

UNDERSTANDING MULTIPLE TASK COORDINATION IN A COMPLEX HEALTHCARE ENVIRONMENT

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UNDERSTANDING TASK COORDINATION IN A COMPLEX HEALTHCARE ENVIRONMENT

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SUMMARY

Understanding multiple task coordination is important in complex life-critical environments. In healthcare, for example, many situations occur in which there are multiple tasks and limited resources for addressing all tasks at the same time. Emergency departments in particular are complex, interruption-driven environments. In many cases, physicians in emergency departments do not complete a single task in isolation. Decisions regarding what tasks to do, and when to do them, can affect performance (e.g., time, accuracy, patient safety). Additionally, some task factors (e.g., priority, difficulty) can drive task coordination behaviors. Characteristics of interruptions, such as frequencies and types, in emergency departments have been studied, but there has been little research on how physicians schedule and manage multiple tasks. The purpose of this research was to investigate multiple task coordination by emergency physicians to understand strategies for task completion, strategies for task scheduling, and management of interruptions.

I conducted two studies to understand how emergency physicians coordinate multiple tasks. The goal of the first study was to understand task scheduling decisions by physicians in emergency departments through a modeling approach. This study consisted of an online questionnaire conducted with 170 emergency physicians (120 attending and 50 resident physicians). There were two primary research aims: to understand (1) task scheduling decisions in a multiple task context, and (2) how task scheduling decisions varied across experience level. Attending physicians' task scheduling decisions aligned more with a parsimonious one-reason rule, where priority was the only factor that influenced decisions. Alternatively, resident physicians' decisions were not driven by priority, but rather were influenced by difficulty, salience, and engagement. This

indicates that physicians may be differentially weighting different cues as they make decisions about how to order tasks, and provides insights for how to support decision making as these strategies are learned.

The goal of the second study was to understand how multiple task demands are managed and coordinated by physicians in emergency departments. This study consisted of questionnaires and interviews with 30 emergency physicians (15 attending and 15 resident physicians). There were three primary research aims: to understand (1) strategies used for multiple task coordination, including both completion and scheduling strategies; (2) how interruptions were conceptualized and coordinated, and (3) how multiple task coordination varied across experience level. I identified and hierarchically categorized a broad set of strategies for task completion, and determined that these strategies did not change with experience. For task scheduling, I confirmed that previously-identified factors drove task scheduling. I also better defined factors (e.g., splitting priority into urgency and criticality) and identified additional factors (e.g., time and its subcomponents, interpersonal skills). Although there were common task scheduling factors mentioned by all 30 participants (e.g., priority, time), other factors were identified more often by attending physicians than resident physicians (e.g., interpersonal skills). I also found that conceptualizations of interruptions in this environment did not significantly differ from existing definitions; however, participants discussed the need to clarify between positive and negative interruptions.

Overall, this research provided insights into task coordination in a complex, interruption-driven healthcare context. In this work, I investigated strategies for task scheduling, including further evaluating known factors (e.g., priority) and identifying additional factors (e.g., time) that drive task scheduling decisions. I combined insights from both quantitative and qualitative methods to evaluate hypothesis-driven models for task scheduling. In this case, findings from Study 1 indicated that a one-reason priority-only model best captured attending physicians' task scheduling decisions and a multi-

attribute model best captured resident physicians' task scheduling decisions; however, findings from Study 2 indicated a rich set of factors that are used by emergency physicians beyond those factors in the models. This indicates more parameters should be included in modeling studies to better evaluate task scheduling decisions. The results of this dissertation have implications for improving training and evaluation of physicians as well as designing tools to support multiple task coordination.

CHAPTER 1

INTRODUCTION

Imagine you are an emergency physician in charge of a triage zone of an Emergency Department (ED) in a large, public hospital. The main tasks you are responsible for include, but are not limited to: triaging patients; examining acute and non-acute patients; writing order forms for medicine, blood tests, and imaging studies; evaluating test results; supervising students; communicating patient plans with other healthcare professionals both in the immediate vicinity and remotely; and documenting findings. These tasks do not occur in isolation; rather, the physicians interleave the tasks in a manner that is not always predictable. Deciding what tasks to do when can result from top-down organizational mandates, time pressures, availability of resources, and goal-oriented outcomes (e.g., speed of processing patients, accuracy in treating patients).

However, in many cases, emergency physicians do not complete a single task in isolation. One attending emergency medicine physician described his work as follows: “I’ve got 20 patients to care for at the same time. By the time I return to my desk, everyone wants my attention: nurses with medication dosing questions, technicians with ECGs to review, medical students waiting to present their patients ... all while my phone is ringing - a clinic wants to transfer a patient to me” (Drummond, 2013, p. 1). It is common for one task (e.g., a junior colleague asking a question about a treatment plan for Patient A) to overlap with another task (e.g., another emergency physician detailing patient notes and a treatment plan for Patient B after an examination). Simultaneously, other cues in the environment can be competing for attention and acknowledgement (e.g.,

a phone ringing to discuss transferring Patient C, Patient D asking for directions to a different part of the hospital, a machine alerting in Patient E's room).

These types of chaotic scenarios lead to the following questions: How does the physician decide which task to complete first? How does the physician ensure all necessary tasks have been completed by the end of a shift? How do interruptions influence these other aspects of task coordination? Ultimately, how do these competing demands affect emergency physicians' abilities to perform their jobs in an accurate, timely fashion? If an emergency physician was working on a critical task, consequences could be severe.

Goal and Scope

To understand the overarching research question of how multiple tasks are coordinated in a complex healthcare environment, I first reviewed how this has been studied in the literature. I clarified what I meant by a "complex" healthcare environment and highlighted studies and examples from this domain.

Additionally, I am investigating strategies for multiple task coordination. My definition of a strategy is as follows: 1) goal-directed, 2) uses some procedure or method towards achieving or working towards the goal, 3) requires some amount of resources, and 4) are not required actions. Strategies for multiple task coordination includes strategies for task completion, task scheduling, and managing interruptions.

Multiple task coordination includes task completion, task scheduling, and integrating interruptions. For example, this is what one emergency physician said about task completion: "I see problems with completing tasks every shift. For residents it's more of the smaller things like I forgot to put in this order. Or I forgot to tell the nurse

this. I forgot to do something. On the attending level it's more of a systems problem. Like hey this order was put in four hours ago but it hasn't happened yet. Where's that breakdown. Why's the patient, why haven't they gotten their scan yet?"

The main way multiple task coordination has been studied to date is through investigating the effects of interruptions on outcomes (e.g., time, performance, behaviors), which is only one specific case of task coordination. In the literature, there is a clear distinction between an interrupting task and an ongoing task, neither of which are related through a higher-level goal. However, this distinction may not adequately capture how people actually think about tasks and behave in a complex environment, including how interruptions have been studied more generally outside of complex healthcare environments. Theories and models of interruptions can inform understanding of interruptions and task coordination. However, methodological limitations in this space, which limits understanding of the strategies and decisions underlying task coordination. The overarching research goal was to understand multiple task coordination, including strategies for task completion and task scheduling. I conducted two studies to answer this research question through a focus on 1) strategies for coordinating multiple tasks, including task scheduling, task completion, and interruption management, and 2) how experience affects strategies for multiple task coordination.

Strategies

Strategies are defined in a few different ways in the literature. For example, one definition is that a strategy is a "procedure that is nonobligatory and goal-directed" (Siegler, 1988, p. 11). Other definitions describe strategies more broadly as being "an approach to a task" (Hassall & Sanderson, 2012), or as directing time and effort towards

achieving objective(s) (Loft, Sanderson, Neal, & Mooij, 2007). Overall, the literature suggests that strategies are: 1) goal-directed, 2) use some procedure or method towards achieving or working towards the goal, 3) require some amount of resources, and 4) are not required actions.

However, these and other definitions have slightly different focuses and leave some open questions about what a strategy entails. For example, do there have to be multiple potential approaches towards achieving the goal to be “non-obligatory” actions? Is inaction a type of procedure or method for achieving a goal? Even though they require some form of resources (e.g., time, effort) to achieve, are strategies necessarily conscious actions? Are strategies completed at the level of a person or an organization? And are strategies short-term or longer-term approaches?

For this dissertation, I used the following definition. First, a strategy must be goal-directed, meaning that arbitrary actions are not necessarily a strategy. Second, the operator must use some approach, including purposeful inaction, towards achieving the objective. Third, a strategy requires some amount of resources. Fourth, strategies must arise from a set of multiple potential approaches, meaning that a choice is made as opposed to being obligatory actions. Finally, strategies discussed in this paper are from the perspective of a person’s approaches in-the-moment, as opposed to broader organizational or team approaches.

Complex Environments

Emergency departments are generally discussed as complex environments; however, what distinguishes a complex environment? Emergency departments are hierarchically composed of different interrelated units (e.g., emergency department,

inpatient units) and providers (e.g., attending and resident physicians, nurses, unit staff), each of which has its own internal hierarchy (e.g., hospital over emergency department over triage area, attending physician over resident physician, charge nurse over other nurses). At times, these different subsystems can have the same or different goals, which may or may not emphasize different outcomes. For example, both the attending and resident physicians have the same goal of good patient health outcomes. However, a resident physician asking for help with a single patient at a given point in time can interfere with the attending physician's goal of attending to all patients in the department, which involves management of large amounts of data, people, processes, and resources.

There is not a fully agreed-upon definition of system complexity. Mitchell (2009) identified different ways complexity of a system can be identified, including the system's size, entropy, algorithmic information content, logical or thermodynamic depth, statistical complexity, fractal dimensions, and hierarchy, which appears to be the leading attribute used in research. Simon (1962) defined a complex system as being "made up of a large number of parts that interact in a nonsimple way. In such systems, the whole is more than the sum of the parts [...]. Given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole" (p. 468). Simon (1962) discussed the prevalence of hierarchies within a complex system, wherein interrelated subsystems comprise the system.

Extending this, complexity of an environment can be thought of as the amount of processing needed to coordinate multiple tasks and stimuli towards achieving a goal, although at a systems level, complexity, and difficulty are largely entangled concepts and are thus discussed as "complexity" for systems throughout the rest of this paper. For

example, lower complexity office work can require a worker to remember and understand information for data entry, but not require the worker to then synthesize or evaluate these data.

Complex emergency departments require physicians to remember and understand multiple patients' histories to synthesize multiple data sources and evaluate them while also managing other tasks in a life-critical context. In one emergency department, physicians were observed experiencing a brief switch in attention 30.9 ± 9.7 times and a switch in task 20.7 ± 6.3 times during a 180-minute span (Chisholm, Collison, Nelson, & Cordell, 2000). In this example, the emergency department is more complex than the office work, but this does not always have to be the case. Understanding how people coordinate tasks in complex environments (e.g., task coordination strategies, task selection decisions) is important for overall system performance.

Research in Complex Healthcare Environments

Multiple task coordination and complexity have been studied in healthcare environments, mostly focused on the interruption-driven domain of emergency departments and with the majority of studies using physicians (see Table 1). Complexity of work has been discussed in terms of describing the frequencies and characteristics of both tasks and interruptions in this dynamic context with shifting tasks and demands. In the healthcare space, most studies have focused on interruptions as the primary aspect of task coordination and as a means to describe the complexity of this environment.

Level of experience, which can be operationalized by job role (e.g., attending physician vs. resident physician), is an important aspect of these environments. The different emergency physicians' roles can influence both the nature of the work (e.g.,

numbers and types of tasks, how other people approach them as interrupters vs. interruptees). Crew Resource Management suggests that there could be power imbalances in interpersonal relationships that could affect how people are expected to coordinate tasks and in which order (e.g., Pizzi, Goldfarb, & Nash, 2001). For example, an attending physician and resident physician could be managing a section of an emergency department together, but the attending would be more focused on ensuring patients are dispositioned in a timely manner and keeping throughput of patients high, whereas the resident might be more focused on taking patients' histories and ordering diagnostic tests, but have to manage a higher volume of unrelated questions such as where to find the nearest restroom.

Comparing experience levels, which serves as a proxy for novices and experts, has been used in previous work in skill acquisition and expertise to understand how to help people become more skilled and knowledgeable (Chi, 2006; Rogers, Maurer, Salas, & Fisk, 1997). Novices and experts detect different patterns of cues in complex environments (e.g., Klein, 1999). For example, a senior attending physician and a junior resident physician could both be examining a patient together. Depending on how each physician interprets the cues from the patient's primary medical history, the attending and resident could cognitively attribute different values for the patient's difficulty and priority values, and thus treat the patient more or less urgently.

A study of emergency physician activities over approximately 400 hours of observation periods found that the majority of the physicians' time was spent on indirect patient care activities (e.g., charting, reviewing records and tests, consults), as opposed to direct patient care activities (Chisholm, Weaver, Whenmouth, & Giles, 2010). Another

study found that time spent on indirect patient care varied by healthcare provider role (Hollingsworth, Chisholm, Giles, Cordell, & Nelson, 1998). In the span of two hours, physicians at academic hospitals were interrupted a median of 12 times (range 1 to 32 interruptions), and physicians at community hospitals were interrupted a median of 6 times (range 0 to 19 interruptions; Chisholm et al., 2010). However, physicians are not always successful at managing multiple tasks when interrupted; one study found following 20% of interruptions, physicians failed to return to the interrupted task (Westbrook et al., 2010). Ultimately, physicians regularly had to provide care for multiple patients (median > 5 patients) simultaneously, with high amounts of variability in workload over time (Chisholm et al., 2010).

Table 1

Studies Involving Multiple Task Coordination in Complex Healthcare Environments

Study	Participants	Location of Study	Interruptions Findings	Method
Allard, Wyatt, Bleakley, & Graham (2012)	<ul style="list-style-type: none"> 1 senior physician 	Emergency Department	<ul style="list-style-type: none"> Average of 6 interruptions/hour (718 total, with 498 “successful”) Most common interruptions were: verbal advice, telephone calls and interpretation of x-rays (electronic communications → increased “success” of interruptions) 	<ul style="list-style-type: none"> Self-observations (119 hours)
Brixey, Robinson, Johnson, Johnson, Turley, Patel, & Zhang (2007)	<ul style="list-style-type: none"> 5 physicians and 8 nurses 	Emergency Department	<ul style="list-style-type: none"> Developed hybrid method of categorizing interruptions: 3 categories- subordinate, superordinate, interaction with technology Categories of interruption- intended recipient, unintended recipient, indirect recipient, self-interruption, distraction, organizational design, artifacts not available, initiator 	<ul style="list-style-type: none"> Observations (60 hours, 14 mins total)
Brixey, Robinson, Turley, & Zhang (2010)	<ul style="list-style-type: none"> 5 physicians and 8 nurses 	Emergency Department	<ul style="list-style-type: none"> Physicians and nurses received more interruptions than initiate (face- to-face interactions, telephone) Attending physicians performed fewer tasks but were interrupted more frequently than nurses 	<ul style="list-style-type: none"> Observations Case study (70 hours total)
Brixey, Tang, Robinson, Johnson, Johnson, Turley,... & Zhang (2008)	<ul style="list-style-type: none"> 5 physicians (29 hours, 31 mins) 8 nurses (40 hours, 9 mins) All had 6 months+ experience 	Emergency Department	<ul style="list-style-type: none"> Nurses were interrupted slightly more, and resumed tasks slightly more, than physicians Physicians and nurses usually returned to the original, interrupted activity more often than leaving the activity unfinished (especially if fewer interrupting tasks were stacked) Still possibilities of errors after task resumption. Most interruptions were by people 	<ul style="list-style-type: none"> Observations (physicians: 29 hours, 31 mins; nurses: 40 hours, 9 mins)

Table 1 continued

Study	Participants	Location of Study	Interruptions Findings	Method
Chisholm, Collison, Nelson, & Cordell (2000)	<ul style="list-style-type: none"> • 30 physicians 	Across 3 Emergency Departments	<ul style="list-style-type: none"> • For each study period the physicians had a mean of 67.6 +/- 15.7 tasks • Average # interruptions: 30.9 +/- 9.7; average # breaks-in-tasks 20.7 +/- 6.3 • The number of interruptions and the number of break-in-task per observation period were positively correlated with the average number of patients simultaneously managed • Emergency physicians are "interrupt-driven" • Emergency physicians are frequently interrupted and many interruptions result in a break-in-task 	<ul style="list-style-type: none"> • Observations • (180 minute periods)
Chisholm, Dornfeld, Nelson, & Cordell (2001)	<ul style="list-style-type: none"> • 22 emergency physicians • 22 office-based primary care physicians (PCPs) <ul style="list-style-type: none"> ○ 6 pediatric ○ 6 internal medicine ○ 6 family medicine ○ 4 pediatric internal medicine 	Across 5 nonteaching community hospitals and 22 primary care offices	<ul style="list-style-type: none"> • "Emergency physicians were interrupted an average of 9.7 times per hour compared to 3.9 times per hour for primary care physicians • Emergency physicians spent an average of 37.5 minutes per hour managing 3 or more patients compared with 0.9 minutes per hour for primary care physicians. • PCPs spent significantly more time performing direct patient care • Emergency physicians spent significantly more time analyzing data, charting, and taking reports on patients 	<ul style="list-style-type: none"> • Observations using time-motion • Task analysis

Table 1 continued

Study	Participants	Location of Study	Interruptions Findings	Method
Coiera, Jayasuriya, Hardy, Bannan, & Thorpe (2002)	<ul style="list-style-type: none"> • 6 physicians • 6 nurses 	Across 2 Emergency Departments (1 urban, 1 rural)	<ul style="list-style-type: none"> • 30.6% of communication events (comms) were interruptions (11.15 interruptions / hour) • 10% of comms included 2+ simultaneous • 90% of comms were informal interactions • Nurses had higher communication loads than physicians 	<ul style="list-style-type: none"> • Observations • (35 hours, 13 mins total)
Grundgeiger, Sanderson, Orihuela, Thompson, MacDougall, Nunnink, & Venkatesh (2010) – Study 1	<ul style="list-style-type: none"> • 10 senior nurses 	ICU	<ul style="list-style-type: none"> • Nurses finished task on hand before attending the interruption • Nurses held artifacts such as syringes in the hand while dealing with interruptions • Sometimes placed reminders in the environment that represented the to-be resumed task 	<ul style="list-style-type: none"> • Observations with eye trackers • (27 hours)
Grundgeiger et al. (2010) – Study 2	<ul style="list-style-type: none"> • 24 senior nurses 	ICU	<ul style="list-style-type: none"> • Theories about task resumption only accounted for a third of variance. • Interference between the interrupting and ongoing tasks may be affecting resumption time. • Reminders that are not specifically associated with a specific action seem <i>not</i> to prompt memory. • Might be beneficial for nurses to try to solve interruptions on the spot and to keep interruptions short 	<ul style="list-style-type: none"> • Interviews • Stimulations with eye trackers • (27 hours)

Table 1 continued

Study	Participants	Location of Study	Interruptions Findings	Method
Jeanmonod, Boyd, Loewenthal, & Triner (2010)	<ul style="list-style-type: none"> Physicians Physicians-in-training 	Emergency Department	<ul style="list-style-type: none"> Physicians were commonly interrupted in all clinical activities but most frequently during reviewing of data and charting. Most commonly interrupted by other healthcare providers. Interruptions only rarely resulted in a physician changing tasks before completion. Interruptions tended to be brief with an average length of 0.78 minutes. 	<ul style="list-style-type: none"> Observations (132 hours total)
Johnson, Motavalli, Gray, & Kuehn (2014)	<ul style="list-style-type: none"> Triage nurses 	Emergency Department	<ul style="list-style-type: none"> Interrupted 48.2 times during an 8-hour shift (7 interruptions per hour) Only 22% of interruptions were related to patient care; most included opening the door, visitor assistance, “how much longer” questions 	<ul style="list-style-type: none"> Self-observations (10 days)
Koh, Park, & Wickens (2014)	<ul style="list-style-type: none"> 10 experienced nurses 10 novice nurses 	Operating Room	<ul style="list-style-type: none"> Experienced nurses showed better task prioritization in the display of greater resistance to interruptions during their tasks, especially to non-surgeon triggered interruptions during their surgical counts Experienced nurses also had better anticipation in aiding the surgeon 	<ul style="list-style-type: none"> Observations for 1 surgery each using eye trackers
Kosits & Jones (2011)	<ul style="list-style-type: none"> 30 nurses 	Across 3 Emergency Departments	<ul style="list-style-type: none"> Nurses were most frequently interrupted by another nurse, followed by a physician Interruptions were much less frequently caused by phone calls or other categories 200 interruptions; 3.3 per hour per nurse 	<ul style="list-style-type: none"> Observations (60 hours)

In summary, healthcare providers coordinate multiple tasks throughout most of their work. There are some differences in tasks, interruptions, and coordination performance based on experience level, context, provider types, and tasks (e.g., Werner & Holden, 2015). The majority of the studies on task coordination in emergency departments used physicians as subjects; for that reason, the rest of the dissertation will focus on this provider type.

The main methodologies used in these studies were field-based observations, with limited insights into how emergency physicians coordinate multiple tasks, nor why they use these approaches to task coordination. It is still unclear how physicians in emergency departments coordinate complex, concurrent tasks, including when faced with interruptions. Knowledge elicitation in the context of coordination studies has not been well-described, so there may be value in using some other methodologies that have not been used in this context.

There has been a recurrent theme of studying interruptions in healthcare; however, most studies do not define what is meant by an interruption, nor do they link definitions with cognitive understandings of what constitutes an interruption. These studies have described the types, frequencies, and counts of both tasks and interruptions in this space. However, it is unclear whether emergency physicians view interruptions in this space as interruptions versus simply another task to be coordinated. Providing a distinction between multiple task coordination and interruptions may not change cognitive mechanisms or strategies for approaching interruptions, but this may be relevant to research and methodologies exploring interruptions in healthcare environments, as well as training for managing tasks and interruptions.

What is an Interruption

The literature on interruptions has lacked a consistent, comprehensive definition of an interruption, instead almost exclusively relying on colloquial understanding of interruptions or arbitrary time-based distinctions between interruptions and non-interruptions. This was a critical gap; if researchers interpret interruptions differently, individuals might be confused and there exists the possibility of results from studies being taken out of context and misrepresented at a larger scale (e.g., incorrect generalizations, problematic meta-analyses). In a recent review of interruptions in emergency departments, researchers created a definition of interruptions for that context:

“Interruptions in a complex sociotechnical system are a process of multiple unfolding events, including but not limited to suspending one task to work on another. The interruption process: (a) is shaped by system factors and (b) can produce immediate and delayed outcomes—positive, negative, or neutral—for multiple individuals” (Werner & Holden, 2015, p. 251).

An additional, non-context dependent evaluation and synthesis of the few existing interruption definitions informed a similar comprehensive definition of an external interruption:

“An **external interruption** is the process of managing ongoing task(s) in the presence of an abrupt perceived stimulus or event outside of a person’s control. This redirects some or all of the person’s attention and cognitive resources away from ongoing task(s). The perceived stimulus or event is interpreted, triaged, and scheduled for performance or discarded. The

process has potential consequences for task coordination and performance.” (Barg-Walkow & Rogers, 2015, pp. 33-34).

In both definitions, interruptions are discussed as being a process. This process includes some form of task coordination, and also affects overall outcomes. Although both definitions allude to potentially resuming the interrupted task given specific task scheduling, neither definition addresses how this can occur. Another relevant concept is prospective memory, which is remembering to execute tasks in the future (McDaniel & Einstein, 2007; Meacham & Leiman, 1982). Interruptions and coordinating multiple tasks can create the implicit prospective memory task of remembering to resume the task which is scheduled for the future (Dismukes, 2012; Dodhia & Dismukes, 2009). These definitions provide a shared, scientific, literature-based understanding of an interruption.

How Have Interruptions Been Studied

Interruptions are a specific type of multiple task coordination, where attention is shifted from one task to another task either voluntarily (e.g., self-interruption) or involuntarily (e.g., external interruption). Interruptions have been extensively studied. However, most studies focused on non-complex, dual-task contexts, where a person shifts between a single ongoing task and a single interrupting task. Although these experimental designs allow for direct investigation of targeted variables, this approach may miss interactions between variables that could occur in complex environments. For example, if a person switches to the interrupting task, that then becomes the ongoing task, which may continue to be switched. As referred to in the section on research in complex healthcare environments, it may be inappropriate to differentiate between interruptions and multiple task coordination in research in specific complex domains.

Some variables have been studied extensively, potentially to the exclusion of other relevant variables. Commonly-studied variables in interruptions research were identified in a meta-analysis of over 700 research articles on interruptions (Wickens, Santamaria, & Sebok, 2013). These variables were: 1) difficulty of the ongoing task, 2) modality of the interrupting task, 3) surface and deeper similarities between the ongoing and interrupting tasks, 4) fluency of switching, 5) time to return, and 6) ongoing task performance. However, these studies did not investigate multiple interruption variables interacting in complex contexts.

Empirical investigations have examined the variables influencing how interruptions affect task outcomes, including task, person, and context variables—see Barg-Walkow and Rogers (2015) for a review and conceptual model of the relationships between task, person, context, and outcome variables. These studies have focused on outcomes (e.g., task switches, time, accuracy) without much emphasis on the process managing interruptions of tasks. Existing models describe outcomes of interrupting task, but there is a gap in the literature on peoples’ strategies for managing tasks and interruptions in complex environments.

Field studies in complex environments have also been undertaken to describe and understand interruptions and their effects. In emergency departments, for example, there have been multiple studies using direct observations. These studies primarily reported counts of number, types, and sources of interruptions. For example, reports include who was interrupted, by whom, during what task, what comprised the interruption, the duration of the interruption, and whether or not an interrupted task was eventually resumed. In complex environments, however, it can be challenging to identify

interruption outcomes (e.g., accuracy), especially given that outcomes can be delayed. Little has been reported about strategies for managing the process of coordinating multiple tasks when presented with interruptions, and the details for peoples' task scheduling decisions (e.g., order of tasks, why/when/how resume tasks).

Ultimately, the main types of studies have been dual-task experiments using homogenous tasks in simple contexts, with a smaller subset of studies consisting of field observations of multiple heterogeneous tasks in context environments. These studies have included a large variety of manipulations, outcome measures, and definitions of interruptions. There have been limited links made between field studies, experiments, and theory. Although there has been a large body of research on the relationship between different variables and outcomes, not much is known about strategies and underlying reasoning underlying task coordination in complex environments.

How are Interruptions Conceptualized

Researchers have created models of interruptions based on cognitive theories and models to understand relationships between variables and outcomes. These models can be used to identify how people coordinate multiple tasks and to predict behavior, which could bridge the gap between explaining field-based observations and applying laboratory-based experiments. In general, interruptions are discussed in terms of changes of attention (e.g., selective attention, divided attention); specific mechanisms are not regularly cited. The main interruption models—most of which are based on an ACT-R cognitive architecture—include the Memory for Goals model, the Memory for Problem States model, Threaded Cognition, the Unified Theory of Cognition, and the Strategic Task Overload Management.

The Memory for Goals model was developed to model how people remember task status in goal-driven, complex, single tasks (e.g., Altmann & Trafton, 2002). The primary focus of the model is task goal suspension and resumption. Task goals and sub-goals are “stacked” temporally, with newer goals to be achieved and performed next sequentially placed at the top of the stack. Execution of the next goal depends on activation-based memory for the goals: specifically, activation levels and associative priming. When a task is suspended—for example, in the presence of an interruption—users have to hold the status of the current goal in working memory to be retrieved upon task resumption. The activation levels of these suspended goals decay over time, making task resumption more challenging and time-consuming. To compensate, users can rehearse the goals during an interruption and associative priming for cueing to their previous goal state, both of which can aid task resumption. The Memory for Goals model includes three predictive constraints about memory for task goals: 1) interference from previous goals, 2) strengthening/decaying over time, and 3) priming from cues. In general, the Memory for Goals model predicts that the greater amount of time spent away from a task, the longer it takes to resume the task upon return. However, the Memory for Goals model cannot easily explain outcomes resulting from some interrupting task variables, such as complexity and timing.

The Memory for Problem States model was created to address limitations of the Memory for Goals model (Borst, Taatgen, & van Rijn, 2010, 2015). In this model, problem states contain specific task-relevant information needed for successful completion of a task. These problem states are based on cognitive requirements of tasks, as opposed to general task goals. The primary focus of the Memory for Problem States

model is also task goal suspension and resumption. In general, the Memory for Problem States model predicts that greater task complexity and interruption duration leads to worsened task outcomes.

Threaded Cognition, also based on an ACT-R cognitive architecture, was created to represent multiple, simultaneous threads of thought leading to concurrent multitasking behavior, or performing multiple tasks at the same time (Salvucci & Taatgen, 2008). Similar to Memory for Goals, independent threads each represent a task goal. The interleaved threads combine to create overarching task and system goals. This model integrates processing across available resources without executive control. Main outcomes modeled are resumption lag and time on task. The model predicts procedural interference when tasks are similar, but also predicts that practice can reduce interference.

More recently, the Unified Theory of Multitasking integrated Threaded Cognition, ACT-R, and the Memory for Goals model (Salvucci & Taatgen, 2011). This unified theory models task interleaving on a continuum, from full overlap of tasks (e.g., concurrent multitasking as modeled in threaded cognition) to performing one task for minutes or hours between switching to a second task. In terms of interruptions, the primary outcomes modeled are interruption lag and resumption lag. For interruptions, the model predicts that interruption timing, pre-interruption alerts, and task types affect outcomes. Although the model attempts to predict all aspects of multitasking, it does not account for individual differences (e.g., working memory capacity) that could moderate the effects of interruptions on task outcomes.

Collectively, the aforementioned models do not predict behavior based on different task attributes. The Strategic Task Overload Management (STOM) model is a

framework to understand factors underlying how people decide to change tasks (Wickens et al., 2013; Wickens, Gutzwiller, & Santamaria, 2015). Unlike the other models presented here, STOM is not based on the ACT-R cognitive architecture. Instead, the model is an adaptation of the SEEV model, in which salience (S), effort (E), expectancy (E), and value (V) of the information sources predict attention (Wickens, Helleberg, Goh, Xu, & Horrey, 2001). This multi-attribute decision model focuses on a person's behavior (e.g., remain on task, switch to another task), as opposed to the other models' focus on the quality of task switches and resumption. In general, the model predicts a perseverance to avoid switching tasks (or task inertia). When a person is switching tasks, predictors of switching include high priority, low difficulty, and high salience and interest in the task. However, this model has not addressed individual differences. It may be appropriate to change the granularity of the different task attributes—each of these factors could potentially be broken down into multiple underlying task attributes. For example, in a complex healthcare environment it is likely important to disentangle the components of a task's priority into urgency of a task (e.g., time-based priority) and the criticality of the task (e.g., performance-based priority), both of which could influence behavior in task selection.

Multiple models have been developed to explain behavior when people are interrupted (e.g., the Memory for Goals model, the Memory for Problem States model, Threaded Cognition, the Unified Theory of Cognition, STOM, A conceptual model of external interruptions). However, these models have mostly focused on performance outcomes following interruptions in a dual-task context. Additionally, these models have not been used to explain results from observation field-based studies. Although our

understanding of task coordination for two tasks is informed by these models, more work is needed to be able to represent these relationships and behavioral outcomes in complex environments.

Task Scheduling

A main way of identifying how people approach coordinating multiple tasks is through using the outcome of task scheduling, which is a general, high-level strategy for task coordination. Task scheduling refers to people's decisions of when to perform ongoing and interrupting tasks in relation to one another. There are several descriptions from the interruption management literature on interruptions for how and why this occurs. Versions 1 and 2 describe a person's behaviors of performing the ongoing task vs. the interrupting task. Versions 3 and 4 describe the variables that affect those behaviors.

Version 1 (e.g., Salvucci & Bogunovich, 2010). Upon interruption, the person can: 1) switch to the interrupting task immediately, 2) continue working on the ongoing task, then switch to the interrupting task after a delay, or 3) continue working on the ongoing task. Variations on this version of scheduling behavior are the most frequently used in the literature. A fourth, not generally discussed, alternative is for a person to work on neither task for a period of time following an interruption.

Version 2 (Interruption Stage Management Model; Latorella, 1998; McFarlane & Latorella, 2002). Upon interruption, the person can: 1) fail to detect the interruption—"oblivious dismissal", 2) interpret the interruption as not significant—"unintentional dismissal", 3) interpret the interruption as significant, but choose not to perform the interrupting task—"intentional dismissal", 4) encounter a forced task-switch—

“preemptive integration”, or 5) decide how best to integrate the interrupting and ongoing tasks—“intentional integration”.

In cases 1-3, the person does not perform the interrupting task. In case 4, the person switches to the interrupting task immediately. In case 5, the person can choose to switch to the interrupting task immediately or after a delay. The outcomes (e.g., switch vs. continue on tasks) are similar to Version 1, but Version 2 allows for within-outcome distinctions and outcome combinations.

Version 3 (Reactive Prioritization Model of Task Management; Freed, 2000). In Version 3, task scheduling is influenced by the tasks’ relative urgency, importance, and duration, in addition to switching and interruption costs. However, this conceptual identification of important variables has not been validated with empirical data. Weightings of the different variables relative to one another were not specified.

Version 4 (STOM; Wickens et al. 2013, 2015). Version 4 addressed shortcomings in Version 3 by using empirical data about how people manage tasks. In this version of scheduling two tasks in a complex environment, the ongoing task is not treated as qualitatively different from the interrupting task; instead, a resumption of the task you left is the same as a switch from the task you went to. However, not all of the variables identified by Freed (2000) were investigated in STOM. In Version 4, task scheduling is influenced by switch avoidance, task salience, and comparative task easiness, priority, engagement (Wickens et al. 2013, 2015). In general, people demonstrate switch avoidance, meaning that people are more likely to stay on an ongoing task than switch to a second task, especially if the ongoing task has higher difficulty (Wickens et al., 2015).

However, when a person is switching tasks, predictors of switching to the second task include low second task difficulty, high priority, high salience, and high engagement.

There have been a few studies on strategies for task scheduling. One study found that people are able to strategically shift task scheduling to support the primary goal of performance in a dual-task driving context (Janssen & Brumby, 2010). In a field- and laboratory-based study, policies within the workplace for prioritizing one task over another influenced task scheduling (Eyrolle & Cellier, 2000). Additionally, when comparing self-interruptions to external interruptions in a voluntary task switching paradigm, self-interruption was found to introduce an extra cost of decision, making decisions to switch more costly (Katidioti, Borst, & Taatgen, 2014). In another study of voluntary task scheduling of two tasks from a choice of three tasks found that some participants were able to adapt towards combinations of tasks resulting in better performance outcomes (Nijboer, Taatgen, Brands, Borst, & van Rijn, 2013). This suggests that people can be taught how to strategically schedule tasks.

Voluntary task scheduling has been most studied through the STOM model and its attention-based antecedent. In a study of attention allocation during surgery, there were differences by experience level, with higher experience nurses paying more attention to the highest priority aspect of the task (Koh, Park, Wickens, Ong, & Chia, 2011). In a study using the cockpit environment, pilots were more likely to schedule high priority tasks, especially when experiencing an increased workload (Raby & Wickens, 1994). In a study where participants imagined two astronaut-based tasks, the task attributes of difficulty, salience, and engagement drove task scheduling decisions, whereas priority did not (Wickens et al., 2016).

Task scheduling has been described in a few ways in the context of interruptions. For the most part, task scheduling involves deciding whether to complete the ongoing task, the interrupting task, neither, or some combination of interleaving those options. In general, interruptions have been largely studied as involuntary task-switching between two homogenous tasks, such as identifying numbers as high or low (see Wickens et al., 2015). Very few experimental approaches have investigated voluntary task switching in a more heterogeneous, naturalistic environment. Additionally, there is little understanding for the underlying rationale and strategies underlying task scheduling decisions.

Task Resumption

As a part of task coordination, task resumption is returning to the ongoing task following some period of not performing that task. Task resumption research has mostly been conducted with dual-task, laboratory-based experiments. Timing of the tasks involved in interruptions affects peoples' ability to resume tasks following interruptions. Multiple studies identified that timing of the stage of the ongoing task (e.g., end of task) affects task resumption, with people generally being less able to resume a task after being interrupted in the middle of completing the task (e.g., Adamczyk & Bailey, 2004; Cutrell, Czerwinski, & Horvitz, 2001; Czerwinski, Cutrell, & Horvitz, 2000; Edwards & Gronlund, 1998; Monk, Boehm-Davis, & Trafton, 2004; Monk, Trafton, & Boehm-Davis, 2008; Zijlstra, Roe, Leonova, & Krediet, 1999). Delays in switching to the interrupting task can help improve performance when people resume the ongoing task through enabling rehearsal of cues for task resumption (e.g., Hodgetts & Jones, 2006). However, Gillie and Broadbent (1989) did not find this effect.

Delays in resuming the ongoing task after completing the interrupting task can either help or hinder task resumption—a short delay can reduce quick, incorrect responses (e.g., Brumby et al., 2013), but longer delays can reduce the likelihood of a task being resumed through task goal decay (e.g., Altmann & Trafton, 2002). Once people have resumed an ongoing task, it is likely to take longer to complete, and it is also likely to be interrupted more (e.g., Czerwinski, Horvitz, & Wilhite, 2004).

There are gaps in the literature on supporting task resumption; the vast majority of interventions have focused on *preventing* interruptions. Only one tool for aiding task resumption has evidence supporting it as a tool for aiding task resumption (Tran, 2009). It is possible for people to develop their own strategies and aids for task resumption, but this has not been empirically studied.

There have been a few studies on strategies for task resumption. One study found that people would typically fail at resuming the initial computer-based task after completing an interrupting task; however, a short pause or reminder of the initial task following the interrupting task improved performance (Dodhia & Dismukes, 2009). In a study of cockpit performance, task resumption and completion were impaired if there was an interruption a normal, highly-practice sequence of tasks (Loukopoulos, Dismukes, & Barshi, 2009).

More research is needed to investigate how people resume tasks in complex tasks situated in a specific context to better understand factors influencing task resumption decisions. Very few experimental approaches have investigated voluntary task switching in a heterogeneous, naturalistic environment with multiple tasks as options for switching. Research needs to move beyond the binary decision of whether or not the original task

was resumed, towards linking our understanding of task resumption with task scheduling and others models predicting underlying factors (e.g., STOM). There may be value in using additional methodologies that have not been used in this space to better understand task resumption in context.

Overview of Studies

Multiple task coordination is common in many contexts and domains. The present research focused on emergency departments (EDs) as a specific instance of a complex environment. Given that concurrent task demands are not always controllable, it is important to focus on how people respond to multiple task situations. Understanding how people currently respond to task demands is an important first step towards helping people better manage multiple task coordination.

Most research on how emergency physicians coordinate multiple tasks in EDs has centered on describing characteristics of interruptions (e.g., frequency, types of interruptions) through field observations. However, these studies have not investigated how people are coordinating tasks, but rather frequencies and challenges of managing tasks with interruptions. Current models of interruptions may not adequately describe how multiple tasks are coordinated in complex environments, given that there are other aspects of task coordination (e.g., supervising colleagues treating other patients, ensuring all patients are seen in a timely manner) that are important to performance.

Most interruption and multiple task coordination research outside of hospitals has been laboratory-based experiments using simple, homogenous tasks. Prior work has mostly focused on dual-task switches, which may not adequately capture the complexity of operational environments requiring multiple task coordination. In both experiments

and field studies, there has been some research on task performance (e.g., completion) and task scheduling (e.g., ordering of tasks).

However, there has been limited research understanding *how* people coordinate multiple tasks in complex environments. For example, how do emergency physicians make sure they complete all tasks? How do emergency physicians decide how to schedule tasks? What factors influence these decisions? Additionally, there is a need to understand how interruptions, a specific case of multiple task coordination, are conceptualized and coordinated with other tasks.

Therefore, in this dissertation, I investigated strategies used by higher and lower experience emergency physicians for coordinating multiple tasks in a complex, dynamic, interruption-driven environment. This included strategies for task scheduling, ensuring task completion, and integrating interruptions.

I conducted two studies to understand how emergency physicians coordinate multiple tasks. The goal of the first study was to understand task scheduling decisions by physicians in emergency departments and consisted of an online questionnaire conducted with 170 emergency physicians; 120 attending physicians and 50 resident physicians. There were two primary aims: understand (1) task scheduling decisions in a multiple task context, and (2) how task scheduling decisions varied across experience level.

The goal of the second study was to understand how multiple task demands are managed and coordinated by physicians in emergency departments. The second study consisted of questionnaires and interviews with 30 emergency physicians; 15 attending physicians and 15 resident physicians. There were three primary components of the study: (1) strategies used for multiple task coordination, including both scheduling and

completion strategies; (2) how interruptions were conceptualized and coordinated and (3) how multiple task coordination varied across experience level.

CHAPTER 2

STUDY 1 – OVERVIEW

Judgment analysis, or “policy capture”, quantitatively describes relationships between information or cues and decisions (Stewart, 1988). This method has been used in organizational research to investigate how cues drive decisions, as well other studies such as expert judgment studies (e.g., Aiman-Smith, Scullen, & Barr, 2002). The goal of this study was to identify how task scheduling cues drive decisions. However, traditional judgment analysis methodology assumes 60-90 minutes of participation involvement but that study length would not be appropriate for the intended population of emergency physicians, who have limited time to participate in studies. Based on SME feedback, the target duration of the entire study was under 10 minutes. Therefore, I used a computational modeling approach to determine the best combination of task attributes, tasks, and scenarios to maximally differentiate between different theoretical models of task scheduling decision making.

The task attributes of difficulty, priority, salience, and engagement emerged from the Strategic Task Overload Management (STOM) architecture, which also aligned with factors from other task scheduling models (e.g., Freed, 2000; Wickens et al., 2013, 2015). A recent study modeled the STOM architecture with two heterogeneous, complex tasks (Wickens et al., 2016). In this modeling of STOM, referred to here as STOM—no priority (STOM-NP), the parameters of difficulty, salience, and engagement equally drove task switches whereas priority did not affect outcomes.

There are alternative ways to model STOM-NP. The recognition heuristic, or a one-reason rule, is that "weighting only one variable and ignoring all others produces the same risk as ignoring the single variable and weighting all others" (Davis-Stober, Dana, & Budescu, 2010). In this case, the inverse of the 2016 STOM-NP model's equal weightings of difficulty, salience, and engagement, the one-reason rule would predict that a priority-only model which only used priority to predict outcomes (ignoring all other factors) would yield similar results, despite occupying a different vector space. This heuristic could be useful in streamlining training and decision aids by focusing on fewer task attributes. For example, training could focus on evaluating the relative priorities of tasks, both in written scenarios and simulations. If priority is the primary driver of decisions (with difficulty, salience, and engagement mostly ignored), or if the models were equal, this could indicate the parsimonious one-reason rule is an alternative explanation for STOM-NP.

The goal of the first study was to understand task scheduling decisions by physicians in emergency departments. There were two primary components of the study: (1) task scheduling decisions in a multiple task context, and (2) how task scheduling decisions varied across experience level. I predicted that the Wickens et al. (2016) recent modelling of STOM-NP, with difficulty, salience, and engagement equally driving task scheduling, would be the best fit for the data. I further predicted that the priority-only one-reason rule would generally explain the data about as well as the recent STOM-NP model (e.g., Davis-Stober et al., 2010). When comparing participants with different experience levels, I expected the attending physicians to use fewer cues to drive their task scheduling decisions, given their greater experience (e.g., Klein, 1999).

CHAPTER 3

STUDY 1 – METHOD

Participants

Participants were recruited using snowball sampling, with the goal of testing as many participants as possible within the study period of November 21st, 2016 through December 16th, 2016. Initial contacts for the snowball sampling included hospitals used in Study 2, officers of national emergency medicine organizations, and personal contacts, all of whom were asked to recruit additional potential participants from their acquaintances. Participants lived in 24 different states; 11 states had 5 or more participants: GA (40), IL (22), MD (21), MA (20), AR (10), IA (8), TX (8), FL (7), WA (7), CA (6), and NJ (5). Participants practiced in academic hospital systems (124), community settings (26), or both settings (24). The participants were given the opportunity to enter into a raffle of 6 \$50 Starbucks gift cards for their participation in the 10-15 minute online questionnaire study.

One hundred seventy-two emergency physicians participated in this study (see Table 2). All participants at the time of the study were: licensed emergency physicians; currently employed by a hospital's emergency department as an attending or resident emergency physician and working at least 20 hours per week in this position; at least 18 years old; and fluent in English. Two participants were excluded: 1 participant was a trauma surgeon and 1 participant was a fellow in emergency medicine.

Participants were grouped by provider role in the emergency departments, with 120 participants in the higher experience group (attending physicians) and 50 participants in the lower experience group (resident physicians). The participants had a range of

experience in emergency medicine as denoted by their postgraduate year (PGY). The racial breakdown of participants included: 132 White Caucasian; 14 Asian; 6 Black or African American; 6 Other; 6 Multi-racial; and 6 Did not wish to answer.

Table 2
Study 1 Participant Characteristics

	Postgraduate Year	Age (years)	Gender
Attending physicians (N=120)	Range = 4-43 $M = 13.97$ $SD = 8.00$	$M = 42.42$ $SD = 8.00$	45 females 75 males
Resident physicians (N=50)	Range = 1-4 $M = 2.20$ $SD = 0.88$	$M = 28.84$ $SD = 3.59$	18 females 32 males

Materials

Materials included the Demographics and General Work Experience Questionnaire and the Scenario Response Questionnaire.

Demographics and General Work Experience Questionnaire

The 29-item Demographics and General Work Experience Questionnaire was developed for this study to identify characteristics of the participants and the healthcare systems in which they work (See Appendix A). The 3 free-response items were state, job title, and a description of physician role. There were 8 integer-based items, which included: age, years of experience, general number of tasks, and maximum number of tasks. There were 14 items with a set of response items, which included: hospital characteristics (e.g., academic vs. community, number of beds in their emergency department), comfort in performing tasks, and job role. There were 4 questions on a scale

of degree of confidence (0-100%) in their ability to complete different aspects of multiple task coordination (overall, completion, scheduling, and adapting to changing conditions).

Scenario Response Questionnaire

Development of the Scenario Response Questionnaire

The scenario response questionnaire is a pared-down approach of judgment analysis (“policy capture”) to identify the design matrix that best distinguishes between different decision models. This questionnaire was designed to have scenarios with multiple tasks varying in dimensions that are presumed to influence decision making for task scheduling: difficulty, priority, salience, engagement, and time. Overall, the initial model space included 10 scenarios: each scenario with 3 tasks; each task with 4 attributes (difficulty, priority, salience, engagement); and each attribute with 2 levels (high vs. low). The objective was for participants to receive verbal descriptions of each set of three tasks, and to then select the order for task scheduling. Order selection was used to indicate weighting of task attributes, which was compared to the different methods for task scheduling decisions.

Models of task scheduling decisions and their task attribute weightings were derived from the literature (e.g., STOM) as well as SME interviews and observations, and included both compensatory and non-compensatory strategies for decision making. A compensatory model is when the weights of a more important attribute is less than the sum of the less important attributes, so the less important attributes can “outweigh” more important one. A non-compensatory model involves factors that cannot be outweighed by any combination of the other factors.

The different models included were: STOM-NP, priority-only, a non-compensatory model focusing on the factor of priority-first, equal weightings of task attributes, and random selections for task scheduling (see Table 3). STOM-NP weightings were derived from recent model weightings of the STOM architecture (Wickens et al., 2016) and equally weights the task attributes of difficulty, salience, and engagement. Priority-only was a one-reason rule that only used the priority weightings and ignored all other task attributes. SME interviews suggested that priority is the most critical variable, which led to the development of a non-compensatory weighting method of priority-first, where priority was the highest weighted attribute followed by difficulty, salience, and engagement, in that weighted order. Equal weights incorporated all task attributes, each with the same weightings. Finally, random selection did not weight task attributes; rather, the task outcomes were randomly generated. Each of these models comprised simple weight spaces, and did not include disjunctive/conjunctive rules or interaction rules, such as saying factor X is high only in cases when factor Y is low.

Table 3
Model Weights

	STOM-NP	Priority only	Urgent first	Equal weights	Random selection
Priority	0	1	0.71	0.25	N/A; randomly selected task orders without weighting task attributes
Difficulty	0.33	0	0.05	0.25	
Salience	0.33	0	0.23	0.25	
Engagement	0.33	0	0.01	0.25	

I used a genetic algorithm to determine the combination of scenarios comprised of a combination of tasks and task attributes that would maximally differentiate the models for task scheduling decisions (e.g., using STOM-NP model weightings vs. other weightings). A genetic algorithm optimizes designs with respect to measures of fitness. The measures of fitness in this case were the normalized differences in expected likelihoods for each pattern of responding for each model on each scenario based on the order set. There were six different possible sets of order selections for each scenario of the three tasks. I first specified an initial randomly-populated set of 2,000 design matrices with randomly-assigned tasks and task attribute levels to complete the set of scenarios, with the parameter that task attributes would have a value of “high” between 3 and 7 times within the set of 10 scenarios, to ensure variation in levels for each task attribute.

In each cycle of the genetic algorithm, the randomly-populated design matrices were crossed to create offspring, and offspring were randomly selected to remain unchanged or to randomly mutate by randomly switching some levels of task attributes throughout the design matrix. The product of all fitness measures were used to identify the top 100 best design matrices, or “elites” in each cycle of the genetic algorithm. These elites were added to the subsequent cycle unchanged to ensure the design matrices continued to improve in fit. At the end of the 70 cycles, the top design matrix was identified that best maximized normalized differences in expected likelihoods; in the case of ties, the algorithm chose the most-differentiated model to proceed.

I then cycled through this process 60 times, starting with a new initial randomly-populated set of 2,000 design matrices each time. The best models for each of the 60 initial random-populated design matrices generally reached convergence at around 50

cycles, ensuring that the final best fit design matrix was found for each initial randomly-populated design matrix. Finally, the top design matrices were compared across the 60 initial randomly-populated design matrices, and the best design matrix was identified.

Five emergency physicians identified and then verified common emergency room tasks that mapped on to the specified task attributes for each task. From there, I built the set of tasks and the set of scenarios to be used in the Scenario Response Questionnaire. All tasks and scenarios were tested with an additional 2 SMEs to check for validity.

Final Scenario Response Questionnaire

The Scenario Response Questionnaire consists of ten scenarios, each of which includes three common tasks in the emergency department (see Appendix B). All scenarios consist of verbal descriptions of tasks to ensure all participants focus on the same information and cues. The tasks within each scenario were set up to be rank ordered to reflect how a participant would schedule the three tasks across 10 different scenarios, which will provide insights into reasoning underlying their task scheduling decisions. All participants receive the same sets of tasks in the same order to compare how participants would interpret and respond to the same situations.

For example, in Scenario 1 includes three tasks that vary on the four task attributes: Task A (low difficulty, high priority, low salience, low engagement), Task B (high difficulty, high priority, low salience, high engagement), and Task C (low difficulty, low priority, high salience, low engagement). Three tasks that map on to Tasks A, B, and C include: A) ordering labs to initiate a patient's workup, B) intubating a patient with gradually declining mental status, and C) responding to the patient yelling

for pain medication. Participants would then indicate the order in which they would complete these three tasks, and then repeat this process for each of the ten scenarios.

Procedure

All participants were tested remotely online using Qualtrics, an online survey platform. The online questionnaire was open from the period of November 14th, 2017 through December 16th, 2017.

Participants first read the informed consent document. If they proceeded to complete the questionnaire, they waived documentation of informed consent. All participants had the option to enter their email addresses into a raffle for 6 prizes of \$50 each. Participants were informed that they could enter the raffle and win the prizes without having to actually complete the questionnaire.

Participants first completed the Demographics and Work Experience Questionnaire. Next, participants completed the Scenario Response Questionnaire. Upon completion of the entire online study, participants were debriefed and thanked for their participation. Participants took an average of 9.85 minutes ($SD = 6.46$, $Range = 4.05$ - 61.40) to complete the study.

CHAPTER 4

STUDY 1 – RESULTS

The alpha level was set to .05 for all statistical tests. T-tests were used to analyze differences between attending physicians and resident physicians for the Demographics and Work Experience Questionnaire. Bayesian statistics were used to compare model fits. A one-way ANOVA used to analyze differences between attending physicians and resident physicians for the top-fitting models to test the null hypothesis that there were no differences between groups. A Pearson correlation coefficient was calculated to assess the relationship between years of experience and model fits. Portions of the data collected from the Demographics and General Work Experience Questionnaire are not presented.

General Experience with Multiple Task Coordination

Attending physicians had more confidence than resident physicians for several aspects of multiple task coordination. More attending physicians (95%) than resident physicians (86%) said they were comfortable coordinating multiple tasks ($t = 2.02$, $p = 0.04$). When asked to rate their perceived ability on a scale of 0-100% ability, attending physicians had higher confidence than resident physicians in their abilities to coordinate, complete, and schedule all tasks during a shift, as well as their ability to adapt to changing conditions (Table 4).

Table 4

Study 1 Participants' Perceived Abilities for Multiple Task Coordination

	“Please rate how certain you are that you can _____ during a shift” (0-100%)			
	Coordinate all tasks	Complete all tasks	Appropriately schedule all tasks	Adapt to changing conditions
Attending physicians (N=120)	$M = 81.79$ $SD = 17.12$	$M = 80.36$ $SD = 18.62$	$M = 72.10$ $SD = 22.15$	$M = 90.06$ $SD = 10.15$
Resident physicians (N=50)	$M = 66.36$ $SD = 17.48$	$M = 68.94$ $SD = 23.82$	$M = 63.76$ $SD = 20.11$	$M = 77.26$ $SD = 13.81$
Significance Test	$t = 5.32$ $p < 0.001$	$t = 3.35$ $p = 0.001$	$t = 2.30$ $p = 0.02$	$t = 6.71$ $p < 0.001$

How are Task Scheduling Decisions Made, and Does This Change by Experience?**Hypothesis-Driven Model Fits**

The primary outcome measure was task scheduling, or the rank-order in which the participant planned to complete the three tasks for each scenario. Using the likelihoods identified in the method section in combination with each participant's order data, I derived the following Bayesian likelihood ratio test statistics for each participant for the hypothesis-driven models of STOM-NP, priority-only, priority-first, equal weights, and random selection:

- Bayesian Information Criterion (BICs; used to determine fit of a mathematical model to observed data)
- Delta BICs (changes in BICs used to determine the relative fit of two models)
- Bayes Factors (BFs; used to express the relative fit of two models as an odds ratio)

I used BFs when reporting relative model fits given that BFs represent “the standard Bayesian solution to the hypothesis testing and model selection problems” (Lewis & Raftery, 1997, p. 648). In general, BFs greater than 100 demonstrate extreme evidence

for Model 1 over Model 2 and BF_s less than -100 demonstrate extreme evidence for Model 2 over Model 1 (Andraszewicz et al., 2015).

I first identified which of the hypothesis-driven models was the most likely for each participant through identifying the model with the greatest BICs for each participant. The best a priori models for all participants were either STOM-NP or priority-only; the priority-first, equal distribution, and random selection models were never a top model. Participant role of attending physician or resident physician affected the top model choice ($F = 5.485, p = .02$). Priority-only was the top model for the majority of attending physicians ($n = 69$). STOM-NP was the top model for the majority of resident physicians ($n = 31$).

I next aggregated the BF_s for each group to compare the relative fits of the hypothesis-driven models (Table 5). All model comparisons presented extreme evidence in support of one model over the other. In all comparisons, the model fits for both STOM-NP and priority-only outperformed urgency, which outperformed equal weights, which outperformed random selection. This was true for both attending and resident physicians. In other words, STOM-NP and priority-only were the best hypothesis-driven models for task scheduling.

Table 5

BF comparisons of Model 1 vs. Model 2 by group for all hypothesis-driven models. BF_s greater than 100 demonstrate extreme evidence for Model 1 over Model 2. Negative numbers indicate support for Model 2 over Model 1.

	STOM vs Priority	STOM vs Urgent	STOM vs Equal	STOM vs Random	Priority vs Urgent	Priority vs Equal	Priority vs Random	Urgent vs Equal	Urgent vs Random	Equal vs Random
Attending (N=120)	-821	5455	6669	8770	6276	7491	9592	1214	3316	2101
Resident (N=50)	266	2428	2856	3734	2162	2590	3468	428	1306	878

The comparison of STOM-NP versus priority-only revealed the way in which attending physicians and resident physicians' task scheduling decisions supported different models. Attending physicians' data supported priority-only over STOM-NP, whereas resident physicians' data supported STOM-NP over priority-only. When analyzed at the participant level, there was no relationship between years of experience as an emergency physician and BF for STOM-NP vs. priority-only ($r = -0.04$, $n = 170$, $p > 0.05$).

The evidence for comparing STOM-NP vs. priority-only qualified as extreme support for both attending and resident physicians. However, the comparison between STOM-NP and priority-only was the weakest comparison; there was approximately 10 times stronger evidence about which model was more supported when comparing either STOM-NP or priority-only against any of the other hypothesis-driven models of priority-first, equal weights, and random selections (e.g., STOM-NP vs. equal weights). This indicates that the differences between STOM-NP and priority-only is much smaller than the differences between those two models versus the other hypothesis-driven models.

CHAPTER 5

STUDY 1 – DISCUSSION

The goal of Study 1 was to understand how task scheduling decisions are made, and whether that changes by experience. In this study, I used STOM-NP as the basis for structuring my set of a priori model weights given its prominence in the task scheduling literature. Portions of my findings were in support of STOM-NP as a best model for task scheduling, in line with Wickens et al. (2016). There was strong evidence that STOM-NP explained task scheduling decisions significantly better than the models of priority-first, equal weights, and random decisions. This was true for both attending physicians and resident physicians.

Priority-only, the model developed to test the one-reason rule by using the inverse model weightings as STOM-NP, performed equivalently with STOM-NP. As with STOM-NP, there was strong evidence that priority-only explained task scheduling decisions significantly better than the models of priority-first, equal weights, and random decisions. This was true for both attending physicians and resident physicians. The similarity in the findings for STOM-NP and priority-only models is in line with the predictions by Davis-Stober et al. (2010) that a one-reason rule is analogous to a model that equally weights the other cues.

Both the STOM-NP and priority models fit the data well, suggesting that physicians are either only focusing on one variable or they are ignoring that one variable while focusing on all the others. When comparing STOM-NP and priority-only against each other, there were differences by group, with attending physicians' task scheduling

decisions more in line with priority-only and resident physicians' decisions more in line with STOM-NP. Given that experts tend to be better at pattern recognition and more likely to rely on fewer cues than novices (e.g., Klein, 1999) and priority-only relies on one task attribute vs. the three task attributes in STOM-NP, this aspect of skill acquisition could be driving the group differences between model fits, where the higher experience participants (attending physicians) were more likely to use the one-reason rule (priority-only) and the lower experience participants (resident physicians) were more likely to use the model that equally weighted three cues (STOM-NP).

This study expanded upon the existing methodology for understanding of task scheduling decisions. First, this study incorporated a novel methodological approach of modified judgment analysis, which reduced the study duration. This methodology was selected as it can be more rapidly administered while still retaining the ability to uncover individuals' policies or strategies for decision making. Participants were all emergency physicians as opposed to undergraduate students, which is common in task scheduling studies. These participants were tested with stimuli involving common, representative tasks in the emergency department. These characteristics together improve both the specificity and generalizability of findings.

The one-reason rule was applied as a parsimonious analog to STOM-NP, the existing best behavior-based model for task scheduling, resulting in the inclusion and assessment of the priority-only model. Incorporating the one-reason rule with existing modeling work provides verification and advancement of modeling work. Additionally, I investigated the role of experience when making task scheduling decisions. There were experience differences for whether participants' decisions fit with the priority-only or

STOM-NP model, and I also found that both of these models outperformed the other hypothesized models.

Results from this study provide insights into current task scheduling decision making strategies. Given that STOM-NP and priority-only models both work better than other models, using a priority-only model in place of the STOM-NP model could be useful in streamlining training and decision aids by focusing on fewer task attributes. For example, training could focus on evaluating the relative priorities of tasks, both in written scenarios and simulations. In practice, electronic medical records (EMRs) in emergency departments already display a patient's overall acuity when they are initially triaged; hospitals could better support priority-driven decisions by ensuring this initial acuity assessment is accurate, updating this overall acuity throughout a patient's stay, and enabling identification of specific tasks' priorities (e.g., initializing lab work).

Group differences in which models best align with task scheduling decisions could be used to guide training. For example, because the more-experienced physicians primarily used the priority-only model, education and training should focus on identification and assessment of different patients' and tasks' priority levels and use examples of priority trade-offs. Furthermore, knowing that resident physicians primarily use the STOM-NP model, it could be beneficial to their training and work to reduce extraneous stimuli, given that salience of tasks is one of the factors that drive decisions. Identifying the task attributes that physicians weigh when making task scheduling decisions (e.g., priority vs. a combination of difficulty, salience, and engagement) could be used to evaluate a physician's skill level.

However, this study only assessed the task scheduling decisions, not the qualitative reasons underlying these responses. There was mixed evidence when comparing the priority-only vs. STOM-NP models, which could be disentangled through qualitative investigations. Although I was able to assess how different task attributes drove task scheduling decisions, there may be additional factors (e.g., urgency, time). Finally, task scheduling is only one aspect of task coordination; it is also necessary to investigate task completion strategies and interruption management to understand multiple task coordination.

CHAPTER 6

STUDY 2 – OVERVIEW

Multiple task coordination has been primarily studied using the methods of laboratory-based experiments and field-based observations. However, there is a gap between these two types of studies; little is known about strategies for task coordination and scheduling, including reasoning underlying these decisions. Alternative methods could be used to elicit knowledge about how people coordinate multiple tasks.

Knowledge elicitation is “a process in which a worker is scaffolded in generating descriptions of his or her domain knowledge and reasoning” (Hoffman, 2008, p. 1). This can include naturalistic decision making (e.g., critical incident interviews), wherein experts have superior decision making skills compared to novices, particularly in complex, ill-structured settings characterized by time pressure and high stakes. For example, the Critical Incident Interview was derived from the critical decision method described by Flanagan (1954) and Klein, Calderwood, and MacGregor (1989). This method uses a set of probes to study the cognitive bases of judgment and decision making in naturalistic settings with individuals of varying levels of expertise or experience. This method has been used in the context of healthcare previously, including nurses in neonatal intensive care units (Crandall & Getchell-Reiter, 1993) and certified nursing assistants in assisted living facilities (McBride, 2014).

Task scheduling includes decisions such as whether to switch to an interrupting task or continue working on the ongoing task (e.g., Eyrolle & Cellier, 2000). As discussed in Study 1, there are some known task factors that drive task scheduling,

including priority, difficulty, salience, and engagement from the STOM architecture (Wickens et al., 2013, 2015) and urgency, importance, and duration from Freed's Reactive Prioritization Model of Task Management (2000). People can employ performance-optimizing and workload-optimizing strategies (e.g., workload, situation understanding, management; e.g., Delaney, Reder, Staszewski, & Ritter, 1998; Durso & Alexander, 2010; Sperandio, 1971). However, none of these factors have been assessed in a complex healthcare environment, which could affect their relative importance.

There has been a recurrent theme of studying interruptions in healthcare; however, most studies do not define what is meant by an interruption, nor do they link definitions with cognitive understandings of what constitutes an interruption. These studies have described the types, frequencies, and counts of both tasks and interruptions in this space. However, it is unclear whether emergency physicians view interruptions in this space as interruptions versus simply another task to be coordinated. Providing a distinction between multiple task coordination and interruptions may not change cognitive mechanisms or strategies for approaching interruptions, but this may be relevant to research and methodologies exploring interruptions in healthcare environments, as well as training for managing tasks and interruptions.

The goal of the second study was to understand how multiple task demands were managed and coordinated by physicians in emergency departments. There were three primary aims of the study: (1) strategies used for multiple task coordination, including both scheduling and completion strategies; (2) how interruptions were conceptualized and coordinated and (3) how multiple task coordination varied across experience level.

For task completion, I hypothesized that participants would use a range of strategies for task completion, because numerous strategies for task completion were observed and elicited during observations and interviews with Subject Matter Experts (SMEs). I further hypothesized that attending physicians and resident emergency physicians would generally use similar strategies for task completion but would differ in which strategies they use most frequently. Healthcare providers in different roles tend to work on different proportions of types of tasks (Hollingsworth et al., 1998; SME observations and interviews). People with higher levels of experience tend to have a larger set of strategies for managing tasks than people with lower levels of experience (Koh et al., 2014).

For task scheduling, I hypothesized that attending physicians and resident physicians would generally use similar strategies for task scheduling but would differ in which strategies they use most frequently. People with higher levels of experience will have a larger set of strategies for scheduling tasks than people with lower levels of experience (Koh et al., 2014). Factors relating to the tasks (e.g., difficulty), person (e.g., workload), context (e.g., workplace policies), and outcomes (e.g., immediate vs. longer-term goals) could influence strategy selection.

For interruptions, I hypothesized that participants' perceptions of what comprises an interruption will include factors (e.g., estimated length of the interrupting task, relevance to overarching goals) that go beyond previously-reported definitions of interruptions, and would not differ by experience. In the interruptions literature, researchers have identified factors that comprise interruptions (e.g., perceived secondary task leading to a shift of attention, task scheduling; Barg-Walkow & Rogers, 2015;

Werner & Holden, 2015; Chisholm et al., 2001; Dismukes, 2012). However, most definitions do not include length of the interrupting task and instead view a shift of attention or performance of any perceptible length as an interruption. One definition based on observations in healthcare environments did use a time-based threshold to distinguish interruptions from non-interruptions (Chisholm et al., 2001). One SME reported length of an interrupting task as a component of an interruption. Some SMEs reported definitions of an interruption depended on whether a competing task interfered with the overarching goal of patient care interviews and observations. This definition is different in that if the interrupting task supports the overarching goal, then it is not considered to be an interruption even if it cognitively draws attention away from an ongoing task.

CHAPTER 7

STUDY 2 – METHOD

Participants

Thirty-one emergency physicians were recruited to participate in this study (see Table 6). This sample size was chosen based on suggested sample sizes for qualitative research using hypothesis and data-driven categorizations of 20-30 (Creswell, 1998) or 30+ participants (Morse, 1994). All participants at the time of the study were: licensed emergency physicians; currently employed by a hospital's emergency department as an emergency physician and working at least 20 hours per week in this position; at least 18 years old; and fluent in English. One participant was excluded due to being the only physician tested from a hospital.

Table 6
Study 2 Participant Characteristics

	Postgraduate Year	Age (years)	Gender
Attending physicians (N=15)	Range = 4-33 $M = 12.93$ $SD = 8.13$	$M = 40.80$ $SD = 8.26$	8 females 7 males
Resident physicians (N=15)	Range = 1-4 $M = 2.07$ $SD = 0.96$	$M = 28.67$ $SD = 1.54$	9 females 6 males

Participants were grouped by provider role in the emergency departments, with 15 participants in the higher experience group (attending physicians) and 15 participants in

the lower experience group (resident physicians). The participants had a range of experience in emergency medicine as denoted by their postgraduate year (PGY). The racial breakdown of participants included: 20 White Caucasian; 6 Asian; 3 Multi-racial; 1 Black or African American; and 1 Other/Middle Eastern. Eight attending physicians and nine resident physicians participated in both Study 1 and Study 2.

Participants were recruited from two academic hospital systems in the United States to account for potential differences in organizational cultures. The two academic hospital systems were: Grady Memorial Hospital in Atlanta, GA (10 attending physicians, 10 resident physicians) and Boston Medical Center in Boston, MA (5 attending physicians, 5 resident physicians), both of which are public urban hospitals with Level 1 trauma centers. The third hospital that only had one participant who was later excluded from analyses was the University of Alabama at Birmingham. Recruitment included emails, flyers, word of mouth, and presentations at resident and attending emergency physician meetings. The participants were compensated with \$10 Starbucks gift cards for their participation in the 45 minute study.

Materials

The mixed-methodology study consisted of three primary components: the Demographics and General Work Experience Questionnaire; the Strategies for Completion Questionnaire; and a structured interview.

Demographics and General Work Experience Questionnaire

The Demographics and General Work Experience Questionnaire was the same as described in Study 1, with the exception of removing questions regarding characteristics of their hospital systems.

Strategies for Completion Questionnaire

The Strategies for Completion Questionnaire was used to identify the range of strategies that participants use for task completion, including those that were not discussed during the interview. The set of strategies for task completion was elicited from five different Subject Matter Experts. For each of the 24 included strategies, participants indicated how often they use each method for coordinating multiple tasks on a 5-point scale from never to always. Participants could also write in and rate how often they use any additional strategies that were not already included. Participants were prompted to sketch out any visual or verbal task completion strategies for further reference.

Structured Interview

The structured interview had three main subcomponents: general task coordination, critical incidents, and interruption perceptions. At the end of the interview, participants were given an opportunity to add any additional information about how they coordinate multiple tasks that had not otherwise been addressed. The full interview script is provided in Appendix C, and is described here.

General Task Coordination

The general task coordination portion of the interview was used to understand the nature of typical task demands and strategies for coordinating multiple tasks. Participants

were asked to think about coordinating tasks during a typical shift in the emergency department, and then respond with how they prioritize and complete tasks. They were also asked to identify if they had any concerns about how they coordinate multiple tasks.

Critical Incidents

The Critical Incident technique used a set of probes to study the cognitive bases of judgment and decision making in naturalistic settings with individuals of varying levels of expertise or experience. Participants were asked to recall specific incidents during a recent shift when they had to coordinate multiple tasks as well as instances in which they experienced challenges coordinating multiple tasks. In addition to describing the incidents, participants were asked about the outcomes and the specific strategies for prioritization and completion that they used to coordinate multiple tasks. Probe questions were used to identify what facets of knowledge were drawn upon during the incident to enable them to react in that manner. They were also asked to recall specific incidents during a recent shift when they or their colleagues faced challenges with coordinating multiple tasks. Additional questions were asked to identify how they learned these strategies and how they would teach these strategies to further identify critical factors underlying these strategies.

Interruptions Perceptions

The interruptions perceptions portion of the interview was used to understand participants' conceptualizations of interruptions. Participants were asked to define an interruption. Participants were also asked how they coordinate interruptions with other tasks, including whether they try to prevent interruptions in their workflow.

Procedure

Interviews were conducted in the location of the participants' choosing, including private spaces (hospital conference rooms, offices, homes), semi-public spaces (secured-entry physician break rooms), and public spaces (coffee shops, hospital lobbies). After providing informed consent, the goals of the study were discussed with participants and any questions were answered by the interviewer. All interviews were audio recorded.

Participants first completed the Demographics and General Work Experience Questionnaire. The interviewer then conducted the structured interview. Upon completion of the structured interview, participants completed the Strategies for Completion Questionnaire. Participants were then debriefed, compensated, and thanked for their time.

CHAPTER 8

STUDY 2 – RESULTS

Data Analysis

The alpha level was set to .05 for all statistical tests. A one-way ANOVA was used to assess differences between patterns of strategy use for all participants in the Strategies for Completion Questionnaire. T-tests were used to analyze differences between attending and resident physicians for both the Demographics and Work Experience Questionnaire and the Strategies for Completion Questionnaire. T-tests were used rather than Wilcoxon signed-rank tests for the overall differences between patterns of attending and resident responses on the Strategies for Completion Questionnaire given the generally equivalent Type I error rates and reduced Type II error rates for t-tests when analyzing Likert-type 5-point scales with small sample sizes (de Winter & Dodou, 2010; Meek, Ozgur, & Dunning, 2007). A Chi-Square goodness of fit test was used for the Strategies for Completion Questionnaire to test the null hypothesis that there were no differences between in patterns for average use of overall categories of completion strategies.

Chi-Square tests for goodness of fit were used to analyze differences between the task attributes from STOM with the aforementioned hypothesis of distributions among attributes. Chi-Square tests for independence were used to analyze differences between attending and resident physicians for the categorical interview data to test the null hypothesis that there were no differences between groups. Portions of the data collected from the Demographics and General Work Experience Questionnaire are not presented.

Segmentation and Coding Scheme Development

The interview transcripts were analyzed according to a coding scheme to identify patterns and themes from the discussions. The audio recordings were first transcribed verbatim with any personal information omitted, including any potential identifiers of patients or colleagues. Transcripts were then segmented into units of analysis for each section of the interview. A segment was defined as a statement or description that included the following dimensions: any utterance of a (1) strategy for task scheduling, (2) strategy for task completion, (3) mention of training, or (4) components of an interruption related to multiple task coordination. Each segment was situation-specific. For example, a statement such as *“I always read EKGs first—they take very little time to complete”* was coded as one segment. However, the following was split into two segments to represent two different situations: *“I always triage urgent patients first because that’s a top priority, although, I’m not so sure I would immediately go see a critical but stable patient because the status won’t change.”*

The segments from the interviews were then categorized using a hierarchical coding scheme. Prior to beginning data analyses, I developed a hypothesis-driven coding scheme consisting of themes identified in the existing literature on multiple task coordination, including strategies for task scheduling (e.g., scheduling decisions driven by attributes from STOM), strategies for task completion (e.g., internal rehearsal of to-do list), types of training (e.g., formal training), and perceptions of interruptions (e.g., abrupt perceived stimulus or event). The full coding scheme is presented in Appendix D. The segments were initially categorized using the hypothesis-driven coding scheme. If a response did not map onto any of the categories in the coding scheme, a new category was added to represent that class of response, creating data-driven coding categories. The scheme was thus revised iteratively until all the responses in the transcripts were

subsumed under the categories in this combination hypothesis-driven and data-driven coding scheme coding scheme.

Inter-coder agreement was calibrated by conducting three rounds of independent coding by two coders on a single randomly selected transcript which alternated between a transcript for an attending physician and a transcript for a resident physician for each round of coding (two attending physician transcripts, one resident physician transcript). Percent agreement was calculated as the percentage at which different coders agreed and remained consistent with their assignment of particular codes to particular segments, with a general minimum standard benchmark of 85% agreement (Saldana, 2012). Discussion of discrepancies and revisions to the coding scheme and definitions followed each round of coding that did not meet this benchmark. The final round of calibration resulted in an average of 90.67% agreement between the two coders. After inter-coder agreement was reached, the remaining transcripts were divided among the two coders to code independently; one coder was responsible for approximately three-quarters of the remaining data, and the second coder was responsible for the remaining one-quarter of the remaining data.

Hierarchical data-driven categories of completion strategies for both the Strategies for Completion Questionnaire and the interview data were determined using a card sort task by the two independent raters. The categories were refined until there was 100% agreement on all categories and sub-categories.

General Experience with Multiple Task Coordination

Attending physicians had similar confidence as resident physicians for several aspects of multiple task coordination. The majority of both attending physicians (86.67%) and resident physicians (86.67%) said they were comfortable coordinating multiple tasks. When asked to rate their perceived ability on a scale of 0-100% ability, attending

physicians had higher confidence than resident physicians in their abilities to coordinate and complete all tasks during a shift (Table 7). Unlike the participants in Study 1, there were no differences by group in the participants' comfort coordinating multiple tasks, confidence in their abilities to schedule all tasks during a shift, nor their ability to adapt to changing conditions.

Table 7
Study 2 Participants' Perceived Abilities for Multiple Task Coordination

	“Please rate how certain you are that you can _____ during a shift” (0-100%)			
	Coordinate all tasks	Complete all tasks	Appropriately schedule all tasks	Adapt to changing conditions
Attending physicians (N=15)	$M = 81.00$ $SE = 2.14$	$M = 81.00$ $SE = 2.80$	$M = 65.00$ $SE = 5.88$	$M = 85.00$ $SE = 3.48$
Resident physicians (N=15)	$M = 66.67$ $SE = 6.58$	$M = 65.00$ $SE = 6.32$	$M = 69.00$ $SE = 6.06$	$M = 82.67$ $SE = 3.99$
Significance Test	$t = 2.07$ $p < 0.05$	$t = 2.31$ $p = 0.03$	$t = 0.47$ $p > 0.05$	$t = 6.71$ $p > 0.05$

In terms of learning how to successfully coordinate multiple tasks, only one participant received any formal training. All participants had been exposed to informal training in strategies for multiple task coordination. Informal training approaches included utilizing the apprenticeship model, having a gradually increased workload over time (particularly throughout residency), shadowing, attempting trial-and-error, and discussing situations and strategies with colleagues.

What strategies are used for task completion, and do strategies for task completion vary across experience?

In this section I will first describe general patterns of task completion strategies for all participants. I will then explore whether there were differences between attending physicians and resident physicians.

What strategies are used for task completion?

*“I think most ED docs are pretty good at multitasking. I think it's a job requirement, I think, given the volume of patients we see and things like that. So I think it's a little bit about how you are. People would argue that from a system's perspective, we should give people less stuff to do, so they don't make mistakes and forget. I would agree with that. But every ED doc lives in their current reality, which is, I hate it when people say it is what it is, but it is what it is. **You have this number of tasks you have to do and you have to get it done and you have to keep track of it however you can.**”*

Given that there was no such structured set of strategies in the literature, task completion strategies were organized into hierarchical data-driven categories. The highest level of organization was based on whether the participant strategy was based more on structured or unstructured organization of cues: active creation and reinforcement of to-do lists versus reliance on available cues. Using shared decision making was another high-level completion strategy when discussed with respect to task completion.

Active creation and reinforcement of to-do lists included the subcategories of internal rehearsals of to-do lists and external representations of to-do lists. Internal rehearsals of to-do lists involved active, effortful, memory-based rehearsal. Some examples of this included: thinking through tasks by patient, thinking through tasks by category (e.g., orders, documentation), keeping running stacks of tasks in memory organized by patient, keeping running stacks of tasks organized by priority, and running the board in memory. External representations of to-do lists involved physical, accessible,

explicit reminders. Some examples of this included: creating semi-structured notes on blank paper, writing on a self-drawn patient form on blank paper, using checklists or forms (either self-made or provided), writing notes on EMR patient board printouts, and typing notes into the comment boxes in EMRs.

Reliance on available cues included the subcategories of placing cues into the surrounding context and using cues from the surrounding context. Placing cues into the surrounding context involved creation of personalized priming cues. Some examples of this included: placing papers upside down (e.g., to complete, once completed), placing papers in specific place (e.g., left vs right stack on top of desk), leaving intentional blank spaces on pieces of paper, leaving a patient chart open, and leaving a mouse cursor in specific place on the computer screen. Using cues from the surrounding context involved interpreting external cues to prompt action. This included: noticing changes in the "results" column in EMR to know when diagnostic tests have been completed, being prompted by the EMR that there is missing information in a patient's record (e.g., use of cannot sign until replace ***), and noticing changes in patients when walking around the ED.

Participants used a range of strategies for task completion. Of the 24 strategies included in the Strategies for Completion Questionnaire, 19 strategies were used by at least half of the participants ($N \geq 15$) except for the following strategies: leave intentional blank spaces on pieces of paper ($N=13$); place papers in specific place (e.g., left vs right stack, on top of desk; $N=12$); place papers upside down (e.g., to complete, once completed; $N=7$); leave the mouse cursor in specific place ($N=6$); and use of provided checklists ($N=4$). A Chi-Square goodness of fit test was used for the Strategies for

Completion Questionnaire to test the null hypothesis that there were no differences between patterns for average use of overall categories of completion strategies. There were no significant differences between frequencies of strategy use by category in the Strategies for Completion Questionnaire.

In the interview, all participants (N=30) discussed active creation of personalized cues (see Table 8 and Appendix E). Both subcategories of internal rehearsals of to-do lists (N=29) and external representations of to-do lists (N=30) were discussed by almost all participants. Participants also identified reasons for use and disuse for each category. An example of an internal rehearsal of a to-do list was to mentally think through list of patients and what they each need. A reason for use was that it was quick to complete, but a reason for disuse was that memory is fallible. An example of an external representation of a to-do list was to handwrite notes of tasks to complete. A reason for use was that it was easy to view, but a reason for disuse was that it was onerous to keep up-to-date and having outdated information could be potentially dangerous for patients.

Table 8

Binary counts of mentions of task completion strategies by participant and role. Blue shading of a code and its corresponding data indicated the count of physicians in that group who mentioned at least one of the sub-codes within that higher-level code

Code	Sub-code	Sub-sub code	Attending physicians (N=15)	Resident physicians (N=15)	All participants (N=30)
Active creation of personalized cues					
	Internal rehearsal of to-do list		14	15	29
		Mentioned	12	15	27
		Reasons for USE	12	9	21
		Reasons for DISuse or failure	13	10	23

Table 8 continued

	External representation of to-do list		15	15	30
		Mentioned	15	15	30
		Reasons for USE	14	14	28
		Reasons for DISuse or failure	14	11	25
Reliance on available cues					
	Place cues into the surrounding context		2	6	8
		Mentioned	2	6	8
		Reasons for USE	2	4	6
		Reasons for DISuse or failure	1	1	2
	Use cues from the surrounding context		10	10	20
		Mentioned	10	10	20
		Reasons for USE	9	2	11
		Reasons for DISuse or failure	1	1	2
Shared SA / Decision Making			15	12	27

Many participants (N=23) discussed reliance on available cues. The subcategory of placing cues into the surrounding context was only discussed by about a quarter of participants (N=8) whereas the subcategory of using cues from the surrounding context (N=30) were discussed by almost all participants. Participants also identified reasons for use and disuse for each category. An example of placing cues into the surrounding context was setting an alarm at a certain time on a mobile phone to remember to return to a task after enough time had elapsed. A reason for use was that it was customizable, but a reason for disuse was that it required recalling the context surrounding the cue. An

example of using cues from the surrounding context was noticing when the box for test results on the EMR is updated. A reason for use was that the cue updated automatically and was unobtrusive, but a reason for disuse was that the noticing the cue could be delayed or a cue could be missed entirely.

In addition to the individual strategies for task completion, the majority of participants (N=27) also discussed using shared decision making for task completion. An example of shared decision making was discussing all the tasks that need to be completed as a team, including who was responsible for which tasks. For example, one participant noted that “it's the team aspect to emergency medicine, I think, that helps get everything done and makes sure everything gets done well [...] Sometimes, [an attending] will be like, "Oh, have you remembered to do this? And then I'll go back to do that and I may have forgotten."

Do strategies for task completion vary across experience?

Attending and resident emergency physicians used strategies for task completion at similar rates; there were no significant differences in how much they reported using different strategies. There were no significant differences between attending physicians and resident physicians in terms of frequency of strategy use reported in the Strategies for Completion Questionnaire for all comparisons of task completion strategy categories. A Chi-Square test for independence was conducted to determine whether participants' mentioned task completion strategies differed by role. There were no differences between attending physicians' and resident physicians' patterns of discussing categories of task completion strategies, $\chi^2(4, N = 114) = 3.63, p > 0.05$.

What strategies are used for task scheduling, and do strategies for task scheduling vary across experience?

Whereas task completion strategies give insights into the active and passive tools and techniques people use to keep track of and ensure all tasks are completed, task scheduling strategies give insights into which order these tasks are completed in and why. Together, task completion and task scheduling provide information on how multiple tasks are coordinated. In this section I will first describe general patterns of task scheduling strategies for all participants. I will then explore whether there were differences between attending physicians and resident physicians.

As previously discussed, the Strategic Task Overload Management (STOM) model identified four main factors that influence a person's task scheduling behavior: priority, difficulty, salience, and engagement. A recent modeling study found that difficulty, salience, and engagement equally drove task scheduling decisions whereas priority does not have any influence (STOM-NP; Wickens et al., 2016). In Study 1 of this dissertation, I introduced the one-reason rule priority-only model as an alternative to STOM-NP. In the priority-only model, priority alone drives decisions whereas difficulty, salience, and engagement do not have any influence. Comparisons of the two models in Study 1 were inconclusive among overall participants, but when divided by experience, priority-only was a better model for attending physicians whereas STOM-NP was a better model for resident physicians.

What factors influence task scheduling?

Participants' strategies for task scheduling were influenced by a range of factors. Some of these factors were known and supported (e.g., priority), some were known but

not influential (e.g., engagement), and some of these factors emerged from the data (e.g., time and its sub-components, interpersonal skills).

Factors from STOM

If priority-only (see Study 1) has a strong influence on task scheduling decisions, I would expect that it would be very accessible to participants and thus commonly discussed. Indeed, priority was mentioned by every single participant (N=30; see Table 9 and Appendix E). The majority of participants were also specific when they discussed priority, leading to the data-driven sub-categories based on urgency (time-based priority) and criticality (acuity-based priority). The subcategories included mentioning a combination of both urgency and criticality (N=30), urgency only (N=21), criticality only (N=12), or unspecified (N=25).

Table 9

Binary counts of mentions of STOM factors for task scheduling strategies by participant and role. Blue shading of a code and its corresponding data indicated the count of physicians in that group who mentioned at least one of the sub-codes within that higher-level code

Code	Sub-code	Attending physicians (N=15)	Resident physicians (N=15)	All participants (N=30)
Priority		15	15	30
	Both urgency & criticality	15	15	30
	Urgency only	11	10	21
	Criticality only	7	5	12
	Unspecified	13	12	25
Difficulty		7	2	9
Salience		8	6	14
Engagement (interest)		2	1	3

For example, a participant stated: “[Imagine] this EKG in front of me has a STEMI. The first thing I’m gonna do is call the cath lab team and activate the STEMI code because that’s critical and can change the outcome for a patient and has to happen right this second.” In this example, the participant mentioned both urgency/time-based

priority (“has to happen right this second”) and criticality/acuity-based priority (“can change the outcome for a patient”). An example of an urgency-only mention of priority was “when someone does die on you and the family comes and you have to explain this to them, someone will cover all your other tasks for a little bit, in order for you to be able to go and take care of that first thing.” An example of a critical-only mention of priority was as follows: “Last night we had somebody that needed to be intubated eventually, but not right this second emergently.”

If STOM is driving task scheduling decisions, I would expect that the factors of difficulty, salience, and engagement would be very accessible to participants and thus commonly discussed. However, these factors were not discussed by all participants. Salience was mentioned as an influential factor the most, by about half of participants (N=14). Some examples of salience were “squeaky wheel gets the oil” and “If you were standing in front of me, you'd probably get priority. After the person dying, the person who's staring me in the face, telling me to do something, who won't move—they get their thing second.” Difficulty was mentioned by about one-third of participants (N=9). An example of low difficulty was “I look for the easiest thing to do, the thing that'll take the least amount of brain power. And that could be as simple as entering a few orders in for the last patient I saw”. Engagement was mentioned the least of the STOM factors (N=3). One example of low engagement was “I probably also put off things that I'm not as excited about doing, to be perfectly honest.”

To determine whether participants' mentions of strategies for task scheduling were equally distributed among the high-level STOM categories of priority, difficulty, salience, and engagement, a Chi-Square goodness of fit test was conducted. There were

no differences in participants' overall patterns of discussing categories of task completion strategies, $\chi^2(3, N = 56) = 28.71, p < 0.01$. However, the patterns of responses by factor are more aligned with priority-only than STOM.

Additional factors

Time

Multiple factors beyond those identified in STOM emerged from the interviews. One such factor was time, which was also identified by SME interviews and observations in Study 1. Time was mentioned by every participant (N=30; see Table 10 and Appendix E). The majority of participants were also specific when they discussed time, leading to the data-driven sub-categories of disposition (N=29), time patients have been waiting to be seen (N=24), efficiency (N=27), and part of the shift (N=14).

Table 10

Binary counts of mentions of additional factors for task scheduling strategies by participant and role. Blue shading of a code and its corresponding data indicated the count of physicians in that group who mentioned at least one of the sub-codes within that higher-level code

Code	Sub-code	Attending physicians (N=15)	Resident physicians (N=15)	All participants (N=30)
Time		15	15	30
	Disposition	14	15	29
	Time patients waiting to be seen since entering ED	13	11	24
	Efficiency	14	13	27
	Part of the shift	10	4	14
Interpersonal Skills		12	9	21
Self-Management Skills		12	5	17
Knowledge of the institution		12	5	17
Reduce tasks		12	11	23
	Ignore incoming tasks	3	6	9
	Shed tasks/delegate	12	9	21

Disposition (or "dispo") refers to a patient's continued care plan of getting admitted, sent home, transferred, or expiring. Participants were not explicitly asked this, but multiple participants discussed high levels of care and quicker dispositions as the two overarching goals of EDs. For example, "If [a patient] can [be dispositioned and leave the ED], it'll open up a space for somebody else to come in. Dispo, dispo, dispo, dispo.....At that point it's, what is this person waiting on? Why are they still here?"

Time patients waiting to be seen since entering ED is involved in a few metrics: time to first encounter with a physician, time between encounters, and overall length of stay in the ED. In general, participants wanted to try to reduce this time. For example, "I typically try to take care of people who have been waiting the longest first."

Efficiency is about reducing the total time it takes to complete all tasks, including performing tasks in parallel. For example, “I try to be very efficient when I'm working. So making sure that I'm doing everything that I know will take a long time to come back, I try to do that first. And then making sure I'm never, I guess, just sitting around waiting on someone.”

Part of the shift distinguishes strategies for task scheduling based on the beginning, middle, or end of the shift. There can be different demands on and goals for emergency physicians depending on part of shift; for example, physicians need to quickly learn the urgency and acuity of all the patients for whom they are assuming care at the beginning of shift. At the end of the shift, the goals shift towards dispositioning as many patients as possible. For example, one participant stated: “You kinda break your shift up into chunks. So the beginning of the shift, you're just trying to see as many people as possible. In the middle of the shift, you're hopefully still doing that, but you're also kind of trying to get people moving in one way or another and make some of those critical crossroads decisions to see which direction people are going. And then by the end of the shift, that's when I'm going back through and making sure that everything is as tied up as I possibly can get it tied up.”

Knowledge and skills

Each of these factors was mentioned by approximately half to two-thirds of participants (see Table 10 and Appendix E). The knowledge and skills factors included interpersonal skills (N=21), self-management skills (N=17), and knowledge of the institution (N=17).

Interpersonal skills involve using interpersonal knowledge to guide scheduling decisions, such as being respectful to colleagues so they will help you faster. For example, “I give preferential treatment to our nurses and listen and do the things they need first. Having them feel respected and validated with their concerns is very important, because they will stop bringing you concerns if they feel like you do not listen to them.”

Self-management skills use knowledge of self to guide overarching scheduling decisions, such as through managing stress outside of shifts to be able to better focus during a shift. For example, one participant stated “You kind of mentally prepare yourself before a shift to do all the tasks. You gotta almost get yourself into a zone before you start work.” Another participant made sure to take breaks: “I think often what I really need to do that I don't do is just to get up out of my chair, walk away from all of the overstimulation of the emergency department, and just spend five minutes and go have a cup of coffee. Just go get out of the chair and take a five-minute break and remove all of the input so that you can just reset. I think that would probably be the most helpful thing, but it's often when things are the busiest that you need to do that and it feels the most painful to do. I mean just forcing yourself. Little things like getting up to go pee. That seems like a simple thing, but it's often hard to do that when things are just crazy.”

Using institutional knowledge to guide task scheduling strategies includes understanding workplace policies, knowing who to call to move a patient to a different area of the hospital quickly, knowing how long specific tests take, norms. For example, one participant said “Sometimes I see a resident or a new person struggling with how to make something happen or get something done. The navigational hurdle tends to be

system-based things like, ‘Oh, this is how you get ahold of this specific team,’ or, ‘Oh, this is how you actually get your CTs done on your patients.’ It’s system-based things that I think it just takes folks a little bit of time to adjust to and learn.”

Reducing tasks

Reducing tasks was discussed by 23 participants as a strategy for task scheduling (see Table 10 and Appendix E). Reducing tasks includes two sub-categories: ignore incoming tasks (N=9), and shedding tasks or delegating tasks (N=21). Ignoring incoming tasks includes preventing a new task from being added to a person’s workload, which can include turning off a pager so notifications are not received. For example, one participant discussed the challenges and time constraints when completing procedures. Her strategy for deflecting incoming tasks was “I’ll have told someone else that I won’t be able to take any new patients while doing the procedure.” Due to ethical considerations of ensuring patient safety, it can sometimes be challenging to ignore incoming tasks.

Shedding or delegating tasks involves reducing workload by deciding not to complete the task by either assigning it to another person or dropping the task entirely, such as by asking another physician for cover your patients while you take a break. For example, one participant stated “When we have a really busy trauma shift or we have a lot of sick patients come in all at once it tends to be a little bit overwhelming, so it’s either we get an attending from another zone to come over or we have the very senior resident help manage one of the other patients.”

Do strategies for task scheduling vary across experience?

Attending and resident emergency physicians generally used similar strategies for task scheduling but there were some differences in which factors influenced task scheduling (e.g., STOM). I conducted Chi-Square goodness of fit tests to analyze differences between attending physicians and resident physicians for the categorical interview data categorized by type of factor to test the null hypothesis that there were no differences between groups.

Factors from STOM

There were differences between attending physicians' and resident physicians' patterns of discussing categories of task scheduling strategies for the four overall STOM factors, $\chi^2 (3, N = 32) = 8.63, p = 0.03$, in that attending physicians discussed these factors more than residents. In terms of comparing individual factors, the same number of attending physicians and resident physicians discussed priority. There were no differences between groups when assessing priority's sub-categories of both urgency and criticality, urgency only, criticality only, and unspecified priority, $\chi^2 (3, N = 46) = 0.55, p > 0.05$. Priority was discussed by many more participants than the other STOM factors of difficulty, salience, and engagement.

It appears as though the main driver of the group differences for overall STOM factors was difficulty, which showed the greatest difference between the number of attending physicians (N=7) and resident physicians (N=2) discussing that factor. This goes counter to the hypothesis from Study 1 that resident physicians would discuss STOM-NP factors more than attending physicians.

Additional factors

When calculated as a whole, there was a difference between attending physicians' and resident physicians' patterns of discussing categories of task scheduling strategies for additional factors (time, knowledge and skills, and reducing tasks), $\chi^2 (3, N = 63) = 9.64$, $p < 0.05$. Attending physicians discussed the additional factors more than resident physicians.

Time was discussed by every participant, but patterns within time did not change by role, $\chi^2 (3, N = 51) = 6.76$, $p > 0.05$. The time sub-categories of disposition, time patients waiting to be seen, efficiency, and part of the shift were each discussed by more than two-thirds of attending physicians and all except for part of the shift ($N=5$) were discussed by more than two-thirds of resident physicians. There were no differences between attending physicians' and resident physicians' patterns of discussing categories of task scheduling strategies for knowledge and skills, $\chi^2 (2, N = 36) = 2.84$, $p > 0.05$.

Overall, there were a few differences between attending physicians and resident physicians on strategies for task selection. Significantly more attending physicians than resident physicians discussed STOM factors and additional emergent factors when aggregated at this top categorization level. However, there were no differences between groups when analyzed at the more granular level of specific factors (e.g., priority, time).

How are Interruptions Conceptualized?

Interruptions are an integral component of multiple task coordination, along with task completion and scheduling. How a person conceptualizes an interruption may influence their behaviors when managing the interruption. When a person is interrupted,

their task completion and task scheduling strategies may change, in addition to a person's ability to resume a task or switch to another task.

To determine whether participants' conceptualizations of interruptions were analogous to how they are discussed by researchers, I compared the participants' conceptualizations of interruptions to components of interruption definitions from the literature. I also assessed whether participants would try to block interruptions. The follow-up questions from the interview regarding how participants integrate the interruptions into their workflow through task completion strategies and task scheduling strategies were incorporated into their respective sections of this results section.

Components of interruptions definitions from the literature are listed alongside their supporting evidence and binary counts of participant mentions (see Table 11 and Appendix E). The following definition components were mentioned by at least 20 of the 30 participants, demonstrating a strong agreement in a conceptual definition by participants which mapped onto existing definition components:

- Abrupt perceived stimulus or event that is outside of a person's control
- Ongoing task(s)
- Interrupting task(s)
- Interpret/triage/schedule/discard stimulus or event
- Length of time away from ongoing task
- Potential consequences (immediate/delayed, positive/negative/neutral)

Participants' definitions were typically example scenarios illustrating interruptions in EDs. For example, one participant defined an interruption as "[An interruption]'s basically anything that is unscheduled and unplanned, that breaks you

from your current task, whatever that is. It usually comes in the form of a nurse or another colleague or resident, saying to you, "Doctor X, this patient needs this, this, and this." You can usually tell from the urgency in their voice how critical it is, but a lot of times it will come as a request from, like I said, the nurse or the unit secretary, who will say, "Hey, can you put this order in for this patient that you said you would, but you didn't actually put in?" If I'm working on something I know I need to focus on, like say finishing up a note or putting in like a bunch of orders for a patient, I'll usually say to the person, "Can you hold on a second so I can finish this up?" And if they say, "No, I need to talk to you about this now," then obviously I have to stop what I'm doing."

Table 11

Binary counts of mentions of components of interruption definitions by participant and role.

Code	Attending physicians (N=15)	Resident physicians (N=15)	All participants (N=30)
Abrupt perceived stimulus or event that is outside of a person's control ^a	11	11	22
Ongoing task(s) ^{a, d}	15	13	28
Interrupting task(s)...can be multiple ^{a, d}	13	12	25
Interpret/triage/schedule/discard stimulus or event ^{a, d}	13	11	24
Length of time away from ongoing task ^b	1	1	2
Potential consequences (immediate/delayed, positive/negative/ne ^a	11	9	20
Prospective memory for resuming an ongoing task ^c	0	2	2
System factors ^d	0	0	0
Block interruptions from happening	9	8	17

a - Barg-Walkow & Rogers (2015)

b - Chisholm et al. (2001)

c - Dismukes (2012)

d - Werner & Holden (2015)

Attending physicians' and resident physicians' conceptualizations of interruptions were not different from one another, $\chi^2 (7, N = 73) = 3.32, p > 0.05$. All participants' definitions mapped on to several components of definitions of interruptions from the

literature (e.g., discussing ongoing tasks). However, other aspects of definitions from the literature (e.g., length of time from the ongoing tasks) were rarely, if ever, discussed by participants.

The factors that drive task scheduling (e.g., priority, salience) drive decisions for remaining with the ongoing task or switching to complete the interruption. Thus, many participants noted that one should not block every interruption, because some interruptions are necessary (e.g., sick patient arrives while working on the ongoing task of documentation). For example, one participant highlighted the potential benefits of interruptions, stating “sometimes interruptions are actually important too, though. Just like I was saying, if somebody came up to me and said this patient looks like they needed to be seen immediately, obviously that's a welcomed interruption. So I would say sometimes they're necessary”

The urgency of the interruption drove task scheduling decisions when managing interruptions, so multiple participants mentioned the mixed benefits of being interrupted. For example, one physician stated “It's tough, though, because sometimes people are interrupting you because there is a sicker patient that they're trying to bring me—bring that to my attention. It is important that they are interrupting me. There are other times they're interrupting me for something that's not reasonable, like they need a work note. That can wait. You don't need to interrupt me to ask me to write a work note when I'm doing something that's more critical. I'll try to politely block the interruptions that are not that important, but I feel like, at the same time, it's also important for me to be open to the interruptions, because it's such a dynamic place and it might be important.” There are also negative consequences to being interrupted: “We get interrupted so much in the

course of a day we hardly even notice it anymore, but I feel like I'm becoming increasingly aware of the cognitive burden that that puts on me as a provider.”

CHAPTER 9

STUDY 2 – DISCUSSION

Overall, the goals of Study 2 were to expand knowledge about task completion strategies, task scheduling strategies, and conceptualizations of interruptions, each of which contribute to multiple task coordination. Each of these aspects was also assessed in terms of how they changed for attending versus resident physicians.

The first research aim was to understand what strategies are used for task completion. I hypothesized that participants would use a range of strategies for task completion because numerous strategies for task completion were observed and elicited during observations and interviews with SMEs. This hypothesis was supported; participants used a wide range of completion strategies, including both active and passive cues for completion. This study contributed to theory by both eliciting and then hierarchically organizing a set of task completion strategies. In addition to identifying strategies for task completion, this study also elicited both reasons for use and reasons for disuse for each of these strategies.

I hypothesized that attending and resident emergency physicians would differ in which strategies they use most frequently because healthcare providers in different roles tend to work on different proportions of types of tasks (Hollingsworth et al., 1998; SME observations and interviews). People with higher levels of experience generally have a larger set of strategies for managing tasks than people with lower levels of experience (Koh et al., 2014). However, reported use of these task completion strategies did *not* vary

across experience in either the Strategies for Task Completion questionnaire or the interview study.

One limitation of my analysis approach is that I compared strategy use at an aggregate level of strategies; it could still be that physicians vary in their use of individual strategies. Also, this study focused on eliciting a wide range of strategies; even though this set was accessible to participants, they might rely on completion strategies at different rates when actually working. The participants in my study were not true novices; even the lower experience resident physicians had an average of two years of experience, meaning that they may have already identified some successful completion strategies and discarded less successful strategies.

My second research aim was to identify what strategies are used for task completion. I hypothesized that participants' strategies would be driven by factors identified in STOM: priority, difficulty, salience, and engagement. My findings supported that these four factors are used in task scheduling decisions. This study advanced STOM by identifying sub-categories of priority. I identified additional emergent factors from the interview, including time and its sub-categories, knowledge and skills, and reducing tasks, which influence task scheduling. Both priority and time were mentioned by every participant; future work on modeling and understanding task scheduling decisions should incorporate both factors. Ultimately, this research both supported and expanded the set of factors influential in task scheduling.

In terms of how task scheduling strategies change with experience, based on Study 1 I expected attending physicians to focus on priority more than difficulty, salience, and engagement, as well as to discuss priority more than resident physicians,

and vice versa. Attending physicians discussed the STOM factors and emergent factors more than resident physicians; however, this finding was only significant at the aggregate level, not the granular level of comparing factors.

Although time was identified as a factor influencing task scheduling decisions, more work is needed to unpack what comprises “time”. In this study, I identified the subcomponents of disposition, time patients have been waiting to be seen, efficiency, and part of the shift. I also discussed urgency as the time-based aspect of priority. Time on task, although it did not emerge in this study, has been well-established in the literature as affecting voluntary task switching (e.g., Gutzwiller, Wickens, & Clegg, 2016). This study focused on the primary outcomes of which task would be completed next, and not how long participants would spend on each task. Future work could assess time on task as well as switching behaviors between the tasks, rather than a simple ordering of tasks, which would be more appropriate in a naturalistic setting.

Furthermore, anticipated amount of time it will take to complete a task has sometimes been used as a proxy for difficulty. However, in this study, anticipated time was encompassed by “efficiency”—how physicians maximize the different lag times and ultimate completion times of all tasks together. Future work should differentiate between the estimated time to complete vs. scheduling in lag times and to actually ask participants about this distinction; the data in this study were not explicit enough to be able to make that distinction.

The third research aim was to understand how interruptions are conceptualized. I hypothesized that participants’ perceptions of what comprises an interruption would include factors (e.g., estimated length of the interrupting task) that would go beyond

previously-reported definitions of interruptions. In the interruptions literature, researchers identified factors that comprise interruptions (e.g., perceived secondary task leading to a shift of attention, task scheduling; Barg-Walkow & Rogers, 2015; Werner & Holden, 2015; Chisholm et al., 2001; Dismukes, 2012). However, most definitions have included length of the interrupting task and instead view a shift of attention or performance of any perceptible length as an interruption. One definition based on observations in healthcare environments did use a time-based threshold to distinguish interruptions from non-interruptions (Chisholm et al., 2001), so I would have expected that to transfer to this study focusing on emergency physicians.

Participants' perceptions of interruptions were generally similar to definitions from the research literature, including many of the same components. Participants tended to focus more on outcomes, such as coordinating interruptions with existing workflow (e.g., triaging and task scheduling). However, almost no participants discussed length of time away from an interruption in their definitions. Additionally, participants highlighted positive, negative, and neutral consequences of interruptions as well as mixed desires about blocking interruptions from occurring. Interruptions also influence multiple task coordination:

"I tell people it's amazing that we get things right as much as we do because, in theory, we probably should not be getting things as right as we do. Because when you think about how many interruptions per hour the average emergency medicine physician encounters, it seems impossible that we should be able to function in that environment, yet we do day in and day out. So my biggest concern is always that I get interrupted and let a patient languish and not take care of whatever they need to get taken care of, and then that leads to their condition getting worse."

Incorporating interruptions involves dynamic updates to strategies for task completion and strategies for task scheduling. Taken together, these advance understanding of multiple task coordination in a complex healthcare environment. This

study identified and hierarchically categorized strategies for both task completion and task scheduling. There had been no known existing set of task completion strategies. Although some factors for task scheduling had been known, I evaluated existing factors and identified additional factors that influence task scheduling, expanding the known set of task scheduling strategies. This study also identified how interruptions are conceptualized in this dynamic healthcare environment and found that components of the literature-based definitions strongly mapped on to contextualized definitions, indicating that they can be used in place of one another.

This broader methodology, encompassing multiple aspects of task coordination, provides insights into how healthcare providers think about coordinating multiple tasks in an interruption-driven context. In addition to better understanding strategies for task completion and task scheduling, there is also evidence to support how they are making these decisions. For example, knowing reasons for use and disuse of completion strategies could be used to identify, evaluate, and design support tools to support physicians. One completion strategy was noticing when the box for test results on the EMR was updated (using cues from the surrounding context). A reason for use was that the cue updated automatically and was unobtrusive, but a reason for disuse was that the noticing the cue could be delayed or a cue could be missed entirely. Therefore, researchers could identify a design that would support the reasons for use while reducing the consequences of reasons for disuse. In this case, EMR designers could set customizable parameters in the EMR to say that if the cue had not been attended to in X time it would become more salient in the same modality (e.g., bright color, flashing), in Y time it would use a secondary modality (e.g., auditory tones), or in Z time it would

contact the physician in an alternative manner (e.g., email, pop-up alert, text message, page).

Understanding the role of interruptions and how they interface with task completion and task scheduling can be leveraged to better support coordinating tasks in the event of an interruption. For example, the priority and salience of the interrupting task drives task scheduling decisions in the event of an interruption. Not all interruptions are negative (e.g., need to ensure that urgent needs of patients are addressed in time); however, there are many unnecessary interruptions. Task completion becomes a bigger concern when switching due to an external event, which could worsen task coordination performance. Thus, context-independent solutions for addressing interruptions (e.g., interruption free zones) are not always ideal.

Instead, there should be a multi-pronged approach with multiple quick checks. For example, all patients are triaged and assigned an initial acuity value upon arrival to the ED. A first check could be only allowing new patients with a critical acuity value to lead to interruptions. A second check could be identifying patients with worsening vital signs throughout a patient's stay. A program could be built into the EMR, or a person could serve as an in-person check, to determine whether the physician should receive the interruption. Physicians should be trained to take a few moments (except in the case of direly urgent situations) to make note of their status on the ongoing task. Generally, this is enough time to aid in task completion without having an adverse impact on patient care.

CHAPTER 10

GENERAL DISCUSSION

Effective multiple task coordination is a major priority for emergency physicians; they are invested in understanding this process and learning how to improve. For example, one participant made a statement about how he and other ER physicians view multiple task coordination:

“Probably overall ER doctors think they’re better at task coordination than they really are. I think that the problem is most people can’t handle that many tasks at one time and so this is a job through time has evolved into this multi-tasking machine and we’re not always capable of the number of things we’re being asked to take care of. I often thought to myself, could I provide much better care to a patient if I only had one patient, and the answer is definitively yes. 1 million percent sure: yes. The problem is that it’s not justifiable use of resources and my time to take care of one patient. So then you say, can I do equally as good of job with three? No, but I can do a pretty good job. Can I do an equally good job with nine? No, but I can do a still pretty good job. Can I do an equally good job with 18? Probably not. So there’s some point where you reach this maximum of you’ve balanced the things you’re really, really good at and the time that you’re putting in and the danger of multi-tasking just because a human mind cannot really take care of that many tasks at one time. I mean coordinating task involving patients is different than making sandwiches at subway. If I make a mistake and someone didn’t get jalapeños on their sandwich like they wanted, I might get a nasty response. If I forget to dose a patient with medication because I was overwhelmed with other sick patients, that’s inappropriate and that’s a danger to that patient and that’s a danger to me because I’m not providing the care that I know I can provide. I want to provide great care and it’s a balancing act of how much I can do.”

Multiple task coordination is common in many contexts and domains, and may be inevitable in some complex environments. Task coordination includes task completion, task scheduling, and integration of interruptions. When multiple tasks are present, people need to be able to perceive the tasks, interpret characteristics of the tasks, triage the relative importance of tasks, and then either discard the tasks or schedule them for

performance. The tasks in these complex environments can be dynamic, meaning that there can be changes in the number, types, importance, and timing of these tasks, each of which can affect performance. Understanding how people currently coordinate multiple tasks may provide guidance for training to help people better manage performance in complex environments.

Emergency Departments (EDs) are one specific use case of a complex, interruption-driven environment wherein multiple task coordination is required. In this context, workers such as emergency physicians need to manage multiple aspects of patient care and job performance. In this dynamic space, this can include: switching between tasks; triaging of patients and incoming information; managing and working with colleagues; resuming working on a patient after assessing a different patient; and ensuring that all tasks are completed. Multiple task coordination involves the emergency physicians making a decision of which task to complete next, as well as ensuring that they are able to manage and complete all tasks.

In many cases, physicians in emergency departments do not complete a single task in isolation. Deciding what tasks to do and when can affect performance (e.g., time, accuracy, patient safety). Understanding multiple task coordination is especially important in complex life-critical environments such as healthcare, which incurs many situations where there are multiple tasks and limited resources for addressing all tasks. However, it was unclear how these tasks are coordinated, including strategies for task completion, strategies for task scheduling, and management of interruptions. The majority of previous research has focused on the frequencies and characteristics of interruptions, and has lacked an understanding of how people complete tasks, schedule

tasks, and integrate interruptions with existing tasks. Therefore, the purpose of this research was to understand multiple task coordination by emergency physicians in the specific complex environment of emergency departments.

I conducted two studies with emergency physicians with the aims of (1) understanding and modeling task scheduling, (2) identifying and categorizing strategies for task coordination, and (3) understanding how interruptions are conceptualized. For each of these aims, I investigated the role of experience (e.g., attending physicians vs. resident physicians).

The focus of multiple task coordination studies has primarily been on the effect of interruptions on outcomes (e.g., time, accuracy, behaviors). Less work has focused on reasoning and strategies underlying these behaviors, either qualitatively or quantitatively. Consequently, use of alternative research methods—such as quantitative modeling (incorporating judgment analysis) and qualitative interviews (incorporating Critical Incident Interviews)—may bridge the gap between experiments and observations through identification of how people coordinate multiple tasks.

Task scheduling strategies were investigated in both Study 1 and Study 2. I used a mixed-methods approach with both qualitative and quantitative aspects. Most studies on task scheduling are either quantitative or qualitative in nature; using both provides deeper insights into what strategies are being used and why in this specific complex healthcare environment. This dissertation was conducted with experienced participants queried on realistic tasks.

I used the STOM architecture as the basis for my findings and comparisons. In modeling, STOM-NP outperformed all other hypothesis-driven models, with the only

exception being the comparison with the priority-only model with attending physicians. STOM-NP was the best-fitting model for resident physicians. However, interview data did not support STOM or STOM-NP as clearly; fewer participants mentioned the STOM task attributes of difficulty, salience, and engagement.

As a comparison to the STOM-NP model, I also tested a priority-only model based on the one-reason heuristic. Similar to STOM-NP, priority-only outperformed all other hypothesis-driven models, with the only exception being the comparison with the STOM-NP model with resident physicians. Priority-only was the best-fitting model for attending physicians. Interview data strongly supported the priority-only model, with every participant discussing how the factor of priority drove their task scheduling strategies. This is in contrast to STOM-NP, which would have predicted priority *not* to be a top task attribute influencing task selection.

Some of the results from the two studies appear to support the priority-only model. The data from the modeling study aligned with expected results with the one-reason rule, with priority-only and STOM-NP predicting task scheduling decisions pretty much equally. Priority-only performing as the top model for attending physicians is in line with research from the expertise and skill acquisition literature, wherein experts make decisions using fewer cues than novices.

However, other results from the two studies offer mixed evidence for priority-only versus STOM or STOM-NP. First, the best-fit models appear to operate with weight vectors between those of priority-only and STOM-NP. This work has used the four attributes from STOM. In the interview study, I identified additional factors (e.g., time, knowledge and skills, reducing tasks) that influence scheduling decisions which had not

previously been represented in STOM, priority-only, or other models of task scheduling which I used in the modeling study. Based on the interview data, priority can be further differentiated into time-based priority (urgency) and acuity-based priority (criticality). It is possible that urgency is driving some of the model fitting given the inherent time-pressure. Time could also be categorized at a more granular level. Future work could include modeling these additional factors and with different amounts of granularity.

There could be more sophisticated model parameters at play; most if not all of the modeling for task scheduling both in this dissertation and in the literature have used simple weight vectors without any trade-offs or dependencies, such as disjunctive/conjunctive rules or interaction rules, such as saying factor X is high only in cases when factor Y is low. The models could be fleshed out to be more complex, such as through incorporating additional factors (e.g., time, urgency) and more levels of factors beyond binary high/low task attribute weightings (e.g., sliding scale). Another limitation of the modeling employed in this study was that using an optimization of differences between hypothesis-generated models on the front end when creating the design matrix impaired the ability to determine final best fit data-driven models. This approach to modelling was fitting the data to the task scheduling decisions; two separate models could have the same outcomes without being differentiated.

STOM-NP and priority-only mimic each other, which align with the predictions for the one-reason rule. Therefore, I paired the modeling in Study 1 with the qualitative interview in Study 2. However, there still were not clear-cut differences in models. Additional methods could be paired with modeling and interviews, such as using eye

trackers to investigate which cues are being attended to, for better understanding of which factors influence task scheduling.

Task scheduling decisions are one component of multiple task coordination. In the interview study, it became abundantly clear how multiple task coordination emerges from the combination of task scheduling, task completion, and interruptions. Indeed, interruptions can be thought of as a special case of task coordination that involves dynamic strategies for task scheduling and task completion. Different aspects of task coordination interact in the context of an interruption: task scheduling strategies are used for integrating interruptions and task completion strategies are used to ensure the ongoing and interrupting tasks are completed. For example, in the case of an interruption, the physician would first have to weigh the different factors that influence task scheduling decisions. For example, imagine a physician had been ordering labs to initiate another patient workup (high priority) when she was interrupted by a patient yelling for pain medications (high salience). The decision for which task to complete first is not necessarily clear-cut. The context of the interruption, including some task scheduling factors, could play a role (e.g., How many times had the physician recently been interrupted? Was a nurse asking for the physician to get the pain medications for the patient? How many tasks is the physician currently responsible for, and is the physician currently in the process of trying to reduce tasks?). The physician may be in the middle of a step in data entry that makes it challenging to get to a stopping point, or the physician may be close enough to completing the task that she would decide to finish the ongoing task before addressing the interrupting task. Or perhaps the physician can see various aids (e.g., post-it notes, papers) that could serve as an external representation of a to-do list to

track the task she will need to return to complete. Driving some of these decisions would be the physician's conceptualization of the interruption as being potentially positive, neutral, or negative. This was an illustrative example; there are other ways that task scheduling, task completion, and interruptions can interact when coordinating multiple tasks. More research is needed at these intersections to better understand these complex coordination decisions.

Additional Limitations and Future Directions

One limitation that has not yet been discussed is the limitations of the scenarios to assess task scheduling strategies. The Scenario Response Questionnaire in Study 1 used stimuli that were frequently-occurring for *both* resident physicians and attending physicians. However, these roles have different responsibilities (e.g., attending physicians supervise multiple resident physicians, resident physicians perform more direct patient), such that models may look different if the stimuli were customized to the role. The Critical Incident Interview in Study 2 asked participants to recall accessible situations, which could include both frequently-occurring situations as well as extreme situations, which may have influenced which factors were driving the task scheduling strategies (e.g., extreme situations would likely have more focus on urgent factors). Thus it may be appropriate to split scenarios comprising only frequent tasks apart from highly resonant scenarios to first understand their outcomes in isolation before in combination.

The scenarios in Study 1 were simple task comparisons, missing the additional types of factors and context as identified in Study 2; future work could create more fleshed-out scenarios. For example, the task attributes could go beyond simple high/low weightings to better represent the full scale of possibilities. The Scenario Response

Questionnaire could be set up to specify an existing ongoing task and allowing participants to remain on the ongoing task or switch to a different task. These results could align with existing research on voluntary task switching and incorporate the measure of Time on Task. Future tasks could be built to incorporate additional factors, such as specifying the part of the shift.

Future directions for this work could include adding pressures and constraints to ensure more complexity. For example, task scheduling decisions could incur consequences (e.g., penalties for certain selections). Resources such as time, staff, and equipment could be included to assess non-ideal parameters. To better understand task coordination as a whole, it would also be important to pair task scheduling with task completion, interruptions, or both. For example, instead of making a task selection in each scenario and then moving to the next, unrelated scenario, a study could be set up such that all tasks would need to be completed during the study. Participants could be interrupted while making task scheduling decisions, forcing more dynamic strategies for scheduling, with the ultimate goal being more naturalistic decision making.

Another limitation is the differences between what people say they will do vs. what they actually do (e.g., Nisbett & Wilson, 1977; White, 1980). For example, as previously discussed, differences in pressures and constraints could influence what physicians would say they would do on the Scenario Response Questionnaire vs. on the job in an emergency department. In the interview study, participants self-reported scenarios and how they responded to that specific scenario; they may have reported additional factors that they did not actually consider or omitted other influential factors. Self-reporting of these cues and responses was reliant on their memories, as well as the

incidents' recency, severity, or uniqueness. The value of these methods is that they identified what factors were accessible to participants and how they drove decisions.

One way to address some of these limitations is through incorporating simulations. These simulations could vary in fidelity, presence, task types, and environments (e.g., other healthcare professionals, multiple patient rooms, multiple computers). Observations in actual complex healthcare environments could also be conducted; however, in that case variables can only be observed, not manipulated.

This study focused on a very specific population: emergency physicians, including both attending physicians and resident physicians. Future work could study additional physicians with other levels of experience (e.g., medical students, fellows). Other provider roles (e.g., nurses) would be important to investigate given that there is both overlap and separation in types of tasks. This work could be applied to other complex healthcare environments (e.g., comparing EDs from different hospital systems, ICUs). Although this point was not queried systematically, some participants volunteered their personal experiences that there are some differences between hospital systems (e.g., culture of not writing things down, availability of scribes to help with documentation), although the general task coordination strategies for both completion and scheduling tend to stay the same.

Practical Implications

The results from this research have practical implications for supporting performance for healthcare providers coordinating multiple tasks. Testing both higher and lower experience emergency physicians enables a deeper understanding of how task attributes are differentially weighted and used in task scheduling decisions, which could

inform future training (e.g., focus on specific task attributes for task scheduling, identify strategies for task scheduling). Knowledge of the breadth and depth of strategy use is a first step towards future work in evaluating the effectiveness of different strategies for multiple task coordination. As one participant noted:

“I find it interesting that we're not talking about these things a lot more in emergency medicine, how you think of task coordination. I think it's a good thing and it's something that we probably need to teach medical students and residents early on, so that they recognize these things. And I also think hospitals should be a lot more supportive of the things that we know help with task overload.”

Both attending physicians and resident physicians used a wide range of task completion strategies. Medical schools, residency programs, and hospital systems could introduce all physicians to the range of strategies both early in training and throughout training and practice. Learning of task completion strategies is generally ad-hoc in the apprenticeship model and trial-and-error methods for learning multiple task coordination. Providing the range of strategies and allowing more up-front individual testing of and informed discussion about different task completion strategies could help customize different strategies for each physician. For example, physicians could have both informal and formal demonstrations of different task completion strategies they have tried. As a part of this process, they could elaborate on reasons for use and reasons for disuse, including how these reasons may change with experience and depending on the context. For example, many attending physicians used shared decision making for task completion; this may be related to interpersonal skills used in task scheduling.

In this dissertation, I identified and then hierarchically categorized a range of strategies for task completion. Future work could evaluate the effectiveness of these different completion strategies. Although the range of completion strategies generally did

not vary by experience, relative values of these strategies may vary (e.g., rely more on structured external representations of to-do lists when less-experienced and therefore are less able to “chunk”, integrate, and apply information). The relative values of these strategies could also vary by context, such as in routine situations versus task overload situations. This knowledge could be used to design new support tools or improve existing support tools. For example, many physicians use comment boxes in patients’ EMRs to share information; the comment boxes could be redesigned to support this goal, such as by having structure to indicate important information or tasks that need to be completed.

This dissertation also identified factors driving task scheduling strategies. Current testing and training for multiple task coordination is generally focused on appropriate identification, triaging, and treatments of chief complaints, as well as being able to coordinate a set amount of patients a given period of time. Alternatively, knowledge of the factors for task scheduling could be used to guide training and evaluation.

Identification of how accessible factors change with experience could be used to direct focus to specific factors in training and guided support. For example, physicians could be trained and tested on the specific factors influencing strategies for task scheduling (e.g., priority-only). In addition to being able to identify these factors, it is important to also consider trade-offs between factors.

In terms of skill acquisition, resident physicians could be taught to consider factors that are more accessible to attending physicians (e.g., self-management skills, interpersonal skills). Training on how to parsimoniously direct attention to cue(s) that hold the most relative value (e.g., priority) would support skill acquisition. This information could be leveraged to design new support tools or improve existing support

tools. For example, designers could add additional important task scheduling factors in EMRs beyond existing metrics (e.g., patient acuity upon initial triage, patient's total time in the ED, # of patients in ED).

This dissertation also highlighted the potential positive value of interruptions. Physicians highlighted positive, negative, and neutral consequences of interruptions. Although most work is on how to prevent interruptions from happening, there are instances where interruptions are necessary (e.g., treat an unstable patient). It is necessary to be able to distinguish between positive and negative interruptions, because successful interventions must allow positive interruptions while blocking negative interruptions.

For example, attending physicians can physically move to an isolated area and use resident physicians as interruption "gate-keepers". In the case of a positive interruption, the resident physician can triage the importance of an interruption (e.g., patient is crashing and needs urgent care) and decide when to contact the attending physician. In the case of a negative interruption, being located in a physically removed area reduces the likelihood of other interruptions (e.g., family member asking where the bathroom is located).

Conclusions

Multiple task coordination involves task completion, task scheduling, and managing interruptions. I identified and categorized a range of strategies for task completion, which should be evaluated for their effectiveness. Findings from this dissertation extended current task scheduling frameworks (e.g., STOM architecture, Freed's Reactive Prioritization Model). There are many factors that drive task scheduling, including those from existing models (e.g., difficulty), better-defined factors (e.g.,

splitting priority into urgency and criticality), and additional factors (e.g., time and its subcomponents, interpersonal skills). Definitions of interruptions in this complex healthcare environment do not differ from other definitions, although it is important to pay attention to differentiating positive vs. negative interruptions.

This dissertation used experienced emergency physicians tested on multiple tasks that they frequently see in regular work. This dissertation highlighted the need for understanding multiple task coordination in a complex environment given some of the emergent findings, such as the interplay between interruptions and task scheduling. In this space, a priority-only one-reason rule appears to be a potential parsimonious analog for more-complex decision-making models (particularly for more-experienced workers), which could inform training by focusing attention. However, while findings from Study 1 indicated that a one-reason priority-only model best captured attending physicians' task scheduling decisions and that a three-attribute model best captured resident physicians' task scheduling decisions, findings from Study 2 indicated a rich set of factors that are also used by participants.

In addition to understanding factors driving current task coordination, this dissertation has implications for practice. Healthcare providers could be better trained with cues, including cue detection and interpretation paired with response selection. For example, less-experienced physicians could be trained to identify cues used by more-experienced physicians (e.g., interpersonal skills), interpret the cues (e.g., nurse requests have high importance), and select the appropriate response (e.g., perform the action required by the nurse unless there's a more urgent, critical task that needs to be performed first). This knowledge could be used to inform technology interventions and

environment redesigns. For example, knowledge of positive vs. negative interruptions could lead to designs that support reducing unnecessary salient cues while promoting time-based cues.

APPENDIX A

DEMOGRAPHICS AND GENERAL WORK EXPERIENCE QUESTIONNAIRE

What is your sex?

- ☐ Male
- ☐ Female
- ☐ Other _____
- ☐ Do not wish to answer

What is your age?

Do you consider yourself Hispanic or Latino?

- ☐ Yes
- ☐ No
- ☐ Do not wish to answer

How would you describe your primary racial group?

- ☐ American Indian/Alaska Native
- ☐ Asian
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ Black or African American
- ☐ White
- ☐ More than one race
- ☐ Other (please specify) _____
- ☐ Do not wish to answer

Are you fluent in English?

- ☐ Yes
- ☐ No

What state in the US do you work in? (e.g., GA)

Did you participate in an interview with Laura about your strategies for multiple task coordination in EDs earlier this year?

- ☐ Yes
- ☐ No

What type of practice setting is your primary Emergency Department?

- ☐ Academic
- ☐ Community
- ☐ 50/50 split between academic and community

Approximately how many patient visits per year are there at your primary Emergency Department?

- ☐ More than 150,000 patient visits per year
- ☐ 100,000 - 149,999
- ☐ 50,000 to 99,999
- ☐ Fewer than 50,000 patient visits per year

What is the Trauma designation at your primary Emergency Department?

- ☐ Level 1
- ☐ Level 2
- ☐ Level 3
- ☐ None

What other designations does your primary Emergency Department have? Select all that apply.

- ☐ Stroke center
- ☐ STEMI center
- ☐ Burn center
- ☐ Cath lab
- ☐ Other _____

What is your job title?

What is your current physician role?

- ☐ Attending
- ☐ Fellow
- ☐ Resident
- ☐ Intern
- ☐ Other (please list) _____

Please describe your current physician role (brief):

How many years have you been in the above (current) role?

How many total years have you been practicing as an emergency physician, including training? PGY ____

Is this survey occurring.....:

- ☐ Immediately before beginning shift
- ☐ During a shift
- ☐ Immediately after completing shift
- ☐ Day off
- ☐ Other (please list) _____

How many days ago was your most recent shift in an emergency department? If your most recent shift in an emergency department was within the last 24 hours, please answer "0".____ days ago.

Think about a typical shift for you in the emergency department.

What is the maximum number of tasks you have managed simultaneously? _____ tasks

What is the maximum number of tasks you feel comfortable managing simultaneously? If you are still not comfortable, please answer "0"._____ tasks.

In general, how many tasks are you simultaneously working on at any given time? Select one.

- ☐ 0
- ☐ 1 - 2
- ☐ 3 - 4
- ☐ 5+

In general, how often do you work on multiple tasks at the same time? Select one.

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Very Often
- ☐ Always

Think about your current role in the emergency department.

Do you feel comfortable coordinating multiple tasks in your current role?

- ☐ Yes
- ☐ No

Answer If Do you feel comfortable coordinating multiple tasks in your current role? Yes Is Selected

When did you begin feeling comfortable coordinating multiple tasks in your current role? _____ years ago

Think about your current role in the emergency department. Rate your degree of confidence by recording any number from 0 to 100 using the scale given below as a guide: 100 - Highly certain can do 90 80 70 60 50 - Moderately can do 40 30 20 10 - Cannot do at all

Please rate how certain you are that you can coordinate all tasks during a shift (0-100):

Please rate how certain you are that you can complete all tasks during a shift (0-100):

Please rate how certain you are that you can appropriately schedule all tasks during a shift (0-100):

Please rate how certain you are that you can adapt to changing conditions throughout a shift (0-100):

APPENDIX B

SCENARIOS, TASKS, AND TASK ATTRIBUTES FOR THE SCENARIO

RESPONSE QUESTIONNAIRE

		Difficulty	Priority (criticality / urgency / acuity)	Engagement (Interest in the task)	Salience (in your face, like alarms or a person standing in front of you)	FINAL TASKS
Scenario 1	Task 1	0	1	0	0	Order labs to initiate patient workup
	Task 2	1	1	1	0	Intubate patient with gradually declining mental status
	Task 3	0	0	0	1	Respond to the patient yelling for pain meds
Scenario 2	Task 4	0	1	0	0	Place discharge orders when the ED is full
	Task 5	1	0	1	0	Perform a complex laceration repair
	Task 6	0	0	0	1	Reprint discharge instructions upon a nurse's request
Scenario 3	Task 7	0	0	0	1	Answer a phone call from clinic regarding a patient they want to send to ED
	Task 8	0	0	0	1	Place pain medication for patient upon a nurse's request
	Task 9	0	1	0	0	Place admit order for a sick patient
Scenario 4	Task 10	0	1	0	0	Order fluids on hypotensive patient
	Task 11	0	0	0	1	Have a discussion with

						a family member standing at desk with questions about patient
	Task 12	1	1	1	1	Evaluate STEMI alert patient
Scenario 5	Task 13	0	1	0	0	Order CT A/P on abdominal pain patient to further work up
	Task 14	0	0	0	1	Have a discussion with a patient stopping you in hallway for food
	Task 15	0	1	0	0	Order antibiotics for confirmed sepsis patient
Scenario 6	Task 16	1	0	1	1	Debride a dirty extremity laceration following a fall in mud (from follow-up with Sid)
	Task 17	1	0	1	1	Place central line on intubated patient who needs pressors/antibiotics
	Task 18	0	1	0	0	Order blood for patient with symptomatic anemia
Scenario 7	Task 19	1	1	1	1	Evaluate a Code Stroke patient
	Task 20	0	1	0	0	Give admitting team sign out on admitted patient over the phone
	Task 21	1	0	1	1	Log roll patient on backboard expeditiously
Scenario 8	Task 22	1	1	1	0	Evaluate patient with moderate shortness of breath
	Task 23	1	1	0	0	Perform pelvic exam on severely tachycardic female with active vaginal bleeding
	Task 24	0	0	0	1	Talk socially to disruptive patient on stretcher in front of MD

						desk
Scenario 9	Task 25	1	0	1	1	Obtain history from low-acuity foreign language speaking patient with aid of translator
	Task 26	0	1	0	0	Obtain consent for emergent procedure
	Task 27	1	0	1	0	Cauterize mild recurrent nose bleed
Scenario 10	Task 28	0	1	1	0	Perform fecal disimpaction
	Task 29	0	0	0	1	Reprint prescription upon a nurse's request
	Task 30	0	0	1	1	Have a discussion with a colleague who approaches to discuss an interesting case from the last shift

Participant view of the Scenario Response Questionnaire

For the following set of questions, you will be presented with tasks performed in Emergency Departments. Think about the order in which you would actually perform these tasks in your current Emergency Department.

Scenario 1 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Order labs to initiate patient workup
- _____ Task B: Intubate patient with gradually declining mental status
- _____ Task C: Respond to the patient yelling for pain meds

Scenario 2 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Place discharge orders when the ED is full
- _____ Task B: Perform a complex laceration repair
- _____ Task C: Reprint discharge instructions upon a nurse's request

Scenario 3 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Answer a phone call from clinic regarding a patient they want to send to ED
- _____ Task B: Place pain medication for patient upon a nurse's request
- _____ Task C: Place admit order for a sick patient

Scenario 4 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Order fluids on hypotensive patient
- _____ Task B: Have a discussion with a family member standing at desk with questions about patient
- _____ Task C: Evaluate STEMI alert patient

Scenario 5 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Order CT A/P on abdominal pain patient to further work up
- _____ Task B: Have a discussion with a patient stopping you in hallway for food
- _____ Task C: Order antibiotics for confirmed sepsis patient

Scenario 6 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Debride a dirty extremity laceration following a fall in mud
- _____ Task B: Place central line on intubated patient who needs pressors/antibiotics
- _____ Task C: Order blood for patient with symptomatic anemia

Scenario 7 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Evaluate a Code Stroke patient
- _____ Task B: Give admitting team sign out on admitted patient over the phone
- _____ Task C: Log roll patient on backboard expeditiously

Scenario 8 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Evaluate patient with moderate shortness of breath
- _____ Task B: Perform pelvic exam on severely tachycardic female with active vaginal bleeding
- _____ Task C: Talk socially to overly-talkative patient on stretcher in front of MD desk

Scenario 9 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Obtain history from low-acuity foreign language speaking patient with aid of translator
- _____ Task B: Obtain consent for emergent procedure
- _____ Task C: Cauterize mild recurrent nose bleed

Scenario 10 of 10. Please rank the order in which would you complete these 3 tasks (1 = first, 3 = last):

- _____ Task A: Perform fecal disimpaction
- _____ Task B: Reprint prescription upon a nurse's request
- _____ Task C: Have a discussion with a colleague who approaches to discuss an interesting case from the last shift

APPENDIX C

INTERVIEW SCRIPT

General Introduction

Thank you for participating in this research study. Before we get started, if you don't mind and are not on call, would you please turn off or silence your cell phone so we do not have any interruptions? Thank you.

My name is Laura, and I am a graduate student at Georgia Tech. Today I would like to talk to you about your thoughts and experiences related to managing your tasks in the emergency department.

Before any research can be conducted, I want make sure that you understand what you will be asked to do and that you know that you may end your participation at any time for any reason. I will ask you to read an informed consent document. The informed consent form tells you what the experiment is about as well as your rights as a research participant. It is very important that you read the informed consent form carefully and if you have any questions please feel free to ask me. If you agree to participate in the study please sign and date the form on the last page.

[Give them the informed consent form, allow participant to read the informed consent form, answer any questions they have, and ensure that they signed AND dated the form (x2). Experimenter then signs the consent form. Both the experimenter and the participant get a copy of the consent form.]

People like you who work in an emergency department typically have to coordinate multiple tasks. So what I am really hoping to understand is how you do this.

I would like to turn on the recorder now. As a reminder, your comments will not be shared with your employers or supervisors. It is possible for the audio recording to be recognized/identifiable by the sound of the voice. The audio recording will be labeled with a code number rather than your name, so it will not be identifiable as coming from you.

[Turn on recorder.]

Please remember that there are no right or wrong answers for anything we will discuss today. I am interested in learning about your thought process and your experiences. Some of my questions may seem repetitive, so it is okay if your answers overlap.

Do you have any questions for me?

Demographics and General Work Experience Questionnaire

The first thing I would like you to do is fill out this demographics and general work experience questionnaire.

[Give them the demographics and general work experience questionnaire. When they are finished, collect the form.]

Do you have any questions before we continue?

Structured Interview

(skip to Strategies Questionnaire after 40 minutes have elapsed)

General Task Coordination:

The next thing I would like you to do is answer some questions about task coordination.

[Administer the semi-structured interview, which includes the sections of general task coordination, critical incident interview, and perceptions of interruptions.]

Think about coordinating tasks during a typical shift in the emergency department.

- On a typical shift, how do you prioritize tasks?
- How do you think about what you need to do now vs. what you need to do over the next few hours? (short-term vs. long-term planning)
- On a typical shift, how do you make sure you accomplish everything you need to do?
 - Prompt: Do you use any cues/have any methods to make sure you do everything?
- Do you have any concerns about how you coordinate all of your tasks?
 - If yes: How do you address these concerns?
- Is there anything else you would like to add about how you coordinate multiple tasks?

Critical Incident Interview

Think about times during a shift in your current emergency department when you had to coordinate multiple tasks. This might include situations in which you had to manage multiple patients, work with other healthcare providers or staff, have direct interactions with patients or family members, conduct testing, interpret results, or answer phone calls.

I am interested in how you prioritized and scheduled tasks. Think for a moment about an example.

For each incident, proceed through the following interview questions before moving on to the next incident.

- Let's talk about the first example. Please give me an overview of the situation.
 - [Prompt]: "What were the details? Talk through tasks x/y, person y, context, etc.)"
- "How did you decide how you scheduled the order of the tasks?"
- "How did you make sure you accomplished everything you needed to do?"
 - **Probe:** *If response is something vague like "make sure I do all the tasks", ask the following:* "Is there anything specific you did to coordinate and keep track of the tasks?"
 - "How successful is this method for coordinating multiple tasks? Does this ever fail?"
 - "How did you learn this way of coordinating multiple tasks? Did you have any on-the-job experience? Informal training (e.g., taught by colleagues? Formal training (e.g., school, workshops)?
 - "How would you teach someone else these methods for coordinating multiple tasks?"
 - [Prompt]: How would you teach a newly-graduated resident?
 - [Prompt]: How would you teach a peer transferring from a different hospital?
- "Is there anything else you did, perhaps later on? Are there any other ways you coordinate multiple tasks?"
 - If yes: cycle through above questions again
- "Are you aware of any ways of coordinating multiple tasks that your colleagues use that you do not use or you find do not work for you? Why?"

After exhausting all incidents, move on to the following incident elicitation:

Next I would like to switch topics. I understand that coordinating multiple tasks in the emergency department can be really difficult. With that in mind, can you think of any examples where, in hindsight, you had a shift where you experienced challenges with coordinating multiple tasks? For example, have you ever tried anything else in the past that *was not* successful for managing multiple tasks? Perhaps looking back on it now, you might think to yourself, "That approach did not work", or "I should have reacted differently."

- Please give me an overview of the situation.
 - "Why was this shift challenging?"
 - "In what ways did this method fail (e.g., lost track of tasks, scheduling, etc.)?"
 - "How did you realize that this method was not successful?"
- Do you think you could have done anything differently in that situation?
If yes aka failure was associated with an inappropriate or lacking response:

- What do you think you should have done instead?
- Why did you do [*reported response*] instead of what you think you should have done?
- Can you think of anything that might have helped you in that situation?
 - Follow up: Can you think of any training, knowledge, or information could have helped you in that situation?
- How often has this happened?
 - If infrequent:*
 - How long had you been working in the emergency department when this happened?
 - How long had you been working in that specific hospital when it happened?

Can you now think about any examples of someone else, such as other resident or attending physicians, having the same problems with coordinating multiple tasks?

- Please give me an overview of the situation.
- Do you have any ideas about why he/she had problems with coordinating multiple tasks]?
- Can you think of any training, knowledge, or information could have helped him/her in that situation?

After exhausting all incidents, move on to interruptions.

Interruption Perceptions:

- How would you define an interruption?
- Do you ever try to prevent interruptions?
 - If yes: What methods do you use to try to prevent interruptions?
- How do you coordinate interruptions with your other tasks?

Do you have any questions before we continue?

Strategies Questionnaire

The final thing I would like you to do is fill out a questionnaire about how you coordinate tasks.

[Give them the strategies questionnaire. When they are finished, collect the form.]

[If time remains, prompt participants to explain their responses on the questionnaire]

[If developed own artifacts, ask them to share with me]

Debrief:

Now I want to describe the purpose of this study to you.

[Give debriefing form and read parts to the participant. Ask if they have any questions.]

Payment:

Thank you for your participation in this research study.

[Provide compensation, and get written confirmation of receipt of compensation.]

General Probes (to be used throughout interview as needed to elicit or clarify interviewee responses).....bring on separate card

- Can you tell me more about that?
- Can you tell me what you mean by ____*<repeat participant's wording>*____?
- *If participant is having difficulty answering the question, then say: "Please, take a moment and think about it. Then give me your best guess."*

APPENDIX D

FULL CODING SCHEME

Code	Subcode	Subcode	Definition	Example(s)
Completion				
	Active creation of personalized cues			
	Internal rehearsal of to-do list		Active, effortful, memory-based	Thinking through tasks by patient, thinking through tasks by category (e.g., orders, documentation), keeping running stacks of tasks in memory organized by patient, keeping running stacks of tasks organized by priority, and running the board in memory
		Mentioned		
		Reasons for USE	Facilitators, reasons for why or when a strategy is used	
		Reasons for DISuse or failure	Barriers, reasons for why or when a strategy is NOT used or NOT successful	
	External representation of to-do list		Physical/accessible/explicit reminders	Creating semi-structured notes on blank paper, writing on a self-drawn patient form on blank paper, using checklists or forms (either self-made or provided), writing notes on EMR patient board

				printouts, and typing notes into the comment boxes in EMRs
		Mentioned		
		Reasons for USE	Facilitators, reasons for why or when a strategy is used	
		Reasons for DISuse or failure	Barriers, reasons for why or when a strategy is NOT used or NOT successful	
	Reliance on available cues			
	Place cues into the context around you		Use personalized cues to prompt you with regard to the to-do list (you --> environment)	Placing papers upside down (e.g., to complete, once completed), placing papers in specific place (e.g., left vs right stack on top of desk), leaving intentional blank spaces on pieces of paper, leaving a patient chart open, and leaving a mouse cursor in specific place on the computer screen
		Mentioned		
		Reasons for USE	Facilitators, reasons for why or when a strategy is used	
		Reasons for DISuse or failure	Barriers, reasons for why or when a strategy is NOT used or NOT successful	
	Use cues from the context		Use external cues to prompt updates for to-do list	Noticing changes in the "results" column in EMR to

	around you		(environment --> you)	know when diagnostic tests have been completed, a provider returning at a later time (e.g., when labs are back), being notified that there is missing information in an EMR (e.g., use of cannot sign until replace ***), and noticing changes in patients when walking around the ED
		Mentioned		
		Reasons for USE	Facilitators, reasons for why or when a strategy is used	
		Reasons for DISuse or failure	Barriers, reasons for why or when a strategy is NOT used or NOT successful	
	Shared SA / Decision making			
Scheduling				
	Time			
		Disposition	Length of time until patient is dispositioned; completing tasks that lead to patient disposition	Disposition (or "dispo") refers to a patient's continued care plan of getting admitted/ sent home/transferred/ expiring. Note: dispo is one of two overarching goals in the ED; two goals: low time to dispo, high levels of patient care
		Time	Length of stay in	See the patient who

		patients have been waiting to be seen since entering ED	ED, time to first encounter, time between encounters	has been waiting the longest
		Efficiency	Reduce the total time it takes to complete all tasks	Includes time it takes self vs. others vs. hospital to complete tasks; Timing tasks to maximize performance and reduce overall time (NOTE: this may include some aspects of time (self) and time (others)). Such as complete one task waiting for other tasks.
		Part of the shift (beginning/middle/end)		
	Priority			
		Both URGENT & CRITICALITY	Acuity/sickest patient BUT has to mention or imply both criticality AND urgency (e.g., do things for the sickest patient who needs an intervention right now)	Intubate a patient who can't breathe; mention of expiration/death if not performed
		URGENT only	Time-sensitive priority; patient needs that must be accomplished immediately	Place IV immediately so tests can be ordered, talking to family following patient death
		CRITICAL	Patient acuity	Order tests for a

		LITY only	priority; patient needs related to ultimate well-being	stable-but-critical patient who is going to be admitted; drain an abscess before a patient leaves
		Unspecified	Not always differentiated--can overlap	Highest acuity patient (I do things for the "sickest" patient first...not saying if it's time-based or acuity-based)
	Difficulty		Mental workload imposed by a task	Task that has a lot of sub-components
	Salience		The ability of the arrival of a task to "call attention to itself"	Whiny patients, EKG techs at desk
	Engagement (interest)		Interest in a task	Uncommon procedure or confusing diagnosis
	Interpersonal Skills		Using interpersonal knowledge to guide approach	Feeling harassed or intimidated, being nice to colleagues so they'll help you out later, power dynamic of attending and resident physicians
	Self-Mangement Skills		Using knowledge of self to guide approach	Meditation, relaxation, etc. so can best handle tasks
	Knowledge of the institution		Using institutional knowledge to guide approach	Workplace policies, knowing how long specific tests take, norms
	Reduce tasks			
		Ignore incoming tasks	Prevent a task from being added to your workload	Don't acknowledge person approaching the computer
		Shed tasks / delegate	Reduce workload by deciding not to complete the task	Ask another physician to complete a task for

			by either assigning it to another person or dropping the task entirely	you
	Switch cost		Stay on a task and reduce the number of times you switch tasks	Complete entire note before addressing the interrupting person
	Complete tasks in a specific order		Complete tasks in a specific order through batching them together	Complete all tasks for upcoming needs first (e.g., order labs before rest of documentation), complete all tasks one at a time (e.g., see all patients one after the next), complete all tasks for one patient at a time (e.g., immediate chart after seeing a patient)
	Low priority		Tasks that are low priority, but still should be scheduled/completed	Charting needs to be completed following a shift, but is not as vital for patient care
	(Note: also see Non-systematic/ad-hoc codes)			
Interruption (definition only)	Overarching goal(s), which includes utility of incoming information			
	Usual vs. unusual activity			
	Abrupt perceived stimulus or event that is			

	outside of a person's control			
	Ongoing task(s)			
	Interrupting task(s)			
	Interpret/triage/schedule/discard stimulus or event			
		Relevant vs. irrelevant interruptions		
	Length of time away from ongoing task			
	Potential consequences (immediate/delayed, positive/negative/neutral)			
	Other			
		Prospective memory for resuming an ongoing task		
		System factors		
Miscellaneous				
	Block interruptions from happening		Strategies to keep an interruption from occurring	Move to a different space (with fewer people/access) to chart
	Training/learning			

		Informal	Informal training to learn ways to coordinate multiple tasks	On-the-job experience, taught by colleagues
		Formal	Formal training to learn ways to coordinate multiple tasks	School, workshops
Non-systematic/ adhoc approach (both scheduling and completion)				
	(Intentionally)) Prompted by others		Ask other people (e.g., healthcare providers, patients, etc.) to remind you to do something or ask them come back at a specified time	Have nurse return after completion of phone call
	(UNintentionally) Prompted by others		Another person reminds you to do something or approaches <i>without you initiating this action</i>	Nurse asks if the medication has been ordered
	Random choices		Randomly select next task	
Other				

APPENDIX E

CODING SCHEME WITH COUNTS OF NUMBER OF PHYSICIANS BY GROUP WHO MENTIONED THOSE FACTORS

Blue shading of a code and its corresponding data indicated the count of physicians in that group who mentioned at least one of the sub-codes within that higher-level code. Note that these counts represent whether a factor was mentioned; this does not include how many times it was mentioned.

Category of Strategies	Code	Sub-code	Sub-sub code	Attending physicians (N=15)	Resident physicians (N=15)	All participants (N=30)
Completion						
	Active creation of personalized cues					
		Internal rehearsal of to-do list		14	15	29
			Mentioned	12	15	27
			Reasons for USE	12	9	21
			Reasons for DISuse or failure	13	10	23
		External representation of to-do list		15	15	30
			Mentioned	15	15	30
			Reasons for USE	14	14	28
			Reasons for DISuse or failure	14	11	25
	Reliance on available cues					
		Place cues into the context around you		2	6	8
			Mentioned	2	6	8
			Reasons for USE	2	4	6
			Reasons for DISuse or failure	1	1	2
		Use cues from the context around you		10	10	20
			Mentioned	10	10	20
			Reasons for USE	9	2	11
			Reasons for DISuse or failure	1	1	2
	Shared SA / Decision Making			15	12	27
Scheduling						0
	Time			15	15	30
		Disposition		14	15	29
		Time patients waiting to be seen since		13	11	24

		entering ED				
		Efficiency		14	13	27
		Part of the shift		10	4	14
	Priority			15	15	30
		Both URGENCY & CRITICALITY		15	15	30
		URGENCY only		11	10	21
		CRITICALITY only		7	5	12
		Unspecified		13	12	25
	Difficulty			7	2	9
	Salience			8	6	14
	Engagement (interest)			2	1	3
	Interpersonal Skills			12	9	21
	Self-Management Skills			12	5	17
	Knowledge of the institution			12	5	17
	Educating residents			12	3	15
	Reduce tasks			12	11	23
		Ignore incoming tasks		3	6	9
		Shed tasks/delegate		12	9	21
	Switch cost			3	2	5
	Complete tasks in a specific order			11	11	22
	Low Priority			12	9	21
Interruptions						0
	Abrupt perceived stimulus or event that is outside of a person'			11	11	22
	Ongoing task(s)			15	13	28
	Interrupting task(s)...can be multiple			13	12	25
	Interpret/triage/schedule/discard stimulus or event			13	11	24
	Length of time away from ongoing task			1	1	2
	Potential consequences (immediate/delayed, positive/negative/ne			11	9	20
	Other					
		Prospective memory for resuming an ongoing task		0	2	2
		System factors		0	0	0
	Block interruptions from happening			9	8	17
Misc.						0
	Training/learning			15	15	30
		Informal		15	15	30
		Formal		0	1	1
	Non-systematic/adhoc approach (both scheduling and completion)			13	11	24
		(Intentionally) Prompted by others		11	6	17
		(UNintentionally) Prompted by others		7	7	14
		Random Choice		5	3	8
	Other			4	7	11

REFERENCES

- Adamczyk, P. D., & Bailey, B. P. (2004). If not now, when?: The effects of interruption at different moments within task execution. *Human Factors in Computing Systems: Proceedings of CHI'04* (pp. 271-278). New York, NY: ACM Press.
- Aiman-Smith, L., Scullen, S. E., & Barr, S. H. (2002). Conducting studies of decision making in organizational contexts: A tutorial for policy-capturing and other regression-based techniques. *Organizational Research Methods*, 5(4), 388-414.
- Allard, J., Wyatt, J., Bleakley, A., & Graham, B. (2012). "Do you really need to ask me that now?": A self-audit of interruptions to the 'shop floor' practice of a UK consultant emergency physician. *Emergency Medicine Journal*, 29(11), 872-876.
- Altmann, E. M. & Trafton, J. G. (2002). Memory for goals: An activation-based model. *Cognitive Science*, 26, 39-83.
- Andraszewicz, S., Scheibehenne, B., Rieskamp, J., Grasman, R., Verhagen, J., & Wagenmakers, E. J. (2015). An introduction to Bayesian hypothesis testing for management research. *Journal of Management*, 41(2), 521-543.
- Barg-Walkow, L. H., & Rogers, W. A. (2015). *Toward a conceptual model of external interruptions and task outcomes in complex environments* (HFA-TR-1502). Atlanta, GA: Georgia Institute of Technology, School of Psychology, Human Factors and Aging Laboratory.
- Borst, J. P., Taatgen, N. A., & van Rijn, H. (2010). The problem state: A cognitive bottleneck in multitasking. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 36(2), 363.
- Borst, J. P., Taatgen, N. A., & van Rijn, H. (2015). What makes interruptions disruptive? A process-model account of the effects of the problem state bottleneck on task interruption and resumption. *Human Factors in Computing Systems: Proceedings of CHI'15* (pp. 2971-2980). New York: ACM Press.
- Brixey, J. J., Robinson, D. J., Johnson, C. W., Johnson, T. R., Turley, J. P., Patel, V. L., & Zhang, J. (2007). Towards a hybrid method to categorize interruptions and activities in healthcare. *International Journal of Medical Informatics*, 76(11), 812-820.
- Brixey, J. J., Robinson, D. J., Turley, J. P., & Zhang, J. (2010). The roles of MDs and RNs as initiators and recipients of interruptions in workflow. *International Journal of Medical Informatics*, 79(6), e109-e115.
- Brixey, J. J., Tang, Z., Robinson, D. J., Johnson, C. W., Johnson, T. R., Turley, J. P., ... & Zhang, J. (2008). Interruptions in a level one trauma center: A case study. *International Journal of Medical Informatics*, 77(4), 235-241.

- Brumby, D. P., Cox, A. L., Back, J., & Gould, S. J. (2013). Recovering from an interruption: Investigating speed–accuracy trade-offs in task resumption behavior. *Journal of Experimental Psychology: Applied*, 19(2), 95-107.
- Chi, M. T. H. (2006). Laboratory methods for assessing experts' and novices' knowledge. In K. A. Ericsson, N. Charness, P. J. Feltovich & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance*. (pp. 167-184). New York, NY US: Cambridge University Press.
- Chisholm, C. D., Collison, E. K., Nelson, D. R., & Cordell, W. H. (2000). Emergency department workplace interruptions: Are emergency physicians “interrupt-driven” and “multitasking”? *Academic Emergency Medicine*, 7(11), 1239-1243.
- Chisholm, C. D., Dornfeld, A. M., Nelson, D. R., & Cordell, W. H. (2001). Work interrupted: A comparison of workplace interruptions in emergency departments and primary care offices. *Annals of Emergency Medicine*, 38(2), 146-151.
- Chisholm, C. D., Weaver, C. S., Whenmouth, L., & Giles, B. (2011). A task analysis of emergency physician activities in academic and community settings. *Annals of Emergency Medicine*, 58(2), 117-122.
- Coiera, E. W., Jayasuriya, R. A., Hardy, J., Bannan, A., & Thorpe, M. E. (2002). Communication loads on clinical staff in the emergency department. *The Medical Journal of Australia*, 176(9), 415-418.
- Crandall, B., & Getchell-Reiter, K. (1993). Critical decision method - A technique for eliciting concrete assessment indicators from the intuition of NICU nurses. *Advances in Nursing Science*, 16(1), 42-51.
- Cutrell, E., Czerwinski, M., & Horvitz, E. (2001). Notification, disruption, and memory: Effects of messaging interruptions on memory and performance. In M. Hirose (Ed.), *Human-Computer Interaction-INTERACT 2001 Conference Proceedings* (pp. 263-269). Amsterdam, NL: IOS Press.
- Czerwinski, M., Cutrell, E. & Horvitz, E. (2000). Instant messaging: Effects of relevance and time. *People and Computers XIV: Proceedings of HCI 2000* (Vol. 2, pp. 71-76). Swindon, UK: British Computer Society.
- Czerwinski, M., Horvitz, E., & Wilhite, S. (2004). A diary study of task switching and interruptions. *Human Factors in Computing Systems: Proceedings of CHI'04* (pp. 175-182). New York, NY: ACM Press.
- Dargar, S., Kennedy, R., Lai, W., Arikatla, V., & De, S. (2015). Towards immersive virtual reality (iVR): A route to surgical expertise. *Journal of Computational Surgery*, 2(2), 1-26.

- Davis-Stober, C. P., Dana, J., & Budescu, D. V. (2010). Why recognition is rational: Optimality results on single-variable decision rules. *Judgment and Decision Making*, 5(4), 216-229.
- De Winter, J. C., & Dodou, D. (2010). Five-point Likert items: T test versus Mann-Whitney-Wilcoxon. *Practical Assessment, Research & Evaluation*, 15(11), 1-12.
- Dismukes, R. K. (2012). Prospective memory in workplace and everyday situations. *Current Directions in Psychological Science*, 21, 215–220.
- Dodhia, R. M., & Dismukes, R. K. (2009). Interruptions create prospective memory tasks. *Applied Cognitive Psychology*, 89, 73–89.
- Edwards, M. B., & Gronlund, S. D. (1998). Task interruption and its effects on memory. *Memory*, 6(6), 665-687.
- Eyrolle, H., & Cellier, J. (2000). The effects of interruptions in work activity: Field and laboratory results. *Applied Ergonomics*, 31(5), 537-543.
- Fairbanks, R. J., Bisantz, A. M., & Sunm, M. (2007). Emergency department communication links and patterns. *Annals of Emergency Medicine*, 50(4), 396-406.
- Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin*, 51(4), 327-358.
- France, D. J., Levin, S., Hemphill, R., Chen, K., Rickard, D., Makowski, R., ... & Aronsky, D. (2005). Emergency physicians' behaviors and workload in the presence of an electronic whiteboard. *International Journal of Medical Informatics*, 74(10), 827-837.
- Freed, M. (2000). Reactive prioritization. *Proceedings of the 2nd NASA International Workshop on Planning and Scheduling in Space*. Washington, DC: National Aeronautics and Space Administration.
- Gillie, T., & Broadbent, D. (1989). What makes interruptions disruptive? A study of length, similarity, and complexity. *Psychological Research*, 50, 243-250.
- Grundgeiger, T., Sanderson, P. M., Orihuela, C. B., Thompson, A., MacDougall, H. G., Nunnink, L., & Venkatesh, B. (2010). Distractions and interruptions in the intensive care unit: A field observation and a simulator experiment. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (pp. 835-839). Santa Monica, CA: Human Factors and Ergonomics Society.
- Gutzwiller, R. S., Wickens, C. D., & Clegg, B. A. (2016). The role of time on task in multi-task management. *Journal of Applied Research in Memory and Cognition*, 5(2), 176-184.

- Hassall, M. E. & Sanderson, P. M. (2012). A formative approach to the strategies analysis phase of cognitive work analysis. *Theoretical Issues in Ergonomics Science*, 1-47.
- Hodgetts, H. M., & Jones, D. M. (2006a). Interruption of the tower of London task: Support for a goal-activation approach. *Journal of Experimental Psychology-General*, 135(1), 103-115.
- Hodgetts, H. M., & Jones, D. M. (2006b). Contextual cues aid recovery from interruption: The role of associative activation. *Journal of Experimental Psychology-Learning Memory and Cognition*, 32(5), 1120-1132.
- Hoffman, R. R. (2008). Human factors contributions to knowledge elicitation. *Human Factors*, 50(3), 481-488.
- Janssen, C. P., & Brumby, D. P. (2010). Strategic adaptation to performance objectives in a dual-task setting. *Cognitive Science*, 34(8), 1548-1560.
- Jeanmonod, R., Boyd, M., Loewenthal, M., & Triner, W. (2010). The nature of emergency department interruptions and their impact on patient satisfaction. *Emergency Medicine Journal*, 27(5), 376-379.
- Johnson, K. D., Motavalli, M., Gray, D., & Kuehn, C. (2014). Causes and occurrences of interruptions during ED triage. *Journal of Emergency Nursing*, 40(5), 434-439.
- Hollingsworth, J. C., Chisholm, C. D., Giles, B. K., Cordell, W. H., & Nelson, D. R. (1998). How do physicians and nurses spend their time in the emergency department?. *Annals of Emergency Medicine*, 31(1), 87-91.
- Katidioti, I., Borst, J. P., & Taatgen, N. A. (2014). What happens when we switch tasks: Pupil dilation in multitasking. *Journal of Experimental Psychology: Applied*, 20(4), 380.
- Klein, G. (1999). *Sources of power: How people make decisions*. Cambridge, MA: The MIT Press.
- Klein, G. A., Calderwood, R., & MacGregor, D. (1989). Critical decision method for eliciting knowledge. *Systems, Man and Cybernetics, IEEE Transactions on*, 19(3), 462-472.
- Koh, R. Y., Park, T., & Wickens, C. D. (2014). An investigation of differing levels of experience and indices of task management in relation to scrub nurses' performance in the operating theatre: Analysis of video-taped caesarean section surgeries. *International Journal of Nursing Studies*, 51(9), 1230-1240.
- Koh, R. Y., Park, T., Wickens, C. D., Ong, L. T., & Chia, S. N. (2011). Differences in attentional strategies by novice and experienced operating theatre scrub nurses. *Journal of Experimental Psychology: Applied*, 17(3), 233.

- Kosits, L. M., & Jones, K. (2011). Interruptions experienced by registered nurses working in the emergency department. *Journal of Emergency Nursing*, 37(1), 3-8.
- Latorella, K. A. (1998). Effects of modality on interrupted flight deck performance: Implications for data link. *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting*. Santa Monica: HFES.
- Latorella, K. A. (1999). *Investigating interruptions: Implications for flight deck performance* (Technical Memorandum NASA/TM-1999-209707). Hampton, VA: NASA-Langley Research Center.
- Lee, S. B., Lee, L. L., Yeung, R. S., & Chan, J. T. (2013). A continuous quality improvement project to reduce medication error in the emergency department. *World Journal of Emergency Medicine*, 4(3), 179.
- Lewis, S. M., & Raftery, A. E. (1997). Estimating Bayes factors via posterior simulation with the Laplace-Metropolis estimator. *Journal of the American Statistical Association*, 92, 648-655.
- Loft, S., Sanderson, P., Neal, A., & Mooij, M. (2007) Modeling and predicting mental workload in en route air traffic control: critical review and broader implications. *Human Factors*, 49(3), 376-399.
- Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. (2009). The multitasking myth: *Handling complexity in real-world operations*. Burlington, VT: Ashgate.
- McBride, S.E. (2014). *Understanding the cognitive processes of problem detection and decision making among assisted living caregivers*. Unpublished doctoral dissertation, Georgia Institute of Technology, Atlanta, GA.
- McDaniel, M. A., & Einstein, G. O. (2007). *Prospective memory: An overview and synthesis of an emerging field*. Thousand Oaks, CA: Sage.
- McFarlane, D. C., & Latorella, K. A. (2002). The scope and importance of human interruption in human-computer interaction design. *Human-Computer Interaction*, 17(1), 1-61.
- Meacham, J. A., & Leiman, B. (1982). Remembering to perform future actions. In U. Neisser (Ed.) *Memory observed: Remembering in natural contexts* (pp. 327–336). San Francisco, CA: Freeman.
- Meek, G. E., Ozgur, C., & Dunning, K. (2007). Comparison of the t vs. Wilcoxon signed-rank test for Likert scale data and small samples. *Journal of Modern Applied Statistical Methods*, 6(1), 91-106.
- Monk, C. A., Boehm-Davis, D. A., & Trafton, J. G. (2004). Recovering from interruptions: Implications for driver distraction research. *Human Factors*, 46(4), 650-663.

- Monk, C. A., Trafton, J. G., & Boehm-Davis, D. A. (2008). The effect of interruption duration and demand on resuming suspended goals. *Journal of Experimental Psychology: Applied*, 14(4), 299.
- Nijboer, M., Taatgen, N. A., Brands, A., Borst, J. P., & van Rijn, H. (2013). Decision making in concurrent multitasking: Do people adapt to task interference?. *PLOS ONE*, 8(11), e79583.
- Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review*, 84(3), 231.
- Pizzi L., Goldfarb N. I., Nash D. B. (2001). Crew resource management and its applications in medicine. In K. G. Shojana, B. W. Duncan, K. M. McDonald, & R. M. Wachter (Eds.), *Making health care safer: A critical analysis of patient safety practices* (501-510). Rockville, MD: Agency for Healthcare Research and Quality.
- Raby, M., & Wickens, C. D. (1994). Strategic workload management and decision biases in aviation. *The International Journal of Aviation Psychology*, 4, 211–240.
- Rhodes, K. V., Vieth, T., He, T., Miller, A., Howes, D. S., Bailey, O., ... & Levinson, W. (2004). Resuscitating the physician-patient relationship: Emergency department communication in an academic medical center. *Annals of Emergency Medicine*, 44(3), 262-267.
- Rogers, W.A., Maurer, T.J., Salas, E., & Fisk, A.D. (1997). Training design, cognitive theory, and automaticity: Principles and a methodology. In J.K. Ford (Ed.), *Improving training effectiveness in work organizations* (pp. 19-45). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Salvucci, D. D., & Bogunovich, P. (2010). Multitasking and monotasking: The effects of mental workload on deferred task interruption. *Human Factors in Computing Systems: Proceedings of CHI'10* (pp. 85-88). New York, NY: ACM Press.
- Salvucci, D. D., & Taatgen, N. A. (2008). Threaded cognition: An integrated theory of concurrent multitasking. *Psychological Review*, 115, 101–130.
- Salvucci, D. D., & Taatgen, N. A. (2011). *The multitasking mind*. New York, NY: Oxford University Press.
- Schwab, J. A. (2002). *Multinomial logistic regression: Basic relationships and complete problems*. Retrieved from <http://www.utexas.edu/courses/schwab/sw388r7/SolvingProblems/>
- Siegler, R. S. (1988). Strategy choice procedures and the development of multiplication skill. *Journal of Experimental Psychology: General*, 117, 258-275.

- Sit, R. A., & Fisk, A. D. (1996). Retention of multiple-task performance: Age-related differences. *Proceedings of the 40th Human Factors and Ergonomics Society Annual Meeting* (pp. 128-132). Santa Monica, CA: HFES.
- Spencer, R., Coiera, E., & Logan, P. (2004). Variation in communication loads on clinical staff in the emergency department. *Annals of Emergency Medicine*, 44(3), 268-273.
- Stewart, T. R. (1988). Judgment analysis: Procedures. In B. Brehmer & C. R. B. Joyce (Eds.), *Human judgment: The SJT view* (pp. 41-74). Amsterdam, North-Holland: Elsevier.
- Tran, Q. T. (2009). *Visual summaries augmenting memory recall of repetitive actions* (Unpublished doctoral dissertation). Georgia Institute of Technology, Atlanta, GA.
- Werner, N. E., & Holden, R. J. (2015). Interruptions in the wild: Development of a sociotechnical systems model of interruptions in the emergency department through a systematic review. *Applied Ergonomics*, 51, 244-254.
- Westbrook, J. I., Coiera, E., Dunsmuir, W. T., Brown, B. M., Kelk, N., Paoloni, R., & Tran, C. (2010). The impact of interruptions on clinical task completion. *Quality and Safety in Health Care*, 19(4), 284-289.
- White, P. (1980). Limitations on verbal reports of internal events: A refutation of Nisbett and Wilson and of Bem. *Psychological Review*, 87(1), 105-112.
- Wickens, C. D., Gutzwiller, R. S., & Santamaria, A. (2015). Discrete task switching in overload: A meta-analysis and a model. *International Journal of Human-Computer Studies*, 79, 79-84.
- Wickens, C. D., Helleberg, J., Goh, J., Xu, X., & Horrey, W. J. (2001) *Pilot task management: Testing an attentional expected value model of visual scanning* (ARL-01-14/NASA-01-7). Savoy, IL: University of Illinois Aviation Research Lab.
- Wickens, C. D., Santamaria, A., & Sebok, A. (2013). A Computational Model of Task Overload Management and Task Switching. *Proceedings of the Human Factors and Ergonomics Society 57th Annual Meeting* (pp. 763-767). Santa Monica, CA: Human Factors and Ergonomics Society.
- Wolf, L. D., Potter, P., Sledge, J. A., Boxerman, S. B., Grayson, D., & Evanoff, B. (2006). Describing nurses' work: Combining quantitative and qualitative analysis. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 48(1), 5-14.

- Woloshynowych, M., Davis, R., Brown, R., & Vincent, C. (2007). Communication patterns in a UK emergency department. *Annals of Emergency Medicine*, 50(4), 407-413.
- Zijlstra, F. R. H., Roe, R. A., Leonora, A. B., & Krediet, I. (1999). Temporal factors in mental work: Effects of interrupted activities. *Journal of Occupational and Organizational Psychology*, 72(2), 164-185.