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TURF for Teams: Considering Both the Team and I in the Work-Centered Design of Systems

Vickie Nguyen

University of Texas Health Science Center at Houston, Vickie.D.Nguyen@uth.tmc.edu

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By

Vickie D Nguyen, MA, MS

APPROVED:

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Amy Franklin, PhD, Chair

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Jiajie Zhang, PhD

_____

Nnaemeka G Okafor, MD, MS

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TURF for Teams:
Considering Both the Team and I in the Work-Centered Design of Systems

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Vickie D Nguyen, MA, MS

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Dissertation Committee:

Amy Franklin, PhD[1], Advisor
Jiajie Zhang, PhD[1]
Nnaemeka G Okafor, MD, MS[2]

[1]School of Biomedical Informatics
[2]McGovern School of Medicine and Memorial Hermann Health System

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ABSTRACT

Teams are an inherent part of many work domains, especially in the healthcare environment. Yet, most systems are often built with only the individual user in mind. How can we better incorporate the team, as a user, into the design of a system? By better understanding the team, through their user, task, representational, and functional needs, we can create more useful and helpful systems that match their work domain.

For this research project, we utilize the TURF framework and expanded it further by also considering teams as a user, thus, creating the TURF for Teams framework. In addition, we chose to examine teams in the emergency department environment. We believe that designing a system with the team also fully incorporated and acknowledged in the work domain will be beneficial for supporting necessary team activities.

Using TURF for Teams, we first conducted an observational field study in the emergency department to get a better understanding of the users, teams, tasks, workload, and interactions. We then identified the need for team communications to be better supported, especially in the management of interruptions, and further categorized the interruptions by their function in order to design a team tool that could help team members better manage their interruptions by focusing on the necessary, or domain, types of interruptions and more easily disregarding the unnecessary, or overhead, types of interruptions.

We then administered some surveys and conducted a card sort and cognitive walkthrough with emergency clinician participants to help us better identify how to design interfaces for the team tool and simulation that would better match the needs of team communication behaviors observed and reported by emergency clinicians.

After designing and developing the team tool and simulation, we conducted an evaluation of this system by having emergency medicine, medicine, and informatics graduate student teams go through the system and utilize the team tool and simulation as a team. Though we had a small sample size, we found that emergency medicine teams found the team tool and simulation to be very usable and they reacted favorably to its potential in helping them better understand and manage their team communications.

In summary, we were able to utilize the TURF framework for incorporating teams into the design of systems, in this case a team communication tool and microworld simulation for the emergency department. Our findings suggest that TURF for Teams is a viable framework for designing useful and helpful team based systems for all work domains.

Field of Study

Biomedical Informatics

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CHAPTER 1: INTRODUCTION

1.1. OVERVIEW OF THE INTRODUCTION CHAPTER

This dissertation is centered upon determining how systems might be better designed for clinical teams. While both work-centered and user-centered design take into account the efforts of the end user, these models do not often incorporate the emergent needs of teams. Here, we worked on enriching a usability framework, TURF (Zhang & Walji, 2011) to build out team needs. As an example, we have developed a tool and microworld simulation around this framework to support team communication in the Emergency Department, specifically interruptions.

In this dissertation, we describe the process by which we first examined emergency department clinical team interactions, modeled these interactions with a focus on the team communicative act of interruptions, obtained user requirements and feedback in the design of a team tool to help manage interruptions, developed this team tool, and created a simulation to evaluate this team tool. This chapter provides a description of the research problem, motivation, aims, hypotheses, objectives, and significance. In addition, we include an outline of the dissertation sections.

1.2. RESEARCH PROBLEM

Critical care teams, such as those in the emergency department (ED), are constantly under

high levels of workload as patient care decisions must be quickly made based on large quantities of information and resources within the dynamic environment (Patel, Kaufman & Magder, 1996). Improving support of these teams in teamwork activities, such as streamlining communication and coordination, are vital to improving patient safety and quality. However, the work of the emergency department is complex. As each individual clinician multi-tasks to care for their cadre of patients, they also work collaboratively with many other clinicians. Their efforts are sometimes synchronous and on other occasions they must interrupt the activities of others in pursuit of their separate goals. This is particularly true in emergency departments where past work by Chisholm in 2011 estimates on average 30 interruptions per 180 minutes of work.

We will argue here that interruptions are an example of a communication breakdown. Not in the sense that interruptions fail to exchange information, but rather interruptions are poor mechanisms of information sharing and limited situation awareness resulting in this 'work-around' solution. We will demonstrate how some interruptions are appropriate to the demands of the situation while other interruptions emerge unnecessarily. Additionally, we will describe our intervention to help manage the unnecessary disruptions to work.

Interruptions are used here as an example of a team need. Group communication across a full array of individuals is required to complete coordinated work. Optimizing the team communication activity of interruptions through a team support tool can help improve task performance by decreasing workload burden and align team roles and responsibilities (Graetz, Reed, Rundall, Bellows, Brand & Hsu, 2009).

The long-term goal of this project is to study the team decision making and patient care process, enrich team situation awareness in the emergency department through team tool interventions, better teamwork, reduce errors, and inform a framework for the design of team support tools. We used theories from team cognition (DeChurch & Mesmer-Magnus, 2010; Gibson, 2011; Hollingshead, 2008; Klimoski & Mohammed, 1995; Smith-Jentsch, 2009), the TURF framework of usability (Zhang and Butler, 2007; Zhang & Walji, 2011), and the method of work- and user-centered design (Johnson, Johnson & Zhang, 2005; Zhang, Patel, Johnson, Malin & Smith, 2002).

1.3. RESEARCH MOTIVATION

Our research motivation mainly focuses on: How can we design systems to accommodate team needs? We would like to find a way to design technology to support team activities in the healthcare setting, such as helping teams manage interruptive communications in the Emergency Medicine environment.

1.4. RESEARCH AIMS

We propose the following aims:

> Research Aim 1: Describe team needs in the management of interruptions
> for the Emergency Department environment.

An empirical study will be conducted to investigate current team communication methods, including interruptions, team communication needs, and the impact of interruptive behavior on the patient care process in the ED.

> Research Aim 2: Design a team tool to support appropriate communication for the Emergency Department environment.

Work and user-centered designed team support tools can improve team performance in the ED. We will create a team interruption support tool based off of the information found in Specific Aim 1 and using a modified TURF framework built on a team focused work- and user-centered design model.

> Research Aim 3: Evaluate the impact of the team tool in the Emergency Department environment.

The team designed support tool is based on satisfying team needs and supports teamwork tasks. We will evaluate the team interruption support tool's effect on teamwork factors.

1.5. RESEARCH HYPOTHESES

Our hypotheses are:

> Research Hypothesis 1: Supporting team interruptions can reduce workload burdens and improve teams and their patient care efficiency.

Research Hypothesis 2: Models of work- and user-centered design can be

modified to include teams as users.

Research Hypothesis 3: Team designed systems will not only be more useful,

but satisfying for team members.

1.6. RESEARCH OBJECTIVES

Data from ethnographic observations and surveys will be gathered and analyzed for patterns

using current interruption classification methods and team needs. A prototype of a team

interruption support tool for a mobile device will be designed based on these findings. We

will then evaluate subjective impressions of the team tool in a simulation.

1.7. RESEARCH SIGNIFICANCE

Much of healthcare depends on distributed systems of clinical providers (Patel, Cytryn,

Shortliffe & Safran, 2000) within complex clinical environments. However, health

information technologies (HIT) have generally failed to support clinical teams in areas such

as communication, collaboration, coordination, and temporal awareness as systems are often

only designed for the individual user and often only fulfill system-based objectives as

opposed to clinical team needs (Ash, Berg & Coiera, 2004; Bria & Shabot, 2005; Chaudhry,

Wang, Wu, Maglione, Mojica, Roth et al., 2006; Collins, Bakken, Vawdrey, Coiera & Currie,

2011; Harrington, Kennerly & Johnson, 2011; Horsky, Kaufman & Patel, 2003;). Emergent

features of teams such as the management of interruptions, strategy formulation, situation

monitoring, and leadership may require more specific support (Fernandez, Vozenilek, Hegarty, Motola, Reznek, Phrampus et al., 2008; Zaccaro, Heinen & Shuffler, 2009).

Improving our understanding of team users' needs will help in the interface design of systems in healthcare settings. The ideal method in the design of interfaces is to first identify users and their needs, to complete required tasks, and then design the system according to those factors (Johnson, Johnson & Zhang, 2005; Zhang, Patel, Johnson, Malin & Smith, 2002). For instance, a single user in the healthcare setting is a physician, and their needs are to use a system, such as a dashboard, to determine whether or not a patient's labs have returned. The need to determine when the patient's lab information has returned helps the physician proceed in the patient care process within a timely manner. However, the healthcare setting includes more than just one user; it also includes teams of users, such as other physicians of varying specialties, nurses, and residents with additional needs to assist in the team patient care process. These users work together to administer patient care, but as the environment is quickly changing around them, a lot of information or tasks may be displaced or repeated as there is no system designed to manage the needs of the team (Patel, Kaufman & Magder, 1996). Therefore, a system designed towards team needs would benefit healthcare settings.

By taking what we have learned from research conducted in similar team related fields, such as, sports and athletics, the military, aviation, and industrial/organizational psychology, and current information on team users' needs in the healthcare environment regarding HITs, we can create a HIT system that will provide better clinical support as it fully addresses both an

individual and team user's needs. Patient safety and quality will improve through the enhancement of each clinician team's efficiency, effectiveness, coordination, communication, and acceptance and use of the HIT.

The broad goal of this project is to develop an interface to support teams. Our focus will be based on an emergency department as the environment for studying critical care teams and team activities requiring additional support for teams. We will focus on utilizing a TURF for Teams framework to design a tool to help teams manage the team communication activity of interruptions in the emergency department. In addition, we will focus on the influence of the team support tool, created with the TURF for Teams framework, on team performance, teamwork tasks, and the patient care process.

1.8. DISSERTATION OUTLINE

The rest of the dissertation continues with Chapter 2 illustrating how this work differs from and expands upon the existing work related to health information technologies, the emergency department environment, teams, interruptions, healthcare, and mobile devices in our journey to understanding our research problem. Chapter 3 describes the underlying Task, User, Representation, and Function (TURF) analyses framework and methods we will be using to address our research problem and objectives. In Chapter 4, we examine microworld simulations, its use in healthcare, and our motivations for its use in the current work. Chapter 5 presents our ethnographic study completed to gain an understanding of clinical team interactions in the emergency medicine environment, interruptions, and to depict a novel application of the TURF framework. Chapter 6 illustrates the emergency

medicine environment, teams, and communication processes in greater detail. In Chapter 7, we describe how we take what we have learned from the previous chapters and apply them in to the design of a team communication tool. For Chapter 8, we outline our method for creating a simulation to work with and test our team communication tool. Chapter 9 provides a description of the team communication tool and simulation evaluations and its results. Chapter 10 ties all of the sections together and presents a discussion of what we have discovered in relation to the research problem and approach. Finally, Chapter 11 provides a conclusion of our efforts and an end to the dissertation.

1.9. SUMMARY OF THE INTRODUCTION CHAPTER

In this chapter, we have provided an overview of our research approach in determining how to better design systems for clinical teams in critical care environments. The research problem, motivation, aims, hypotheses, objectives, and significance are described along with an outline of the upcoming chapters in this dissertation.

CHAPTER 2: LITERATURE REVIEW

2.1. OVERVIEW OF THE LITERATURE REVIEW CHAPTER

To determine how to better design systems for clinical teams in the emergency department environment, we examine work previously completed concerning health information technologies, emergency medicine, team interactions, and mobile device applications. By examining these relevant works, we will differentiate between what has been conducted and what still needs to be completed. We will attempt to answer these gaps through the work of this dissertation.

2.2. HEALTH INFORMATION TECHNOLOGIES AND TEAMS

Current systems and tools, such as electronic health records, PACS, Kardex, and track boards, used within healthcare settings are designed for individual roles. This is evidenced by how certain functions and information views are only available to certain roles, for instance, a physician view versus a nurse view. This individual role form of design does not lend itself well to helping healthcare teams accomplish teamwork type tasks necessary for many patient care processes. Health information technology support is needed for these teamwork tasks like coordination of shared activities. By supporting these teamwork tasks, we can help healthcare teams maintain shared mental models, or task and goal models, for executing patient care. It can also help increase temporal awareness across team members and should then assist teams in managing and monitoring patient care processes in a timely manner.

We hypothesize that systems designed to support teams should improve individual and team performance and improve its adoption and use.

Areas where HIT have failed to support clinicians fall mainly in team related areas such as communication, collaboration, coordination, maintaining shared mental models, and temporal awareness (Bria & Shabot, 2005; Chaudhry, Wang, Wu, Maglione, Mojica, Roth et al., 2006; Collins, Bakken, Vawdrey, Coiera & Currie, 2011; Harrington, Kennerly & Johnson, 2011; Horsky, Kaufman & Patel, 2003). HITs are designed mainly with individual users in mind, but a team is more than the sum of its parts. Eccles and Tenenbaum (2004) state that "team members, compared to individual performers, must acquire additional knowledge about teamwork, must share this and other knowledge with other members by communicating, and must cope with an increased cognitive demand, in order to achieve team coordination" (Eccles & Tenenbaum, 2004). These additional demands on individuals are the exact team features that are not supported by current HIT designs.

In an attempt to address these concerns and improve HIT systems, user-centered design (UCD) methods have been adopted and utilized. Yet, it has been found, by both those creating and using these systems, that there are several gaps in fully obtaining a fairly optimal system. Examples include failure in understanding that external interruptions to the user will occur during the use of the system (i.e., aspects of teamwork), the interface information elements incorrectly follow the current work practice workflow (i.e., environment), and the misconception of clinicians believing that by entering in information into the system, proper communication of plans to other clinicians can be replaced (i.e., coordination and

communication) (Ash, Berg & Coiera, 2004). This may be due to the fact that only individual user's needs are addressed in the design and redesign of HIT interfaces.

Health Information Technology systems have the potential to improve patient safety and quality, yet they have failed to achieve an increase in acceptance and use as clinicians have found, through experience and perception, that these systems do not correctly reflect their mental models of information needs and priorities and teamwork activities, and, consequently, fail to meet their needs in providing optimal patient care (Chaudhry, Wang, Wu, Maglione, Mojica, Roth et al., 2006; Harrington, Kennerly & Johnson, 2011). As a result, not only does the potential of HITs, clinicians, and patients suffer, their efficiency and effectiveness are also compromised.

2.3. THE EMERGENCY MEDICINE ENVIRONMENT

We have selected the emergency department as the setting for our research project. This is a perfect setting to test our hypotheses on designing for healthcare teams as the emergency department is a critical care environment that is highly dynamic, utilizes team based care, is prone to many types of communication acts like interruptions, provides high information demands on its clinicians, employs interdisciplinary care, and has high turnover, especially if the emergency department also serves as a teaching environment to its clinicians.

In this respect, the emergency medicine environment is similar to other complex environments examined in the military and aviation fields, but it also contains the aspect of extended work, or work required to be passed on to new teams and team members over an

extended time period such as handoff of patients. Additionally, this environment has multiteams, two or more teams that directly work together or interdependently to complete tasks (DeChurch & Mathieu, 2009), such as teams of nurses teams of residents working together within a larger collective team. All of these teams contain team members with various roles and varying levels of expertise.

With such an environment, greater chances of possible medical errors and adverse events can occur (Kilner & Sheppard, 2010; Manser, 2009; Pham, Aswani, Rosen, Lee, Huddle, Weeks et al., 2012). It has been found that clinical teams believe teamwork activities, like communication, will help increase work satisfaction and patient care and quality (Kilner & Sheppard, 2010; Manser, 2009; Pham, Aswani, Rosen, Lee, Huddle, Weeks et al., 2012). Likewise, better communication and satisfaction will help reduce chances of medical errors and adverse events (Kilner & Sheppard, 2010; Manser, 2009; Pham, Aswani, Rosen, Lee, Huddle, Weeks et al., 2012).

There is a need to better understand teams within this type of environment and to better support these teams through technologies designed to help with team activities. Based on subjective input from the clinical teams themselves, it can be seen that additional support in team activities, like support tools, may be beneficial in reducing chances in medical errors and improving patient care. These tools must help team members to communicate, coordinate, and collaborate more effectively to better enhance shared knowledge and awareness amongst team members.

2.4. TEAM COGNITION

Teams are defined as two or more individuals, interdependent, viewed collectively, and share responsibilities towards completing the same goal within an organizational context (Cohen & Bailey, 1997; Hackman, Wageman, Ruddy & Ray, 2000; Katzenbach & Smith, 1993; Mathieu, Heffner, Goodwin, Salas & Cannon-Bowers, 2000; Salas & Fiore, 2004; Sundstrom, DeMeuse & Futrell, 1990). Aspects of teamwork include communication, collaboration, and coordination (Essens, Vogelaar, Mylle, Blendell, Paris, Halpin et al., 2009). Communication serves as a window into team cognition as this activity allows team members to share their knowledge and activities with one another, which then enhances the team's shared awareness of team needs to accomplish goals (Cooke, Salas, Kiekel & Bell, 2004). Collaboration is defined as team members acting autonomously as a part of the team, but must work together and answer towards the whole (Elias & Fiore, 2012), whereas, coordination is seen as the constraints to the actions executed by the team (Marks, Mathieu & Zaccaro, 2011). These teamwork processes, in turn, impact team performance, both individually and collectively as a team, and team effectiveness on the task or tasks at hand (Essens, Vogelaar, Mylle, Blendell, Paris, Halpin et al., 2009). The interdependent nature of teams requires that artifacts designed for teams essentially must be designed for nested intelligences (Morrow & Fiore, 2013).

Leadership in a team is another important component of the teamwork model. Team leaders help facilitate communication, coordination, and collaboration of the team and have a great impact on facilitating the expertise level of the team (Zaccaro, Heinen & Shuffler, 2009). For instance, in a healthcare setting, the team leader may help convert team members in a new

team towards the next rank of a novice team, then to the next rank of an expert team, and then towards a more adaptive team by various actions promoting team activities (Kozlowski, Watola, Jensen, Kim & Botero, 2009). For instance, with a novice team, the team leader may help increase the efficacy of the team by assigning certain tasks to the team allowing them to test their strength on that task. With the right amount of assistance and team reflection, team members will learn from their actions and increase their shared knowledge in how to react to similar situations in the future as a more experienced team. Such leadership can increase the team's satisfaction in their work and improve patient care (Kilner & Sheppard, 2010; Manser, 2009; Pham, Aswani, Rosen, Lee, Huddle, Weeks et al., 2012).

Cognitive research has mostly focused on individual-centric, rather than team-centric, factors including the interaction of an individual user and the computer, individual decision-making, and the situational awareness of pilots separate from the flight crew (Cooke, Gorman & Winner, 2007). Yet, increasingly more complex environments and associated systems require teams. In addition, these environments use technology-based work systems that require teams to operate them. Therefore, in recent years, what we have learned from individual-centric cognitive research has some bearing on team-centric cognitive research.

Two major theories underlying Team Cognition, and are of interest for this research project, are the information-processing perspective and the ecological psychology perspective (Cooke, Gorman, & Rowe, 2009). The information-processing perspective examines individual-centric constructs such as shared mental models and situational awareness within a team where each team member provides input to be processed (Cooke, Gorman, & Rowe,

2009), whereas, the ecological perspective takes into account the team as a whole working together to complete tasks, team coordination and communication, their environment, and team situational awareness (Cooke, Gorman, & Rowe, 2009). As teams are interdependent entities, it is best to employ both information-processing and ecological perspectives when examining team cognition. Just like an interlocking burr wood puzzle, each team member must provide and be aware of their various notches, or mental models and functions, which must be correctly interlocked, or communicated and coordinated, in just the right way to form a whole and solid object, or team cognition, the complete and cohesive mindset of the team as a whole.

As communication provides an important insight into team cognition and has the potential to promote safe, efficient, and effective work, it is important to provide some support to this team activity. It has been found that more efficient communication practices are correlated to lower task and mental workload (MacMillan, Entin & Serfaty, 2004). Efficient communication practices help to ground team members and promote shared awareness and knowledge (Clark, 1996; Monk, 2009; Morrow & Fischer, 2013). Designing a technology aid to support communication helps in reducing the mental demands that arise due to the complex environment, provides a way for users to track multiple threads of information, and gives greater accessibility to information provided earlier on during a shift or extended work period, which in turn, can help inform and remind users of what to do next or to revise their actions to complete a task process for the team.

Team cognition has steadily progressed to fill in the paucity in team-centric research. However, more work must be conducted to further illuminate how teams function in the "wild", teamwork processes operate, environment impacts teams, to consider multiteam entities, to accurately identify team measures, and simulations and artifacts can influence teams (Salas & Wildman, 2009; Smith-Jentsch, 2009).

2.5. INTERRUPTIONS

An emergent feature of teams is the communicative action of interruptions. Interruptions are defined as a break in task to execute an unplanned task initiated by an internal or external source resulting in the pause or termination of the original task (Berg, Källberg, Göransson, Östergren, Florin & Ehrenberg, 2013). These breaks in task are an inherent team activity as they are a form of coordination and communication between team members (Berg, Källberg, Göransson, Östergren, Florin & Ehrenberg, 2013). Issues in team coordination and communication of tasks and resources caused by interruptions have been shown to be a significant cause of medical errors as interruptions can derail one from completing the initial task being executed before the interruption occurred or cause interference in the execution of this task (Coiera & Tombs, 1998; France, Levin, Hemphill, Chen, Rickard, Makowski et al., 2005; Institute of Medicine, 2003). A common interruption that can be harmful to patient care is the interruption caused by team members to nurses as they organize and administer medications to their patients (Grundgeiger & Sanderson, 2009; Rivera & Karsh, 2010; Westbrook, Coiera, Dunsmuir, Brown, Kelk, Paoloni et al., 2010). While unnecessary interruptions have the potential to lead to increased patient risk (Chisholm, Dornfeld, Nelson & Cordell, 2011; Grundgeiger & Sanderson, 2009; Li, Magrabi & Coiera, 2012;

Rivera & Karsh, 2010), some interruptions are in fact necessary to the work process (Berg, Källberg, Göransson, Östergren, Florin & Ehrenberg, 2013). For example, it is necessary to interrupt an Attending physician to examine an electrocardiogram reading as time sensitive protocols may need to be activated if the electrocardiogram reads irregularly for a patient. A delay in getting a read and sign-off on the electrocardiogram from the Attending physician could be detrimental to the patient.

It has been observed that emergency department physicians in the United States have been shown to experience interruptions, such as being interrupted in completing a physician task by a verbal communication from another clinician, losing documentation necessary for the completion of a task, or receiving an auditory and visual notification from a pager, on average, 10 times per hour during a shift (Chisholm, Dornfeld, Nelson & Cordell, 2011; France, Levin, Hemphill, Chen, Rickard, Makowski, Jones & Aronsky, 2005; Grundgeiger & Sanderson, 2009) while ED nurses have been shown to be interrupted as much as up to one interruption every 4.5 minutes (Grundgeiger & Sanderson, 2009; Li, Magrabi & Coiera, 2012). These numbers of interruptions are much greater than the occurrences of interruptions that clinicians in similar dynamic environments in other countries experience (Allard, Wyatt, Bleakley & Graham, 2012; Grundgeiger & Sanderson, 2009). These numbers imply that much more needs to be understood about teams in order to better support clinical team activities and help clinical teams have the potential of providing good patient safety and quality, efficiently completing patient and physician tasks, and managing their communication, coordination, and situational awareness.

Interruptions not only impact the clinical team, but have also been found to be correlated to lower patient satisfaction (Jeanmonod, Boyd, Loewenthal & Triner, 2010). The interruptions the clinical teams experience may impact their ability to provide more optimal patient care which in turn can influence the patient's perception and satisfaction of care.

As it has been shown that not all interruptions are bad (Berg, Källberg, Göransson, Östergren, Florin & Ehrenberg, 2013), it has also been found that the act of interruptions can help increase shared knowledge amongst team members (Zellmer-Bruhn, 2003). With efficient communications between team members, new knowledge or work routines can be shared and can help improve the team's performance on completing tasks (Zellmer-Bruhn, 2003). Likewise, it has been shown that interruptions can positively impact task performance, the emotional state, and social attribution depending on the current cognitive load of people during task executions (Adamczyk & Bailey, 2004). It has been suggested that an interruption manager, or support tool, can help to reduce the negative effects of interruptions and retain the positive interruptions to help increase the awareness of a user and lessening any disruptive effects to their work (Adamczyk & Bailey, 2004; Bailey, Konstan & Carlis, 2011). This can also be applied to teams.

Interruptions have currently only been examined considering the rate of interruptions (Allard, Wyatt, Bleakley & Graham, 2012; Chisholm, Dornfeld, Nelson & Cordell, 2011; Li, Magrabi & Coiera, 2012), interrupted activities (Adamczyk & Bailey, 2004; Allard, Wyatt, Bleakley & Graham, 2012; Chisholm, Dornfeld, Nelson & Cordell, 2011; Li, Magrabi & Coiera, 2012), and those receiving or initiating interruptions (Berg, Källberg, Göransson,

Östergren, Florin & Ehrenberg, 2013; Brixey, Robinson, Turley & Zhang, 2010).

Interruptions have not yet been examined by their content or function. This focus may help us further understand team needs.

2.6. TEAM RESEARCH AND HEALTHCARE

In general, members of teams have an organized understanding and a mental representation of knowledge about the relevant environment. Teams must work to store, use, share, and coordinate their knowledge to accomplish individual, team, and organizational goals. However, due to the complexity of the healthcare environment, we must take into account not only a single user's mental model, but a team's mental model, as well. Healthcare teams include attending, residents, charge nurses, nurses, consulting physicians, technicians, and administrative staff. Teamwork is a necessary component of healthcare as there are a variety of roles, different timeframes and physical locations where multiple patients, clinicians, resources, and information may arrive into the environment.

In order to properly measure a mental model of a team, we need to consider the environment, individuals, and sub-teams within the environment itself. We must also consider their interactions through communication and coordination efforts, information needs, tasks, and workflow. Additionally, any artifacts used by the team must be noted including electronic, visual, and auditory aids. Emergent features of teams that are not present for individuals include knowledge, skills, attitudes, coordination, and leadership over a group of multiple people (Burke, Salas, Wilson-Donnelly & Priest, 2004; Fernandez, Vozenilek, Hegarty, Motola, Reznek, Phrampus et al., 2008).

Currently, to our knowledge, there is a small amount of research that focuses on teams in the healthcare environment. Research often focuses on team behaviors, training of team skills (Burke, Salas, Wilson-Donnelly & Priest, 2004; Fernandez, Vozenilek, Hegarty, Motola, Reznek, Phrampus et al., 2008; Salas, Diaz Granados, Klein, Burke, Stagl, Goodwin et al., 2008), and the complexity of team structures. Team research within the healthcare setting has only focused on a small range of tasks like handoff procedures (Abraham, Kannampallil, Patel, Almoosa & Patel, 2012; Collins, Mamykina, Jordan, Stein, Shine & Reyfman et al., 2012). The gaps found in team knowledge research have found that there is a need to study: 1) relationships between team knowledge constructs; 2) mediating mechanisms between team knowledge and performance; 3) relationships with criteria outside of team performance; and 4) the creation of a more holistic theoretical approach (Wildman, Thayer, Pavlas, Salas, Stewart & Howse, 2012).

Improving our understanding of including team users' needs will help in the easier acquisition of teams' needs for proper interface design of many systems in and out of the healthcare setting.

Within the healthcare setting, by properly comprehending each clinician teams' concepts and priorities, we will be better equipped in addressing each team's workflow needs and mental models through the HIT interface design and hopefully help to improve patient safety and quality through the improvement of each clinician teams' efficiency, effectiveness, coordination, communication, and acceptance and use of the HIT.

2.7. MOBILE DEVICES AND HEALTHCARE

The emergency medicine environment, team composition and interactions, and design of health information technologies are all important factors that can also impact patient safety and quality. As mobile devices are becoming more ubiquitous, a way to improve team interactions and communications may be through a mobile device designed for the purpose of medical team coordination and communication.

Mobile devices have only been recently used as a means for managing communication between clinicians in the clinical environment. The benefits of the mobile device include reducing the number of objects that clinicians have to carry while performing patient care tasks, providing a more streamlined approach to communicating between team members, and supplying a more secure and HIPAA compliant medium for team communications (Przybylo, 2013).

Many clinicians are already unofficially utilizing mobile devices in the healthcare environment for both personal and work related tasks (Planitz, Sanderson, Kipps & Driver, 2013). It has also been shown that by using a mobile device, these clinicians have a greater predilection for accepting other new technologies in their environment (Planitz, Sanderson, Kipps & Driver, 2013), which may bode well for future acceptance of other device interventions and implementations.

Wireless communications, such as pagers, have led to increased acts of interruptions and disruptions to work (Solvoll & Scholl, 2008). This seems to imply that a communication tool

that can displace the pager and is designed toward properly managing interruptions or providing communications relevant to teamwork processes may be helpful.

Artifacts designed to help improve shared knowledge amongst team members and teams would be helpful (Endsley, 1988). Recently, it has also been found that users prefer to have their work systems retain some of the same features as their personal systems (Liu, Stappers, Pasman & Taal-Fokker, 2013). This seems to imply that familiarity in interface features matching work processes, or external representations of the current work process, and functions would increase the chances of acceptance and adoption of technologies.

Only a few technologies have been studied within the healthcare setting. These systems include Vocera (Vocera, 2013), Medigram (Medigram, 2013), and Care Thread (Care Thread, 2015).

The Vocera Communication Badge is a hands free device that enables users to instantly contact and communicate with other team members using limited device screen real estate (Vocera, 2013). It looks more like a mini recorder. Vocera has also increased their product line to include tablet based messaging devices (Vocera, 2013). Vocera is not academically grown. Medigram is a mobile device application that helps users communicate through texts, images, and documents with other team members in order to provide patient care, which is a greater extension to the capabilities offered by Vocera (Medigram, 2013). It was created by a team of Stanford University students. Care Thread is a mobile application based on the inspiration of micro-blogging and takes the interface of Vocera and Medigram to another

level (Care Thread, 2015). It was created by a team of researchers and programmers. Care Thread includes a patient-centered stream for clinicians to communicate upon.

The first two devices have been formally studied, using ethnographic observation after implementation of the device and surveys, and have shown that there is some interest amongst the participant users. Vocera has been shown to reduce the call length of interruption-type communications (Ernst, Weiss & Reitsema, 2013) while Medigram has been shown to seem helpful to participant users (Przybylo, 2013). Beyond the actual implementation and surveying of users, Care Thread also obtained input on the design of the device from actual users and used an iterative process to improve their device (Collins et al., 2015; Dalal et al., 2014).

Other mobile technologies in the existing market are more similar to the Medigram system, but have not been formally studied. Each system has provided testimonials and small case studies pushing for their product to potential consumers. Only one system provides a connection to HIT in the environment. The existing features, offered by these few clinically focused mobile application companies accommodating clinical team communications, mainly consist of labeling one as occupied to other users while still receiving messages, providing the ability for users to leave quick message responses when messaged, listing contacts, and showing whether or not someone has seen a message that has been sent (Przybylo, 2013).

A few examples of current messaging interfaces of similar applications display messages that can be found in the server log archives, message directionality between users, message timestamps, and message urgency notations using color (Medigram, 2013; QliqSoft, 2013; Voalte, 2013). Care Thread also provides a more patient focused approach to the organization of the information provided to the clinical team (Collins et al., 2015).

A mobile device application seems to provide more versatility in managing all types of communications. It seems that developers have not yet fully supported team needs as additional features may provide healthcare teams with more useful ways of maintaining teamwork processes like communication and enhance their shared awareness and knowledge. Utilizing TURF for Teams will be helpful in creating a more useful and satisfying support tool that fits team needs and their environment.

We hope to add to the current basic functions provided by such technologies by providing users with an interface designed for teams through TURF for Teams and the ability to sort through their messages from their mobile device in order to determine whether or not the interrupting message needs an immediate response based on the criticality of the patient stated, by the type of contact, or through the team's specific needs. In addition, customizable functionality will be provided to users so that they will be able to have easier access to communications in order to maintain shared awareness and knowledge. Team leaders may also have the option of having a means of helping novice team members to learn how to prioritize their tasks more effectively, which in turn may be a way to share knowledge and teamwork processes.

2.8. SUMMARY OF THE LITERATURE REVIEW CHAPTER

Here, in Chapter 2, we investigated past research pertaining to health information technologies, the emergency medicine environment, team interactions, healthcare, and mobile devices and have pinpointed how to better design systems for clinical teams in the emergency medicine environment.

CHAPTER 3: MICROWORLD SIMULATION

3.1. OVERVIEW OF THE MICROWORLD SIMULATION CHAPTER

In this chapter, we describe the motivation behind the creation of our microworld simulation, how it relates to TURF for Teams, and its importance to the evaluation of team tools and systems. Additionally, we examine the use of teams and simulation work from previous research and explain how our work differs from these previous endeavors.

3.2. MICROWORLD SIMULATION OBJECTIVES

A microworld in simulation is defined as a microscopic focus of a subsection of the natural universe within an artificial setting alongside synthetic tasks and exposures closely mimicking real-world experiences (Cooke, Gorman, Myers & Duran 2013). Microworlds are simulations of the team task environment that are conducive for evaluating multiple participants simultaneously (Cooke, Gorman, Myers & Duran 2013). They have been used in other team related domains, like aviation, and are created using cognitive engineering methods (Cooke, Gorman, Myers & Duran 2013). As it is often difficult to obtain the necessary approval, time, and environment for testing tools and systems to determine its design and functional success, a microworld simulation is a useful channel for closely evaluating these items in close to real world conditions and constraints.

Microworld simulations are becoming increasingly more popular in testing systems (Cooke,

Gorman, Myers & Duran 2013), but they are still constrained to individual user testing

protocols or specific procedural tasks with little focus on teamwork (Deutsch, Dong,

Halamek, Rosen, Taekman & Rice, 2016). One of our goals for this research project is to

evaluate tools designed for teams with a team of users completing individual and team tasks.

Currently, it is difficult to assess how well team designed tools and systems work for teams.

For example, an electronic health record (EHR) system is utilized by a team of caregivers to

help them document, administer, and monitor patient care practices and information.

Multiple members in the team throughout the unit and the hospital work together on the

same patient cases to achieve the same patient goals. However, role based views of the

system may limit access to a shared display. That is, a nurse may see the order to administer a

medication, but may not have the same interface display as the physician. The physician

orders and keeps an eye on the medication and its dosage and scheduled intake through a

Computerized Provider Order Entry (CPOE) interface for the patient while the pharmacist

examines and manipulates the patient's Medication Administration Record to reflect the

ordered medication and its dosage and scheduled intake and, at the same time, the nurse

must reorganize the patient's medications in order to continually view the ordered

medication and its dosage and scheduled intake through the Medication Reconciliation List.

If we were to evaluate this system within a microworld simulation, we might explore how

this team functions when looking at one shared interface or three individualized views.

However, the current infrastructure for testing group scenarios, let alone group interactions

on different interfaces, is limited. A fully developed system for testing teams using

technology could improve the design which in turn could benefit the patient safety and quality of the patient care process and relieve healthcare provider teams' chances at creating adverse events in the system.

To evaluate a system for team usage requires a use case and environment that not only allows for team related tasks, communications, interactions, and workflows, but also provides room for teams to explore these interdependencies at variable times. The use case and environment needs to be a medium that closely approximates the collaboration and dependencies across tasks that users within a team often experience. Unlike evaluating a simulation designed for examining teamwork alone, these simulations should also incorporate asynchronous elements to better demonstrate shared workflow behaviors and needs.

The objective of this research project's microworld simulation is to effectively provide an immersive team environment and experience for testing team designed technology systems.

3.3. CURRENT STATE OF MEDICAL SIMULATIONS AND ITS USES

In Deutsch et al.'s 2016 paper on healthcare simulation and human factors research, the authors report on a growth in the use of healthcare simulations, its increasing ability to be of high quality and fidelity, and the need for incorporating human factors into the healthcare simulations in order improve patient safety and quality. Its current uses can be broken down into seven categories (Deutsch, Dong, Halamek, Rosen, Taekman & Rice, 2016). The first category describes the use of simulation to examine, understand, and potentially improve

individual performance in such areas as increasing proficiency in laparoscopic tool use or in

decision making skills for something as vague and life threatening as cardiac arrhythmia

telemetry monitoring (Deutsch, Dong, Halamek, Rosen, Taekman & Rice, 2016; Segall,

Hobbs, Granger, Anderson, Bonifacio, Taekman, et al., 2015). The second category refers to

the utilization of simulations as a way of investigating and teaching human factors principles

honed in fields like aviation to improve team performance such as enhancing situation

awareness by specifically placing team members or monitors in specific areas around the

patient's bed or following more efficient debriefing guidelines (Deutsch, Dong, Halamek,

Rosen, Taekman & Rice, 2016). Another category depicts the use of simulations to help

inform and improve leadership skills of higher-ups unfamiliar with patient safety guidelines

or inexperience in how to best handle uncommon emergency situations (Deutsch, Dong,

Halamek, Rosen, Taekman & Rice, 2016). Simulations can also be used for the improvement

of systems by giving healthcare professionals and researchers an opportunity to learn about

the healthcare environment, commonly found workarounds that have been established by

users, or improving system iterations tested in the simulation during the product

development lifecycle (Deutsch, Dong, Halamek, Rosen, Taekman & Rice, 2016). The fifth

category outlines the use of simulation as a computational model for examining potential

outcomes of specific situations, such as modeling how increasing beds in the ED might

affect throughput, and offering possible real life solutions and recommendations based on

these models (Deutsch, Dong, Halamek, Rosen, Taekman & Rice, 2016). The last two

categories talk about using simulation to support research endeavors in discovering,

understanding, and substantiating behaviors or new theoretical frameworks and referring to

simulation as a tool for broadly providing lifelong learning opportunities for various fields

and demographics (Deutsch, Dong, Halamek, Rosen, Taekman & Rice, 2016). Healthcare simulation has the potential to branch out from these seven common uses by further exploring teams and technology interactions.

As Deutsch et al. 2016 article categorizes the general uses of healthcare simulations, likewise, in Gaba's 2004 article, the author writes in more detail of the eleven dimensions, or uses, of simulation applications. The purpose and aims of the simulation activity can usually refer to providing an applied education aspect, training, an assessment of performance, a clinical rehearsal, or use in human factors research (Gaba 2004). The unit of participation in the simulation can be by an individual, crew, team, work unit, or entire organization (Gaba 2004) while the experience level of simulation participants can range from those not medically trained to those in residency or receiving continuing education (Gaba 2004). The health care domain in which the simulation is applied can model relatively low stress environments like Radiology to more procedural areas, like surgical units, or high hazard areas, such as the emergency department environment (Gaba 2004). The health care discipline of personnel participating in the simulation can span from clerks and technicians or healthcare providers to managers or legislators (Gaba 2004), and the type of knowledge, skill, attitude, or behavior addressed in simulation can be as specific as displaying conceptual understanding or technical skills to harder concepts such as decision making skills or attitudes and behaviors (Gaba 2004). The age of the patient being simulated can vary from neonates to the elderly (Gaba 2004) while the technology applicable or required for simulations can be as simple as verbal role playing or use of standardized patients to virtual environments or high fidelity replications of clinical areas (Gaba 2004). Similarly, the site of simulation participation can

range from home or library to the replicated environment or real world unit (Gaba 2004).

The extent of direct participation in simulation can also vary from remotely viewing the

situations with or without participation to complete immersion into the scenario, and the

feedback method accompanying simulation can range from delayed critiques to real time

critiques and debriefing (Gaba 2004). Healthcare simulations provide great versatility and

range for almost any situation.

Even though there has been increasing work with teams and healthcare simulations, existing

medical simulations, especially for teams, are typically procedural vignettes. That is, they are

often limited to a specific type of interaction or case. For example, Advanced Cardiovascular

Life Support (ACLS) protocols require teams to work together in administering a set of

clinical interventions related to cardiac or stroke events (Barsuk, Cohen, Nguyen, Mitra,

O'Hara, Okuda, et al., 2016; Zavotsky, McCoy & Royal, 2016). Simulations may bring

together a team to examine their interaction, but only as it relates to a structured protocol.

Other examples of team medical simulations across time include learning and utilizing Team

Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS) to improve

patient safety by the team in the clinical environment (Keebler, Dietz, Lazzara, Benishek,

Almeida, Toor, et al., 2014; Lazzara, Benishek, Dietz, Salas & Adriansen, 2014; Salas, Diaz

Granados, Klein, Burke, Stagl, Goodwin, et al., 2008) or using virtual training simulations on

situations ranging from training anesthesiologists on how to treat chemical warfare casualties

(Berkenstadt, Haviv, Tuval, Shemesh, Megrill, Perry et al., 2003) to training nurses on how to

better prioritize their patient case loads (Josephsen & Butt, 2014). During these medical

simulations, only a few patient case examples may be used to help nursing students transition to clinical practice (Chunta & Edwards, 2013), determine whether or not EHRs are helpful in guiding physicians to diagnostic accuracy (Ben-Assuli, Sagi, Leshno, Ironi & Ziv, 2015), or improve teamwork simulation training methods for ED teams (Kobayashi, Shapiro, Gutman & Jay, 2007; Murray, Freeman, Boulet, Woodhouse, Fehr & Klingensmith, 2016; Small, Wuerz, Simon, Shapiro, Conn & Setnik, 1999). The patient cases may be administered through the use of actors, simulation mannequins, role playing, or a mix of all of these elements (Cooke, Gorman, Myers & Duran 2013). In 2010, Pennathur et al. seem to be the only researchers that have tried to most mimic emergency department patient case loads in medical simulations by simulating more than just three patients at a time. Though they utilize a more complex simulation environment similar to the actual emergency department environment, they do so to evaluate patient tracking systems with single or double user(s) instead of the actual team of users and provide a more standard and controlled timeline of patient workflows, communications, and interactions (McGeorge, Hegde, Guarrera-Shick, La Vergne & Bisantz, 2015; Pennathur, Cao, Sul, Lin, Bisantz, Fairbanks et al., 2010).

Teamwork simulations are costly as they require a full cadre of participants. They are often used only when needed to train entire groups rather than training an individual amongst a cohort of confederates or to test technology.

Medical simulations examining team communication are mostly concerned with building up team skills that will help improve communication as it relates to decision making (Murray, Freeman, Boulet, Woodhouse, Fehr & Klingensmith, 2015), team reasoning (Coenen, Raafat

& Chater, 2011), increasing competency (Galloway, 2009), meta-cognitive skills (Cobbs, Pincetl, Silverman, Liao & Motta, 1994), teamwork training (Hunt, Shikofski, Stavroudis & Nelson, 2007; Miller, Riley, Davis & Hansen, 2008; Shapiro, Morey, Small, Lanford, Kaylor, Jagminas et al., 2004), comparing communication between units (Blasak, Starks, Armel & Hayduk, 2003), and improving patient safety and quality through coordination (Hirsch & Homer, 2004) while standardizing all other environmental, situational, and system aspects. In Salas, Diaz-Granados, Weaver, and King's 2008 paper outline the five coordinating mechanisms of teamwork and eight principles for team training in healthcare. These guidelines examine aspects of teamwork such as team leadership, mutual performance monitoring, backup behavior, adaptability, team orientation, shared mental models, mutual trust, and closed-loop communication, but are mostly exhibited and discussed through verbal acts of communication, rating evaluations, or debriefings in a simulated setting and do not look at other aspects necessary for teamwork in the medical environment such as individual task load burdens while simultaneously working as a team or uses of technology necessary for further facilitation of team needs such as increasing communication opportunities when team members of one patient are far apart or effectively sharing patient data with team members across units (Salas, Diaz-Granados, Weaver & King, 2008). These are aspects of teamwork that still need to be considered and further researched.

Medical simulations testing the technology system itself are often focused on specific constrained cases mimicking actual situations, but may not showcase the complete complexity a team can encounter. In addition, this area of simulation manipulation seems to be underutilized, as it seems healthcare simulations are mostly focused on healthcare

professionals and their interactions, and is used for systems that are in later production states of the design lifecycle. Two cases where a technology system has been tested within a medical simulation has ranged in the use of a discrete event simulation looking at a team of two people handling multiple patients while using an emergency department trackboard (Pennathur, Cao, Sul, Lin, Bisantz, Fairbanks et al., 2010) or having individual participants test an emergency department electronic medical record on two mannequin patients in simulation (Belda, Puppe, Laack & Goyal, 2013). With such a constrained and simplified view of real life conditions, the complete picture of how a technology should or could function in the real world environment may be incomplete preventing it from being as effective as it could be when implemented and utilized in the actual environment.

Medical simulations are commonly used in several ways to model workflow in the real world environment. These ways include using a computational model to prognosticate conditions or as a simplified training exercise showing participants how to react in certain situations. In 2012, Cabrera, Taboada, Iglesias, Epelde, and Luque used an agent based modeling simulation to help them design a decision support system for the emergency department. Although this type of simulation considers team members in the emergency department, it uses mathematical formulas to forecast potential situations at certain numeric amounts, such as patient load during high capacity, and then determines when teams should decide to order labs in order to help assist the patient care process and reduce overcrowding in the emergency department. The use of team involvement is more hypothetical and does not often display its complexity of interaction.

Similarly, in 2003, Baesler, Jahnsen and DaCosta used a computational model to determine the maximum capacity of the emergency department and what it could potentially handle while Mishra, Clamp & Johnson (2014) used simulation to show patient flow and the impact of point of care testing. Examples of workflow through actual hands on practice of individuals include demonstrating how nurses should prioritize their patients (Chunta & Edwards, 2013; Eaves & Flagg, 2011; Josephsen & Butt, 2014), showcasing procedures during specific types of patient emergency cases (Berkenstadt, Haviv, Tuval, Shemesh, Megrill, Perry, et al., 2003; Couto, Farhat & Schvartsman, 2013), and replicating environment stressors and processes in the emergency department through the use of multiple patient cases (Kobayashi, Shapiro, Gutman & Jay, 2007). During these examples of workflow simulations, the cases are mostly navigated by individual participants or very small teams, and are more concerned with building confidence and experience within the individual participant rather than illuminating complex team communication and interactions.

In summary, medical simulations have generally focused on teamwork, procedural skill, and single user testing of technology systems designed for teams. A microworld simulation designed for testing technology systems designed for teams requires more than just these components and our efforts brings something new to this body of work.

3.4. OUR MICROWORLD SIMULATION

We built a microworld simulation to allow for a multi-party extended exchange environment that included communication, technology, and workflows with the goal of determining a successful team build. The microworld is an integrated system that takes into account the

socio-technical model outlined and tested by Sittig and Singh in 2010. This model outlines eight elements that must be considered in order to successfully design, develop, implement, use, and evaluate health information technologies (HITs) in complex healthcare environments. This model has been used to evaluate current states of HIT or elements of HIT, such as bar code medication administration or clinical decision support systems, and has produced recommendations for improving the design and integration of these HITs into the healthcare environment (Kelly, Harrington, Matos, Turner & Johnson, 2016; Wright, Sittig, Ash, Erickson, Hickman, Paterno et al., 2016).

We integrated Sittig and Singh's socio-technical model into our simulation is as follows: a basic hardware and software computing infrastructure (our simulation EHR), clinical content (our simulated ED patient cases), human-computer interface (our simulation EHR and team mobile application), people (our ED team), workflow and communication (our simulated ED patient cases and ED team interactions), internal organizational policies, procedures, and culture (our simulated ED patient cases and ED team), external rules, regulations, and pressures (our simulated ED patient cases), and system measurement and monitoring (in this case, the use of SUS and NASA-TLX) (Sittig & Singh, 2010).

In addition, we used interruptions as the crux of team activities in our microworld simulation to illuminate team communications and interactions to assist in the thorough use of the technology system. Through interruptions, or breaks in tasks (Berg, Källberg, Göransson, Östergren, Florin & Ehrenberg, 2013), we can see the extreme extent of the interactions that occur in teams, show how users of various roles work together in teams, and observe the

hierarchical dependencies and resulting actions that occur to complete tasks by teams. By creating these interruptions, both overhead and domain, as part of the team interactions in the microworld simulation, we are deviating from only procedural team interactions and adding in some more complexity that can help further distinguish how teams use the systems being tested.

We created the microworld simulation using TURF for Teams, which is fully illustrated in Chapter 8. In broad strokes, the microworld simulation was populated with simulated EHR ED Board Patient Cases at varied points in the ED patient care workflow to mimic real world conditions. As an example of the concurrent varied ED team and patient case workflow, one patient may already have a diagnosis, is stabilized, and is now waiting for a bed after being accepted for hospital admission while another may be awaiting a dire scan interpretation. The EHR itself is very basic, but it provided a way for team users to investigate, type in, and extract patient information at any given time during the simulation. A team mobile application was also utilized to facilitate the communicative interactions between ED team members as they worked together to complete the patient cases, and this is described in more detail in Chapter 7. For instance, the nurse on the team may need to verify a specific patient's medication order from the resident or attending physician while the resident may need to find the attending in order to present their findings and initial diagnosis on a patient, but with the attending indisposed, the resident will have to wait or find another way of communicating with the attending. As described, these interactions add in interruptions and add in the complexity mimicked by real world ED team conditions.

In the end, we feel our microworld simulation was created in such a way as to emphasize team communications, interactions, and workflows for testing technology systems designed for teams and team tasks.

3.5. SUMMARY OF THE MICROWORLD SIMULATION CHAPTER

Evaluating a system for team use requires an environment that embodies team interdependencies, tasks, communications, and workflows. Current microworld simulations evaluating teams in the healthcare environment only examine teamwork and procedural tasks and do not focus on the team itself. Similarly, the whole team is not considered when designing or testing systems for team needs and uses. Creating a microworld simulation fully embodying teams as the user and their needs may help in providing better designs and tests of team based technology systems in the healthcare environment.

CHAPTER 4: TURF AND RESEARCH FRAMEWORK

4.1. OVERVIEW OF THE TURF AND RESEARCH FRAMEWORK CHAPTER

To answer our research question, "How can we better design systems to support teams?",
we first modeled emergency medical team interactions using the TURF framework. Using
the Usability Lifecycle and our knowledge from our model, we then designed and built an
emergency medical team communication tool. This team tool was then evaluated in an
emergency medical team simulation built based on our model. Here, we describe in more
detail our rationale for using this research framework and these methods.

4.2. THE TURF FRAMEWORK

In 2012, Zhang and Walji's expanded Zhang's 2007 UFuRT usability framework for system
design and evaluation to TURF: Toward a Unified Framework of EHR Usability. This
model brings us closer to improving the design of health information technology systems by
systematically focusing on Tasks, Users, Representations, and Functions (Zhang & Walji,
2011; Zhang & Butler, 2007; Nahm & Zhang, 2009; Zhang & Patel, 2006; Zhang &
Norman, 1994). The TURF framework, a method of Work-Centered Design, provides a
qualitative and quantitative means of developing systems through task, user, representational,
and functional analyses (Zhang & Walji, 2011; Zhang & Butler, 2007; Nahm & Zhang, 2009;
Zhang & Patel, 2006; Zhang & Norman, 1994). The creation of the TURF framework
provides a systematic and informative way to design a system by taking into account all of

the factors necessary for successful creation, implementation, and acceptance of a system, both technological and non-technological, for specific users to complete specific tasks within a specific environment (Zhang & Walji, 2011; Zhang & Butler, 2007; Nahm & Zhang, 2009; Zhang & Patel, 2006; Zhang & Norman, 1994). This versatile framework can be used to design a system for any setting, such as an infusion pump interface in the healthcare environment or a futuristic car dashboard in the automobile industry. In its current state, TURF assesses and addresses individual users' needs, but we believe it can also be extended to the assessment of team needs.

For this research project, we used the TURF framework for understanding usability and as a method of design. The TURF framework includes four components taken from Human Factors methods of design: Tasks Analysis, Users Analysis, Representational Analysis, and Functional Analysis (Figure 4.1).

Figure 4.1. Task, User, Representational, and Functional Analyses (TURF)

Tasks Analysis identifies the tasks needed to be completed and the breakdown of how those tasks are executed including the required user's physical and mental actions as well as the complexity, environmental conditions, and frequency of the tasks. For Representational Analysis, the graphical depiction of the elements in the interface necessary for helping the user complete the necessary tasks are determined. This includes the correct orientation of the object in terms of figures and fonts employed based on user needs and specific user types. It also considers basic graphical design principles and the correct written descriptors that go along with the figures. In Functional Analysis, functions necessary for completing the task are compiled along with the tasks that users wish to have and are willing to use. Through this analysis, tasks that users would not use would not be included in the design of the system.

TURF compared to similar frameworks, such as the socio-technical model, cognitive work analysis (CWA), and basic UCD, has some experimental and applied success as it has been shown that when applied, an electronic health record interface can be improved and increases usability and user satisfaction (Harrington, Wood, Breuer, Pinzon, Howell, Pednekar et al., 2011). The socio-technical model has also been successful in some cases improving HITs in healthcare environments (Sittig & Singh, 2011), but it has also been shown to be more time intensive and costly and requires further modifications in order to be adopted more regularly (Baxter & Sommerville, 2011). Similarly, theoretically, CWA has shown that it can successfully map out team mental and task requirements, but has shown, when applied, that further work needs to be conducted in order to successfully produce a viable ecological interface (Ashoori & Burns, 2012; Jiancaro, Jamieson & Mihailidis, 2013).

Lastly, UCD alone often forgets to bear in mind the work domain and related functions (Mayhew, 1999).

In this research project, we expand the Users Analysis portion of the framework to include Teams. Users Analysis only examines the identification of roles, characterization of each role's responsibilities, examination of the work environment, and ascertaining the expertise level of each role. By including a Team component to the Users Analysis, we have included an examination of temporal awareness for completing tasks by each role, goal agreement, and an agreement on roles and each role's responsibilities. These overarching factors will help to align team users towards similar task and goal models, share knowledge, and share awareness. An overview of the comparison between what exists now within Individual Users Analysis and what can be added with Team Users Analysis can be seen in Figure 4.2.
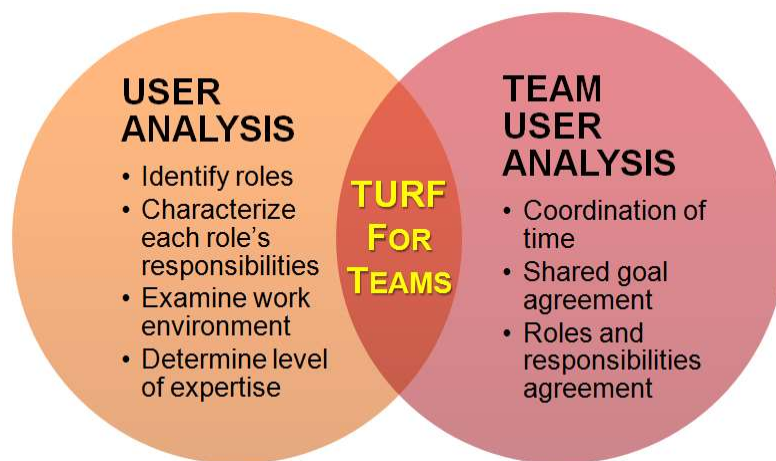
Figure 4.2. TURF and TURF for Teams

4.3. ETHNOGRAPHY

To help us get a better understanding of the teams, their work, and the emergency

department environment needs, we used a popular method in the field of anthropology,

ethnography (Fetterman, 1998). We immersed ourselves in the environment using methods

such as observation and artifact identification to further enrich our comprehension of the

extent of the intricacies of teamwork, system use, and the patient care process in the

environment, which is greatly detailed in Chapters 4 and 5.

By using this technique, we were able to focus TURF for Teams on the creation of a team

communication tool to help examine interruption behaviors as well as build an

accompanying microworld simulation through our knowledge of the users, tasks, and work

in the environment.

4.4. CODING SCHEME

We took what we learned of the work environment based on our observations and analyses

to drill down on a specific team function to consider in our system design. To do this, we

used the TURF framework and classified the communication act of interruptions as either a

domain or overhead function.

The term overhead has traditionally been used in the business organizational context to refer

to expenses required in operating a company such as paying rent for the facilities to manage

production. Overhead is *not directly connected* to the items produced. In such examples, these

extraneous outlays are part of "operating costs." Similarly, the term has been used in the

engineering and computational domain to describe design and algorithm features that require additional features from the system in order to reach a goal such as expending additional energy to run a circuit or transmitting signals in addition to computing data. By contrast, in these contexts, domain functions are used to describe the elements *directly required in the work.* That is what is needed to create the product.

Zhang, Butler, and colleagues (2007 & 2011) expand on the use of domain and overhead terms to describe required and extraneous functions used to operate systems (Zhang & Walji, 2011; Zhang & Butler, 2007; Butler, Zhang, Esposito, Bharami, Hebron & Kieras, 2007). For example, a well designed interface would only display the domain, or required, operations users must click through in order to execute a command. A poorly designed system would have additional overhead, or unnecessary, operations interspersed throughout the system which may generate unnecessary effort. Couched more tangibly, when domain and overhead functions were applied to an electronic health record (EHR) allergy entry workflow, researchers discovered 99 overhead, and thus, extraneous functions. This is in stark comparison to the 28 domain functions (Harrington, Wood, Breuer, Pinzon, Howell, Pednekar et al., 2011). This nearly 4:1 ratio of overhead to domain functions had the potential to dramatically impact the usability of this system.

We further expand on the use of domain and overhead functions by using these terms to describe the interruptions within a clinical context (Figure 4.3). An overhead interruption refers to non-clinically dependent communications that disturb existing work processes. Some examples of overhead interruptions include: tracking down clinicians, repeating tasks

already completed by other clinicians, completing tasks unrelated to the realms of your

responsibilities, and performing workarounds of poorly implemented systems. Domain

interruptions are therefore, interruptions whose communication fits within the needs of

work. Examples of domain-type interruptions are providing updates on patient care plans,

interpreting electrocardiography (EKG) or lab results, or verifying patient disposition

decisions. Overhead interruptions can delay or impede the patient care process as they are

not a necessary part of the required work while domain interruptions clearly support the

patient care process as they are a part of the required work. Differentiating between these

two types of interruptions may help us further understand how to better manage

communications. We seek to support domain interruptions while mitigating the cognitive

and workload burdens created by overhead-type interruptions.

Based on this understanding of the interruption function type, we can better design team

tools to better support this type of team communication in the emergency department.

4.5. USER-CENTERED DESIGN

To help us in our design of team systems, we also used user-centered design methods to help

us pinpoint what best ways were needed to display the information teams would need

through methods like survey, card sort, cognitive walkthroughs, and interviews. We go into

greater detail of these methods in Chapter 7 and 8 as we design and develop a team based

system.

Through the use of these techniques, we were able to understand how to best represent

interfaces to teams that correctly matched the task and necessary function within the team

designed system.

4.6. IMPLICATIONS

By using the TURF framework, ethnography, our coding scheme geared towards team

communications and their function type, and user-centered design methods, we have created

a way to consider both teams and individual users in the creation of systems, by

understanding the user, task, representational, and functional needs, that will fulfill the team

component of patient care work in the emergency department through TURF for Teams. A

system correctly addressing these work domain factors can only promote good patient safety

and quality.

4.7. SUMMARY OF THE TURF AND RESEARCH FRAMEWORK CHAPTER

Improving our understanding of team user's needs is very beneficial in the interface design

of systems in the healthcare settings. The TURF framework, a method of Work-Centered

Design, provides a qualitative and quantitative means of developing systems through Task,

User, Representational, and Functional (TURF) analyses (Zhang & Walji, 2011; Zhang &

Butler, 2007). In its current state, TURF assesses individual user's needs, but we believe and

have shown it can also be extended to the assessment of team needs. The broad goal of this

project is to develop a systems to help manage team activities, like communication, using the

TURF framework modified to include Teams as users. Patient safety and quality can

improve through the enhancement of each clinician team's efficiency, effectiveness,

coordination, communication, and acceptance and use of possibly any HIT based on the results of these efforts.

CHAPTER 5: OBSERVATIONAL FIELD STUDY OF THE EMERGENCY DEPARTMENT

5.1. OVERVIEW OF THE OBSERVATIONAL FIELD STUDY OF THE ED CHAPTER

In this chapter, we describe an ethnographic study conducted in the emergency department to identify types of interruptions and interactions among emergency medicine clinicians as they completed patient care tasks. From our observations, we created a model for understanding the emergency medical team and their interactions.

5.2. OBSERVATIONAL FIELD STUDY OF THE ED OBJECTIVES

The objectives of this study were to identify the types of interruptions and decision making found among ED team members, characterize the different interruption types by using the TURF for Teams model, validate the necessity of our model, and to inform our design of the team support tool.

5.3. OBSERVATIONAL FIELD STUDY OF THE ED METHODS

As part of a study examining decision making and information foraging in the ED, we were able to conduct a series of ethnographic non-participant observations on ED clinicians, specifically, attendings, residents, and nurses, during two different shifts of a time period of four hours each over several months for a total of 168 hours. A convenience sample of

participants for our observations was used. Participants were given written informed consent before observations began.

Two non-clinical graduate students shadowed the clinicians. These observers recorded every possible detail, action, and interaction of the participants to other team members, patients, and health information technologies using pen and paper, a digital wristwatch with the time in seconds, and an audio recorder. The amount of information noted was based off of a standardized field note taking procedure established in previous ethnographic studies (Franklin, Liu, Li, Nguyen, Johnson, Robinson et al., 2011). The audio recording device (Franklin, Liu, Li, Nguyen, Johnson, Robinson et al., 2011) was placed within a pocket on the participant's person and its microphone clipped at the participant's white coat or scrub shirt collar.

We used a decision-making categorization framework created by Brixey et al. (Brixey, Robinson, Johnson, Johnson, Turley, Patel et al., 2007) and Franklin et al. (Franklin, Liu, Li, Nguyen, Johnson, Robinson et al., 2011) to identify the types of interruptions and decision making that occurred among the ED team.

Table 5.1. Definitions used to classify interruptions, its type of function, and its direction.

Terms	Definitions
Interruption	"A break in the performance of a human activity initiated by a source internal or external to the recipient. This break results in the suspension of an initial task to perform an unplanned task which results in a break or termination of the primary task" (Berg, Källberg, Göransson, Östergren, Florin & Ehrenberg, 2013).
Overhead	Interruptions that are not clinically dependent and create disturbed work processes (*e.g.*, Technology Workarounds). Often caused by the implementation of poorly designed systems or workflow methods (Zhang & Walji, 2011; Zhang & Butler, 2007; Butler, Zhang, Esposito, Bahrami, Hebron & Kieras, 2007).
Domain	Interruptions necessary for the completion of clinical tasks and create undisturbed work processes (*e.g.*, Interpreting EKGs) (Zhang & Walji, 2011; Zhang & Butler, 2007; Butler, Zhang, Esposito, Bahrami, Hebron & Kieras, 2007).
Initiator	A person who initiates and interruption (Brixey, Robinson, Turley & Zhang, 2010).
Recipient	The person to be interrupted (Brixey, Robinson, Turley & Zhang, 2010).
Indirect Care	Care delivered for the patient, but not at the patient's bedside (e.g., Data Analysis, Charting, Reporting) (Chisholm, Dornfeld, Nelson & Cordell, 2011).
Direct Care	Care delivered to the patient at the patient's bedside (e.g., Surgical Procedure) (Chisholm, Dornfeld, Nelson & Cordell, 2011).

After data collection was completed, the observers compared the observation notes and transcribed the audio recordings to supplement the notes on any instances of interaction missed during the observations. The observers then individually categorized their observation notes based on the definitions of the above framework and then compared the categorizations for consistency and reliability in coding and had a reliability of $\kappa=.80$.

We then further classified our interruptions by using operational definitions created by the forerunners in interruption research framed through the TURF for Teams framework. The

TURF framework consists of identifying Tasks, Users, Representational, and Functional components of a system and designing towards these attributes in order to produce useful, usable, and satisfying systems (Zhang & Walji, 2011). The TURF for Teams framework utilizes the same framework, but also acknowledges factors important to a team as part of the user analysis. To satisfy the task analysis portion of the TURF for Teams framework, we classified interruptions by whether or not the clinicians are participating in direct patient care (e.g., performing patient procedures at the bedside) or indirect patient care (e.g., typing in patient information into their chart) (Chisholm, Dornfeld, Nelson & Cordell, 2011).

Similarly, for the user analysis, we examined the directionality of the interruption, whether the clinician in question is the recipient or initiator of the interruption (Brixey, Robinson, Turley & Zhang, 2010), and whether or not the interruption is an overhead (i.e., unnecessary communication for the completion of a task or maintaining team shared knowledge and awareness) or domain-type (i.e., necessary for completing task or maintain team needs) interruption (Zhang & Butler, 2007).

Only descriptive statistical analysis was conducted as the data coded here is a pilot for further analysis of similar data. Representational analysis will be conducted at a later time as this requires direct interaction with participants, through means of interviews or focus groups, to obtain an understanding of the graphics and data that users would like to have in their systems.

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After categorizing the interruptions by directionality and type of function from each clinical role's perspective, we performed a triangulation of the data comparing the occurrences of overhead and domain-type interruptions for a comprehensive analysis of the emergency department team's interactions. By comparing the difference perspectives of interruptions, we can validate each angle and further understand how each clinical role communicates and interacts with one another to determine how to better manage interruptions in the emergency department environment.

5.4. OBSERVATIONAL FIELD STUDY OF THE ED RESULTS

Attending Perspective

910 interruptions occurred during the 48 hours of observations of the six emergency department attending physicians ($M = 18.96$ interruptions per hour). First, considering the directionality of the interruptions, that is creator or receiver, we found that attending physicians are more often interrupted (91%) rather than the source of interruptions (9%). 52% of interruptions were initiated by residents with only 13% initiated by nurses. When we consider the function, domain or overhead, served by these interruptions, we found 23% are overhead-type interruptions unnecessary for completing clinical tasks or maintaining teamwork needs. Common overhead-type interruptions that attending experienced were: being asked to help locate other clinicians, relaying information to other clinicians, and EHR problems (*i.e.*, technical issues). Again, residents were the primary source of these overhead interruptions (35%) with a small portion contributed by consultants (10%) and nurses (14%).

Resident Perspective

For the resident physicians, a total of 697 interruptions occurred during the 40 hours of observations (M = 17.43 interruptions per hour). 26% of interruptions received by the residents were initiated by attendings while nurses initiated 21% of these breaks in task. As initiators of interruptions, residents caused (52%) interruptions for attendings and (20%) interruptions for nurses.

For our functional analysis, we found 30% of the interruptions (n = 208) were classified as overhead-type interruptions. The overhead-type interruptions that residents experienced were: finding information for other clinicians, helping clinicians find patients, and helping other clinicians navigate the EHR. Overhead-type interruptions were initiated by attendings (24%), consultants (14%), other residents (15%), and nurses (12%).

Nurse Perspective

Forty hours of nursing data was included in this secondary analysis. In that time frame, nurses experienced a total of 1053 interruptions (M = 26.33 interruptions per hour). Of the total interruptions, nurses initiated breaks in task on only 18% of the occasions observed. Residents contributed to 17% of the nurse-recipient interruptions.

Considering the function of the interruptions, 40% of the total interruptions observed were classified as overhead-type interruptions. These most often included inquiries by other nurses (45%).

Triangulation of Clinical Perspectives

After categorizing the interruptions by directionality and type of function from each clinical role's perspective, we performed a triangulation of the data comparing the occurrences of overhead and domain-type interruptions for a comprehensive analysis of the emergency department team's interactions (Figure 5.1).
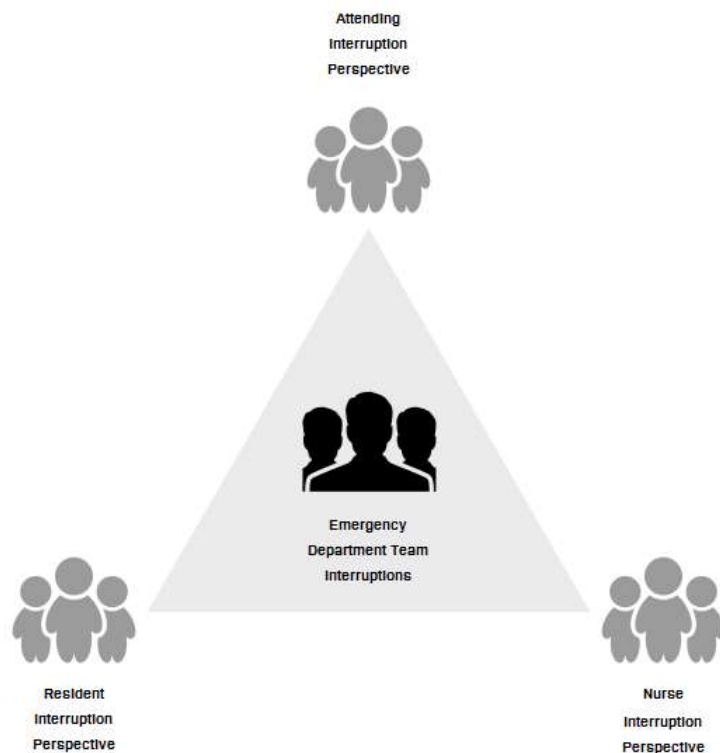
Figure 5.1. Triangulation of interruption perspectives by clinical role to validate the clinical team perspective.

By comparing the difference perspectives of interruptions, we can validate each angle and further understand how each clinical role communicates and interacts with one another to determine how to better manage interruptions in the emergency department environment.

Comparison of the different clinical role perspectives indicate an increasing number of domain interruptions from attending physician to nurse (Figure 5.2).
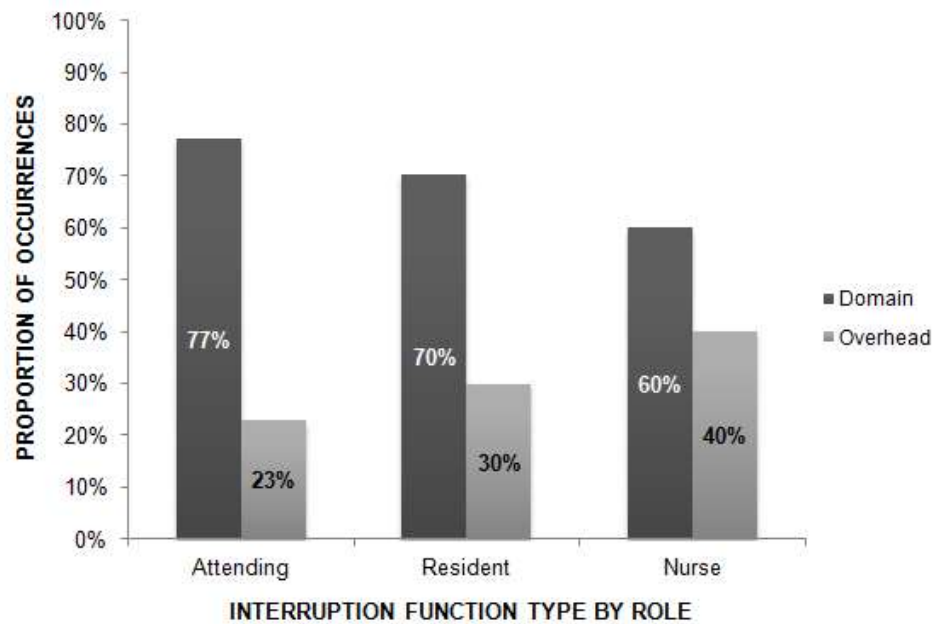
Figure 5.2. Percentage of domain and overhead types of interruptions experienced by role.

Breaking down the interruption functions by initiators and recipients of interruptions along with role demonstrates that although everyone received more interruptions than they initiated, there are differences in clinical role and interruption role (Figure 5.3). Nurses initiated more domain interruptions when compared to physicians, and though comparable, residents initiated more overhead breaks in task.
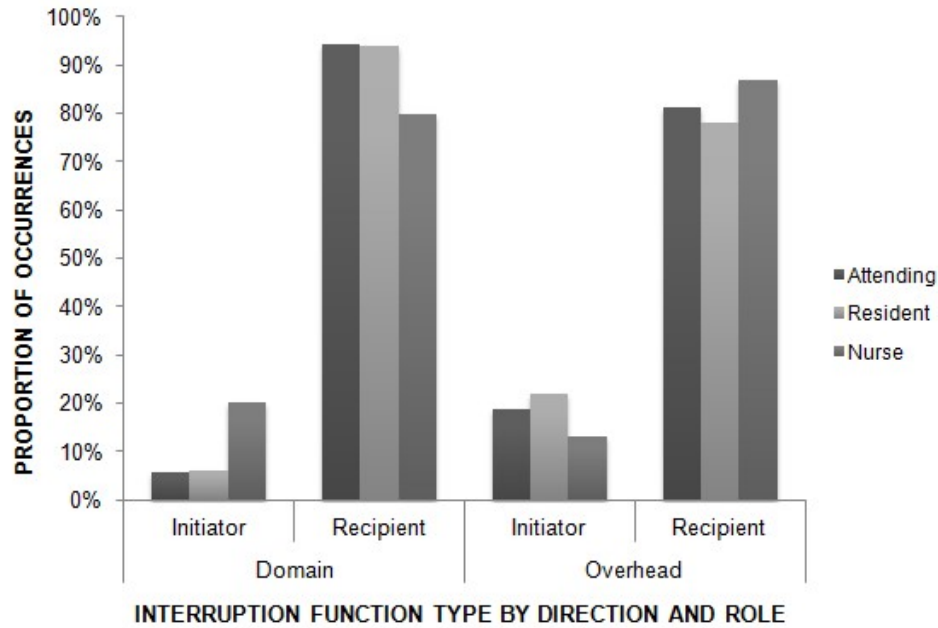
Figure 5.3. Classification of identified interruptions by function, domain/overhead, direction of communication, and clinical role.

5.5. OBSERVATIONAL FIELD STUDY OF THE ED DISCUSSION

These findings state that there is a need for the management of interruptions, especially interruptions unnecessary to clinical tasks, and have a potential to inform our TURF for Teams framework. Examining the content and function of interruptions reveals that assistance is needed to manage overhead-type interruptions often initiated during indirect patient care activities and directed towards the team leader to complete tasks unrelated to the work process and their role and responsibility to the team. We anticipate the completed analysis will provide a comprehensive view of the amount and types of interruptions received and initiated by clinician types and by clinical tasks.

The numbers found by the classification of interruptions, in terms of task, match findings

from previous studies on interruptions (Chisholm Dornfeld, Nelson & Cordell, 2011), and

further illuminates the great potential for interruptions to occur based on the attending's

perception, and likely other team members, of whether or not another team member is ready

to accept an interruption which may impact the work process for the team member and the

team and the overall patient's care.

Nearly a quarter of all interruptions are overhead-type interruptions (e.g., finding clinicians

to relay information or fixing technical problems that could be easily resolved) and should be

removed. Additionally, residents seemed to transfer more responsibilities unnecessary to the

attending's work process to the attending's list of tasks which could delay patient care

activities. Team interruptions relevant to the work process like interpreting EKGs, patient

notifications, and communication between team members need further support and the

extraneous interruptions should be lessened. It seems clear that shared team knowledge and

awareness are lacking or not being optimally supported.

We believe we can use these findings to apply the TURF for Teams framework to the design

and evaluation of a support tool to help better manage the necessary interruptions while

mitigating the unnecessary interruptions. Improving our understanding of team user's needs

may help in the interface design of systems in healthcare settings. Our application of the

TURF for Teams framework in the design of a support tool managing the team activity of

interruptions can help provide further support in the importance of designing systems for

the team. Patient safety and quality may improve through the enhancement of each clinician

team's efficiency, effectiveness, coordination, communication, and, more broadly, future acceptance and use of possibly any implemented technology, such as HIT.

5.6. SUMMARY OF THE OBSERVATIONAL FIELD STUDY OF THE ED CHAPTER

In this chapter, we conducted an ethnographic field study on emergency medical teams. We analyzed the emergency medical teams' interactions using the TURF Framework.

CHAPTER 6: THE EMERGENCY DEPARTMENT ENVIRONMENT

6.1. OVERVIEW OF THE ED ENVIRONMENT CHAPTER

Based on our observational data covering of non-participatory ethnographic observation, we have mapped out a rich Emergency Department contextual foundation for our understanding of critical care team communication and interactions.

6.2. ED ENVIRONMENT SETTINGS

Though Emergency Departments are conducted by similar components in the United States, every institution has additional layers that can aid or additionally convolute the practice of Emergency Medicine and its patient care process. Therefore, it is worthwhile to examine several Emergency Departments from different types of institutions.

6.2.1. Sites

We visited two hospitals in the Gulf Coast Region of Texas to gather information on the context surrounding critical care teams, such as the types of roles, teams, tasks, patients, workflow, and hospital layout to help us obtain an understanding and feel for the required team user requirements and work executed in various types of Emergency Departments.

The first hospital we visited, Hospital A, is a major medical center teaching hospital affiliated with one of the local medical schools and is one of only two Level I Trauma Centers in the

city. It belongs to a system of eight other hospitals in the surrounding area. The hospital has 627 licensed adult beds and 234 children's beds, 200 of which are Trauma beds. The Emergency Department sees more than 40,000 patients a year. Of these patients, 4,740 are adult cases and 1,325 are pediatric cases. Typical cases seen include motor vehicle accidents, falls, burns, assaults, auto pedestrian accidents, and sports injuries. The hospital is also home to six emergency helicopters. The layout of the Emergency Department in this hospital consists of a waiting room, triage area, trauma unit, medicine unit, pediatrics unit, quick care, unit, trauma bay, and is close to the radiology office. Though separated into sections, each section is relatively small and next door to one another. The design of the layout provides a relatively unencumbered line of sight for clinicians within units and a circuit of the units can be completed in a short of amount of time.

Hospital B is a teaching community hospital affiliated with the same local medical school as Hospital A, but within a different hospital system. The hospital has 332 licensed beds and is the busiest Level III Trauma Center in the state. The Emergency Department sees about 70,000 patients a year. The layout of this Emergency Department consists of a waiting room, triage area, quick care unit, trauma bay, critical care unit, and four pod areas. The four pods contain beds for trauma and medicine cases like Hospital A. The layout is spread out with large units enclosed off from one another. Within units, there are a lot of alcove-like areas that can interfere with the line of sight of clinicians. Though the area is walkable, it takes more time to complete a full circuit of the units.

6.2.2. Departments

All hospital Emergency Departments have the same basic characteristics of goals and broad care team roles, but each takes a different approach in communicating with one another, how to expedite safe patient care, and have different floor plan configurations. They can also pull medical consultations from specialties within the hospital, which adds another member to the team component.

Hospital A houses several areas of expertise that the Emergency Department can call upon, such as a burn and cancer center, ear, nose, and throat, heart and vascular, maxillofacial, neurology and stroke, ophthalmology, orthopedics and sports medicine, pulmonology, physical therapy, radiology, various surgery sub-specialties, and women's health and maternity. Hospital B has similar departments, but also specializes in community and geriatric medicine.

6.2.3. Artifacts

The artifacts used by the Emergency Department teams at both hospitals are very similar. Hospital A uses a Cerner branded electronic health record system and uses a variety of items to document patient care and communicate with between team members. Clinicians on call are given a pager and a non-smart mobile phone. A phone with a land line connection is also utilized as well as the clinicians' own personal smart phone. In extreme emergencies, a PA system is also sometimes used. The simple act of answering a person across the room is also used. Individual paper notes specifically constructed by clinicians for each shift are often constructed from an amalgamation of standard size printer paper, patient bar code stickers,

and amended notes. In addition to the electronic health record charts, there are also paper charts, in case of network connectivity issues or electrical disturbances, and patient folders holding patient electrocardiogram print-outs and paper discharge instructions and prescriptions. A pen is a necessary accessory as a clinician will have to sign multiple forms and it is also used to take notes on the fly. Patient imaging scans are most often already uploaded into the PACS system and electronic health record, but sometimes, if the patient brings in copies, they may be of the actual scan or on a compact disc. Patients when triaged are given a specific patient number which is then printed onto a sheet of bar code stickers. These can be used to affix on anything related to the patient and the patient's care process, such as the patient, charts, or test samples. Test samples are delivered to other areas of the hospital by a pneumatic tube system or to the quick lab nearby.

Hospital B uses similar artifacts, such as the use of paper for notes and patient information, as Hospital A, but uses the EPIC branded electronic health record system. Their clinicians do not carry a pager, and only carry non-smart mobile phones. The PA system is heavily utilized in this hospital to alert and contact clinicians for both moderate and critical situations.

6.2.4. Modes of Communication

How the clinicians communicate with one another and with their patients are very similar at both hospitals. For both hospitals, clinicians usually talk to their patients face-to-face. Between clinicians, they often communicate face-to-face, through their non-smart mobile phone, personal smart phone, the Emergency Department landline, through clinical notes in

the electronic health record system or through a patient's folder, and by passing information through a team member proxy to be relayed at another time. Hospital A also uses a pager to convey incoming patients and their emergency severity level. Hospital B uses a PA system instead of a pager to announce incoming patients and to notify clinicians if they are not easily found or currently indisposed.

6.3. ED ENVIRONMENT TEAMS

The Emergency Department team consists of the same basic team members, but it may vary due to institution type and administrative needs.

6.3.1. Task Workflow and Goals

Hospital A and Hospital B follow similar task workflows that are inherent in the practice of Emergency Medicine. Their main goal is to provide efficient, safe, and high-quality patient care. Patients who arrive to the waiting room or ambulance bay are screened and assigned an emergency severity index level, which helps clinicians prioritize their patient load by how serious the patients' condition is and by how much resources the patient will consume. The emergency severity index level, ranging from one to five with one being most critical and five being less urgent, also helps direct which area of the Emergency Department the patient will be placed, which leads to the next part of the workflow, assigning the patient to an available bed or placing them in line for the next available bed in the corresponding unit which corresponds to the patient's emergency severity level.

When the patient is taken to their bed, Patient Care Technicians (PCT) take the vitals of the patient and enter the information into the electronic health record for the clinicians to examine. If an electrocardiogram (EKG) is needed, the PCT also takes the reading and prints it out and has an Attending Physician examine the EKG and sign-off on it for two reasons. The first reason is to ensure there are no abnormal readings in the EKG and the second reason is to confirm that the EKG has been assessed. If the PCT is unable to complete the vitals evaluation of a patient or to enter in the information into the patient's electronic health record, due to a heavier than number of patients, etc., then the Nurse will take or enter in the vitals information when they complete their screening and assessment of the patient. After completing this initial assessment of the patient, the nurse will enter in the nurse's assessment of the patient into the patient's electronic health record and, depending on the nurse's experience and the patient's case, the nurse will start to prepare supplies for the patient in terms of potential tests or medications that may be ordered by other clinicians on the team who are also caring for this specific patient.

The Resident is next to take their initial assessment of the patient after the Nurse and PCT. Based on their assessment, the Resident will enter in their notes and orders, for medications, tests, and scans, into the patient's electronic health record. The Resident and Nurse may discuss the patient, such as the Nurse may ask the Resident for verification of an order placed in the electronic health record, but this may also not occur at this point. The Resident will try to update the Attending Physician on the patient before the Attending Physician makes their own assessment of the patient and signs off on the patient. Additional orders may be made at this point. Discussion between the Resident and Attending Physician may be

further explored if they have not yet spoken to one another about the patient or if further items need to be discussed.

The Nurse will then monitor the patient and administer or help process whichever order was ordered by the Resident and the Attending Physician using the reassessment guidelines ranging from one to five with one being most critical and five being less urgent. For example, a patient listed as critical at one, vital signs would be taken every five to fifteen minutes every hour for four hours and then every two hours if clinically stable. The Resident will also periodically check in on the patient and will update the Attending Physician. Depending on the patient's progress and another assessment after the administration of procedures and medications, a decision will be made to either admit or discharge the patient or to obtain further consultation from a specialty. This requires additional paperwork and sign-off by the Resident or Attending Physician with the Nurse finalizing the discharge process with the patient or moving the patient to another part of the hospital for admittance.

During this process, any present family members and members from the Business Office will be gathering information for the patient's case or from the patient for billing purposes. When there is patient turnover, the Patient Care Technician or Nurse prepares the bed for the next incoming patient.

6.3.2. Team Compositions

Hospital A's team is composed of the Attending Physician, two Residents, four or five Nurses, one or two Patient Care Technicians, and the patients and the patients' families. The

Resident pairing is usually of one with a higher and lower ranking Resident, or two of the same ranking Resident. For instance, a third year with a second or first year Resident could be one combination or two second year Residents as a combination on the team. Sometimes a Swing Resident, a higher-ranking Resident whose shift overlaps the main shift hours of the pair of Residents. Attendings work eight-hour shifts and Residents, Nurse Practitioner, Physician Assistant, and Nurses work twelve-hour shifts. In addition, a Nurse Practitioner or Physician Assistant may utilize the current shift's Attending Physician and Residents as a resource while working in another unit, usually Quick Care, of the Emergency Department. A Pharm-D may also be available during hand-offs and for very critical cases. Depending on the case, several physicians may provide a specialty consult to the team, as well. A Business Administrative Staff member may also be available to take the patients' information. There are also a Charge Nurse, Nurse Manager, and Triage Nurse to help with patient placement, bed and supply allocation, as well as serving as an extra resource or a substitute for Nurses. These roles help to provide a steady patient flow through the patient care process.

Hospital B's team composition is very similar to Hospital A's team composition except a Nurse Practitioner or Physician Assistant is also included in the same unit's team instead of solely working in a separate unit of the Emergency Department. For instance, there is a Quick Care unit that has a Nurse Practitioner and Physician Assistant as well as a Nurse Practitioner or Physician Assistant with the two Residents, Attending Physician, and Nurses in each of the other units in the Emergency Department.

6.3.3. Equipment

Both hospitals use similar equipment found in Emergency Medicine to execute the patient care process. These include EKG and Ultrasound machines, thermometers, blood pressure monitor, stethoscope, scissors, pen, paper, ED mobile phone, electronic health record system, and PACS. There is also access to Radiology for CT and MRI scans, the pneumatic tube system to send samples to labs to run tests, access to supplies like gauze, alcohol, water, basic food stuffs, medications from a Pyxis machine, and tools for administering or drawing samples, like syringes, providing liquids, and performing simple to complex surgeries.

6.4. ED ENVIRONMENT CHALLENGES

As with most complex work environments, there are a multitude of factors that can contribute to the main process which can either enhance and aid the process, serve as a workaround due to an inefficiency in the process or, at an extreme, impede the process.

6.4.1. Inefficiencies

Both hospitals suffer from the same inefficiencies, but Hospital B may have a slightly larger exacerbation of specific issues due to its widespread layout. A lot of the inefficiencies we observed helped to inform our identification of overhead interruptions.

It seemed that because of the layout of the Emergency Department and the criticality of patients, there were instances of information relay to clinicians, specifically, if a Nurse could not find the specific Resident to obtain or give an update, the Nurse would tell another Resident the information to be passed on to the Resident in question when that Resident

returned. Often, the Nurse may run into the Resident soon after or would check in again to make sure the information was conveyed. There were also periods of time where it would be difficult to find people, especially if the clinician in question might have had to go to another unit to accomplish some task or to find someone themselves. Clinicians would often look in the typical clinicians' homing area or where the clinician usually holes up to complete charting or keeps personal effects, then the patient rooms, and then around the specific unit. If the case was dire, for Hospital B, clinicians would be paged over the PA system. For both hospitals, if the clinician in question happened to remember to carry their non-smart mobile phone, the clinician seeking the missing clinician would attempt to call them. Sometimes, clinicians will forget their communication devices, so there is a lag on the relay of information.

Supplies and medical equipment would often be placed in various areas around the Emergency Department after being used for specific patients. This can increase the time in moving patients as clinicians spend time trying to find these supplies and equipment spread out across the Emergency Department. Clinicians will also recruit other clinicians to help them in their quest in finding specific pieces of supplies and equipment. This takes clinicians away from their own tasks. Towards the end of our observational study, there was a concerted effort to always place the ultrasound machine in a specific location after use to help clinicians easily find the ultrasound machine when needed.

Sometimes tasks would be repeated by clinicians due to failure to update or examine the common forms of notifications like examining notes in the electronic health record or

verbally telling one another a task had been completed. Before the task would be repeated, another clinician may jump in to say that the task has already been completed, or the clinician repeating the task may soon realize the task has already been accomplished. In some occurrences, clinicians will utilize workarounds to manage inefficient systems. There was one instance where an order was placed twice as consulting clinicians had tried to order and then cancel the order for a patient to achieve a specific task.

Additionally, because these hospitals are teaching hospitals, there are a lot of times where additional training will occur between the Attending Physician and Resident while completing specific patient cases. We also observed that unless a clinician is completely engaged with a patient, or in several tasks, a clinician can be pulled into any of the inefficiencies mentioned above. The layout of the Emergency Department is also often restructured and renamed to incorporate alternative test streams of patient care processes in an attempt to improve patient flow output. The changes can be confusing and may change up workflows.

6.4.2. Handoffs

Both hospitals have similar handoff procedures between team members. Attending Physicians often conduct handoffs between themselves. Sometimes, they will also include the Residents currently on shift. Nurse Practitioners and Physician Assistants will also conduct their handoffs between themselves. At Hospital B, the Nurse Practitioner or Physician Assistant within a unit will often also join the handoff being conducted by the Attending Physician during Resident handoffs. For the Resident handoffs, the Attending,

incoming and outgoing Residents, sometimes a Pharm-D, and sometimes Nurse Practitioner or Physician Assistant will be present. Several Nurses may pop in depending on which patient is being discussed and if it is necessary for added information or to obtain information. Nurses usually conduct handoffs between themselves. At Hospital A, the incoming and outgoing Nurses will conduct a group handoff going from patient to patient. Nurses also have meetings before their shifts begin. Attendings have separate meetings outside of their work hours, and Residents have a weekly conference.

6.4.3. Interactions

We observed grouping behaviors of clinicians depending on the clinicians' role and the clinicians' designated computer home during a shift. Groupings of clinicians can be found in specific areas of the units with Residents and Attending Physicians often working in areas more cut off from other areas of the unit and Nurse working at stationary or mobile computer work stations closer to patient rooms. Physician Assistants, Nurse Practitioners, and Pharm-Ds often work in open areas like Nurses, but some of these clinician roles also sit in the same areas as Residents and Attending Physicians. Patient Care Technicians can often be found near the Nurses or spread out across the units. Because of these groupings, Nurses have easier access to the patient's needs and often talk to one another and the Patient Care Technicians. Residents and Attending Physicians often communicate with one another due to proximity, role type, or training purposes. Nurse Practitioners and Physician Assistants talk to one another often due to proximity and role type, but also communicate often with Nurses and Attending Physicians when necessary. Nurses seem to communicate

with Residents and Attending Physicians at a lower rate unless to update or verify patient information.
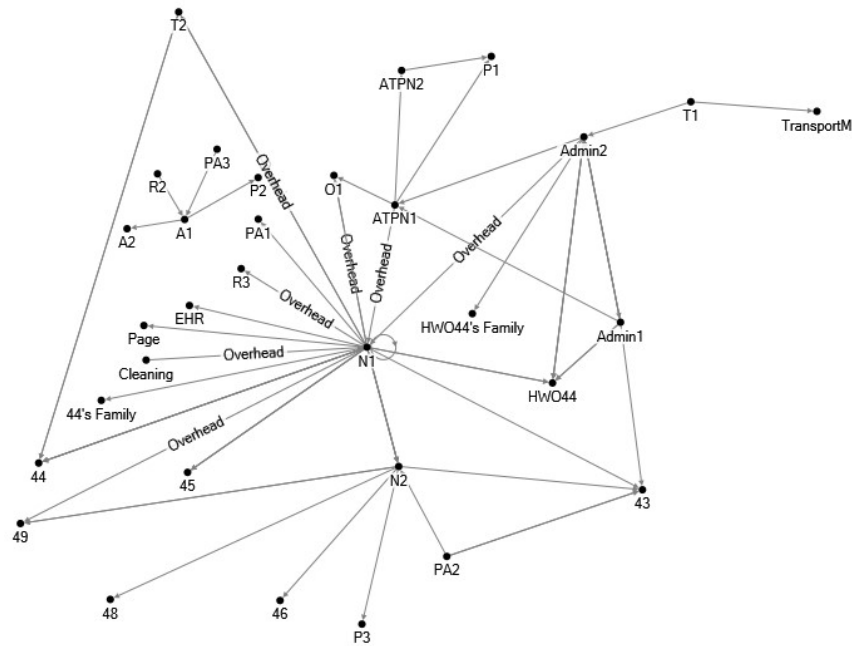
Figure 6.1. Example Emergency Medicine Interactions

6.5. THE ED ENVIRONMENT DISCUSSION

Our in-depth identification of Emergency Medicine practiced in different Emergency Departments helped to provide additional contextual information to the Users and Tasks of our TURF for Teams framework. A lot of interesting factors can impact the Emergency Department's clinical team's administration of the patient care process and the general execution of Emergency Medicine task workflow and goals. The level of training of a clinician, the layout of the Emergency Department, how clinicians place themselves, and

how clinicians interact, use, and place artifacts can greatly influence the team's completion of patient care tasks which also may impact patient flow by increasing wait times and bottlenecks in obtaining beds in the hospital.

We were also able to identify overhead interruptions that occur by examining the task workflow and interactions between team members and identifying those occurrences as gaps needing additional support. Misinformation and wasted effort can be additional byproducts of these interruptions that could be omitted to promote better team performance and patient care.

6.6. SUMMARY OF THE ED ENVIRONMENT CHAPTER

From our observations at two different institutions, we were able to pinpoint and reconstruct and model the team interactions, communications, and workflows of the Emergency Medicine environment. By understanding the users and the users' work domain helps us to better provide solutions for any gaps or issues found within the environment or can help optimize the environment's performance through the design of more helpful and usable tools that matches users' needs, work functions, and timelines. We were able to complete this part of the puzzle of understanding the team and its work domain in the Emergency Department.

CHAPTER 7: TEAM TOOL DESIGN AND DEVELOPMENT

7.1. OVERVIEW OF THE TEAM TOOL DESIGN AND DEVELOPMENT CHAPTER

In keeping with the tenets of User- and Work- Centered Design, several phases of information gathering were performed in order to further understand team user and work needs. These phases included a Team Perception Survey, Communication and Tasks Survey, Card Sort, and Cognitive Walkthrough and are delineated below.

7.2. TEAM TOOL DESIGN AND DEVELOPMENT OBJECTIVES

We wished to supplement our understanding of the users, teams, tasks, and work environment from the emergency department by getting further information on how these users wished to have things represented and functioning in the team designed tools that were built.

7.3. TEAM TOOL DESIGN AND DEVELOPMENT METHODS

We used several methods to help us create a team tool utilizing each part of the TURF for Teams framework.

7.3.1. Institutional Review Board Approval

We obtained Institutional Review Board exemption and approval to recruit and run participants on our surveys, card sort, and cognitive walkthrough studies. Institutional

Review Board approval was obtained from The University of Texas Health Science Center at Houston and was categorized for the exempt review process. All participants read and signed a consent form before participation. They were compensated with gift cards from an online retailer.

7.3.2. Procedure

We first conducted a survey with the emergency department clinicians to get an understanding of how they viewed themselves as a team and what they expected to see as a team. We then conducted another survey to get their thoughts on interruption behaviors.

Using this information, we also had participants participate in a card sort to get a feel for how they wished the team designed tool should look and how the information in the tool should be organized. We then conducted a cognitive walkthrough of the team tool to gather more feedback from users on its functionality and usability.

7.4. EMERGENCY DEPARTMENT TEAM PERCEPTIONS

We first identified team activities commonly found in the emergency department environment. Through a survey administered to ED team leaders, we established attributes of common team communication, collaboration, and coordination behaviors, as well as, examined perceived behavioral cues of "busyness" among the ED team. From the survey, we decided to focus on the team activity of interruptions. We then identified the prevalence of interruptions found amongst ED team members within the context of real world situations. By shadowing ED team members during shifts in the actual ED setting, we were

able to identify types of interruptions and decision making that occurred between the ED team members. Next, we applied the TURF for Teams model to further characterize the interruptions, validate the necessity of our model, and to inform our design of the team support tool. We were able to break down the interruptions into its directionality between team members, occurrence during direct or indirect types of patient care, and type of function. These initial findings confirm that interruptions are a team activity within the ED environment and that the TURF for Teams framework has the potential to help inform team focused system design guidelines. We then decided to apply the TURF for Teams framework to the design of a mobile device application to support interruptions and other types of communications for teams. To get some insight in mobile device use in the clinical environment, we conducted a brief look at existing mobile device technologies used in the clinical environment.

A pilot survey study was administered to ED clinicians to gather insight into emergency department team activities, behaviors, and perceptions.

7.4.1. ED Team Perceptions Objectives

The objectives of this study were to identify an emergency department team activity, determine team behaviors, and examine perceived behavioral cues initiating interruptions among team members.

7.4.2. ED Team Perceptions Methods

Our look into ED team activities began by first conducting a pilot discussion and survey study. We first conducted several iterative discussions with a convenience sample group of five emergency medicine faculty physicians who also work as attending physicians in the emergency department and are our collaborators on various clinical research projects. The discussions were held during our weekly lab meeting outside of the clinical setting.

The attending physicians were asked to list the types of team activities that could be found in the ED environment. The group generated a number of potential themes of team-based work and discussed why they believed those activities were team activities. We then summarized the notes gathered from the discussion. The team activities found in the ED include: management of trauma code procedures, management of resources, particularly in overcrowding situations, and distribution of workload (e.g., communication and coordination of tasks, assignment of new patients to providers/nurses).

From our discussions, we narrowed our efforts to issues on workload, specifically, understanding how resources are allocated in the emergency department. In this case, we define resource allocation as the distribution of resources based on team needs, workload, and the behavioral cues of team members. These factors can influence the immediate decision making process of the ED team (Won & Hannon, 2013). This term does not refer to the organizational context of managing resources based on the work effort of the team in relationship to monetary aspects. Resource allocation in emergency care refers to how resources, such as patient beds, CT scanners, labs, tasks of team members, and the expertise and experience level of team members, are coordinated and communicated by the ED teams

to administer patient care in a timely, effective, and safe manner. All of these factors can impact the workload of the ED team.

Due to the perspective of our initial discussion group, a closed and open response survey was then designed to uncover how ED attending physicians coordinated workload for their team, specifically, in regards to patient allocation to resident-type team members. We also asked which factors they considered when allocating resources and questions regarding their impressions of their own personal workload. These questions also helped to capture how attending physicians determined the workload, or level of "busyness," of members on their team. Additionally, the survey investigated how residents, nurses, and other clinicians might ascertain the availability of the attending physicians as a resource to their own work (i.e., availability for interruption). We also included general demographic questions to determine the experience level of the physicians. Table 7.1 provides a list of the survey questions asked concerning, workload perceptions, behavioral cues indicating the availability of team members for receiving interruptions, and characteristics of an ED team.

Table 7.1. Sample of Team Perceptions survey questions.

Questions
1) Do you actively assign patients to those you supervise? If so, how often during a shift do you assign patients?
2) Does the frequency of your assignment of patients differ depending on that day's team?
3) Please rank the following factors (Experience Level, Patient Acuity, Patient Load, Proximity) in terms of importance in the above decision-making process (1 is Most Important).
4) How do you currently track your own to-be completed tasks?
5) Do you track the to-do list for those you supervise? If so, how?
6) What are three indicators of a harder/busier than average shift?
7) If someone were to view you at work, how would they know that you are having a harder/busier than average day?
8) Conversely, how would someone know that you are receptive to interruptions or available for a task?
9) In calculating someone's current workload, what information should be included?
10) Do you think the ED functions as a Crew, Team, or Other? How so?

We then administered the first survey to the emergency medicine faculty physicians during a monthly luncheon meeting at the medical school. Attending physicians were briefly given a general overview on the purpose of the survey and informed that it was completely voluntary before the beginning of the faculty meeting. Further instructions were given to the attendings to return their completed surveys to a collaborating attending physician once completed. Surveys were returned to our lab within the same week of the meeting and analyzed using descriptive statistical methods.

7.4.3. ED Team Perceptions Results

The survey will be administered to other ED team members, but based on our initial administration of the survey, we were able to glean a view into the coordination of the emergency medicine team workload and the team itself through the attending physician

perspective. Fourteen respondents out of a potential of 20 meeting attendees, a response rate of 70%, provided their insights on teams in the ED. Three of these respondents were female and the experience level of attendings ranged from those freshly graduated from their ED residencies to veterans in the ED field. The breakdown of respondent demographics can be seen in Figure (7.1).
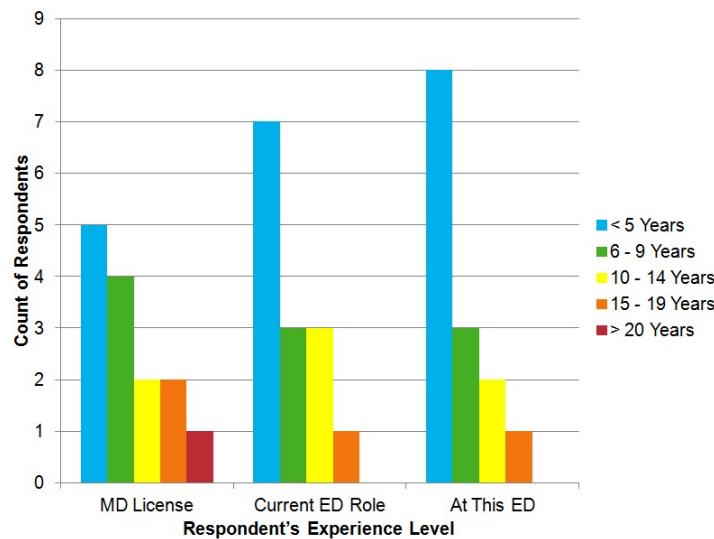
Figure 7.1. Breakdown of survey participants based on years active with a MD license, current ED position, and work at the current ED setting.

Regarding patient allocation, eight respondents stated that they did actively assign responsibilities to residents during their shift. Of these respondents, 50% stated that they assigned patients to residents at least some of the time, or less than twenty percent of the time, while the other 50% stated that they rarely assigned patients to residents. When asked if the attending physicians assigned patients more or less frequently depending on that shift's

team, 50% of the respondents stated that their frequency of patient assignment did indeed vary depending on that shift's team composition.

ED attending physicians also listed factors that displayed how those outside of the team could tell when a shift was particularly hectic. Factors included the experience level of the team, patient acuity, patient load, and delayed charting (Table (7.2)).

Table 7.2. Factors ED attending physicians attributed to busier shifts.

Count	Factors
8	Staffing: Experience level of providers; Number of residents assigned; Inadequate ancillary support; Weak providers
6	Patient acuity/Level of illness
6	High admission rate; Waiting room counts; Number of unseen patients on board; Wait times
3	Availability of inpatient beds
3	Long length of stay; Lack of patient dispositions; Overall movement
2	Incomplete charts/ Number of charts I have yet to write
2	More administrative duties/Administrative issues requiring non-patient care
7	Other: Details start getting missed/overlooked; More interruptions; Impaired situation awareness; Patient dissatisfaction; Noise; Consult times; High procedure demand

The ED attending physicians were then asked to rank the importance of four factors they considered when assigning patients to residents. Factors ranked with a one are more important than those ranked with a two. The four factors that were considered included the resident's patient load, the complexity of the patient case, the proximity of the resident to the attending, and the resident's experience level. The resulting means found that the most important factor considered by the ED attending physicians for assigning patients to residents depended on the resident's patient load followed by their experience level, the

complexity of the patient case, and then the proximity of the resident to the attending

(Figure (7.2) and Table (7.3)).
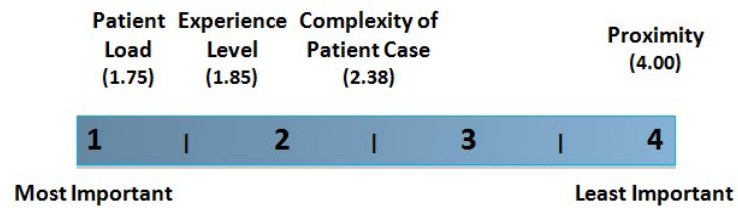
Figure 7.2. Factors attending physicians considered important when assigning patients to

residents.

Table 7.3. Mean and standard deviation of factors attending physicians considered to assign

patients to residents.

	Complexity (n = 13)	**Experience (n = 13)**	**Proximity (n = 11)**	**Workload (n = 12)**
Mean	2.38	1.85	4.00	1.75
SD	0.77	0.55	0.00	0.97

The ED attending physicians were also asked to list the factors that would help illuminate

the workload level that other team members might be experiencing during a shift. These

factors included patient acuity, number of procedures needed for patients, experience level

of the team, pending patient information, delayed charting, and patient load (Table (7.4)).

Table 7.4. Factors attending physicians believed showed that team members were experiencing a heavy workload.

Count	Factors
9	Patient acuity (sicker patients require more time, though not always); Complexity of patients currently being managed
5	Need for procedures; Time requirements of undone tasks; Increase workload for certain exams/procedures such as (pelvic, central line placement, paracentesis, thoracentesis, etc.); Active care vs. passive post stabilization care, i.e., active resuscitation and treatment vs. disposition made waiting for patient departure
3	Number and level (junior/senior/off-service) resident; Level of provider experience; Level and type of training
3	Number of unseen patients in waiting room; Number of active versus boarding patients; Real-time patient/hour rate
3	Pending documentation; Status on writing notes; How many charts they are behind (other providers)
2	Labs/CTs pending on active patients; Progression of care/treatment/management
2	Number of tasks they have pending (other providers); Covering Peds (yes/no)
2	EKG Techs or MLPs preferentially coming to me vs. other faculty
1	Number of items ordered (lab, x-rays, consults)

The attending physicians were then asked how they managed their tasks by stating whether they used a mode of paper, mental capacity, electronic device, some other medium. Six respondents stated that they used paper to track their to-do lists, 11 mentally tracked their tasks, and only four respondents used an electronic device to track their tasks. When tracking tasks of other team members, only six respondents stated that they actually monitored tasks of others on their team. Their mode of tracking the tasks of other team members consisted of an ongoing mental list.

We then asked the ED faculty physicians to list their behavioral cues which may demonstrate to other team members that they were not available for taking on additional tasks. The more popular responses included engagement in direct patient care tasks,

management of administrative tasks, greater movement around the ED, an air of irritability, and delayed charting (Table (7.5)).

Table 7.5. Factors attending physicians identified as behavioral cues of when they were not available for additional tasks.

Count	Factors
5	I am spending more time in patient rooms; Staying in a single patient room for an extended period of time; Managing patients on my own; Carrying my own patients; Revisiting admitted patients
5	Running the board more frequently with staff; Pushing providers; Actively directing residents; Pushing nursing; Spending time with nursing management discussing flow
5	I am constantly moving; Running around, Walking more, Rapidly moving from room to room; I'd be out of my chair more than usual
4	Irritable; Distracted; Harried; Higher level of frustration with minor issues
3	Incomplete charting – Starting late; No time spent documenting; I am spending more time charting at the end of my shift
3	Me on the phone more than usual; Calling bed control to try to speed up the bedding process; Spending more time on phone than charting
2	Less time teaching
2	Never sit down/Leave the ED; No time for lunch
2	Delay in completing task or seeing patients; Less time with each patient
2	Actively engaged in other tasks; On phone and signing EKG/Reviewing lab/X-Ray (performing two tasks at once)
3	Other: Constantly interrupted; Constantly speaking without break (to other providers or patients); Lots of red on track board

Conversely, visual cues that an attending physician would exhibit to demonstrate availability for additional tasks included a receptive attitude to all team members, an increase in chatting behavior with team members and anyone who happened to be nearby, being more stationary and having time to visibly take a break, not having to complete two tasks at one time, and charting (Table (7.6)).

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Table 7.6. Factors attending physicians identified as behavioral cues of when they were available for additional tasks.

Count	Factors
7	Making eye contact; Politeness; Responsiveness; Asking "How can I help?"; Attentive; Not irritable; Welcoming/Receptive attitude/Behavior
6	I am sitting at the counter talking to nurses; Recognize all that approach; Chatting with nurses; Joking around with well appearing patients; Watch flow; I'm talking
4	Sitting down; Taking a break to eat; Taking a water break
3	Not busy with something else; Not performing two tasks at once; I am not actively engaged in a task and not charting
3	Picking up phone on first ring; Always answer phone; Checking e-mail
3	Spending more time in patient rooms; Getting meals/linens, etc. for a patient; I am wandering around the department looking for work
2	Ask me
2	I'm sitting and charting; Sitting down teaching residents as a group
4	Other: I'm not typing; I'm not in a patient room; Not speaking to another provider or patient; Not moving somewhere "on a mission"

Finally, the ED attending physicians were asked to define their ED as a Crew, Team, or another type of group entity. Crews and Teams are both defined as having members that share common goals, but based on task situations, teams are more able to handle revisions or improvisations during the execution of tasks than crews (Schiflett & Elliott, 2009). Team members not only share goals and task models, but also know one another well enough to anticipate each other's needs in order to work together to complete standard and more variable tasks (Schiflett & Elliott, 2009). Crews have a higher rate of turnover, so shared knowledge of common task models may not be as apparent and can inhibit the completion of more variable tasks (Schiflett & Elliott, 2009). Only 29% of the respondents viewed their ED as a Team while 43% defined their ED as a Crew (Figure (7.3)).
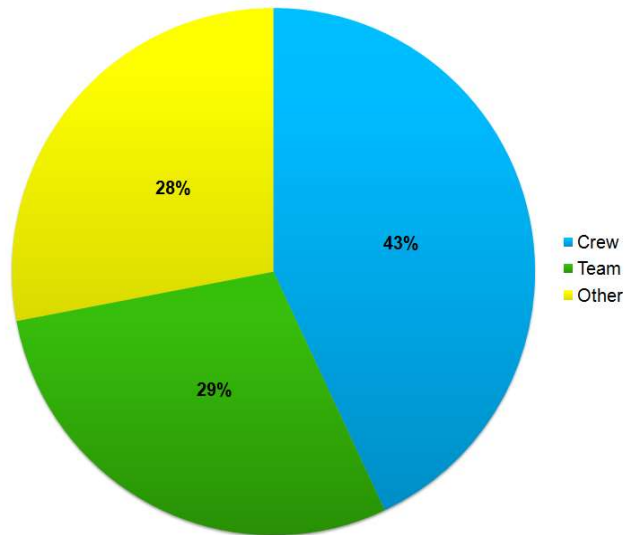
Figure 7.3. Perceptions of how the ED team functions, as a Crew or Team, by attending physicians.

Some other terms that the respondents suggested in describing their ED included working as a chain of people and a bluegrass band. One respondent noted that on a good day, or during a less hectic shift, the ED could be classified as a Team, but on bad days, it would be classified as a Crew.

7.4.4. ED Team Perceptions Implications

From these results, we have discovered that there is a definite need for a team support tool and that the emergency department team activity of interruptions is a viable team activity to apply our expanded TURF for Teams framework in our research project.

Half of the respondents, the leaders of the team, stated that they allocated patients to residents and that their frequency of conducting such an action varied depending on the resident's level of experience. This implies that coordination, communication, and

distribution of workload are unnecessary as the attending and residents with greater experience share task models and can work as a team to execute tasks. In essence, they are an expert team. With more novice residents, some further coordination and communication may be implemented in order to align expectations necessary for completing tasks. In this case, they are a new or novice team.

Elements of a busy shift mostly centered on the variance of the patient load and the severity of the patient's case, which in turn, can create a variety of patient related tasks ranging from simple to increasingly complex. These variances in direct patient care tasks compounded with delays in non-direct patient care activities, such as charting, seems to create a busier perception of a shift to attending physicians. In addition, the team's composition also played a factor. This implies that the attending felt that a shift was more hectic with less experienced team members. Likewise, the emphasis on the number of patients within an ED during a shift and the experience level of team members, specifically, residents, were stated as the most important factors regarding a necessity for coordination and additional communication by the attendings. Some support for managing and communicating tasks might be helpful in lessening the perception of "busyness" during a shift.

Some attributes that attendings wished to see in order to help in coordination and communication tasks within the team during these busy shifts were suggested as possible elements that could be displayed to the attending to understand where various team members were located in their patient care tasks. These factors included previously stated concerns that attendings believed needed to be considered when working with the team,

such as the number of patients admitted and their required procedures and paperwork, the experience level of the team members, and the number of patients waiting to be seen.

Interestingly, attending physicians stated that they managed their own to-do lists through a variety and combination of mediums including paper lists, mental tally, and track board information. The attending physicians that did keep track of the activities of their team members used a mental tally. With multiple members on a team and a dynamic and complex environment, this seems like an additional mental burden and could be supported by a tool that would help improve team situational awareness and lessen workload.

These results also provided us with visual cues, or subjective impressions, ED faculty physicians use to display whether or not they are busy or whether or not other team members are busy during a shift. These subjective impressions are only observable behaviors and may not be reliable. The listed behavioral cues do not include objective factors usually associated to an increase in workload such as the amount of mental work. It is interesting that the attendings believe that they can take on additional tasks, or are more open to interruptions, while completing non-direct patient care tasks such as charting. Entertaining interruptions while entering in patient information can lead to greater risk in making errors (Kalisch & Aebersold, 2010). Also, the attendings stated that they viewed delayed non-direct patient care tasks as increasing their perception of a shift's level of "busyness", so better management of the communication method of interruptions might be necessary in helping team members determine when not to interrupt other team members and to be more aware of each other's tasks.

The survey results also helped us to gain better insight into how the ED clinicians view themselves. They view themselves as a Crew with everyone allotted to a specific role and responsibility sharing similar patient goals. Due to the high turnover of staff, they believe they do not share the same task models, or knowledge, and cannot accommodate needs of others, or situational awareness, as easily. Their actions of not coordinating tasks among their group and having a mentally burdensome form of task management of other group members seems to imply that they actually view their ED as more of a Team. A Team with shared task models and goals who can foresee one another's needs might be more ideal. This viewpoint provides firm support that an increasing our knowledge of team behaviors and the creation of a team support tool for team activities might be beneficial to the ED. Further examination of the ED team through the perspectives of other team members (e.g., residents, nurses) is needed.

In the long run, it seems we can transform this knowledge about teams to design team supported tools that will improve patient safety and quality and lessen workload through better coordination, communication, and collaboration, and general team performance. The limitations of this study are the limited sample of respondents, the use of a convenience sample of just the ED attending faculty physician perspective of the ED team, and the subjective perceptions of the ED team by the respondents. These results may not be generalizable to other complex environments.

7.5. EMERGENCY DEPARTMENT TEAM COMMUNICATION AND TASKS

The clinicians were asked to complete survey questions pertaining to communication behaviors and tasks found in the critical care environment. The survey questions explored the various tasks clinicians must complete, clinical roles and their communication patterns, sources of current communication practices, clinicians' current management of communications and tasks, and clinicians' communication and task needs. This data indicated which types of communications and information are utilized and needed in clinical practice.

7.5.1. ED Team Communication and Tasks Objectives

We next wished to determine how team members communicated with one another and which tasks they communicated. We also wanted to determine how this could be translated into a mobile application and asked participants how they wished these actions to be shown in the application.

7.5.2. ED Team Communication and Tasks Methods

Clinicians were given a paper-based survey asking for basic demographic information, current technology use and experience, frequency of usual communication behaviors, frequency of communication interactions, and the type of tasks. The survey also displayed a sample of a possible mobile application interface. We asked what features the team would like to have related to their to-do list and whether they wished to have the to-do list shared with their team members or to have the to-do list only displayed to themselves. Some to-do list features participants could select related to Emergency Department work were personal

reminders, complete charting, see patient, see person, and settle bed disputes. An additional question asked if specific notifications of tasks should be displayed to the whole team or to specific members of the team. Based on the selection of specific actions and tasks, we could match roles to tasks and determine the importance of the whole team's situational awareness of itself. Sample actions and tasks are "Finding a clinician in your department", "Obtaining notifications about labs or scans", or "Checking on the progress of other clinicians". Other information or notifications that could be featured in the tool, such as patient status updates, patient ready to disposition, or need authorization, were also options to be selected by the team members. We then looked for common themes in communication behaviors and needs as well as a variation based on years of experience, technology use, and type of tasks and roles.

The data collection took approximately thirty minutes to complete and was administered in several locations. We obtained Attending participation after our collaboration lab meetings or by asking for approval and piggy-backing on their own meetings in the meeting room where it was held. For Residents, we asked to be put on their weekly conference schedule and gave out the survey to be completed in the conference meeting at the end of the meeting. We asked for approval to attend pre and post shift Nurse meetings in the hospital and had Nurses complete the survey before, for those beginning their shift, and after the meeting for those ending their shift.

7.5.3. ED Team Communication and Tasks Results

We were able to obtain responses from ten Attendings and eight Nurses as well as thirty-five Residents consisting of nineteen first-years, eight second-years, and seven third-years. Based on the responses, it seemed about 77.36% of the participants believed the team tool could help with their workload and approachability for additional tasks.

For the team tool's suggested information features, team members preferred seeing patient status updates, need for support, labs ready, patient ready to disposition, and patient/family has questions over seeing if something needed authorization or if the consult were on the floor.
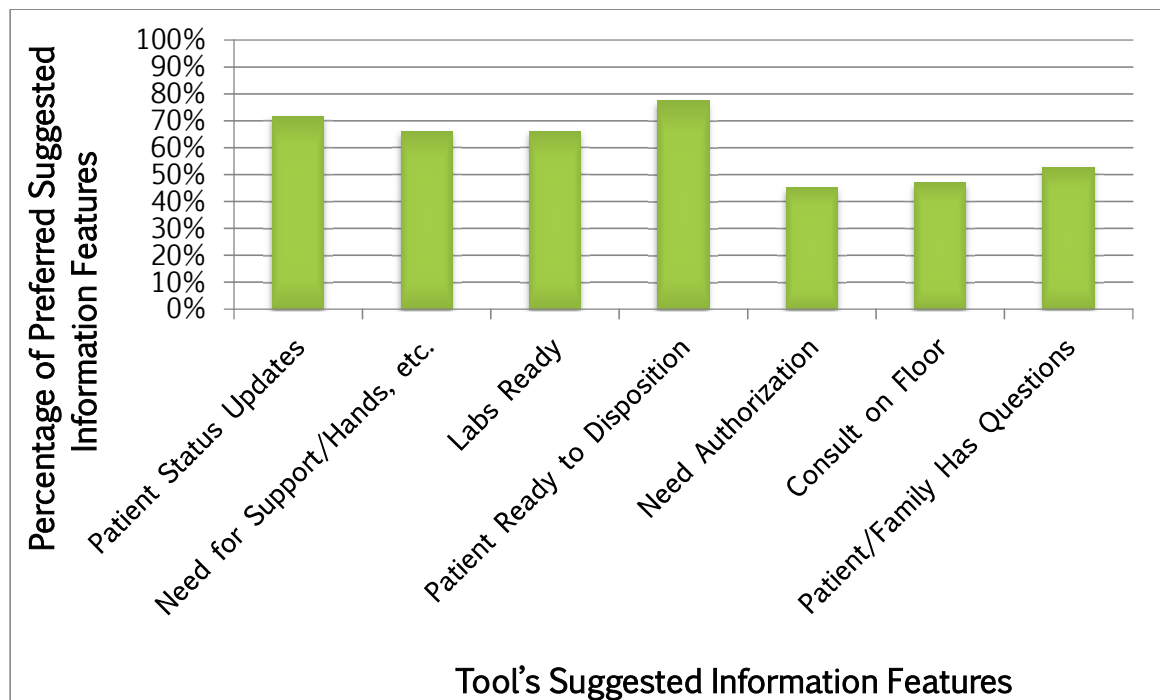
Figure 7.4. Preference of Tool's Suggested Information Features

In general, all of the suggested features we listed, such as status messages, receipt of communication, and group messaging, were selected as desired in the team tool by the team members.
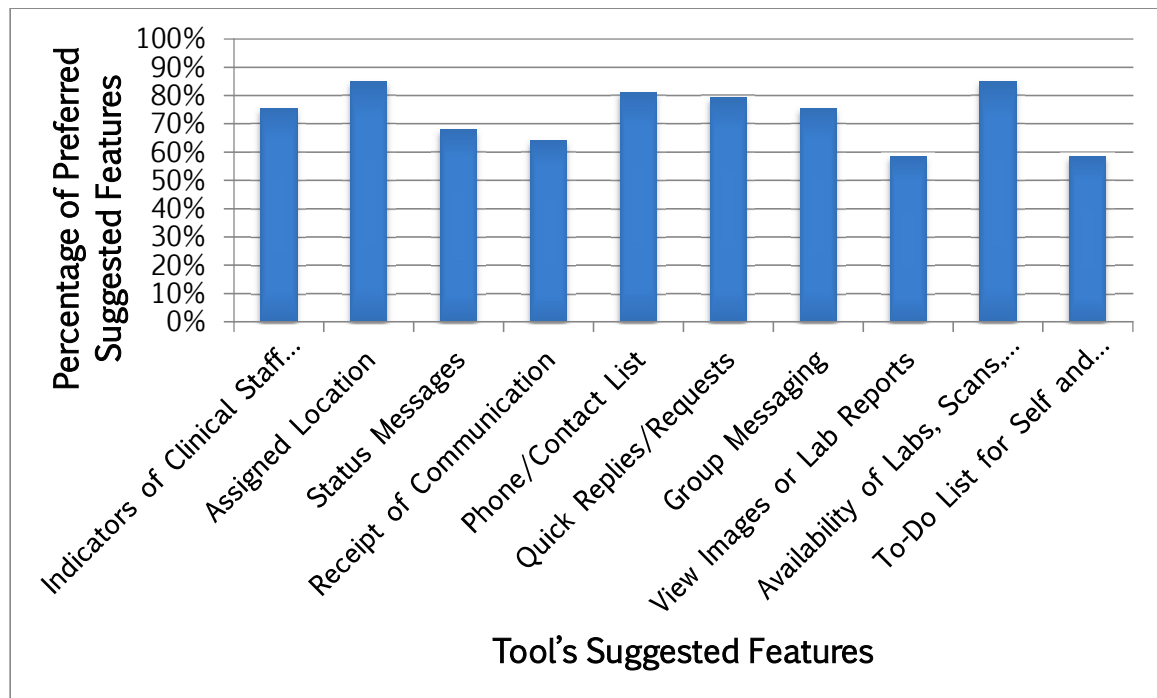
Figure 7.5. Preference of Tool's Suggested Features

Due to the uneven numbers of the participants and a general desirability to have access to all possibly beneficial features, there were some outliers that skewed the responses. In general, there was a desire to display the teams' broad situational state. Many believed specific patient details should be provided to the Attending and more pragmatic or resources related tasks and notifications should be directed solely to Nurses. First year Residents also seemed most open to having all suggested information features available in the team tool while other team members preferred only some of the information provided.
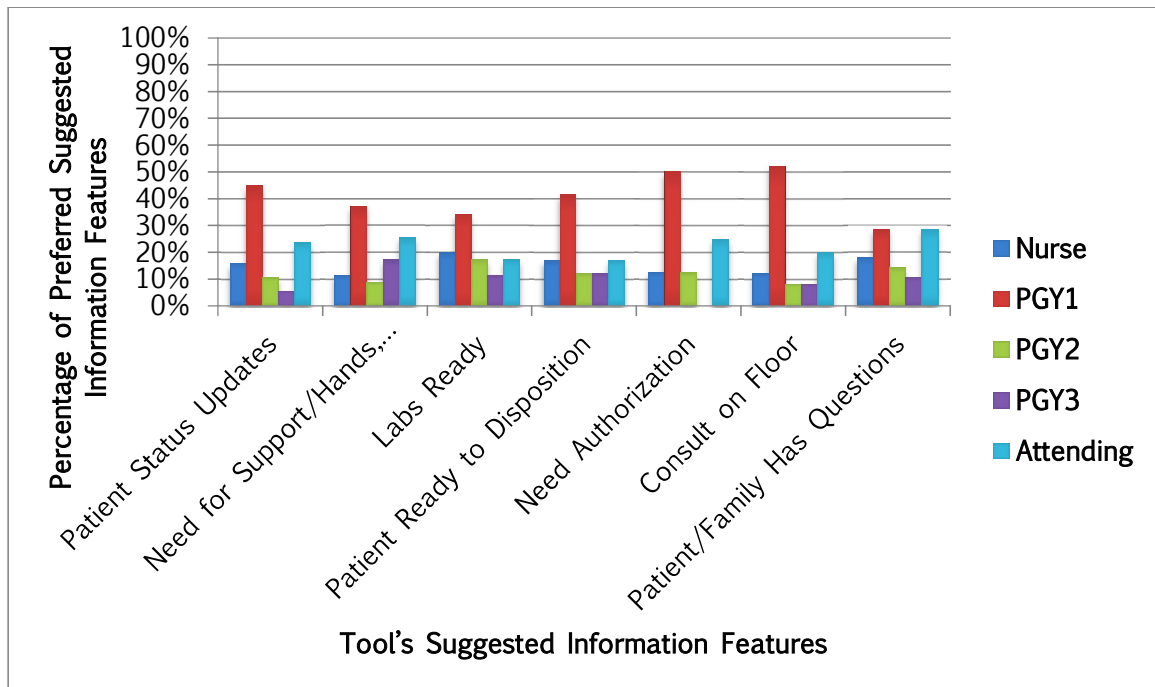
Figure 7.6. Preference of Tool's Suggested Information Features by Role
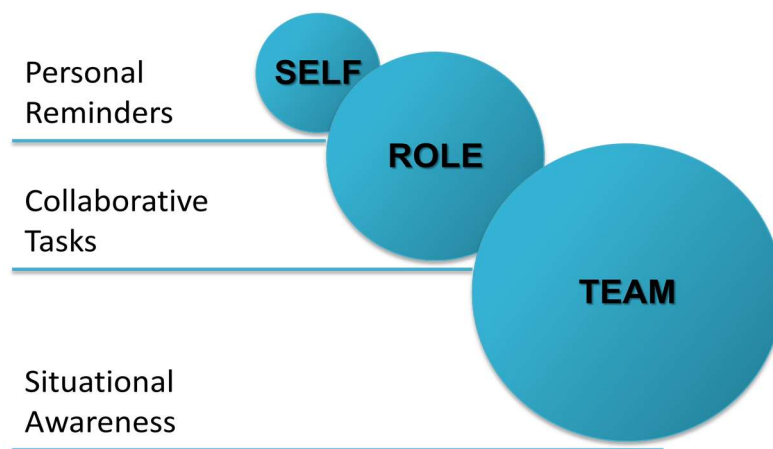
Figure 7.7. How the Team Wishes to See Information

7.5.4. ED Team Communication and Tasks Implications

Our findings from this part of the Team Tool design process helped us to focus in on what potential mobile application communication functions were potentially most useful for the Emergency Department Team in terms of knowing what other team members' workload, managing their own workload, and providing cues and actions to help them manage their communications and tasks.

7.6. TEAM TOOL CARD SORT

Using a card sorting procedure, typically used to create a system's information architecture, we asked clinicians to consider and organize common features found in communication tools. As they created this hierarchy of communication elements, we asked them to articulate the order and reasoning for why they placed certain elements in particular groups while providing a talk aloud. Here, we obtained user input on both the content and information architecture clinicians need in a communication tool to better manage the patient care process.

7.6.1. Team Tool Card Sort Objectives

We next wished to discover how to structure the information architecture of the mobile application that matched with the Emergency Department Team's communication needs.

7.6.2. Team Tool Card Sort Methods

Clinicians completed an individual open card sort (organization of cards containing individual elements into hierarchical categories) regarding communication tool features. The

participants were asked to walk through their reasoning for organizing the tool features after they completed the card sort. This data collection took approximately an hour and a half and was administered in a lab setting as well as through an online card sort program (Concept Codify/Optimal Sort). For both the in-person and online card sort, we provided 600 elements printed on individual cards to be categorized. Additional cards were available for the participants to create their overarching categories or to add additional elements. For the in-person card sort, all groupings were documented by hand and by photographic evidence. The results were combined with the online results where the online program had the ability to create a similarity matrix for displaying clusters and alternate pairings, dendograms for displaying top categorization labels, and participant-centric analysis to display the most popular groupings. We looked for common themes in categorizations of communication tool elements provided by all the team members.

7.6.3. Team Tool Card Sort Results

Four Attending physicians completed the physical card sort in a lab setting. One Attending, two Residents, and two Nurses completed the online version of the card sort. The responses of the participants showed a lot of overlaps in structure with some outliers where one participant grouped categories by function type devoid of the critical care setting and another wished to categorize items in ways to help foresee ways to tackle patient situations. These creative ways of thinking came from the Attending physicians. The layouts of the card categories also created interesting shapes in terms of providing linear movement in the categories and an attempt to show if/then categorizations.
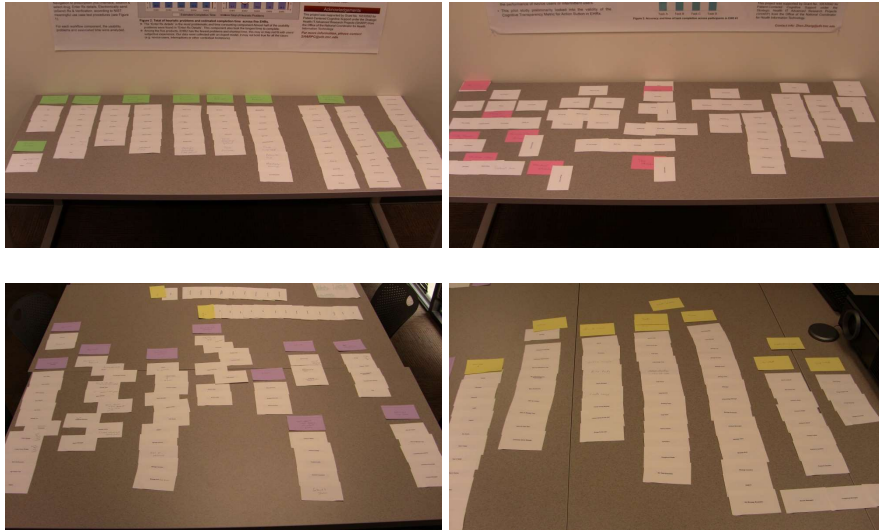
Figure 7.8. Physical Card Sort
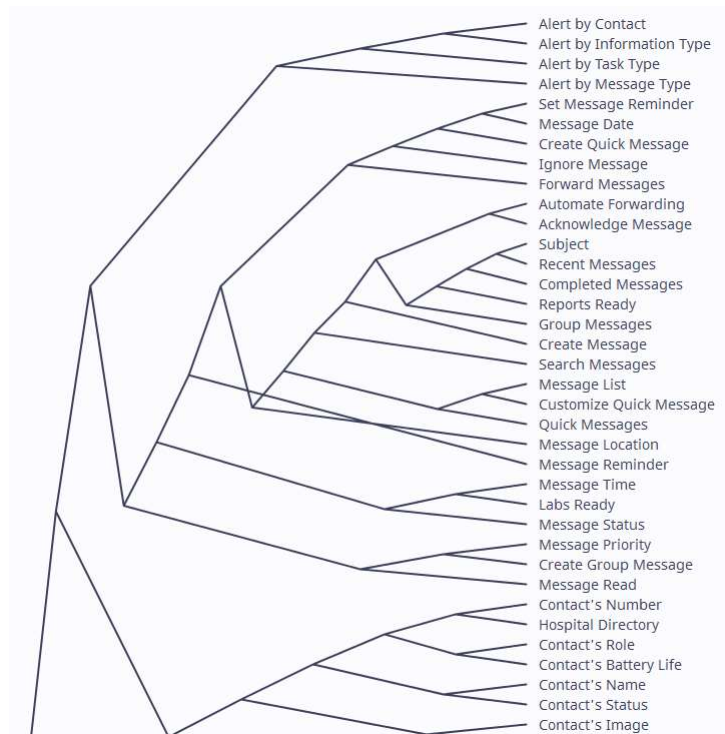
Figure 7.9. Sample Dendogram

96
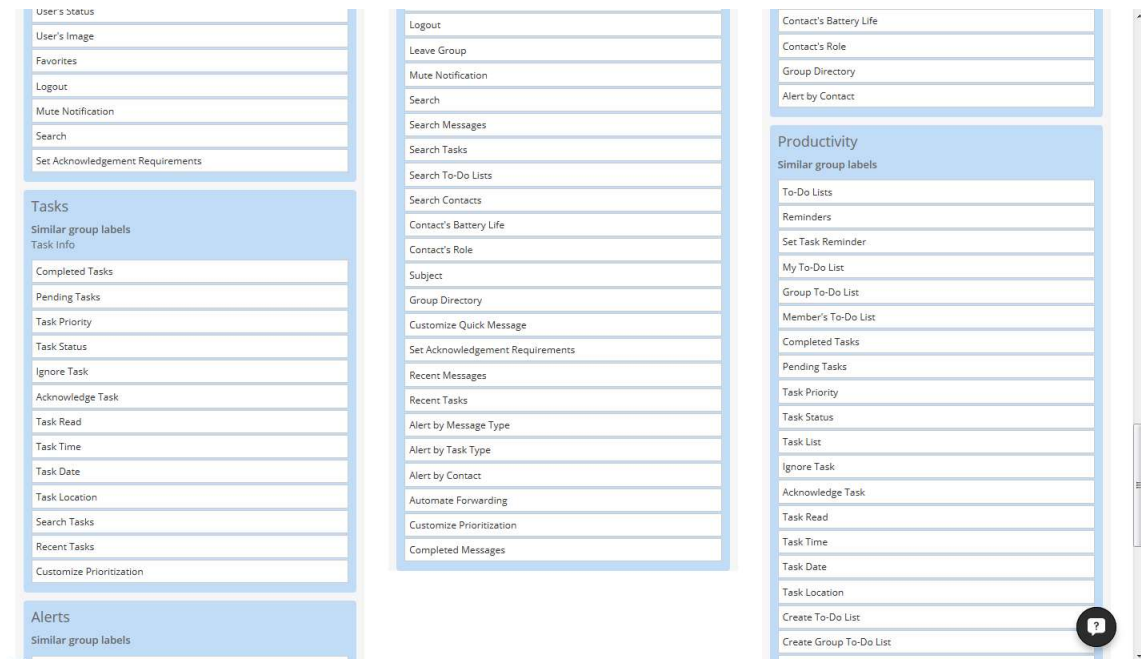
Figure 7.10. Sample Participant-Centric Analysis

We discovered three to seven overhead groupings to be displayed in our team tool. Similar groupings of items were labeled as Main Menu, Settings, Contacts, Tasks, and Messages. Some variations on functions and how these elements could be presented were Search Engine, Navigation, Interface, and Shortcuts.

7.6.4. Team Tool Card Sort Implications

The results we obtained from the card sort from each representative of the Emergency Department team member helped us form a basic structure for the layout of the team tool that has the potential to fit into the Emergency Department team's workflow and communication patterns.

7.7. TEAM TOOL COGNITIVE WALKTHROUGH

From the above studies, we generated displays related to managing clinical communications and tasks. Using electronic displays, we determined its impact on usability. Non-clinicians were also recruited to determine the overall usability of the display.

7.7.1. Team Tool Cognitive Walkthrough Objectives

We wished to determine the ease of the team tool's learnability for new users, especially those in the critical care environment.

7.7.2. Team Tool Cognitive Walkthrough Methods

Participants were given the mobile app on an iPod Touch version running IOS 9.2.1. They were also given a Testing Task List with clinical team related communication tasks with sample tasks of adding contacts to their contacts list, sending group messages, setting up features for showing their availability, and maintaining a to-do list. These tasks were completed in an informal lab setting. After completion of the Testing Task List, participants were asked to complete a SUS, for subjective opinion of its usability, and NASA-TLX, for subjective opinion of its workload, and to provide any additional feedback on the design and functionality of the mobile application. We examined how well participants were able to complete the tasks outlined by using the following four questions: Will the user try to achieve the right effect?, Will the user notice that the correct action is available?, Will the user associate the correct action with the effect they are trying to achieve?, and If the correct action is performed will the user see that progress is being made toward the solution of their task?

7.7.3. Team Tool Cognitive Walkthrough Results

We had four attending physicians complete the cognitive walkthrough using the team tool. All were able to log into the application, create a task list, finding another unoccupied clinician, setting a receipt of communication, setting a status, leaving a group conversation, creating a new quick message, responding to a message with a quick message, acknowledging messages as being seen, forwarding messages, responding to messages, and logging out. There was a 50% failure rate for ranking the task list. This may be due to the icon used and confusion to its meaning. There was a 50% failure rate for the search function as it did not always perform the search as expected for people or messages. There was a 25% success rate for the filtering of messages.

Their impressions of the usability and workload of the team tool ranged from good to bad. This may be due to not being as familiar with the technology used and its role in completing the tasks in the context of the Emergency Department.

Table 7.7. SUS and NASA-TLX Scores of Team Tool

Participants	SUS	NASA-TLX
P1	70.0 (Good)	26.7 (Good)
P2	65.0 (OK)	40.0 (OK)
P3	42.5 (Poor)	35.0 (OK)
P4	10.0 (Worst)	66.7 (Bad)

The participants stated they liked that tasks could be prioritized by patient, that the quick messages had potential, that the design and layout of the application was easy to maneuver through, that there was the ability to filter through items, and that there were different list types, and that a one-way message could save time.

The participants did not like that there was no way to reorder or check off tasks in the To-Do List. They did not like priority marker icons used. The participants also wished to see a complete contacts list and an edit to the filtering messages wording. Some of the participants still preferred using paper as their to-do list rather than the team tool. There was also some issue with the search function during testing which did not properly filter through the messages as expected.

The participants wished to see a revamp of the home page of the team tool, further patient information access like specific patient information, current hospital acuity levels, links to reference materials, a no priority list, a bigger menu, and a notification scroll. Some of these features were recommended with a director of the Emergency Department in mind.

7.7.4. Team Tool Cognitive Walkthrough Implications

The findings from the cognitive walkthrough of the team tool helped us obtain initial reactions to the team mobile application and to determine how easy it was to learn and if the intended tasks of the team tool were completed in an expected way. We took issues observed to inform the next iteration of the team tool.

7.8. TEAM TOOL DESIGN AND DEVELOPMENT RESULTS

From our two surveys, card sort, and cognitive walkthrough, based on the TURF for Teams framework, we created a team communication tool in the medium of a mobile application that could help Emergency Department teams manage domain and lessen overhead interruptions.

Table 7.8. Team Tool Features and Its Management of Domain and Overhead

Interruptions

APP FEATURES	DOMAIN	OVERHEAD
Filtering Messages		X
Forward Messages		X
Group Messaging		X
Individual Messaging	X	
Join/Leave Conversations		X
Message Lists	X	
Message Status		X
Notification Sound/Color	X	X
Phone Directory/Location/Role	X	X
Prioritization of Task List		X
Quick Messages		X

Receipt of Communication		X
Search	X	
Supervision of Junior Level	X	
Task List/To-Do List	X	X
User Status		X

7.9. TEAM TOOL DESIGN AND DEVELOPMENT DISCUSSION

By using the TURF for Teams framework, we were able to gather what and how actual Emergency Department team members wished to structure and organize their team tool to effectively communicate and complete team tasks and view their team workload. Through this, we were also able to determine how to help manage their domain interruptions and potentially lessen their overhead interruptions. From these findings, we went through some iterations to create a team communication mobile application design that could fit into the Emergency Department environment and facilitate team communication.

7.10. SUMMARY OF THE TEAM TOOL DESIGN AND DEVELOPMENT CHAPTER

In this chapter, we delineated the additional steps that we took to formalize the design of the team tool. Using the information that we obtained from our observations, surveys, card sort, and cognitive walkthrough, we were able design a team tool that may be useful to emergency clinicians in managing interruptions.

Chapter 8: SIMULATION DESIGN AND DEVELOPMENT

8.1. OVERVIEW OF THE SIMULATION DESIGN AND DEVELOPMENT CHAPTER

The purpose of this chapter is to describe how we use our findings from utilizing TURF for

Teams to design effective evaluation tools. We outline the tools used to create our

simulation and the reasoning behind the design of the simulation as well as a description of

its different components and its intended manipulation by clinical and non-clinical users and

teams.

8.2. SIMULATION DESIGN AND DEVELOPMENT OBJECTIVES

Our objective is to use TURF for Teams to create and design a microworld simulation to

effectively evaluate a team tool, such as the mobile application designed for helping

emergency department clinicians in communicant with one another and better managing

interruptions.

8.3. SIMULATION DESIGN AND DEVELOPMENT METHODS

To create the microworld simulation, we used the following materials and procedures.

8.3.1. Materials

For our first iteration, we used hand drawn sketches on graph paper, a straight edge, and a

pen. We then used Justinmind to create a version of the simulation interface based on our

hand drawn sketches founded on TURF for Team needs. Justinmind is a prototyping software with a layout similar to Adobe's Photoshop. It is equipped to create static or high fidelity prototypes for responsive designs in mobile applications and websites of static interfaces using drag and drop and a bit of programming.

For our second iteration of the simulation, we used some pre-packaged programs to help us build our vision from our first iteration of the simulation.

We created our simulation utilizing some programs currently available online. For the basis of the simulation, we used Wix, an online website designer site. Wix provides the flexibility of creating websites using drag and drop and some programming, as opposed to other sites which have set templates. It also provides responsive design, so that the site can be viewed on multiple platforms such as by computer or mobile device.

A simulation was created for each role type, so that they would be able to view specific items specific to their roles, but the overarching patient list in the simulation electronic health record was the same for every role. Only thirteen patients were in the emergency department. Their broad chief complaints were based on a moderate level workload in an city teaching hospital created by a collaborating emergency attending. Each patients' information, health history, x-rays, etc., was populated through several sources related to Emergency Board Exam cases. We had our collaborating emergency attendings review a few of these cases for their acceptability before creating the simulation. We also based the structure of the patient information in the system off of data that we obtained through a

previous study on our observation of the main topic points found in emergency department handoffs.

We also used Inklewriter, an open source 'Choose Your Own Adventure' online program to provide a semi-structured script for guiding patients through their patient lists and interactions with the rest of their team members. Ten domain and ten overhead interruptions were embedded into this narrative. Each role had their own version of the 'Choose Your Own Adventure' narrative. It listed their assigned patient list and the corresponding actions needed to complete their patient list by directing the participants with action choices of interaction to obtain information on their patient.

For the simulations' forms, we used a form creator program called Typeform to create an online form and database to handle orders for patients. In this way, users could input information, and the experimenter could delay or release its appearance for other members on the team, similar to the real-world environment to mimic time delays in orders. Some information was additionally made unavailable through the use of page encryption which required a specific role's password access. This also increased the need for interaction between participants.

Along with the TURF for Teams created team communication mobile application, this was our microworld simulation in a simulated electronic health record format.

8.3.2. Procedure

To create the simulation, we first wanted to mimic an actual workload of an emergency department. We based the caseload on the emergency departments we observed in our observational field study. A collaborating attending physician created the typical cases for us. The experience was measured to be a moderate load on any given day in the emergency department. The cases consisted of a full patient room and half filled waiting room. The attending oversaw all thirteen patients while the resident and nurse each had a patient list of five patients. Some patients overlapped between roles while others did not. The teams were not often aware of who was assigned to which patient. Any overlapping team member roles outside of the current three participants were handled through the team tool and microworld simulation by the experimenter.

The general patient scenarios created by the attending was then fleshed out further with data from emergency medicine board exam cases through the use of its data and images. The scenarios were then reviewed by our five collaborating attending physicians from the emergency department.

We then mocked up the interface for displaying the patient cases using pen and paper and then Justinmind. Informal review of the interface by School of Biomedical Informatics and user experience professionals were conducted at this time. Best practices for interface design were utilized.

Our microworld simulation incorporates a mock electronic health record containing the

above patient case load along with a 'Choose Your Own Adventure' narrative interface.

R1
by Anonymous

Thank you for your participation! When you are ready, please begin by clicking below.

Go to Your Patient List

Go to Your Patient List

You have just assumed the role of a Resident physician provider on the trauma side of an emergency department. As a Resident, you work with other Residents, Mid-Levels, and Nurses in providing trauma-patient care under the supervision of an Attending.

For this emergency department, you have split the fifteen patients amongst yourself, the other Resident, and the other Mid-Level and are in charge of five patients. There are eight patients in the waiting room.

These are your patients and their general chief complaints:

Patient 1 – MVC
Patient 6 – MVC
Patient 7 – Head Injury with LOC
Patient 8 – Needlestick Injury
Patient Hallway A
Select a Patient's case to begin.

Go to Patient 1's Case

Go to Patient 6's Case

Patient 1 is a 25 year old woman who was the restrained driver in a 35 mph "t-bone" accident. Her vehicle hit a vehicle that ran a red light on the passenger side. Her airbags deployed.

She is complaining of moderate chest pain, but denies abdominal pain or extremity pain. She did not lose consciousness.

You have just finished seeing her and need to present Patient 1 to your Attending.

What would you like to do next?

Go and Present to Your Attending

Handle Another Patient Case

You go to present to your Attending, but the Attending doesn't seem to be in the near vicinity.

What would you like to do next?

Find the Attending

Wait for the Attending to Find You

Chart on a Patient Case

Handle Another Patient Case

Find the Attending

You walk around the ED, but you can't seem to find the Attending.
What would you like to do next?

Ask Another Clinician If They Have Seen the Attending

Send a Message to Find the Attending

Chart on a Patient Case

Handle Another Patient Case
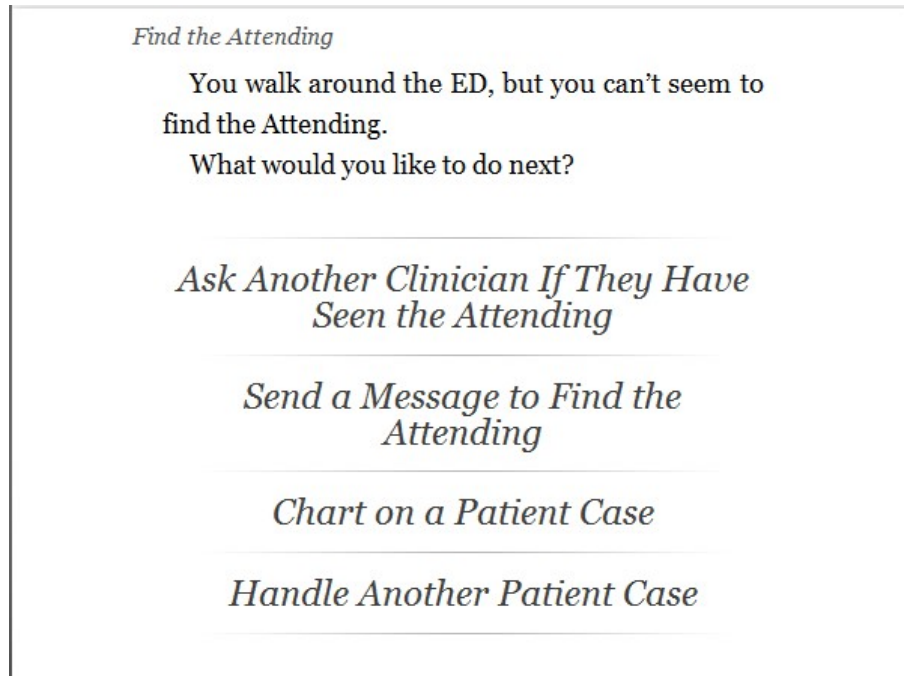
Figure 8.1. Choose Your Own Adventure Sample

The microworld simulation is very flexible and dynamic and does not follow a strict script or timeline besides providing certain data as already given, or when requested through orders or input of disposition. For example, if the clinician wishes to see multiple patient information at any given time, they can generally do so. Actions implemented by clinicians will push other actions in the microworld simulation.

The clinical team in the simulation would have to handle a total of thirteen patients. Each patient included the following information: patient name, age, chief complaint, language, allergies, location within the unit, and image. Each patient had patient history information that could be manipulated by clinicians simultaneously, and some of the information may be restricted due to time and orders, just like in the real environment.

As this is still in an early stage of the iteration, the system is not traditionally integrated, but each role acts separately within the simulation from the other, and the information is inefficiently passed by the experimenter behind the scenes. Using the team tool that we designed, fully completes the typical communication patterns found in the real world.

To force interaction, we embedded events typically found in the emergency department environment. Restricting access to information based on role, having information that another role requires/has in order to access information, or presenting blocks in getting to a certain task based on a need from a specific role or due to a lag in computing. We also inserted twenty types of interruptions into the system. Other interruptions might occur organically due to other issues, but we expected and wanted this to occur as it is just the nature of the environment and work. This is how our microworld simulation differs from others currently being developed or that are in use.

The types of interruptions we put in the system were ten domain and ten overhead type interruptions. These are similar to the types we found through our observation of the emergency department.

After the creation of the microworld simulation, we ran initial tests of the system on graduate students from the School of Biomedical Informatics and our emergency department attending collaborators.

8.4. SIMULATION COGNITIVE WALKTHROUGH

8.4.1. Simulation Cognitive Walkthrough Objectives

The objective of the cognitive walkthrough of the microworld simulation was to see if the system was usable and if any other elements needed to be added.

8.4.2. Simulation Cognitive Walkthrough Methods

8.4.2.1. Institutional Review Board Approval

We obtained Institutional Review Board exemption and approval to recruit and run participants on our cognitive walkthrough study. Institutional Review Board approval was obtained from The University of Texas Health Science Center at Houston and was categorized for the exempt review process. All participants read and signed a consent form before participation. They were compensated with gift cards from an online retailer.

8.4.2.2. Setting

We used any convenient space that might be available and open within the lab or medical offices.

8.4.2.3. Participants

We recruited from a convenience sample of our emergency department collaborators and the graduate students from the School of Biomedical Informatics.

8.4.2.4. Data Collection

We had participants conduct a cognitive walkthrough of our simulation using a Dell laptop and providing feedback through System Usability Scale and NASA Task Load Index surveys within a lab setting. We also obtained additional feedback and comments on the system.

8.4.2.5. Data Analysis

We used the calculations provided with the SUS and NASA-TLX surveys, categorized the feedback, and examined any issues that may have occurred during the cognitive walkthrough. We also examined how well participants were able to complete the tasks outlined by using the following four questions: Will the user try to achieve the right effect?, Will the user notice that the correct action is available?, Will the user associate the correct action with the effect they are trying to achieve?, and If the correct action is performed will the user see that progress is being made toward the solution of their task?

8.4.3. Simulation Cognitive Walkthrough Results

Participants were successfully able to navigate through the Choose Your Own Adventure, through each patient, and through each function. Failures occurred when trying to type in some orders into the input field for patients and when there were lags in the update of patient information after a change in the system causing a temporary stall in the simulation. One participant barely accessed the patient information, but seemed familiar with how to handle the assigned cases at hand.

The participants who completed the simulation cognitive walkthrough gave it usability and workload as being okay or good.

Table 8.1. Simulation SUS and NASA-TLX of Simulation

PARTICIPANTS	SUS	NASA-TLX
SIM P1	67.5 (OK)	13.3 (GOOD)
SIM P2	62.5 (OK)	34.2 (OK)

The participants liked the layout of the simulation and the ease of switching between cases. They also thought the Choose Your Own Adventure style format was nice. The participants also recommended making changes to the organization of information provided. For instance, in the Choose Your Own Adventure format, there is a "Rewinder" link to take users back to the beginning or to a main section of the patient list. This was not seen by the participants because it was hard to see and forced them to use the To-Do List in the mobile application rather than going back through the Choose Your Own Adventure. This feature is embedded in the program and cannot be modified as it is from an external resource. Further recommendations focused on how patient information was conveyed to show a patient's status. Some elements should be pre-filled or unchangeable to simulate that an action has occurred or needs to occur. Also, the ordering of the functions listed on the side menu may lead participants to think that there is a specific order the simulation must cycle through when in fact, the simulation is not constrained by the functions in the menu.

8.4.4. Simulation Cognitive Walkthrough Implications

The findings from this portion of the study helped us determine the simulation's level of learnability and to see if intended tasks worked as expected. Issues experienced were adjusted in the next iteration.

8.5. SIMULATION DESIGN AND DEVELOPMENT RESULTS

The design of the simulation utilizes real world Emergency Medicine tasks, workflow, and workload to provide a realistic environment where the team tool can be tested.
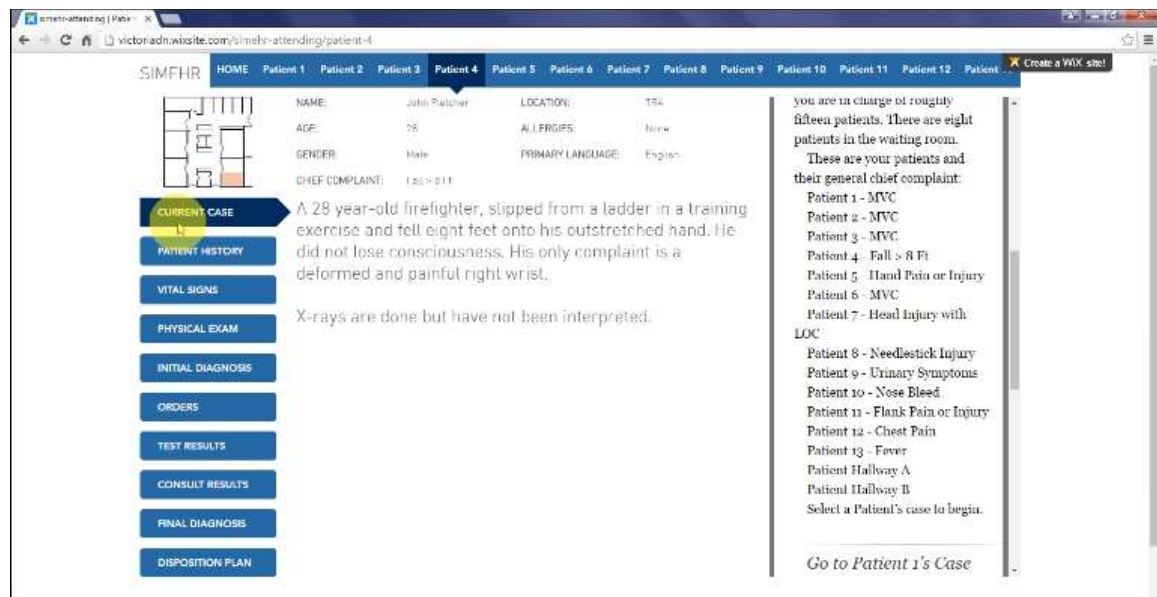
Figure 8.2. Simulation Sample

8.6. SIMULATION DESIGN AND DEVELOPMENT DISCUSSION

We have created a microworld simulation using our knowledge of best interface use practices, but most importantly our findings from TURF for Teams. TURF for Teams

provided us with a framework to really understand the work domain needed to create the microworld. All of its users, how they interact as a team, their tasks, the information they need to handle for patient care, and how the information should be represented to these specific users for this specific environment as a team.

8.7. SUMMARY OF THE SIMULATION DESIGN AND DEVELOPMENT CHAPTER

Using TURF for Teams, we were able to take what we learned form the users, tasks, and work environment to create a microworld simulation that is different from those found currently. We were able to create a simulation including multiple patient cases, rather than ones offered one at a time, and with more than five patients. We also offered flexible functionality for mimicking the actual interactions in the emergency department environment through the elements in our system and the use of real team participants.

CHAPTER 9: TEAM TOOL AND SIMULATION EVALUATIONS

9.1. OVERVIEW OF THE TEAM TOOL AND SIMULATION EVALUATIONS CHAPTER

The purpose of this chapter is to evaluate how well or how badly a TURF for Teams designed mobile team communication application and team simulation environment are able to properly accommodate and support teams, specifically, those found in the Emergency Department environment.

We will describe how users felt about the system combination in terms of design, function, and if they believed this team combination would be helpful in the real world. We will also include all comments, both constructive and laudable, to be used for future directions and iterations of the system.

As we were unable to conduct our evaluation in a real-world setting, and with more user participants, we will focus on how realistically we met users', the teams', and work domain expectations in managing interruptions in the Emergency Department instead of determining actual interruption intervention successes.

9.2. TEAM TOOL AND SIMULATION EVALUATIONS OBJECTIVES

The objective conducting an evaluation of the team mobile application and team simulation is to determine if TURF for Team designed tools and simulation environments might be

useful in demonstrating several team findings. Namely, are tools, especially those designed

for healthcare use, designed for teams able to function well for teams? Do teams believe that

team designed tools satisfy their needs for communication and situational awareness? Are

team designed evaluation microworld simulations able to help identify whether or not team

designed tools might effectively cater to team needs and team work? And, can designing for

teams be a better way of displaying interfaces on healthcare information technologies than

current interface designs catering to just individual needs and work? Proving the perceived

effectiveness of team designed tools can then be translated to domains outside of the

healthcare setting, as well.

9.3. TEAM TOOL AND SIMULATION EVALUATIONS METHODS

9.3.1. Institutional Review Board Approval

We obtained Institutional Review Board exemption and approval to recruit and run

participants on our evaluation study. Institutional Review Board approval was obtained from

The University of Texas Health Science Center at Houston and was categorized for the

exempt review process.

All participants read and signed a consent form before participation. They were

compensated with gift cards from an online retailer. If the participants were participating at

our lab space, they were also provided a parking validation ticket.

9.3.2. Setting

The study was conducted at several locations convenient to the clinician's workplace and schedule, and was made as similar to the real-world environment, as possible.

The first possible location for the evaluation was in the School of Biomedical Informatics National Center for Cognitive Informatics and Decision Making in Healthcare Simulation lab at The University of Texas Health Science Center at Houston.

The simulation lab consists of three separate enclosed rooms. One room, which commonly serves as our control room, was used as the attending's location. The second room consisted of a patient room similar to those found in emergency or surgical units. This was the resident's or mid-level provider's room. The third room consisted of a patient room similar to those found in a primary care physician examination room. This room was reserved for the nurse role.

The attending room consists of only computers, which mimics the physician station in the real-world environment, which is often in an enclosed or semi-enclosed space apart from the patient area. Similarly, the resident room mimics the residents' greater interaction with patients, in comparison to the attending's rate of patient interaction, by housing a sterile setting with a simulation mannequin and limited in-room computer accessibility while the nurse room mimics the nurses' close proximity and constant access to patients by housing a more traditional patient bed and having more computer access closer to patient rooms.

All of the rooms are next to one another and connected by a hallway. All doors were left open to give participants the option to participate in a physical interaction with one another by going into each others' rooms. The close proximity of our lab rooms does not follow the common patient room layouts found in the real-world environment as some environments have clinicians in close proximity where they could shout to one another while others would require some walking to find clinicians. This of course occurs when clinicians are stationary and completing non-direct patient care tasks like charting. Participants were set up with a table and chair within these rooms where the testing system, or simulation EHR, was positioned.

If participants were unable to make the trek to our simulation lab, we reserved a room in the Texas Medical Center Library Health Sciences Resource Center or UTHealth McGovern Medical School, and we gave the participants' the option of choosing the most convenient location that aligned well with the participants' schedules. Both locations are adjacent to our school's teaching hospital and gave a shorter distance to travel for clinicians finishing shifts or starting shifts while still providing enough time for the clinicians to participate in our study.

Because we were only able to reserve one big room at these locations, participants completed the experiment in three areas of the room in unenclosed locations. In this scenario, the areas did not mimic actual real-world environments, but participants still had the option to interact physically or verbally as they would in the real world.

9.3.3. Participants

Recruitment was done through emails, flyers, clinician meetings, clinician introductions, and faculty referrals. Participants were pulled from the UTHealth emergency department such as attending physicians, residents, mid-level providers, and nurses. In addition, participants could also be UTHealth Medicine attending physicians and residents. We also accepted third and fourth year medical and nursing students from the McGovern School of Medicine and Cizik School of Nursing at UTHealth. To get a non-medically trained view of the system, we also recruited Biomedical Informatics graduate students from the School of Biomedical Informatics. Some of the School of Biomedical Informatics students had a background or previous experience in medicine. All participants were 18 years or older.

We ran participants in groups of three to mimic a the most basic components of an emergency medicine team consisting of an attending physician, resident or mid-level provider, and a nurse. Emergency Department teams are larger than these three roles, but due to scheduling and time, we decided on first studying on the basic makeup of the emergency medicine team. Our goal was to examine emergency medicine teams as this group was our target team user, but due to the complexity of recruiting multiple types of roles for the evaluation amongst conflicting schedules and shifts, we also sent out a call of participation to medical clinicians.

9.3.4. Data Collection

9.3.4.1. Materials

Several components went into the collection of our evaluation data. Our two main items to be evaluated were the team tool mobile application and the microworld simulation.

Each participant was given a Dell Latitude E6440, Dell Latitude E7440, or Dell Ultrabook laptop running Windows 7 and Microsoft Office. An optional external mouse was provided, but users could also use the laptop's mouse track pad. The laptops also contained the TURF software of version 4.0, which was used to capture and record each user's screen, video, audio, keystrokes, mouse movement, and actions while manipulating the microworld simulation and partial team tool use by the video. Users also had the opportunity to utilize Microsoft Word to take notes or they could take notes on their team tool or on the external paper copy of the patient trackboard from the simulation.

To access the simulation, participants had Chrome opened on their desktop to the microworld simulation in its browser. The simulation contains two embedded interfaces. One is an Inklewriter interface, which is an open source 'Choose Your Own Adventure' style narrative generator. Embedded in this narrative were ten overhead and ten domain type interruptions that the participants had to manage along with their assigned patient list. The other is an HTML/CSS rendering of a simulated electronic health record consisting of thirteen concurrently running emergency department type patients at varying levels of care and case severity. Each laptop contained a simulation specific to the role of the participant. Further description of the simulation can be found in Chapter 8.

Participants also had access to an iPod Touch running iOS 9.2.1 or iOS 9.3.5 which contained the team tool mobile application. Because we were using an iPod Touch, we used the school's Wifi connection for the team tool to send and receive messages and notifications. The team tool consisted of a Home, Contact List, Task List, Messaging, and Settings page. Each team tool was specific to the role of the participant. A more in depth description of the team tool can be found in Chapter 7.

Along with the paper copy of the emergency department trackboard of current patients, designed like the real world trackboards found in hospital emergency departments, depending on their role, participants were given pieces of information to share with the team or input into the simulation EHR. For instance, the nurse's role received a randomly generated list of password access codes. These access codes gave access to specific roles and blocked other roles from viewing the same information. This was created to increase the interaction between participants. For instance, a resident may wish to view the lab results of a specific patient, but if they were unable to view it due to a delay in an order or access privileges, they could find the right role, attending or nurse, who might have the right code to help them regain access to this information. Additionally, a brief overview of the emergency department workflow was provided to participants with little to no medical background to help provide additional context to the patient cases in the simulation EHR.

System Usability Scale and NASA-Task Load Index surveys were also given to participants to independently evaluate the team tool and microworld simulation. Some feedback questions were also provided to get an idea of how participants felt about how realistic the

microworld simulation was as well as giving them an opportunity to provide feedback for further iterations or general comments on the experience. As expected, a pen was also provided for the participant's use.

9.3.4.2. Procedure

Participants signed up to participate in our experiment and were matched to a group of three for a designated day and time and corresponding room and location. Once the participants arrived they were given a brief overview of the study and a chance to complete the informed consent document. Consent forms were signed and then participants were given a fifteen minute crash course and practice time using the team tool and parts of the simulation.

After fifteen minutes of team tool and simulation tutorials, participants were assigned to their location within the simulation lab or open space medical school room. Each location was already equipped with the laptop, team tool, and role associated papers. The simulation and optional Microsoft Word document were already opened on the laptop and TURF was already activated for recording before the participants began their use of these materials.

Participants were given the chance to look at their assigned patient list and complete as many patient cases as they could within a one hour time limit while using the team tool, or other preferred means of communication, with their team as well as managing tasks and utilizing the microworld simulation to pull patient information and direct patient care. If the team did not start their communications within ten minutes of their start in the evaluation, the

Experimenter sends out a text to the team as the ED Team to help get the team moving in their own method of communication to complete patient care tasks.

After one hour, participants were asked to complete the System Usability Scale and NASA-Task Load Index surveys for the team tool and simulation and feedback questionnaires. The recordings were stopped, saved, and backed up to an additional storage medium, such as the school cloud, while the participants completed these documents. All electronic or written information was also saved and backed up.

The experimenter then collected the survey sheets and reimbursed parking, if necessary. A gift card was then given out. Some more information was given about the study and any questions pertaining to the experiment were answered at this point. In total, the experiment lasted between one and a half to two hours.

9.3.5. Data Analysis

For the usability of our team tool and microworld simulation, we used the typical System Usability Scale and NASA Task Load Index calculations. We also summarized the feedback provided by participants into general categories.

For each team, we created a timeline of events for each role to view how they handled and decided which patient case to start with, see how they handled interruptions that might occur, determine how they continued on with their task completions, by either continuing

with the task they were on before interruption or focusing on a task related to the interruption.

We also looked at interruption behaviors. Were some participants more prone to text, physically find, or wait until another team member was available for their interruption? Did they use the team tool functions to only text a specific role or did they text the whole team for help? We also looked at the duration of time that was experienced before an action occurred as well as how many times the tool was actually accessed, and which features were used the most.

The content of the text or verbal information and information through written notes was also analyzed for what information was provided to help us understand how the team communicated with one another. We also examined the differences found between the different types of teams.

9.4. TEAM TOOL AND SIMULATION EVALUATIONS RESULTS

Due to scheduling conflicts and general participant recruitment timing, we ran one three member clinical team involving only internal medicine residents and one group of informatics students with medically related backgrounds. We would additionally like to mention a test run with some of our ED collaborators to provide a possible contrast between targeted teams versus non-targeted teams. Here, we were able to determine if the team tool and simulation were both user-friendly and effective for clinically trained clinicians and non-clinicians.

The Internal Medicine team consisted of three early in their career residents who knew one another as colleagues, and for two of the residents, as husband and wife. The Internal Medicine team quickly jumped into the simulation after the tutorial period. Some team members were able to prioritize their patients while others chose to chronologically go through their assigned patients. In some patient cases, there was some physical face-to-face interactions to obtain help from other team members, especially between those playing the role of Attending and Resident.

The Internal Medicine team's interactions successfully mimicked real world interactions. The team used the tool to communicate with one another before physical interaction occurred and without any prompting from the Experimenter's texts. They were not able to complete all patient cases, but were able to get to all patient cases within the one-hour test.
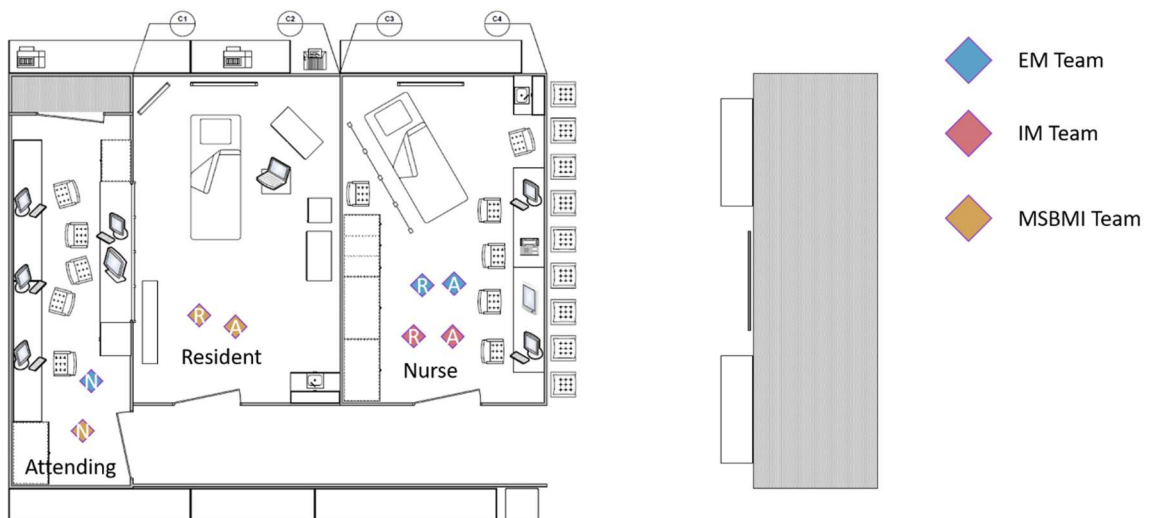
Figure 9.1. Internal Medicine Team Interaction Patterns

Table 9.1. Internal Medicine Team Communication Behaviors

	Internal Medicine Team		
	Texters	Walkers (Look For)	Talkers (Call)
Interruptions (No Waiting)	Text Only	Text and Seeking	None
Tool Use	Texts Images	Texts Seeking	None
Order of Patients	Sequential	Sequential	None
Use of Microworld	Complete	Complete	None

In contrast, the Informatics team of medically trained students handled the case load differently. One team member prioritized their patient list by severity while the others chose to chronologically go through the patients. The Informatics team did not jump immediately into the simulation and were more thorough in acclimating themselves with the tool, simulation, and ED workflow. After fifteen minutes, the Experimenter began some text prompts which encouraged communication with the tool within the team before physical interaction became the norm. If the required role was unavailable, the team communication tool was used. Interestingly, much physical movement and interaction was used by the participants to help one another gather information and handle patient cases. Role seeking was constant in this team. The Attending to Resident behavior mimicked the real world setting as they sought one another more than finding the Nurse. Also, the Nurse would seek

out the Resident more often than the Attending. The Informatics team was not able to complete all patient cases or access all patients within the one-hour test.
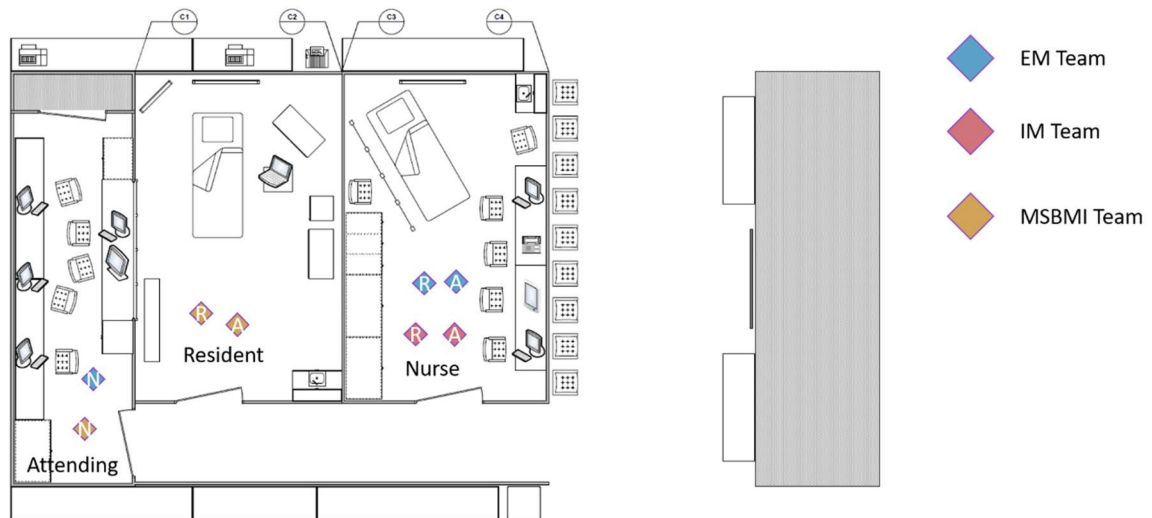
Figure 9.2. Informatics Team Interaction Patterns

Table 9.2. Informatics Team Communication Behaviors

	Informatics Team		
	Texters	Walkers (Look For)	Talkers (Call)
Interruptions (No Waiting)	Texts	Texts and Seeking	None
Tool Use	Text and One Task List	Texts and Seeking	None
Order of Patients	By Severity	Sequential	None
Use of Microworld	Complete	Complete	None

Since we were unable to recruit participants from our targeted work environment, we also looked at the initial run of our study with our ED collaborators who worked with a non-clinical student as a team to go through our simulation. This ED team was able to complete all patient case plans within the one-hour test. Only the non-clinical student working in the Nurse role was unable to get to all of the Nurse's assigned patients. The ED team mimicked real world conditions by prioritizing their patients by severity and communicating in the usual role patterns. Some texting occurred to outside team members, but most interactions were physical.
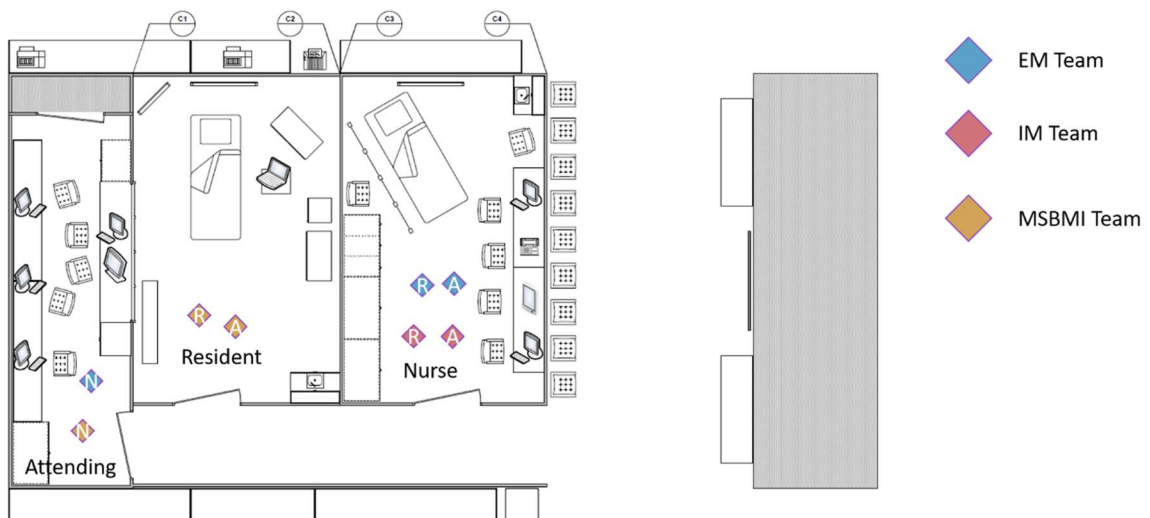
Figure 9.3. Emergency Medicine Team Interaction Patterns

Table 9.3. Emergency Medicine Team Communication Behaviors

	Emergency Medicine Team		
	Texters	Walkers (Look For)	Talkers (Call)
Interruptions (No Waiting)	Text Only	None	None
Tool Use	Text Only	None	None
Order of Patients	By Severity	None	None
Use of Microworld	Complete	None	None

A comparison between the text message interactions between the teams showed that the Internal Medicine Teams used the team tool to communicate more often than finding one another's physical location. The Informatics Team utilized the team tool up to a point before finding each other to communicate face-to-face to verify team roles and patient cases. Emergency Medicine Teams used the team tool to communicate with ED Team members not physically located within the area. The location of team members not within the near vicinity with the team tool was similar for all teams.
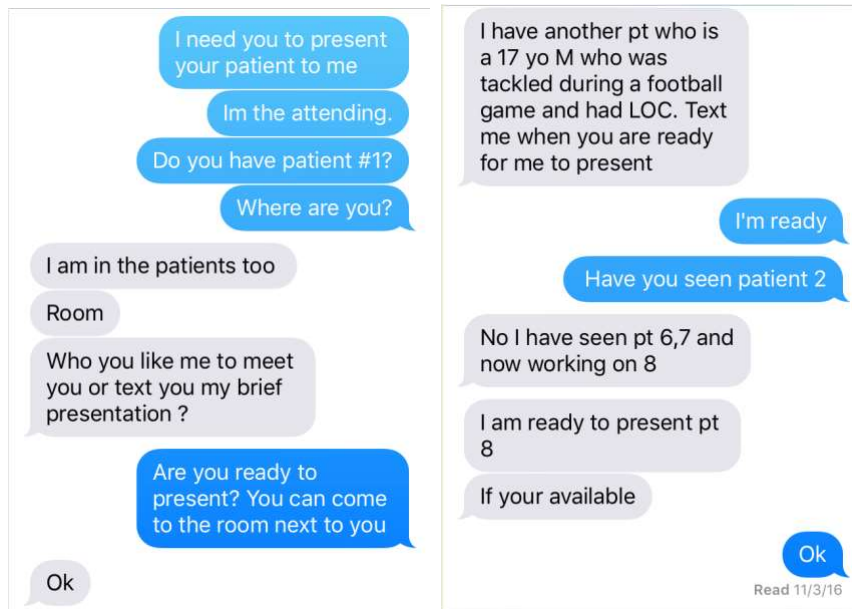
Figure 9.4. Sample Internal Medicine Team Texts During Simulation and Team Tool
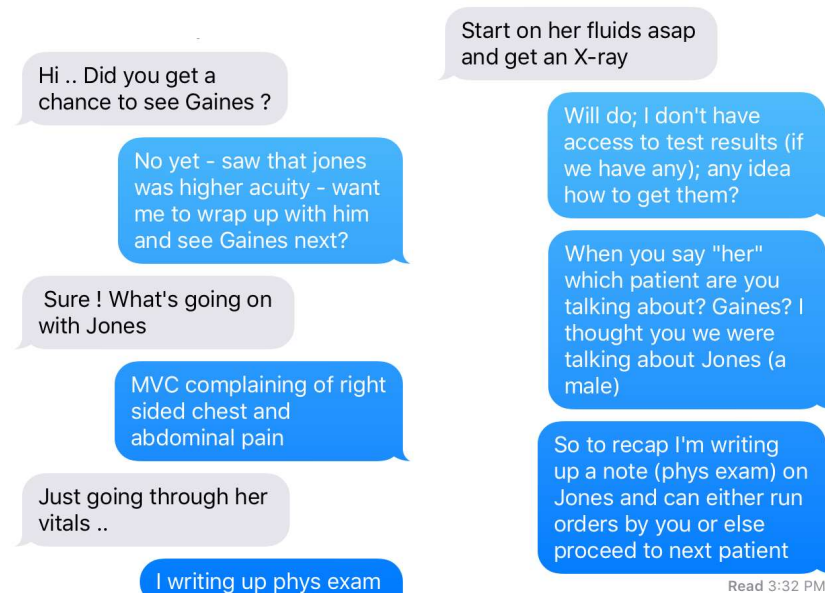
Evaluation

Figure 9.5. Sample Informatics Team Texts During Simulation and Team Tool Evaluation

The average System Usability Score for the microworld simulation was 49.9 with a NASA-

TLX score of 41.9. The average System Usability Score for the team tool was a 71.97 and the

NASA-TLX score was a 26.02. The teams found the simulation and team tool to be usable

and helpful with some suggested improvements.

Table 9.4. Simulation and Team Tool SUS and NASA-TLX

	SUS	NASA-TLX
Simulation	49.9 (OK)	41.9 (OK)
Team Tool	71.97 (Good)	26.02 (Good)

We categorized if the team was able to manage their interruptions within the assigned patient

case with the team tool and also how many patients the team was able to progress through.

We conducted a Pearson's Chi Square, and found that the difference between groups was

significant $X^2 = .025$ df $= 2$ p $< .05$.

Table 9.5. Team Tool Features and Management of Domain and Overhead Interruptions

	Overhead	Domain	Patients
EM Group	0.20	0.50	13/13
IM Group	0.20	0.25	6/13
MSBMI Group	0.00	0.375	5/13

Although, the team tool features were helpful, the team mostly used the messaging features, with a few using the task list features, in order to communicate with one another and to contact members not in the near vicinity.

Table 9.6. Team Tool Features and Its Management of Domain and Overhead
Interruptions Used by Teams During Simulation

APP FEATURES	DOMAIN	OVERHEAD	USED
Filtering Messages		X	
Forward Messages		X	
Group Messaging		X	X
Individual Messaging	X		X
Join/Leave Conversations		X	
Message Lists	X		
Message Status		X	
Notification Sound/Color	X	X	
Phone Directory/Location/Role	X	X	
Prioritization of Task List		X	X
Quick Messages		X	
Receipt of Communication		X	

Search	X		
Supervision of Junior Level	X		
Task List/To-Do List	X	X	
User Status		X	

9.5. TEAM TOOL AND SIMULATION EVALUATIONS DISCUSSION

In general, all user types found the team tool and the system to be somewhat easy to use. A few participants thought the system was a bit cumbersome through the types of forced overhead interruptions that we created and could not look past it, and if not familiar with patient cases, having to learn two new systems within a short time frame was also a hurdle.

For more experienced clinicians, they disregarded the CYOA script and went according to their own experiences. For novices or non-clinicians, the CYOA script was appreciated up to a point before interactions and interruptions forced them to choose other paths. Afterwards, the CYOA script was not taken up again. This is due to the simulation design being simultaneously constraining and built for freeform exploration.

Due to the short run of the study, a few interruptions were captured, but not to a great extent that could show great diversions in tasks or distractions preventing participants from getting off task by going on to complete a diverted task. Or if diverted from their original task, they returned to the original task within a minute finishing their resolution of the interruption. The resolution of the interruption or jumping to another task in the meantime was quickly handled to cause any additional concern, though frustrations were voiced.

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Though tasks lists were mentioned as an interesting feature to have, it was not used. This may be due to the timeframe of the experiment and amount of information to peruse.

The way they communicated and behaved greatly mimicked how each team was trained and their environment. For instance, the Internal Medicine teams are often spread out as their patients are not all located in one area like the Emergency Department patient bed layout. Therefore, they seemed to have a greater affinity with communicating through the team tool than the other teams. As the Emergency Department team is often located within one area, the team seemed to have a greater affinity to find one another first before using the team tool, but they did use the team tool to contact team members not on the floor. The Informatics Team, because of their unfamiliarity with the work environment, showed that they were willing to try multiple ways of communication before finding a steady groove for accomplishing their tasks.

The simulation and tool shows promise of successfully mimicking real world Emergency Department behaviors and workload and has the ability to handle team users, but some more constraints or automation may be needed.

9.6. SUMMARY OF THE TEAM TOOL AND SIMULATION EVALUATIONS CHAPTER

The evaluation helped us see how effective a microworld simulation and team tool designed by using TURF for Teams can be. This evaluation helped us inform our next iteration of the simulation based on our experience examining the team interaction with the team tool and microworld simulation. We described the participants' experience and feedback on the team

communication mobile application and microworld simulation designed by TURF for Teams

in a laboratory setting, and we discovered users reacted favorably to TURF for Teams

designed tools for the healthcare domain.

CHAPTER 10: GENERAL DISCUSSION

10.1. OVERVIEW OF THE GENERAL DISCUSSION CHAPTER

We take our findings from our observations, team tool design process, simulation design, and team tool evaluation, and establish whether or not we were able to resolve our research problem.

10.2. MAIN FINDINGS OF RESEARCH

10.2.1. Observational Field Study of the Emergency Department

We learned about the types of communication between team members that could occur and their frequency. More interruption interactions occurred between attendings and residents while nurses often interrupted one another or just residents. A large amount of overhead interruptions were discovered to occur, which could lead to dire consequences in the patient care process if not managed correctly. This helped to point us in the direction of what to focus on when using TURF for Teams to design our team tool and microworld simulation.

10.2.2. The Emergency Department Environment

The findings from this section further enforced and summarized what we discovered through our observational field study of the emergency department. The information discovered was used as a model for the creation of our microworld simulation.

10.2.3. Team Tool Design and Development

Here, we were able to use TURF for Teams to take what we learned about the emergency department team and tasks to create a team communication mobile application.

10.2.4. Simulation Design and Development

We were able to use TURF for Teams to take what we learned about the emergency department environment and team interactions to create a multi-patient microworld simulation to be used with the TURF for Teams designed team tool for a partially integrated team system.

10.2.5. Team Tool and Simulation Evaluations

Though we had a small sample size, we were able to see some information on how a TURF for Teams designed tool could be helpful in managing interruptions within a team system, but participants used it more as a communication tool despite being interested in all of the features. This may be due to the time constraints of the study. Despite this, participants were able to effectively manage overhead and domain interruptions.

The subjective feelings of the team participants were mostly favorable for our team designed team communication mobile application and microworld simulation, but further modifications must be made to get a full picture of the benefits of also considering the team in work- and user-centered design of systems.

We were able to successfully mimic ED interaction behaviors having Residents and

Attendings interacting with other more often than with Nurses, as well as, hovering

behaviors of clinicians as they waited their turn for obtaining or relaying information with

their teammates.

10.3. RESOLUTION OF RESEARCH

The TURF for Teams framework offers a lot of promise for helping us address both team

and individual user needs in a system for a highly critical environment, such as the

emergency department in the healthcare arena. The framework is generalizable enough to

have the potential to be used in the design for team systems also outside of the healthcare

environment.

Though teams were unable to complete all patient care tasks, they seemed to be able to

manage the interruptions that occurred well with the team tool with a significant chi-square

of $p < .05$ implying the team tool helped manage interruptions. This supports our first

hypothesis that we believed supporting team interruptions can reduce workload burdens and

improve teams and their patient care efficiency.

We were able to include teams as users in the user- and work-centered design of a team tool

which supports our Hypothesis 2 where we believed models of work- and user-centered

design can be modified to include teams as users.

The feedback for the team tool was positive and the teams rated it favorably based on SUS and NASA-TLX scores. Due to time constraints, all of the functions were not used, but appreciated. This supports our Hypothesis 3 stating that team designed systems will not only be more useful, but satisfying for team members.

10.4. LIMITATIONS OF RESEARCH

This study used a limited convenience sample of participants within the trauma portion of a major emergency department as well as the use of participants outside of the emergency medicine field. Consequently, these results may vary in other clinical settings. We were also unable to get a larger sample size of participants. The system may have been overloaded with interruptions due to the ones we embedded and those that naturally occurred. We were unable to follow patients through their care outcomes and were therefore unable to verify if the impact of overhead interruptions greatly hampered the patient care process. Participants were given a very short training period to familiarize themselves with the simulation and tool. For those not familiar with ED patient case loads or processes, this was not ideal. The design of the simulation had the possibility of containing participants to a specific flow, but its current iteration provided a freeform play as well, which may have not provided desired results, but was still informative and similar to real world conditions. Despite these limitations, we were able to outline the emergency department workflow, clinician communication and interaction patterns, and the function of interruptions.

10.5. CONTRIBUTIONS AND INNOVATIONS OF RESEARCH

There is currently a lack of understanding of team interactions, their work process, their environments, the tools they use, and how to acquire team needs and design for teams within the medical environment. The results from this work created a model that will help designers better acquire and understand team needs and incorporate it into their design of team tool interfaces. Better designed team tools will increase their use, user satisfaction, and ease in completing tasks.

The results from this research project yielded findings beyond the identification of user needs and has the potential to benefit both the medical and non-medical environments on determining team needs, designing interfaces for teams, and the impact of supporting teams through team designed support tools by the means of a modified TURF framework incorporating all factors necessary for interface design and team needs. Additionally, the work done here will help advance the field of human factors, emergency medicine, and health informatics by seeking how to design systems for teams. Lessons learned here can be applied to teams of humans, teams of humans and systems, and may even be applied to optimizing the interoperability of systems working independently as a team.

Our findings provide a holistic approach to examining and understanding teams for team research that has not yet been fully illuminated upon. Our research project provides insights into how teams think, feel, and act in real world situations, looks at these factors across time, examines how the environment impacts the teams, and shows how simulations and support tools can benefit teams. Also, importantly, our research provides further explains teamwork

processes, specifically, communication and coordination actions through the team communication activity of interruptions.

10.5.1. Field of Human-Centered Design

There is a great increase in the adoption of technologies into complex environments. As a result, these technologies and environments usually require a team of people who not only need to work together but also with such systems in order to provide efficient, high quality, and safe results to tasks. We have studied team behaviors, composition, cognition, and training, and we have studied how to create usable interfaces and how to test them for their usability. It may be now beneficial to study the two categories and apply those findings to creating usable designs to help teams communicate, coordinate, collaborate, and share knowledge. This research study may be helpful in illuminating this area and taking this field's knowledge to this next step.

10.5.2. Field of Emergency Medicine

Our creation of a multi-patient microworld simulation used to examine emergency department team behaviors may be helpful in training the different team roles, backgrounds, and experiences, found in the high turnover world of emergency medicine, for more effective team work and patient care. The structure of the simulation lends itself for potentially helping teams learn about how to respond to situations and how to communicate more effectively by managing their overhead and domain type interruptions.

10.5.3. Field of Biomedical Informatics

The results will help improve patient safety and quality through more optimal care practices due to better managed team activities and behaviors through team supported tools designed for teams. We have also helped to not only identify the type and direction of interruptions, but also their function. In addition, these results provide another aid to help healthcare clinicians manage the bombardment of data and information and lessen their cognitive load. In an applied sense the results will help improve team coordination and communication practices and reduce the physical devices that clinical teams must manage while on shift. These results may also help to improve the adoption and acceptance of health information technologies if these team design methods are employed.

10.6. RECOMMENDATIONS FOR FUTURE RESEARCH

For future research, we suggest using a more fully integrated system for the next iteration and a larger sample size for evaluating the system. In addition, we would like to provide a longer study period or break the study into two sections where participants will train on the system and then complete the simulation.

10.7. SUMMARY OF THE GENERAL DISCUSSION CHAPTER

In this chapter, we believe our findings will help improve patient safety and quality, and interface design principles through the creation of a TURF framework focused on teams, a better method for acquiring team needs, and further understanding on how to provide systems with a way to display shared knowledge and shared awareness more effectively. With

TURF for Teams, we can better optimize design, development, and implementation within

any environment.

CHAPTER 11: CONCLUSION

TURF for Teams is an expanded version of the TURF framework that also incorporates a focus on teams as a potential user type within work-centered design. We believe this is the framework that will help designers and system evaluators determine how to better design and evaluate systems for team use within a multitude of work domains.

In this research project, we demonstrate the use of TURF for Teams in the creation of a team tool, a team communication mobile application used to help emergency medicine clinicians better manage their domain and overhead interruptions, and a microworld simulation that facilitates and mimics real-world team tasks within the emergency department environment. We started by obtaining and understanding of the users, teams, tasks, and work in the emergency department through an observational field study. Then, we used our findings to model team communication and identify domain and overhead type interruptions. Then we created the team tool and microworld simulation by getting feedback from users on how the interfaces should be designed and how they should function. Finally, we had teams, both clinical and non-clinical, use and evaluate the team tool and microworld simulation to determine how well a TURF for Teams designed system would feel for teams in the emergency department environment.

Our findings suggest there is great acceptance and a need for the consideration of teams in

system design and evaluation through the favorable response to our TURF for Teams

designed system. TURF for Teams may be the answer to how we can better design systems

for teams.

REFERENCES

Abraham J, Kannampallil T, Patel B, Almoossa K, Patel VL. Ensuring patient safety in care transitions: An empirical evaluation of a handoff intervention tool. AMIA Annu Symp Proc. 2012:17-26.

Adamczyk PD, Bailey BP. If not now, when?: The effects of interruption at different moments within task execution. CHI. 2004;6(1):271-278.

Allard J, Wyatt J, Bleakley A, Graham B. "Do you really need to ask me that now?": A self-audit of interruptions the 'shop floor' practice of a UK consultant emergency physician. Emerg Med J. 2012;29:872-876.

Ash JS, Berg M, Coiera E. Some unintended consequences of information technology in health care: The nature of patient care information system-related errors. J Am Med Inform Assoc. 2004;11:104-112.

Ashoori M, Burns C. Team cognitive work analysis: Structure and control tasks. J Cog Eng Decision Making. 2012;7(2):123-140.

Baesler FF, Jahnsen HE, DaCosta M. The user of simulation and design of experiments for estimating maximum capacity in an emergency room. In: Proceedings of the 2003 Winter Simulation Conference. New York City (NY): Association for Computing Machinery, 2003. p. 1903-1906.

Barsuk JH, Cohen ER, Nguyen D, Mitra D, O'Hara K, Okuda Y, Feinglass J, Cameron KA, McGaghie WC, Wayne DB. Attending physician adherence to a 29-component

central venous catheter bundle checklist during simulated procedures. Critical Care Medicine. 2016;44(10):1871-1881.

Baxter G, Sommerville I. Socio-technical systems: From design methods to systems engineering. Interacting with Computers. 2011;23:4-17.

Belda T, Puppe J, Laack T, Goyal D. Use of simulation to test emergency department system for preparedness to implement and roll-out new electronic medical record components involving a complex multiple trauma scenario in-situ. Society for Simulation in Healthcare. 2013;8(6):409.

Ben-Assuli O, Sagi D, Leshno M, Ironi A, Ziv A. Improving diagnostic accuracy using EHR in emergency departments: A simulation-based study. J Biomed Inform. 2015;55:31-40.

Berg LM, Källberg AS, Göransson KE, Östergren J, Florin J, Ehrenberg A. Interruptions in emergency department work: An observational and interview study. Qual Saf Health Care. 2013;00:1-8.

Berkenstadt H, Haviv Y, Tuval A, Shemesh Y, Megrill A, Perry A, Rubin O, Ziv A. Improving handoff communications in critical care: Utilizing simulation-based training toward process improvement in managing patient risk. Chest. 2008;134:158-162.

Berkenstadt H, Ziv A, Barsuk D, Levine I, Cohen A, Vardi A. The use of advanced simulation n the training of anesthesiologists to treat chemical warfare casualties. Anesth Analg. 2003;96:1739-1742.

Blasak RE, Starks DW, Armel WS, Hayduk MC. The use of simulation to evaluate hospital operations between the emergency department and a medical telemetry unit. In:

Proceedings of the 2003 Winter Simulation Conference. New York City (NY): Association for Computing Machinery, 2003. p.1887-1893.

Bria WF, Shabot MM. The electronic medical record, safety, and critical care. Crit Care Clin. 2005;21:55-79.

Brixey JJ, Robinson DJ, Johnson CW, Johnson TR, Turley JP, Patel VL, Zhang J. Towards a hybrid method to categorize interruptions and activities in healthcare. Int J Med Inform. 2007;76:812–20.

Brixey JJ, Robinson DJ, Turley JP, Zhang J. The roles of MDs and RNs as initiators and recipients of interruptions in workflow. Int J Med Inform. 2010;79:109-115.

Burke CS, Salas E, Wilson-Donnelly K, Priest H. How to turn a team of experts into an expert medical team: Guidance from the aviation and military communities. Qual Saf Health Care. 2004;13(*Suppl 1*):i96-i104.

Cabrera E, Taboada M, Iglesias ML, Epelde F, Luque E. Simulation optimization for healthcare emergency departments. Procedia Computer Science. 2012;9:1464-1473.

Chaudhry B, Wang J, Wu S, Maglione M, Mojica W, Roth E, Morton SC, Shekelle PG. Systematic review: Impact of health information technology on quality, efficiency, and costs of medical care. Ann Intern Med. 2006;144:E12-E22.

Chisholm CD, Dornfeld AM, Nelson DR, Cordell WH. Work interrupted: A comparison of workplace interruptions in emergency departments and primary care office. Ann Emerg Med. 2011;38(2):146-151.

Chunta K, Edwards T. Multiple-patient simulation to transition students to clinical practice. Clinical Simulation in Nursing. 2013;9:e491-e496.

Clark HH. Using language. Cambridge (ENG): Cambridge University Press; 1996.

Cobbs E, Pincetl P, Silverman B, Liao RL, Motta C. An interactive learning environment for
   health care professionals. AMIA Annu Symp Proc. 1994:49-53.

Coenen A, Raafat R, Chater N. Investigating convention shifts and team reasoning in multi-
   agent simulations. In: Proceedings of CogSci. Austin (TX): Cognitive Science
   Society, 2011. p. 2365-2370.

Cohen SG, Bailey DE. What makes teams work: Group effectiveness research from the
   shop floor to the executive suite. J Manag. 1997;23:239-290.

Coiera E, Tombs V. Communication behaviours in a hospital setting: An observational
   study. BMJ. 1998;316:673-676.

Collins SA, Bakken S, Vawdrey DK, Coiera E, Currie L. Model development for EHR
   interdisciplinary information exchange of ICU common goals. Int J Med Inform.
   2011;80(*8*):e141-e149.

Collins SA, Mamykina L, Jordan D, Stein DM, Shine A, Reyfman P, Kaufman D. In search
   of common ground in handoff documentation in an intensive care unit. J Biomed
   Inform. 2012;45(2):307-315.

Cooke NJ, Gorman JC, Myers CW, Duran JL. Interactive team cognition. Cognitive Science.
   2013;37:255-285.

Cooke NJ, Gorman JC, Rowe LJ. An ecological perspective on team cognition. In: Salas E,
   Goodwin GF, Burke CS, editors. Team effectiveness in complex organizations:
   Cross-disciplinary perspectives and approaches. New York (NY): Taylor-Francis
   Group; 2009. p. 157-182.

Cooke NJ, Gorman JC, Winner JL. Team cognition. In: Durso FT, editor. Handbook of
   Applied Cognition. England: John Wiley & Sons; 2007. p. 239-299.

Cooke NJ, Salas E, Kiekel PA, Bell B. Advances in measuring team cognition. In: Salas E, Fiore SM, editors. Team cognition: Understanding factors that drive process and performance. Washington (DC): American Psychological Association; 2004. p. 83-106.

Couto TB, Farhat SCL, Schvartsman C. Comparison of high-fidelity simulation and case discussion for teaching medical students pediatric emergencies. Society for Simulation in Healthcare. 2013;8(6):519.

DeChurch LA, Mathieu JE. Thinking in terms of multiteam systems. In: Salas E, Goodwin GF, Burke CS, editors. Team effectiveness in complex organizations: Cross-disciplinary perspectives and approaches. New York (NY): Taylor-Francis Group; 2009. p. 267-292.

DeChurch LA, Mesmer-Magnus JR. The cognitive underpinnings of effective teamwork: A meta-analysis. J Appl Psychol. 2010;95:32-53.

Deutsch ES, Dong Y, Halamek LP, Rosen MA, Taekman JM, Rice J. Leveraging health care simulation technology for human factors research: Closing the gap between lab and bedside. Human Factors. 2016;58(7):1082-1095.

Eaves RH, Flagg AJ. The U.S. Air Force pilot simulated medical unit: A teaching strategy with multiple applications. Journal of Nursing Education. 2001;40(3):110-115.

Eccles DW, Tenenbaum G. Why an expert team is more than a team of experts: A social-cognitive conceptualization of team coordination and communication in sport. J Sports Exerc Psychol. 2004;26(*4*):542-60.

Elias J, Fiore SM. Commentary on the coordinates of coordination and collaboration. In: Salas E, Fiore SM, Letsky M, editors. Theories of team cognition: Cross-disciplinary perspectives. New York (NY): Taylor and Francis; 2012. p. 571-595.

Endsley MR. Design and evaluation for situation awareness. In: Proceedings of the Human Factors Society 32nd Annual Meeting. Santa Monica (CA): The Human Factors and Ergonomics Society; 1988. p. 97-101.

Ernst AA, Weiss SJ, Reitsema JA. Does the addition of vocera hands-free communication device improve interruptions in an academic emergency department? South Med J. 2013;106(*3*):189-195.

Essens PJMD, Vogelaar ALW, Mylle JJC, Blendell C, Paris C, Halpin SM, Baranski JV. Team effectiveness in complex settings: A framework. In: Salas E, Goodwin GF, Burke CS, editors. Team effectiveness in complex organizations: Cross-disciplinary perspectives and approaches. New York (NY): Taylor-Francis Group; 2009. p. 293-320.

Fernandez R, Vozenilek JA, Hegarty CB, Motola I, Reznek M, Phrampus PE, et al. Developing expert medical teams: Toward an evidence-based approach. Acad Emerg Med. 2008;15(*11*):1025-36.

France DJ, Levin S, Hemphill R, Chen K, Rickard D, Makowski R, Jones I, Aronsky D. Emergency physicians' behaviors and workload in the presence of an electronic whiteboard. Int J Med Inform. 2005;74:827-837.

Franklin A, Liu Y, Li Z, Nguyen VD, Johnson TR, Robinson D, Okafor N, King B, Patel VL, Zhang J. Opportunistic decision making and complexity in emergency care. J Biomed Inform. 2011;44:469-476.

Gaba DM. The future vision of simulation in health care. Qual Saf Health Care.
2004;13(Suppl 1):i2-i10.

Galloway S. Simulation techniques to bridge the gap between novice and competent
healthcare professionals. The Online Journal of Issues in Nursing. 2009;14(2):1-9.

Gibson CB. From knowledge accumulation to accommodation: Cycles of collective
cognition in work groups. J Organiz Behav. 2011;22:121-134.

Graetz I, Reed M, Rundall T, Bellows J, Brand R, Hsu J. Care coordination and electronic
health records: Connecting clinicians. AMIA Annu Symp Proc. 2009:208-212.

Grundgeiger T, Sanderson P. Interruptions in healthcare: Theoretical views. Int J Med
Inform. 2009;78:293-307.

Hackman JR, Wageman R, Ruddy TM, Ray CR. Team effectiveness in theory and practice.
In Cooper C, Locke EA, editors. Industrial and organizational psychology: Theory
and practice. Oxford (ENG): Blackwell; 2000. p. 109-129.

Harrington C, Wood R, Breuer J, Pinzon O, Howell R, Pednekar M, Zhu M, Zhang J. Using
a unified usability framework to dramatically improve the usability of an EMR
module. Am Med Inform Assoc. 2011;549-558.

Harrington L, Kennerly D, Johnson C. Safety issues related to the electronic medical record
(EMR): synthesis of the literature from the last decade, 2000-2009. J Healthc Manag.
2011;56:31-44.

Hart SG, Staveland LE. Development of a multi-dimensional workload rating scale: Results
of empirical and theoretical research. In: Hancock PA, Meshkati N, editors. Human
mental workload. Amsterdam (NL): Elsevier; 1988.

Hirsch GB, Homer J. Modeling the dynamics of health care services for improved chronic illness management. In: Proceedings of the 22nd International System Dynamics Conference. Oxford (ENG): System Dynamics Society, 2004. p. 1-23.

Hollingshead AB. Transactive memory and performance in work groups: Specificity, communication, ability differences, and work allocation. Group Dyn. 2008;12:223-241.

Horsky J, Kaufman DR, Patel VL. The cognitive complexity of a provider-order entry interface. AMIA Annu Symp Proc. 2003:294-298.

Hunt EA, Shikofski NA, Stavroudis TA, Nelson KL. Simulation: Translation to improved team performance. Anesthesiology Clin. 2007;25:301-319.

Institute of Medicine. (2003). Health professions education: A bridge to quality. Washington, DC: National Academies Press.

Jeanmonod R, Boyd M, Loewenthal M, Triner W. The nature of emergency department interruptions and their impact on patient satisfaction. Emerg Med J. 2010;27:376-379.

Jiancaro T, Jamieson GA, Mihailidis A. Twenty years of cognitive work analysis in health care: A scoping review. J Cogn Eng Decision Making. 2013;1-20.

Johnson CM, Johnson TR, Zhang J. A user-centered framework for redesigning health care interfaces. J Biomed Inform. 2005;38:75-87.

Josephsen J, Butt A. Virtual multipatient simulation: A case study. Clinical Simulation in Nursing. 2014;10:e235-e240.

Kalisch BJ, Aebersold M. Interruptions and multitasking in nursing care. Jt Comm J Qual Patient Saf. 2010;36(3):126-132.

Katzenbach JR, Smith DK. The wisdom of teams: Creating the high performance

 organization. Boston (MA): Harvard Business School Press; 1993.

Keebler JR, Dietz AS, Lazzara EH, Benishek LE, Almeida SA, Toor PA, King HB, Salas E.

 Validation of teamwork perceptions measure to increase patient safety. BMJ Quality

 & Safety. 2014;0:1-9.

Kelly K, Harrington L, Matos P, Turner B, Johnson C. Creating a culture of safety around

 bar-code medication administration: An evidence-based evaluation framework. The

 Journal of Nursing Administration. 2016;46(1):30-37.

Kelly MA, Hopwood N, Rooney D, Boud D. Enhancing students' learning through

 simulation: Dealing with diverse, large cohorts. Clinical Simulation in Nursing.

 2016;12:171-176.

Kilner E, Sheppard LA. The role of teamwork and communication in the emergency

 department: A systematic review. Int Emerg Nursing. 2010;18:127-137.

Klimoski R, Mohammed S. Team mental model: Construct or metaphor? J Manag.

 1994;20(*2*):403-437.

Kobayashi L, Shapiro MJ, Gutman DC, Jay G. Multiple encounter simulation for high-acuity

 multipatient environment training. Academic Emergency Medicine. 2007;14:1141-

 1148.

Kozlowski SWJ, Watola DJ, Jensen JM, Kim BH, Botero IC. Developing adaptive teams: A

 theory of dynamic team leadership. In: Salas E, Goodwin GF, Burke CS, editors.

 Team effectiveness in complex organizations: Cross-disciplinary perspectives and

 approaches. New York (NY): Taylor-Francis Group; 2009. p. 113-155.

Lazzara EH, Benishek LE, Dietz AS, Salas E, Adriansen DJ. Eight critical factors in creating and implementing a successful simulation program. The Joint Commission Journal on Quality and Patient Safety. 2014;40(1):21-29.

Li SYW, Magrabi F, Coiera E. A systematic review of the psychological literature on interruption and its patient safety implications. J Am Med Inform Assoc. 2012;19:6-12.

Liu W, Stappers PJ, Pasman G, Taal-Fokker J. Making the office catch up exploring interaction qualities at home and at work. ACM Interactions. 2013;20(6):36-41.

McGeorge N, Hegde S, Guarrera-Schick T, LaVergne D, Bizantz A. Supporting the work of ED clinicians: Assessment of a novel emergency department information system in a clinical simulation center. In: Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care. Santa Monica (CA): Human Factors and Ergonomics Society, 2015. p. 81-83.

MacMillan J, Entin EE, Serfaty D. Communication overhead: The hidden cost of team cognition. Team cognition: Process and performance at the inter- and intra-individual level. Washington (DC): American Psychological Association; 2004.

Manser T. Teamwork and patient safety in dynamic domains of healthcare: A review of the literature. Acta Anaesthesiol Scand. 2009;53:143-151.

Marks MA, Mathieu JE, Zaccaro SJ. A temporally based framework and taxonomy of team processes. Acad Manag Rev. 2001;26:355-376.

Mathieu JE, Heffner TS, Goodwin GF, Salas E, Cannon-Bowers JA. The influence of shared mental models on team process and performance. J App Psych. 2000;85(2):273-283.

Mayhew DJ. The usability engineering lifecycle: A practitioner's guide to user interface

    design. San Diego (CA): Academic Press; 1999.

Medigram Screenshot. Medigram; 2013 Dec. Available from: https://www.medigram.com.

Miller KK, Riley W, Davis S, Hansen HE. In situ simulation: A method of experiential

    learning to promote safety and team behavior. J Perinat Neonat Nurs.

    2008;22(2):105-113.

Mishra P, Clamp S, Johnson OA. NETIMIS: Using the healthcare pathway modeling and

    simulation tool to view patient flow and the impact of point of care testing.

    (Internet). 2014. Available from: https://www.netimis.co.uk/case-studies

Monk A. Common ground in electronically mediated conversation. Synthesis lectures on

    human-centered informatics. San Rafael (CA): Morgan & Claypool; 2009.

Morrow DG, Fischer UM. Communication in socio-technical systems. In: Lee JD, Kirlik A,

    editors. The oxford handbook of cognitive engineering. Oxford (UK): Oxford

    University Press; 2013. p. 178-199.

Morrow PB, Fiore SM. Team cognition: Coordination across individuals and machines. In:

    Lee JD, Kirlik A, editors. The oxford handbook of cognitive engineering. Oxford

    (UK): Oxford University Press; 2013. p. 200-215.

Murray DJ, Freeman BD, Boulet JR, Woodhouse J, Fehr JJ, Klingensmith ME. Decision

    making in trauma settings: Simulation to improve diagnostic skills. Sim Healthcare.

    2015;10:139-145.

Nahm M, Zhang J. Operationalization of the UFuRT methodology for usability analysis in

    the clinical research data management domain. J Biomed Inform. 2009;42(*2*):327-

    333.

Patel VL, Cytryn KN, Shortliffe EH, Safran C. The collaborative health care team: The role of individual and group expertise. Teach Learn Med. 2000;12(*3*):117-132.

Patel VL, Kaufman DR, Magder SA. The acquisition of medical expertise in complex dynamic environments. In: Ericsson A, editor. The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games. Hillsdale (NJ): Lawrence Erlbaum Publishers; 1996. p. 127-165.

Pennathur PR, Cao D, Sul Z, Lin L, Bisantz AM, Fairbanks RJ, Guarrera TK, Brown JL, Perry SJ, Wears RL. Development of a simulation environment to study emergency department information technology. Sim Healthcare. 2010;5:103-111.

Pham JC, Aswani MS, Rosen M, Lee HW, Huddle M, Weeks K, Pronovost PJ. Reducing medical errors and adverse events. Annu Rev Med. 2012;63:447-463.

Planitz B, Sanderson P, Kipps T, Driver C. Nurses' self-reported smartphone use during clinical care. HFES. 2013;57:738-742.

Przybylo J. Smarter hospital team communication: Smartphone group text messaging improves efficacy, workflow, and provider satisfaction. Medicine 2.0. 2013;6:321-322.

Qliq Screenshot. QliqSoft; 2013 Dec. Available from: https://www.qliqsoft.com.

Rivera AJ, Karsh BT. Interruptions and distractions in healthcare: Review and reappraisal. Qual Saf Health Care. 2010;19(4):304-312.

Salas E, Diaz Granados D, Klein C, Burke CS, Stagl KC, Goodwin GF, Halpin SM. Does team training improve team performance? A meta-analysis. Human Factors. 2008;50:903-933.

Salas E, Diaz Granados D, Weaver SJ, King H. Does team training work? Principles for health care. Academic Emergency Medicine. 2008;15:1002-1009.

Salas E, Fiore SM. Why team cognition? An overview. In: Salas E and Fiore SM, editors. Team cognition: Understanding factors that drive process and performance. Washington (DC): American Psychological Association; 2004. p. 3-8.

Salas E, Wildman JL. Ten critical research questions: The need for new and deeper explorations. In: Salas E, Goodwin GF, Burke CS, editors. Team effectiveness in complex organizations: Cross-disciplinary perspectives and approaches. New York (NY): Taylor-Francis Group; 2009. p. 525-546.

Schiflett SG, Elliott LR. Synthetic team training environments: Application to command and control aircrews. In: O'Neil HF, Andrews DH, editors. Aircrew Training and Assessment. New Jersey: Lawrence Erlbaum; 2009. p. 326.

Segall N, Hobbs G, Granger CB, Anderson AE, Bonifacio AS, Taekman JM, Wright MC. Patient load effects on response time to critical arrhythmias in cardiac telemetry: A randomized trial. Critical Care Medicine. 2015;43(5):1036-1042.

Shapiro MJ, Morey JC, Small SD, Lanford V, Kaylor CJ, Jagminas L, Suner S, Salisbury ML, Simon R, Jay GD. Simulation based teamwork training for emergency department staff: Does it improve clinical team performance when added to an existing didactic teamwork curriculum? Qual Saf Health Care. 2004;13:417-421.

Sittig DF, Singh H. A new socio-technical model for studying health information technology in complex adaptive healthcare systems. Qual Saf Health Care. 2010;19(Suppl 3):168-174.

Small SD, Wuerz RC, Simon R, Shapiro N, Conn A, Setnik G. Demonstration of high-
fidelity simulation team training for emergency medicine. Academic Emergency
Medicine. 1999;6:312-323.

Smith-Jentsch KA. Measuring team cognition: The devil is in the details. In E. Salas, J.
Goodwin, C.S. Burke (Editors) Team Effectiveness in Complex Organizations.
Edited volume for SIOP Organizational Frontier Series;2009.

Smith-Jentsch KA. Measuring team-related cognition: The devil is in the details. In: Salas E,
Goodwin GF, Burke CS, editors. Team effectiveness in complex organizations:
Cross-disciplinary perspectives and approaches. New York (NY): Taylor-Francis
Group; 2009. p. 491-508.

Solvoll T, Scholl J. Strategies to reduce interruptions from mobile communication systems in
surgical wards. J Telemed Telecare. 2008;14(7):389-392.

Stanton NA, Salmon PM, Walker GH, Baber C, Jenkins DP. Human factors methods: A
practical guide for engineering and design. Hampshire (ENG): Ashgate Publishing;
2005. p. 365-429.

Sundstrom E, DeMeuse K, Futrell D. Work teams: Applications and effectiveness. Am
Psychologist. 1990;45(2):120-133.

Voalte Screenshot. Voalte; 2013 Dec. Available from: http://www.voalte.com.

Vocera Communication Badge. Vocera; 2013 Dec. Available from: http://www.vocera.com.

Westbrook JI, Coiera E, Dunsmuir WTM, Brown BM, Kelk N, Paoloni R, Tran C. The
impact of interruptions on clinical task completion. Qual Saf Health Care.
2010;19;284-289.

Wildman JL, Thayer AL, Pavlas D, Salas E, Stewart JE, Howse WR. Team knowledge
    research: Emerging trends and critical needs. Hum Factors. 2012;54(*1*):84-111.

Won JC, Hannon DJ. Influence of resource allocation on teamwork and team performance
    within self-organizing teams. HFES. 2013;57:270-274.

Wright A, Sittig DF, Ash JS, Erickson JL, Hickman TT, Paterno M, Gebhardt E, McMullen
    C, Tsurikova R, Dixon BE, Fraser G, Simonaitis L, Sonnenberg FA, Middleton B.
    Lessons learned from implementing service-oriented clinical decision support at four
    sites: A qualitative study. International Journal of Medical Informatics.
    2015;84(11):901-911.

Yang M. A multi-faceted model of the consequences of sample size choice in usability
    testing. PhD (dissertation). Houston (TX): Rice University; 2008.

Zaccaro SJ, Heinen B, Shuffler M. Team leadership and team effectiveness. In: Salas E,
    Goodwin GF, Burke CS, editors. Team effectiveness in complex organizations:
    Cross-disciplinary perspectives and approaches. New York (NY): Taylor-Francis
    Group; 2009. p. 83-111.

Zavotsky KE, McCoy JV, Royal S, Sackett K, Tamburri LM, Joiner JM, Ohman-Strickland
    PA. High fidelity simulation improves provider confidence during ACLS training
    even among experienced staff: Are we missing an opportunity? Emerg Med Open J.
    2016;2(1):5-10.

Zellmer-Bruhn ME. Interruptive events and team knowledge acquisition. Manag Science.
    2003;49(4):514-528.

Zhang J, Butler K. UFuRT: A work-centered framework and process for design and
    evaluation of information systems. HCI Int Proc. 2007.

Zhang J, Norman DA. Representations in distributed cognitive tasks. Cogn Sci. 1994;18:87–122.

Zhang J, Patel VL, Johnson KA, Malin J, Smith JW. Designing human-centered distributed information systems. IEEE Intelligent Syst. 2002;17:42–47.

Zhang J, Patel VL. Distributed cognition, representation, and affordance. Cognition and Pragmatics. 2006;14:333–341.

Zhang J, Walji M. TURF: Toward a Unified Framework of EHR Usability. J Biomed Inform. 2011;44(*6*):1056-67.