that I did not control the activities during this time period. In other words, the particpants took all the time they deemed necessary to attend to the alarm and the patient. Table 14 presents the summary statistics for the extended interruption duration.

Groups	Minimum Interruption Duration	Mean Duration	Max Duration	Median	Standard Deviation
Active training	8	24.630	79	22	14.009
Passive training	15	25.423	42	25	7.506
No-training	9	20.885	34	22	7.675

Table 14 Interruption Duration

A linear regression was conducted to test if a relationship exists between the duration of the interruption to the number of either active or latent errors.

The simple linear regression model is given below:

$$Y_i = \beta_0 + \beta_1 X_{i,1} + e_i \ ,$$

Where Y_i is set equal to 1 if there is an active (latent) error and 0 otherwise and X_1 is the duration of the interruption.

The hypothesis test is the following

$H_o : \beta_1 = 0$
versus
H_a: $\beta_1 \neq 0$

The hypothesis test statistic F(1,77) = 0.0169 with a p-value of 0.897 for the active errors fails to reject the null hypothesis of $\beta_1 = 0$. The data suggest that there is no relationship between the duration of the interruption and the number of active errors.

However, for the latent errors, the test statistic F(1,77) = 4.34 with a p-value of 0.04 for the latent errors model indicates that the null hypothesis can be rejected. The data

suggests that there is a relationship between the duration of the interruption and the number of latent errors. However, the coefficient of determination for this equation (r^2) is 0.05. Consequently, the proportion of the latent errors is not well explained by the explanatory variation of interruption duration and this outcome will not be considered further.

CHAPTER 5

DISCUSSION

There were four hypothesis were posed in this study. Each hypothesis and discussion will be discussed separately and then a summary will be provided.

5.1 Discussion for Hypothesis 1

Hypothesis 1, which states that nurses who experience an extended alarm interruption during the medication administration process will commit significantly more errors than those who do not experience an interruption, was supported for active but not latent errors. These findings are consistent with reports of others who have found an increase in errors with interruptions (Westbrook et al., 2010). Westbrook, et al., (2010) identified that each interruption was associated with a 12% increase, on average, both in procedural and clinical errors. The findings of this study also lend further support for the Memory for Goals theory used in this study, which posits that primary task suspension and primary task recovery, due to an interruption, is an effortful cognitive process. Frequent interruptions generated from the alarm could put a strain on the memory system to process constantly changing task goals. The individual's memory system, in a dynamic environment, may not have time to assimilate or accommodate the information that is presented from frequent interruptions resulting in errors.

Of note is that the control (no-interruption) group did demonstrate a reduced error rate for both the active and latent error types compared to the individuals who experienced an interruption during the medication administration task. For example, even though the latent error category did not achieve statistical significance, the interruption group had, on average, a 13.13% increase in latent error rates compared to

the control (no-interruption) group's error rates. This may be explained by the error types defined as latent are not considered to be as necessary in a simulated environment and less focus was given to these procedures.

Future research is needed to evaluate strategies to mitigate the negative impact of interruptions. Complex and cognitively demanding tasks could potentially benefit from the use of checklists. This topic will be discussed in the future research section.

5.2 Discussion for Hypothesis 2

Hypothesis 2, which states that nurses who experience an extended alarm interruption during the medication administration process will take significantly more time to perform the primary task than those who do not experience an interruption (exclusive of the time to perform the interrupting task).

Hypothesis 2 is not supported. In fact, the group who experienced an interruption had a strong "speed-up effect" on the medication administration time. That is, the interruption group performed the medication administration task, on average, 64.33 seconds faster than the control group.

Although this result was not expected based on other prior reports in healthcare (Antoniadis et al., 2014), research in the psychology and decision science domain has identified a speed-up effect on certain tasks. Also, the method used to determine primary task duration in the current study, used the same equation used in these, non-healthcare studies, namely subtracting out the time required to attend to the interrupting task.

Zijlstra, Roe, Lenonora, & Krediet (1999) identified a speed-up effect, on what they called, the "net time" on a primary task. The net time represented the primary task duration without the intervening task time. Zijlstra, et al., also expressed surprise as to

the speed-up outcome from the study. These researchers originally expected the interruption to cause a time degradation to peform the primary task. They theorized that participants "compensated" for the interruption by speeding up performance on the primary task.

Speier, Valachich, et al., (1999) and Speier, Vessey, et al., (2003), also identified a speed-up effect, but for only simple tasks. Simple tasks involved a spatial or symbolic information format that participants had to review and select appropriate information based on the experiment question. These authors dicussed that one explanation for this speed-up effect is supported by the Distraction Conflict theory (Baron, 1986) that states distractions enhance performance on simple tasks but can degrade performance on complex tasks. However, as I have stated previously, the primary and secondary tasks in this experiment are complex, especially for student nurses. Yet, even with this complexity, the interruption resulted in a faster completion time for the primary task.

Another explanation for the speed-up effect may relate to the stress and anxiety caused by interruptions, particularly due to a physiological bedside monitor alarm. Baron (1986) discusses that a feeling of stress or anxiety could cause individuals to complete their work faster. The participants in the current study did report anxiety in the context of hearing medical alarms. Subjects reported, "alarms make people nervous", or make people "go running." These comments support the anxiety created by medical alarm, anxiety that could result in individuals rushing to complete the primary task. The medical literature is replete with reports of alarms as a major of annoyance (Block, Nuutinen, & Ballast, 1999), and that alarms are irritating for workers (Edworthy & Hellier, 2006).

Researchers have pointed out accuracy and time are not independent (Croskerry, 2000; Speier et al., 1999). If interruptions cause a speed-up effect, the question becomes if this effect would also result in increased errors.

Healthcare providers maintain that interruptions cause delays in performing the current activity and overall this is true. The interruption injects a time delay of varying duration. One must separate this delay, however, with the actual time to perform the task which is what my research accomplished. Perhaps, it is that the individual is trying to make up for this delay by speeding up the original task. If this effect is true, future research could explore if information is being missed or ignored due to the primary task being completed faster. This is an important question for the medical field. Future research needs to substantiate the consequences if medical tasks are performed faster due to interruptions and importantly, what if any negative consequences could result from this effect.

5.3 Discussion for Hypothesis 3

Hypothesis 3, which states that nurses who receive training, will make significantly fewer errors than those who do not receive training was supported for the active training method on the active error category only. The Active training group demonstrated a 36.35% decrease in error rates made on the active error types.

The hypothesis was not supported for the active error types for the passive training method. Although the passive training group results did not reach statistical significance, this group achieved a 11.98% decrease in error rate which can be considered clinically important.

The hypothesis was not supported for any training method for the latent error types.

These findings are consistent with reports of others who have identified that active strategies are more effective in general than passive strategies (Romoser & Fisher, 2009) and support the findings of this study.

Of note, the No-training group showed an increase in error rate in both the active and latent errors in the second trial. The No-training group increased the active error rate by 9.52% and the latent error rate by 4.18% providing further support for the effectiveness of training. The increase in the No-training group could have been the result of the participants feeling more familiar with the simulated patient and believed that, for example, since they already knew the patient's condition they did not feel the need to repeat some steps in the procedure

Training healthcare providers to use memory to safeguard information can lessen the disruptiveness of the interruption. The metacognition training focused on simple mental strategies that nurses can use when they are interrupted. The need for simple and efficient strategies, that healthcare workers can use, is stressed in the medical literature (Croskerry, 2000, 2002, 2003). Croskerry contends that healthcare providers need a collection of cognitive strategies that can be used for fast decisions without undue effort, in particular in environments such as emergency medicine.

These results suggest that actively teaching the technique to encode a return placemarker and provide mastery exercises could be more effective to assist the memory system to safeguard information and minimize errors than just discussing the encoding process.

5.4 Discussion for Hypothesis 4

Hypothesis 4, which states that the training leads to improvement in memory was supported with regard to the number of fixations for both the Active and Passive training group. The total amount of fixations in the Interruption Lag increased, on average, by 136.60% for the Active training group and 60.55% for the passive training group. However, due to the influence of one individual who spent a long time fixating before attention was redirected to the secondary task in the Active training group, only the Passive training group achieved strong statistical significance.

The Interruption Lag duration, measured in seconds, also increased for both the Active and Passive training groups. Only the passive training group demonstrated a statistically significant increase. Taken together, the increase in the fixation count and passive group's Interruption Lag duration suggest that a conscious metacognition strategy, to place mark one's position in the current primary task before disengaging, is suggestive of further attention provided to that task. The results are similar to research that states preserving a link, measured by the number of fixations, between the task during phases of an interruption, can permit a higher activation of the primary task goal (Ratwani & Trafton, 2010). This activation, as previously discussed, can support memory for a more accurate recovery. The findings are also consistent with the strengthening function as proposed by the Memory for Goals theory (Altmann & Trafton, 2002). If more cognitive processing is occurring to rehearse the suspending task, suggested by the increased number of fixations, a stronger case can be made that the suspended task will have a higher activation level (Monk et al., 2008) and potentially reduce errors.

Hypothesis 4 additionally stated that the number of fixations in the Interruption Lag and the duration of the Interruption Lag correlate to a reduction of errors. There is evidence of a relationship to these variables to active errors on the medication administration task. However, the results are not in line with the expected direction of the independent variables to the dependent variable. For example, an increase in eye fixations resulted in a higher chance of making an error and a decrease in the interruption lag resulted in fewer errors. While this result has not been reported before, it is worthy of further investigation.

5.5 Future Research

Checklists, especially for safety-critical environments, are advocated in healthcare (Gawande, 2009) and aviation (Diez, Boehm-Davis, & Holt, 2002). Gawande points out there are good checklists and bad checklists, but what type of checklist would best serve a nurse who is interrupted during a medication administration task. I suggest that a making a simple mental 'bookmark', in addition to a simple physical checksheet would provide the combined memory mental note and physical document to ensure all the steps in the procedure are performed. This type of checklist would be comparable to the, "Do-Confirm" method (Gawande, 2009), where the initial first step is based on memory training and the second step is a confirmation based on a physical checklist of the items required to perform the task. Future research could study the effectiveness of this mental-physical checklist to support the healthcare worker in the interruption intensive environments of today's clincial settings.

Additionally, the primary and secondary tasks involved in this experiment were dissimilar in nature. The primary task was the medication administration and the secondary task were activities appropriate to the bedside monitor alarm type.

This fact additionally lessen the disruptiveness of the interruption for the student nurse. The similarity of the secondary task to the primary task has been identified as a factor causing interruption disruptivenss as measured in time delays (Gillie & Broadbent, 1989) and measured in accurary (Edwards & Gronlund, 1998). What direct effect this factor had on the outcome of this research is not determinable, however, future research should address the impact of having a secondary task that is similar in nature to the primary task. This would be particulary important for a medication administration task. For instance, if the interrupting task is a question from a healthcare provider on a medication and the primary task is a medication administration task, would this scenario present an even more disruptive condition leading to a potential error? Future research could address the contribution of this factor leading to medication administration errors.

5.6 Limitations of Research

The limitations of this research are now discussed. A convenience sample was used for this study. This sample was limited in size and presented a threat to internal validity by limiting the power of the statistical analysis for some of the tests.

A single site was used for the research. The site was a simulation laboratory and the outcomes of this study cannot be directly transferred to real-life clinical settings.

Finally, the analysis of Hypothesis 3 needs to be further fleshed out. In the dissertation, a comparison was made of the error rates of the participants in the active, passive and no-training groups to determine whether the training had an effect on both

active and latent errors. For example, the active error rate in the active training group, 0.1667, was compared with the active error rate in the passive training group, 0.2821, using a chi-square test. Had there been only post-training data, this comparison would have by itself been sufficient (similarly for a comparison between the error rates in the active training group and the no-training group and for a comparison between the error rates in the passive training group and the no-training group). However, information was also available on the error rates (both active and latent) for the three training groups before training.

Thus, an additional analysis needs to be carried out comparing the difference in the error rates before and after training of one training group with the difference in the error rates of a second training group. For example, the difference in the active error rates of the active training group in the pre-training (0.2619) and post-training (0.1667) evaluations is 0.0952. The difference in the active error rates of the passive training group in the pre-training (0.3205) and post-training (0.2821) groups is 0.0384. To more completely determine whether the effect of active training was greater than the effect of passive training, given that the pre-training error rates were larger in the passive training group (0.3205) than the active training group (0.2619), the comparison between differences in the effect of training in the active training group (0.0952) need to be compared with the differences in the effect of training in the passive training group (0.0384). Different ways to analyze the data are now being explored.

There are several different ways to analyze the data. Basically, for each participant in each training group there are six different error types that were measured before and

after training. Using the glmer function in R is the most likely alternative, but other approaches are still be explored.

Having said the above, it should be noted that all of the effects are in the predicted direction. In particular, for active errors, the difference between the pre-training and post-training error rates is larger from the active training group than it is for the passive training and no-training groups and it is larger for the passive training group than it is for the no-training group. Similarly, for latent errors, the difference between the pre-training and post-training error rates is larger from the active training group than it is for the passive training and no-training groups. However, for latent errors there is there is no effect of passive training (if anything the effect appears to be negative).

CHAPTER 6

SUMMARY

This research has addressed the impact of an interruption generated by a bedside monitor alarm on caregiver's performance as they deliver medication and thus has contributed to applied research using a theoretical basis. Medical alarms and the interruptions that result are necessary for alerting clinicians to potentially life threatening events. However, numerous studies in the healthcare literature support the adverse effects of extended and momentary interruptions generated by alarms.

The findings of this study support those of other who have reported an increase in errors with interruption, the effectiveness of training in reducing errors, and a speed-up effect with an interruption.

The study limitations included a small sample size and lack of power to achieve statistical significance in some cases as well as the use of a single site and convenience sample which limits the generalizability of the findings.

Future research is needed to evaluate the impact of interruptions with experienced nurses and also to test the effectiveness of other interruption mitigating strategies, such as a checklist, for both simulated and naturalistic environments. Research is also needed that investigates the relationships between interruptions and errors in safety critical environments.

APPENDICES

APPENDIX A

DOCUMENTS

Instructions for the nurse subject participant

This is a simulated environment set up in a purposeful way to facilitate the use of the eye-tracking device as you administer a medication.

As much as possible, avoid rapid, jerky movements of your head. Please do not move the medication administration record (MAR) taped to the medication room table.

The monitor is there to provide you with ongoing, real-time values. You do not need to activate the BP cuff, take a pulse, count respirations, etc.

The only other data available to you is what you receive in the report, on the bedside monitor and on equipment in the room (IV pumps, O2 flowmeter, etc.)

In this simulation scenario, you have been caring for this patient and a new medication has been ordered.

Your only task is to administer the medication. No physical assessment is necessary.

Please ask if you have any questions or if you feel the eye-tracker has moved on your face/head.

Nursing report for Margaret A. Geary

Margaret A Geary

Mrs. Geary is an 85 year-old woman admitted yesterday from a nursing home with dehydration, and pneumonia. Her PMH is significant for hypertension, rheumatoid arthritis, and Type 2 diabetes.

Neuro- Patient is awake and alert but is very hard of hearing- we are waiting for her hearing aids. She is a bit fidgety and so her O2 sat probe keeps falling off her finger.

Respiratory- RR- 20-24, breath sounds equal, occasional non-productive cough. Receiving 2 L/min O2 per Nasal Catheter

Cardiac- Skin warm and dry, HR/BP stable (was orthostatic on admission).

GI- Abdomen slightly distended, bowel sounds normal

Renal- Foley cath- urine dark yellow , approx 20-30/hour

Skin- Small abrasions R forearms (dry dressings)

IV- L arm peripheral IV- at 0.9 NS 75/hr,

Current Vital Signs- HR- 90 (SR), BP-120/70, RR-20, SpO2- 95% (on 2L NC) T- 98.5 F

New medication orders have just been ordered (See MAR)

Medication Administration Record

Geary, Margaret A.	F 85
MR# 600780	DOB: 03-09-1930

ALLERGIES: NO KNOWN ALLERGIES

Date	Time	Medication	Time Admin	Initials
		Ampicillin 500 mg in 100 ml 0.9 NS IV now		

Name: _____ **Initials:** _____

_____ _____

Medication Administration Record

Geary, Margaret A.	F 85
MR# 600780	DOB: 03-09-1930

ALLERGIES: NO KNOWN ALLERGIES

Date	Time	Medication	Time Admin	Initials
		Cefotetan 1 g in 100 ml 0.9 NS IV now		

Name: _____ **Initials:** _____

_____ _____

Medication bag labels

Margaret Geary A. Room 214

MR#600780 DOB: 03-09-1930

Ampicillin 500 mg

In 0.9NS IV
Total Volume 100 mL

Exp: 12-30-2015 E.M.H. RPh

Margaret Geary A. Room 214

MR#600780 DOB: 03-09-1930

Cefotetan 1Gram
(Cefotan)

In 0.9NS IV
Total Volume 100 mL

Exp: 11-30-2015 E.M.H. RPh

Subject ID: _____

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

Mastery Exercises – Active training group

The following mastery tasks were part of the Active training program. A series of up to four exercises were given to the participant. During the exercise, the bedside monitor alerted and I asked them to perform another task. The alarm is activated at the same point in the exercises for all participants. After the secondary task, I asked the participant tell me what they were reading on the primary (first) task when the alarm sounded. The mastery exercises were timed so that the interrupting (secondary task) ranged from approximately 5 seconds to 25 seconds. All participants wore eye tracking during these exercises.

The following statement was read to the participant after they received the metacognition training.

"You will be given a task and during this task the alarm will alert. When this happens, I will give you instructions to perform another task. After you perform this second task, I want to ask you some questions. Thank you. "

Mastery task 1

Statement to the participant, "Please go to the table with the *patient's flow sheet*, this flow sheet contains the patient's vital signs".

When the alarm sounded, I asked them to read the patient's ID band information out-loud to me. This required the participant to move to a different location in the room. After the participant read the patient's ID information to me, I asked them to tell me what piece of information they were reading on the patient flow sheet.

Mastery task 2

Statement to the participant, "Please go to the table with the nursing report and read the first paragraph".

When the alarm sounded, I asked them to read out-loud the information on the patient's allergy band. This required the participant to move to a different location in the room. After the participant read the patient's allergy band information to me, I asked them to tell me what information they were reading on the nursing report when the alarm sounded.

Mastery task 3

Statement to the participant, "Please go to the patient's medication record (MAR) and read the information.

When the alarm sounded, I asked them to walk over to the IV fluid bag and read the information out-loud on the bag. After they read the information to me, I asked what information they were reading on the MAR when the alarm sounded.

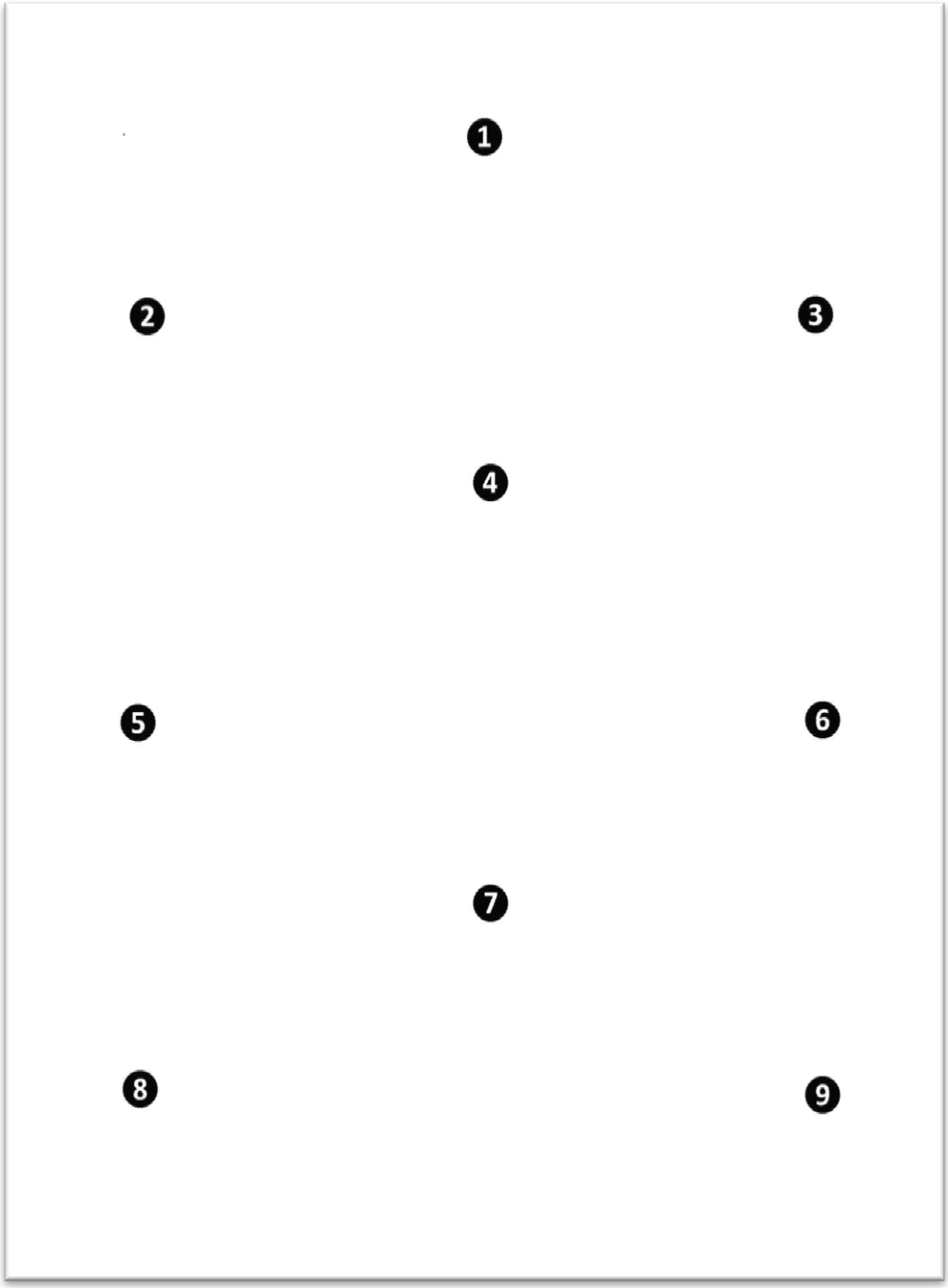
Mastery task 4

Statement to the participant, "Please go to the table with the Baxter Interlink System package and read the information on the front label".

When the alarm sounded, I asked them to walk over to the table where the Nursing Davis Drug Guide Book was located and open the book to the bookmark (page 156-157). I asked them to read the right column on page 157 under Nursing Implications.

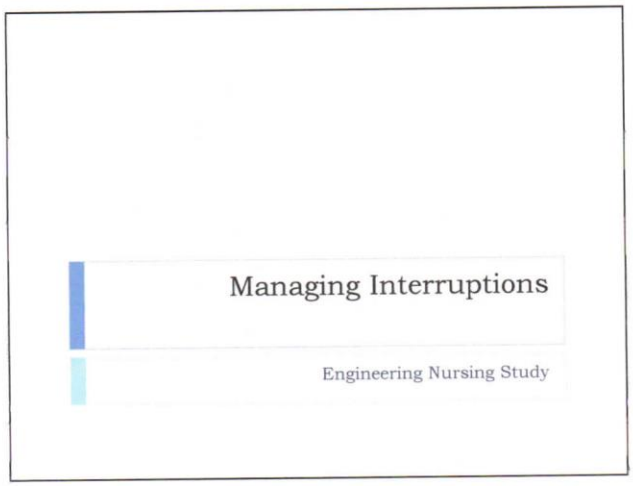
After approximately 25 seconds, I asked them to stop reading and tell me what information they were reading on the front label of the Baxter Interlink package.

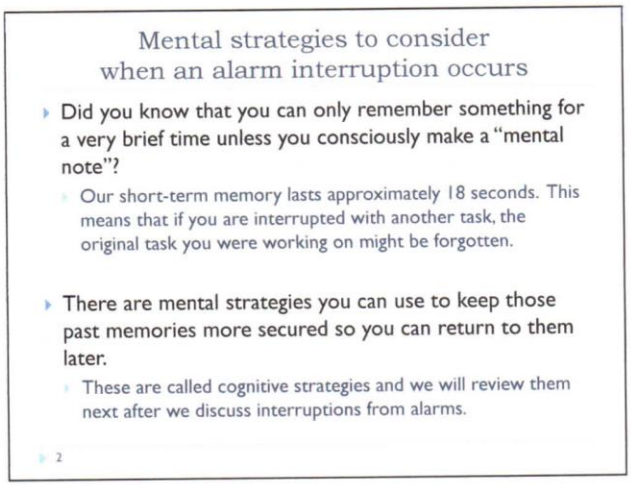
Calibration 9-point Poster



APPENDIX B

METACOGNITION TRAINING





Medical Alarm Interruption

- Medical alarm interruptions inform you of different patient conditions.
- Medical alarms can also cause you to forget where you were in your current task.
  - Think about a mental sequence on how to return to the original task.
- This mental sequence is a conscious act to focus on an object or the current place in your task before you break for the interruption
  - What are we talking about here?
    - Literally 1 to 2 seconds of thinking about the point in the task that you want to return to; a mental placemark of sorts.

3

Different cognitive strategies

- When you are interrupted by an alarm alert consider employing one of these different mental strategies.
- 1. Look at what you are doing when the interruption occurs for a few seconds. This needs to be a conscious act and is called making a mental "note" or mental encoding.
- 2. Finish the task if it is critical and if the time permits. This may not be possible in all situation.
- 3. Immediately disengage from the current task depending on the nature of the alarm or turn your head to observe the alarm importance and if possible make a mental note about your place in the task.

4

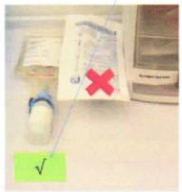
Let's review how to employ a mental place marker

When the alarm interruption occurs

Use a cue – an object – as a placemarker

- Use objects in the environment to placemark the "Where am I position?" or "What do I need to do next?" before attending to the alarm interruption.
- The mental note in the picture would be to return to the medication container on the medication table.

Use a conscious decision strategy for this. "I am going to return here."



5

How interruptions can affect your work

- Let's say you are preparing to check the patient's MAR information to the patient's ID and you are interrupted by an alarm interruption.
  - You attend to the alarm interruption and then want to return to what you were doing.
  - By making a conscious effort, before disengaging your current task of checking the MAR, make a mental note where you are in the current task.
    - For example, "I was just about to check the MAR information and I want to return to this point."
    - This conscious act helps your memory to better recall where you were.
- Is this a technique you think you can use in your work?

6

Summary – Thinking about how you manage alarm interruptions

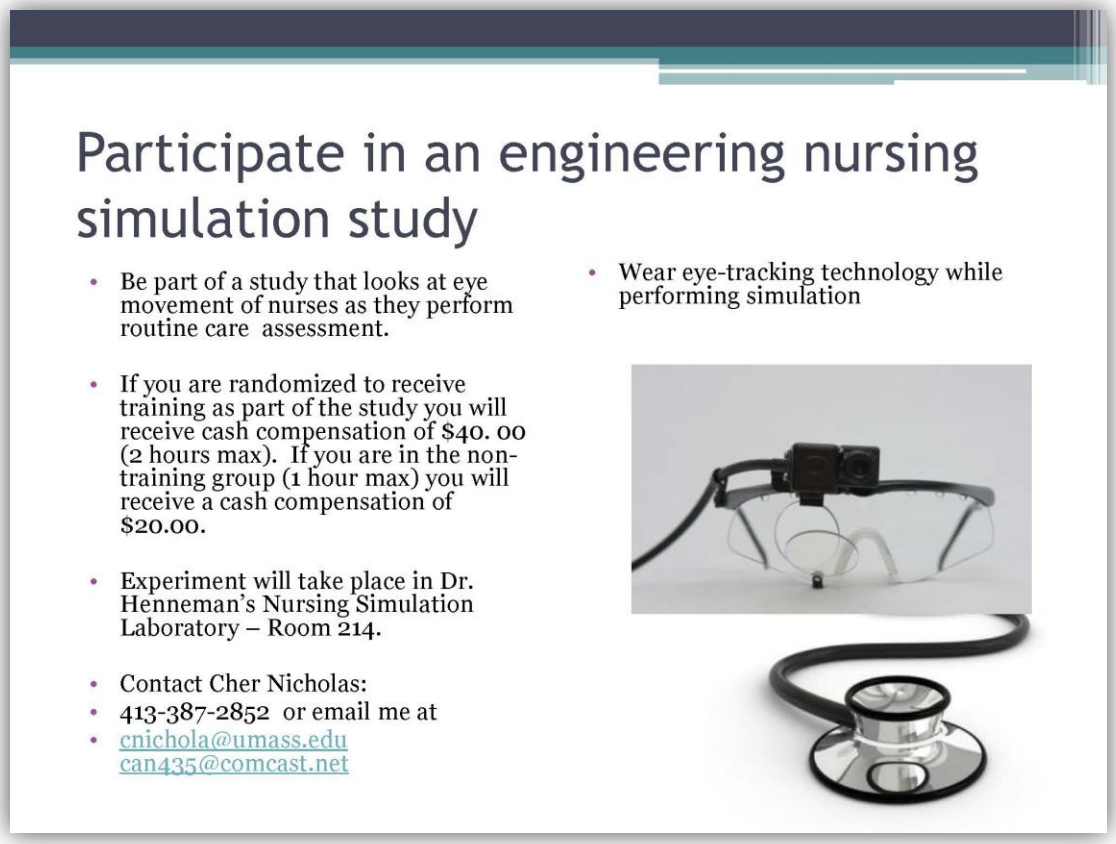
- When you a physiological alarm
- Depending on the nature of the alarm, make a mental note on the item you are holding, reviewing, or moving before you break from a task. This is a mental placemark of sorts.
  - 1-2 seconds of consciously noting where you are in the task, before responding to the alarm interruption, will help you mentally encode and placemark the "*Where was I position*" or "*Where I want to return position*" when you return to the original task.
  - Questions?

7

APPENDIX C

IRB DOCUMENTS

TRAINING ANNOUNCEMENT



EXPERIMENT IRB CONSENT FORM and APPROVAL LETTER

University of Massachusetts Amherst
108 Research Administration Bldg.
70 Butterfield Terrace
Amherst, MA 01003-9242

Research Compliance
Human Research Protection Office (HRPO)
Telephone: (413) 545-3428
FAX: (413) 577-1728

Certification of Human Subjects Approval

Date: June 24, 2015
To: Cheryl Nicholas, Mechanical & Industrial Eng
Other Investigator: Donald Fisher, Mechanical & Industrial Eng
From: Lynnette Leidy Sievert, Chair, UMASS IRB

Protocol Title:A study of eye-movement visual scanning patterns during routine nursing care
Protocol ID: 2015-2587
Review Type:EXPEDITED - NEW
Paragraph ID: 6,7
Approval Date: 06/24/2015
Expiration Date:06/23/2016
OGCA #:

This study has been reviewed and approved by the University of Massachusetts Amherst IRB, Federal Wide Assurance # 00003909. Approval is granted with the understanding that investigator(s) are responsible for:

Modifications - All changes to the study (e.g. protocol, recruitment materials, consent form, additional key personnel), must be submitted for approval in e-protocol before instituting the changes. New personnel must have completed CITI training.

Consent forms - A copy of the approved, validated, consent form (with the IRB stamp) must be used to consent each subject. Investigators must retain copies of signed consent documents for six (6) years after close of the grant, or three (3) years if unfunded.

Adverse Event Reporting - Adverse events occurring in the course of the protocol must be reported in e-protocol as soon as possible, but no later than five (5) working days.

Continuing Review - Studies that received Full Board or Expedited approval must be reviewed three weeks prior to expiration, or six weeks for Full Board. Renewal Reports are submitted through e-protocol.

Completion Reports - Notify the IRB when your study is complete by submitting a Final Report Form in e-protocol.

Consent form (when applicable) will be stamped and sent in a separate e-mail. Use only IRB approved copies of the consent forms, questionnaires, letters, advertisements etc. in your research.

Please contact the Human Research Protection Office if you have any further questions. Best wishes for a successful project.

Consent Form for Participation in a Research Study
University of Massachusetts Amherst

Researcher(s):	Cheryl 'Cher' Ann Nicholas
Study Title:	A study of eye-movement visual scanning patterns during routine nursing care.
Funding Agency:	University of Massachusetts, Amherst Graduate School and Department Funding

1. WHAT IS THIS FORM?

This form is called a Consent Form. It will give you information about the study so you can make an informed decision about participation in this research.

2. WHO IS ELIGIBLE TO PARTICIPATE?

Senior nursing students.

3. WHAT IS THE PURPOSE OF THIS STUDY?

The purpose of this study is to monitor eye-movements during an on-going patient care assessment.

4. WHERE WILL THE STUDY TAKE PLACE AND HOW LONG WILL IT LAST?

The study will be conducted in the University of Massachusetts Amherst College of Nursing Simulation Center. You will be asked to participate in a clinical simulation that mimics a real clinical setting.
If you are randomized to receive training as part of the study you will receive $40.00 (maximum of 2 hours of your time). If you are randomized to the non-training group, the study will take a maximum of 1 hour and you will be compensated $20.00.

5. WHAT WILL I BE ASKED TO DO?

If you agree to participate in the study, you will be asked to participate in a nursing care simulation. You will be asked to wear eye-tracking goggles during the simulations. The simulation will include performing a variety of routine procedures typically performed by nurses in the hospital setting including patient assessment, medication administration, documentation; e.g. medical chart review and general patient care.

6. WHAT ARE MY BENEFITS OF BEING IN THIS STUDY?

There are no direct benefits to you as a participant in this study. Participants in this study are supporting the advancement of health care knowledge, which may contribute to future patient safety.

7. WHAT ARE MY RISKS OF BEING IN THIS STUDY?

There are no known risks associated with this research study; however, a possible inconvenience may be the time it takes to complete the study. You may also feel uncomfortable being observed during the simulation.

8. HOW WILL MY INFORMATION BE PROTECTED

The following procedures will be used to protect the confidentiality of your study records. The researchers will keep all study data in a secure location. Research records will be labeled with a code. A master key that links names and codes will be maintained in a separate and secure location. The master coding key will be

University of Massachusetts Amherst IRB
(413) 545-3428
Approval Date: 08/31/2015 **Protocol #:** 2015-2587
Valid Through: 06/23/2016
IRB Signature:

destroyed 1year after the close of the study. The eye-tracking data will be kept for 3 years to possibly use later for secondary analysis. All electronic files containing identifiable information will be password protected. Any computer hosting such files will also have password protection to prevent access by unauthorized users. Only the members of the research staff will have access to the passwords. At the conclusion of this study, the researchers may publish their findings. Information will be presented in summary format and you will not be identified in any publications or presentations.

9. WILL I RECEIVE ANY PAYMENT FOR TAKING PART IN THE STUDY?

You will be compensated $40.00 if you are assigned to the training group. This study will take a maximum of two hours. You will be compensated $20.00 if you are in the non-training study. The non-training group will take a maximum of one hour.

10. WHAT IF I HAVE QUESTIONS?

Take as long as you like before you make a decision. I will be happy to answer any question you have about this study. If you have further questions about this project or if you have a research-related problem, you may contact the researcher, Cher Nicholas at 413-387-2852 or email me at cnichola@umass.edu. If you have any questions concerning your rights as a research subject, you may contact the University of Massachusetts Amherst Human Research Protection Office (HRPO) at (413) 545-3428 or humansubjects@ora.umass.edu.

11. CAN I STOP BEING IN THE STUDY?

You do not have to be in this study if you do not want to. If you agree to be in the study, but later change your mind, you may drop out at any time. During the study you may withdraw at any part during the study, however, you will only receive compensation upon completion of the study. There are no penalties or consequences of any kind if you decide that you do not want to participate. Participation in this study will not effect your evaluation as a student nurse in any way.

12.WHAT IF I AM INJURED?

The University of Massachusetts does not have a program for compensating subjects for injury or complications related to human subject's research, but the study personnel will assist you in getting treatment.

13. SUBJECT STATEMENT OF VOLUNTARY CONSENT

☐ When signing this form I am agreeing to voluntarily enter this study. I have had a chance to read this consent form, and it was explained to me in a language, which I use and understand. I have had the opportunity to ask questions and have received satisfactory answers. I understand that I can withdraw at any time. A copy of this signed Informed Consent Form has been given to me.

☐ I agree to have my data used for potential, future research projects. The raw the eye-tracking data may be used to improve the way we conduct research using this new technology or answer questions about nursing visual scanning patterns not yet identified.

_____	_____	_____
Participant Signature	Print Name	Date

By signing below I indicate that the participant has read and, to the best of my knowledge, understands the details contained in this document and has been given a copy.

University of Massachusetts Amherst-IRB
(413) 545-3428
Approval Date: 08/31/2015 **Protocol #:** 2015-2587
Valid Through: 06/23/2016
IRB Signature: Mary C. Shea

_____ _____ _____

Signature of Person Obtaining Consent Print Name Date

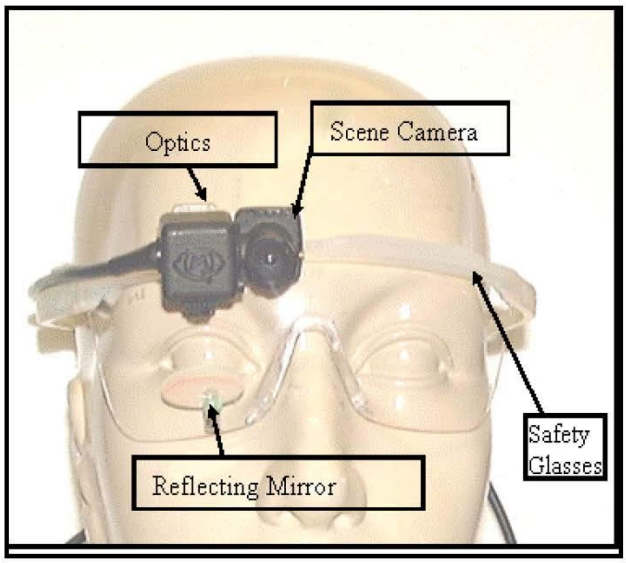


Figure: Eye-tracking goggles

APPENDIX D

PASSIVE TRAINING COMMENTS

Subject ID: JUUP _ JVVP

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

Interruptions can disrupt the flow of what you're doing, like if I was in the middle of 12 o' clock med pass and I got interrupted, it would take me a minute to collect my thoughts and remember which patient or which med I was in the middle of getting. Also, if it was an emergency, I could completely forget or run out of time for giving a med

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

I'm a forgetful person, so I like to say to myself I need to do this at this certain time. Sometimes I forgett, so I write myself reminders. Maybe at work, I can bring sticky notes and leave a mental note for myself to come back to this.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

I could stop, write down what I was in the middle of doing, go handle the interruption, and go back. I could also write "go back to this patient to finish ___".

Subject ID: NPZW

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

When I'm Interrupted I tend to backtrack more frequently. It takes longer to get everything I need to do done. I tend to get less done in the shift. I definitely will forget certain tasks and am more likely to make mistakes.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

- I would definitely take an extra two seconds to look at the item I'm holding or the task I'm performing and make a mental note to go back.
- Sometimes I set alarms on my phone with a time that is tied to a specific task. As soon as the alarm goes off I remember the task.
- I could also see myself writing a note/a word or symbol to remind myself to go back.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

- To move information into long term memory I have to take an extra moment to process the information. In the future I will take an extra 1-2 seconds to look at what I'm doing, before I move on to ~~the~~ attending to the interruption.

Subject ID: CLPB

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

Interruptions can make completing tasks take longer. I think they have the potential for more easily making a mistake on the original task.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

As more of a visual learner I think I could try to take a mental snap shot of a diagram or shape to help remind me what I was doing before the interruption. I think muttering a little reminder of what I was doing under my breath before tending to the interruption might solidify the reminder in my mind. If I know I won't be returning to the original task for a while I try to write a reminder.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

Learning about the limitations makes me wonder if I have ever forgotten to remember something without realizing it. Considering the frequency of interruptions + limitations of short term memory I am more inclined to implement a system for myself to reduce the risk of forgetting.

Subject ID: DAFL

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

Decrease the quality of your work by allowing you to forget what you were doing, therefore ~~pieces~~ steps may be missed in the original process. Interruptions also disrupt the client's comfort — often cause irritability, fear, panic, inability to rest, etc. This can lead to prolonged healing time and overall discomfort of the patient which would affect my working with them.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

Imprinting the image of what I'm doing would allow me to make a mental note and remember to complete the task.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

Make sure to imprint an image for 1-2 seconds to allow the memory to be stored in long-term memory. Also, being aware that after 18 seconds of doing a task the memory transfers to long term memory and can help with remembering to complete certain tasks.

Subject ID: IYVJ

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

Interruptions could affect your work by causing you to forget your placement during an important task such as medication calculation, administration, OR performing a nursing task such as catheter placement or IV insertion. Mistakes during these events because of an interruption could cause harm to the patient and jeopardize your license.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

I am likely to restate where I am out loud by saying "I am leaving off reviewing the pt's MAR, I would like to return to this place" so I can go tend to the interruption, but recall my previous statement of where I left off. I could also visualize a certain object I want to return to after the interruption by staring at it for 2-3 seconds, making a "mental note" of where to return to.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

I would use some of the mental placemarkers I learned from this training to manage interruptions so that I do not rely on my (unreliable) short term memory to remember my place @ my previous task.

Subject ID: JABG

A study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

- having your train of thought interrupted, then forgetting what you needed to ~~do~~ do - ex @ clinical of needing to get someone blanket / drink / book etc. and when I'm in the hall someone asks me to do another task that takes priority, so I end up forgetting to go back to the original task.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

- looking at the physical objects of the task
- looking at the flag in the computer that signals task needs to be done
- close my eyes and think for 1-2 seconds, "I need to come back to looking up infusion rate"

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

I would need to make it a priority to make a mental note within the 10 seconds after the interruption because if not I will most likely forget.

Subject ID: MONV

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

- Vital signs monitor alarm
- Patient interruption (ask question, need something, etc.)
- Family member interruption
- Nurse or other staff member calling out for assistance

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

I like the suggestion that the powerpoint gave - if an interruption occurs I could say to myself "I was doing ___, I am going to come back to it after I've addressed the interruption."
Writing a note to myself may also be effective, such as jotting down "bowel" if that's where I was in my assessment when the interruption occurred.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

Now that I am more aware of the limitations, I realize the importance of making mental notes so that I do not forget to come back to what I was doing before the interruption.

Subject ID: KHFW

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

Interruptions can affect work because they stop you from what you're doing and can draw your focus away from the task at hand, potentionally making you less thourough in the task.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

To make my mental notes I would definetely look at a specific spot on what I am doing and tell myself to go back to that spot because I am a visual learner.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

I think that making a mental note consciously instead of just walking away will hold kind of a "sticky note" in your short term memory to help you improve it.

Subject ID: S1HO

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

- could make me forget the place in my task I'm at, so that I have to start over and lose precious time
- could cause me to skip over an essential task that I hadn't already completed (checking a name band)
- could make me forget assessment information that I had not yet written down yet (vital sign numbers or other observations)

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

I will likely be able to use the mental place marker by focusing on a word or image for a few seconds before addressing the alarm

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

Understanding how fleeting our short-term memory is will make me more aware of my need to focus and reorient myself to tasks after interruptions take place

Subject ID: PKUV

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

Forgetting to go back/do the task after paying attention to the distraction can affect my work.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

I would make mental placemarks on the medication so that after the distraction I would remember I still needed to administer the medication. Also, if I were to be documenting when there is a distraction I could make a mental placemark on the box on the computer to remember to finish charting.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

I would practice using the 1-2 second mental markers to manage interruptions.

Subject ID: WPYM

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

For example, interruptions could affect the medication administration process. Interruptions could also make me forget the list of tasks I need to do which would affect the complete care the patient deserves. Basically interruptions can just make the person all frazzled and mess up their way of thinking.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

Techniques I could use would be to wait a few seconds before changing my attention to the interruption. In those few seconds I would probably make a mental note saying, "I ~~was~~ will do this when I come back."

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

Knowing that short term memory is only 18 seconds and can be forgotten if interrupted, I am more concerns w/ interruptions and how they can affect me. So from now on, I will try to be more aware of my tasks before there are interruptions.

Subject ID: UYEW

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

Alarm interruptions usually indicate an urgent or potentially emergent situation in the workplace. As a result, hearing an alarm usually causes me to drop whatever I'm doing and place all of my focus on that alarm. This could cause me to forget to perform certain tasks at work.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

In the future when I hear an alarm, I will likely take the extra one to two seconds to say to myself, "You need to return to this specific place in this specific task," and I will try to associate this mental not with an object so that I can better return to my task after I address the alarm.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

I will incorporate this by paying attention to the task at hand and making a brief mental note before addressing the alarm. This mental note will only take 1-2 seconds.

Subject ID: PUAJ

A Study of eye-movement visual scanning patterns during routine nursing care

Interruption training

Please answer the following questions. The answers to these questions will not reflect on your academic evaluation in any way. Thank you.

1. In your own words, describe some ways that interruptions could affect your work.

When documenting or charting on a patient, an alarm may make you lose your train of thought or ~~position~~ may lead to an incomplete note if you forget to go back to it.

Also, medication administration; one may forget to go back to checking the correct patient, dose, medication, & route, and may skip directly to administering the medication.

2. The training you just received talked about making mental place markers on your current task before responding to the interruption. Describe some techniques you would likely use to accomplish making these mental notes.

I would think about the physical location I am in (i.e. sitting at the computer desk on the right side of the nurses station) and then also think about exactly what I am doing on the computer at that time, and connect the two thoughts.

3. The training discussed limitations of short-term memory. How would you incorporate this knowledge with managing interruptions?

Taking time to conciously think about the aspects mentioned above to make a concrete memory of what you were engaged in before that alarm.

APPENDIX E

CONCEPTUAL AND OPERATIONAL DEFINITIONS

Term	Conceptual Definition	Operational Definition
Interruption	A disengagement from the primary task to attend to a secondary task	The cessation from the primary task to attend to a secondary task due to an alarm alert.
Extended Interruption	An interrupting event that involves performing a time extended intervening activity of more than 1 to 2 seconds.	An event that could be as complex as a caregiver recognizing that he or she needes to abandon temporarily and immediately the primary task in which he or she is engaged and undertake some secondary task, only later to return to the primary task
Interruption time	The time involved to perform an intervening task.	The time where attention – both visual and physical -is focused on the secondary task.
Interrupting task	The activity that is required as a result of the interruption.	The activities required as a result of a bedside monitor alarm.
Interruption Lag	A Memory for Goals time parameter defining the first seconds after the individual is made aware of the interruption.	The time period where the participant is made aware of the interrupting event to the first visual or physical action toward the interrupting event.
Interruption duration	The time period to perform a secondary task as a result of being interrupted.	The length of time participants are taken away from the primary task to attend to the

		secondary task as a result of the alarm.
Resumption Lag	A Memory for Goal time parameter defining the return cognitive focus back to the primary task.	Not measured in this research
Alarm	An audible signal emitted from a source.	An audible and visible signal emitted from a bedside monitor. A low-level alert such as Oxygen Saturation.
Medication administration task	A medical task that involves performing delivering a medication to a patient.	This medication task consist of delivering either a unit of Ampicillin 500 mg in 0.9 NS IV 100 ml or a unit of Cefotetan 1 gram in 0.9 NS IV 100 ml to the simulated patient
Primary task	A task that constitutes the original intent or activity to be performed.	The medication administration task.
Secondary task	A task that is not the primary function or the primary intent of the individual.	The nursing activities involved with responding to a Sp02 medical monitor alarm.
Encoding	A Memory for Goal term representing a cognitive process.	A conscious, cognitive process indicating that memory is used to rehearse information.
Medication error	The failure to complete a planned action as it was intended, or when an incorrect plan is used, at any point in the process of providing a medication to	Defined as either an active or a latent error.

	patients.	
Active error	A medication administration error, defined as the absence of an activity that if it occurs could result in patient harm.	For example, not checking the patient's ID information prior to delivering the medication.
Latent error	A medication administration error, defined as the absence of an activity that if it occurs, does not necessarily result in patient harm in all cases.	For example, not introducing self to the patient.

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