Design and Evaluation of an Improved Patient Information Management System for Emergency Department Physicians

By

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Abstract

Designing a software interface for healthcare requires thorough domain knowledge, and effective user research and benchmark analysis. This thesis examines the requirements for an improved patient information management system for emergency medicine and describes the iterative process of designing and evaluating the system. I conducted observational study of Emergency Department (ED) physicians’ workflow and information needs, from which I derived a set of functional requirements, created scenarios, performed hierarchical task analysis, and developed a preliminary user model for the patient information management system. Based on these, I developed an interface prototype and evaluated the design with a sample of ED physicians. I review the user testing and design iterations carried out and report on the design improvements made based on the user feedback.
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1. Introduction

Healthcare has lagged in information technology (IT) adoption, despite an urgent need to improve processes and outcomes. Surprisingly, a vast majority of physicians’ work is still carried out manually as of this writing. In Canada, efforts being made at federal and provincial levels to deploy Electronic Health Records (EHRs); however, the use of EHRs is in its infancy and is facing a number of challenges. Why is the adoption of IT so sluggish in healthcare and how is patient information managed at hospitals currently? At the outset of this research I conducted a literature review to answer these questions.

Physicians’ work is unlike that of workers in other domains, such as finance, because information is physically located in different places and the processing of information occurs internally at each location, often with different procedures and formats. A review of prior research reveals other unique characteristics of clinical work that affect the design of information systems. I consider these characteristics of clinical work and the impact of existing IT solutions in healthcare to demonstrate the need for an improved understanding of healthcare users and the development of smarter information systems.

In this research I focus on the use of technology in emergency medicine, an environment where the critical, real-time characteristics of healthcare are amplified. In a time-critical and productivity-driven environment such as the emergency department (ED), physicians are quick to dismiss technological solutions if their benefits are not immediately apparent. Therefore, new systems and interfaces need to be implemented with care so as to help rather than hinder physician’s work.

Designing an effective software interface requires consideration of the users’ environment, tasks, needs, abilities and limitations. In healthcare, the effectiveness of the user interface affects not only users’ productivity but also patients’ well being. In the research reported below I adopt a user-centered design process, with heavy focus on upfront user research and iterative user feedback, in order to propose an improved way for physicians to retrieve, record, communicate, and manage patient information.
In Chapter 2, I explore the nature of physicians’ work and the state of current IT in healthcare, particularly emergency medicine, through a review of relevant literature. Chapter 3 introduces the qualitative user research techniques used to gather requirements for the design process. The results from requirements gathering are also presented and discussed. In identifying the requirements there was a particular emphasis on how physicians currently manage their tasks and patients in the ED, and on how existing information systems are used to assist in the process. In Chapter 4, the requirements from Chapter 3 are transformed into visual user interface designs for a proposed system. Chapter 4 describes the problem-solving and design process, including sketching and wireframing. Chapter 5 describes the methodology used to evaluate the design solution with a sample of users and summarizes the findings from that evaluation. Concrete design changes are recommended based on those finding, and are then applied to the prototype. Chapter 6 summarizes the contributions made in this research, discusses future extensions of the work, and considers potential limitations of the current research.
2. Literature Review

This chapter presents a review of preceding research on information management systems in healthcare.

Information management in healthcare requires considerable amount of collaboration, mobility, and data integration (Muñoz et al., 2003), and existing systems provide inadequate support. It is argued that electronic patient information systems can minimize information gaps and improve the process and outcomes of patient care (Stiell et al., 2003). In this review I investigate the need for an improved information system by exploring the characteristics of healthcare work, examining the state of existing systems, clinicians’ perception of them, and their impediments. The review also covers human factors methodologies that have been used to design and evaluate clinical systems.

2.1. Characteristics of Work in Emergency Medicine

Clinical work in the ED exhibits many characteristics that make deployment of technology challenging, yet highly beneficial. Some of the main characteristics of the clinical environment relevant to the design of associated information systems include:

- **Non-routine**: Emergencies, exceptions, and interruptions occur frequently in hospitals, which makes pre-scheduling of activities difficult (Xiao, 2005). In an ED, patient volume, conditions, and arrival times vary greatly day to day, and the physicians are required to adapt to the situation. In addition, physicians’ tasks are frequently interrupted by patients and other clinicians; one study found that attending physicians and residents were interrupted on average every 9 and 14 min, respectively (Laxmisan et al., 2007).
- **Mobile**: Physicians are constantly moving between patients, medical facilities, and other clinicians in order to gather or report information. Physicians’ work is highly mobile, because “information is located where it is most used (Bardram & Bossen, 2002).” This demonstrates the need for accessing critical, time-sensitive information where they are needed most.
• **Driven by Context**: Physicians are frequently switching from one patient to another, one device to another (Muñoz et al., 2003), and one information system to another. As a result, their activities are constantly paused and resumed, which requires constant readjustment and processing of contextual information. Factors that affect users’ assimilation and interpretation of patient information need to be presented in the interface (Tang & Patel, 1994). Context is critical to information output as well as input; it needs to be clearly indicated in both information display screens as well as data input screens.

• **Highly Collaborative**: Caring for one patient often involves multiple caregivers, for example, cardiologist, radiologist, emergency physician, lab technicians, and nurses can be involved in treating a patient with chest pain. There is a clear need for information to be communicated effectively between clinicians in different roles, shifts, and locations (Bardram & Bossen, 2005, Bossen, 2002). This requires highly collaborative effort (Muñoz et al., 2003), which needs to be supported, if not enhanced, by technology.

• **Multi-tasking**: Each clinician provides care for multiple patients in parallel. Physicians tend to keep track of each patient’s condition, progress, and location in their head. A workflow analysis by Laxmisan et al. (2007) showed that multitasking and shift changes cause gaps in information flow and increased physicians’ cognitive load, which can contribute to medical errors and compromise patient safety.

• **Time-critical**: Muñoz et al. (2003) highlight the time-sensitive nature of healthcare work by noting that a clinical message may only be relevant for a certain period of time. This time-sensitive nature of physicians’ work adds to the complexity of communication between clinicians. In addition, there is often a need to complete certain tasks in a temporal sequence to process patients through the flow; in other words, tasks often need to be performed in certain order.

• **Information Rich**: Physicians’ work is information intensive, where much time is spent looking for, or processing data. Physicians are faced with a constant need to interpret rich data, as they deal with heavy information loads of various kinds (e.g. text, graphs, images) that change with time. For example, in order to diagnose a patient with abdominal pain, physicians are required to process data such as blood test results, sonogram results, and medical history. In addition, physicians’ individual internal knowledge from previous experience often influences the decision making process.
Since physicians are used to dealing with large volumes of data, they prefer viewing information on a single page, rather than paging or scrolling for more information (Tang & Patel, 1994). Thus organizing the interface so as to help physicians assimilate and interpret data is particularly important.

The research discussed in subsequent chapters addresses the challenges these characteristics pose for the tasks of storing, managing, and exchanging of patient information.

2.2. IT Adoption in Healthcare

Information management is fundamental to health care delivery (Chassin & Galvin, 1998). In recent years, the federal and provincial governments are taking initiative to develop interoperable electronic health records (EHRs). A study of Canadian general and acute care hospitals reports that 54% of them have adopted the use of EHRs, although they are in the early stages of transition and still largely use paper-based records (Urowitz et al., 2008). Despite these efforts Canada is still falling behind other industrialized countries in regards to EHR adoption (Protti, 2006, Jha et al., 2008).

2.2.1 Cost and Benefit of IT Adoption in Healthcare

The slow adoption of IT in healthcare can be attributed to the lack of generalizable evidence of the benefits of IT adoption. Although the adoption of EHRs is expected to improve the overall care delivery process and health outcomes (Leonard & Sittig, 2007), many studies have shown conflicting results with respect to the benefits of IT adoption.

A recent study compared the IT adoption and discharge rate between hospitals and reported that hospitals with greater numbers of IT applications were significantly more likely to have desirable quality outcomes (Menachemi et al., 2008). Another review reported that benefits such as increased adherence to guideline-based care, enhanced surveillance and monitoring, and decreased medication errors were observed with the implementation of EHRs (Chaudry et al. 2006). However, it is unclear whether these benefits of IT can be generalized. In addition, measuring the effect of IT in terms of cost, time, and health benefits remains a challenge, as few studies include data on costs, organizational context, process change, and implementation (Shekelle et al., 2006). Some argue that EHRs cause increased cost and reduced productivity,
with no change in clinician-to-patient ratio, and inconsistent error reduction (Sidorov, 2006). The following sections discuss clinicians’ perception of IT in healthcare and the shortcomings of the current systems, to understand why IT often fails to deliver positive outcome despite its projected benefits.

2.2.2 Clinicians’ Perception of IT Adoption in Healthcare

While there are various potential measures of success of the impact of IT in healthcare, I will focus on the perception of clinicians as users of healthcare systems. Physicians have been slow to adopt new technology and are resistant to use anything that fails to enhance their workflow (Lowenhaupt, 2004). Through a systematic review, Ward et al. (2008) found that the attitudes of healthcare professionals can influence the acceptance and efficiency of IT in healthcare practice. Factors that affect their attitudes include education and training, technological infrastructure development, policy changes, as well as usability of the systems.

Further findings by Ward et al. were that due to poor content design and lack of integration, some clinicians saw implementation of systems as a policy requirement rather than an initiative to improve patient care. In addition, clinicians were concerned about inconvenient access to computers, reduced work efficiency, and inability to individualize patient care. From these findings, it can be argued that design improvements and system integration would improve clinicians’ perception towards IT adoption and ease the transition to new systems.

Simon et al. (2007) surveyed physicians about their use of electronic health records (EHRs) and their perceptions in a study in Massachusetts. It concluded that there is considerable variability in the functions available in EHRs and in the extent to which physicians use them. Interestingly, physicians who reported having “full electronic medical record” also indicated that they do not maintain clinical notes or file test orders via their systems, suggesting that they overlook some of the features and do not use those systems to their full capabilities. Steven et al. (2007) also found that functionalities included in EHRs, and physicians’ use of these functionalities, vary widely. Perhaps this is caused by physicians’ failure to recognize the value of unfamiliar features. In addition, the pressure of patient care does not afford them the time to learn how to use new features. Design improvements may lessen the learning curve and help physicians optimize their use of the systems.
2.3. Weakness of Current Healthcare Information Systems

The previous section introduced reasons for the low technology adoption rate in Canada. In this section, we investigate the impediments of existing systems from a human factors perspective. Many of the problems with the current Internet identified by Ng, Chignell, & Cordy (2009) are also observed with respect to healthcare information systems (HISs).

2.3.1 Heterogeneous Information Formats

In healthcare, information is recorded in heterogeneous formats, predominantly using paper or electronic systems. The following excerpt underlines this issue:

*Documentation may occur in a paper and/or electronic chart; orders may be written or electronically entered; requisition forms are paper based or electronic; most referrals are handwritten and faxed to the next office for review; prescriptions may be hand written or electronically generated, and are then transmitted by hand or fax (Sieminowski, 2010b)*.

Since information is documented in varying formats, information retrieval becomes challenging and time-consuming. The physician is unsure of where the required information may be found. To overcome this challenge, some systems scan and store the paper-based patient charts electronically. However, Sujansky (1998) argued that capturing information directly using a computer would be more beneficial than scanning paper-based records. If clinical notes, orders, prescriptions, discharge summaries are typed into the system by clinicians, the information is then available immediately and is searchable. Another study (Dale & Hagen, 2007) compared patient data collection using PDAs versus pen and paper and concluded that the PDA method outperformed the pen and paper method, despite technical difficulties encountered in the study. The studies noted above illustrate the advantages of computer-based systems for patient data collection and advocate digitally consolidating patient data. However, there are challenges facing the implementation of those systems in a clinical setting, particularly with respect to the problem of data input.
2.3.2 Lack of System Integration

Implementation of electronic systems does not necessarily allow patient information to be accessed from one place. Currently patient information is stored in a number of disparate systems, requiring physicians to continually shift resources and applications in order to retrieve desired information. It is important to overcome this “fragmentation of information” by integrating systems to provide more complete and correct data for physicians, so that they can make more informed decisions (Stead et al., 2007). A study by Cordell et al. (1998) identified the integration of information systems as one of four major strategies for modernizing emergency medicine, along with centralized knowledge resources, sophisticated databases, and an improved infrastructure.

Cook & Woods (1994) explains that, when physicians constantly reallocate their attention and mentally integrate data from disparate sources, they may not form a “complete and coherent mental picture of the current state of the system”. Sieminowski (2010b) also notes that there is a need for electronic services supporting “integration and management of information across an entire practice,” including patient history, lab and radiology results, and medication. For such patient-centric records to be successful, the service needs to be user-specific and flexible.

2.3.3 Poor User Interfaces

Lack of good user interfaces has been a major impediment to the acceptance and routine use of computerized information management in healthcare (Tang & Patel, 1994). Previous studies have found that failing to meet user needs in healthcare can lead to wasted time, poor quality of care, and medical errors.

Use of poorly designed systems causes increased errors in order entry and documentation, leading to problems such as assigning orders to the wrong patient and medication mix-ups (Ash et al. 2004). Another study linked usability problems with resulting medical error in the use of a medication prescription system (Kushniruk et al. 2004). Obradovich & Woods (1996) concluded that poor understanding of user needs and system-user interaction in healthcare may have caused increased clinical errors, even though IT has the potential to reduce human errors, streamline workflows, and increase productivity.
2.3.4 Lack of Context Awareness

Context has been defined as the physical and social situation in which a system and its users coexist (Harter et al., 2002). Context-aware systems acquire information about this context and provide appropriate support to a particular context of use. A study by Muñoz et al. (2003) proposed that, for information management and communication to be properly supported in a hospital setting, the following critical contextual elements need to be considered: location of the user, information delivery timing, user roles and responsibilities, and artifact (e.g. devices, patient charts, lab results) location and state. Wachter et al. (2003) posited that contextual information display consistent with user preferences and mental model can lead to improved clinical performance and reduced cognitive load.

2.3.5 Lack of Notifications

As noted earlier, healthcare work is mobile and non-routine. Events such as arrival and scheduling of patients, test results, and adverse events occur frequently, but unpredictably. This generates a need for delivery of critical information to the appropriate person at the appropriate time. Currently these messages tend to be handled on an ad-hoc basis, largely through personal communication and paging. Leape (1995) reports that a lack of relevant information at the point of care is a large cause of medical errors, hence providing appropriate information is important for patient safety and clinical performance.

Researchers (e.g., Kafeza et al., 2004 and Lu et al., 2005) have proposed alert management systems that route messages to an appropriate clinician and appropriate device based on clinical requirements and contexts. They conclude that when up-to-date information is provided to the clinician via handheld applications, it can help clinicians make better-informed clinical decisions at the point of care. In addition, providing intelligent alerts and notifications has the potential to reduce physicians’ cognitive load (Muñoz, 2003).

2.4. Usability Engineering for Clinical User Interfaces

IT has great potential to improve quality and efficiency of healthcare practice. Clinicians’ perceptions on existing IT use discussed in the previous sections imply that some requirements are currently unmet with current systems. To evaluate the effectiveness of IT applications, we need suitable metrics for gauging users’ experience, cognitive process, and satisfaction. We
explore the methodologies that have been used in clinical user interface design to learn about user needs prior to design, evaluate the design with users, and improve the design iteratively.

2.4.1 User Research Methodologies
Implementation of past information systems has typically involved direct transfer of paper-based tasks into the electronic format. This type of design tends to be suboptimal because it fails to take into account the properties and capabilities of electronic interfaces, typically leading to a succession of screens of data and forms to be filled in. Simply analyzing tasks and creating a similar electronic workflow is not enough (Tang & Patel, 1994). User needs for appropriate interaction also need to be considered. The assessment of user needs is a key step in designing and developing a system that meets users’ information requirements. Fafchamps et al. (1992) advocated naturalistic and unobtrusive data collection methods to observe users as they perform routine activities in their natural work environment. They analyzed transcripts of ethnographic observation to develop an understanding of physicians’ clinical information-gathering and decision-making processes. In addition, physicians’ high-level goals were identified, which helped define the physician’s workstation functionality.

2.4.2 Evaluation Methodologies
Usability is an increasingly important aspect when gauging clinicians’ reaction towards information systems and ultimately making purchasing decisions at hospitals. Consequently, there is a pressing need for appropriate usability evaluation methods.

In the frequently used method of iterative design, prototypes are developed and then evaluated by participants who are representative of the target users for the system (Nielsen, 1993b). Nielsen (1994) and Virizi (1992) conclude that 80% of the usability flaws can be identified even with only a modest number of subjects. Data gathered from this type of study can be analyzed to derive design recommendations for changes to improve the interface. Once the changes have been applied to the interface, another set of testing can be conducted with a new set of clinicians to assess the effect of the changes. Getting user test participants to think aloud while performing users tests can help inform and explain the usability problems encountered in user tests. An early example of the use of this approach in healthcare information systems was a study by Patel & Kushniruk (1998), who asked representative users to interact with the proposed system and to verbalize their thoughts while being observed in a laboratory setting.
Another example of a healthcare usability evaluation study by Liljegren & Osvalder (2004) examined the use of various cognitive engineering methods, namely usability questionnaires, cognitive walkthroughs, and usability testing, to evaluate the usability of patient monitoring systems. Usability questionnaires ask the participants to quantify their feedback on the system using rating scales on criteria such as “presentation of information” and “difficulty of tasks”. Usability questionnaires are inexpensive, can be completed at the participating clinicians’ convenience, and are useful for quantifying users’ opinions; however, the data collected is highly subjective. Cognitive walkthrough is a task-focused method of evaluation, where tasks are identified using hierarchical task analysis in cooperation with clinicians. This method requires more expertise and time to carry out than a questionnaire. Usability testing typically begins with a background questionnaire and is used to identify usability flaws in the system. Both objective and subjective data can be gathered and analyzed using this method; however, due to the high volume of data, the analysis of data can be extensive and tedious.

2.4.3 Interface Design Methodologies
User feedback gathered through the aforementioned evaluation methodologies may be used to recommend design improvements. Nielsen (1993a) suggests that this cycle needs to be iterated at least three times to achieve substantial usability improvements. Quantifying the usability improvements based on user feedback revealed that the first few iterations lead to the greatest improvements as major usability flaws get discovered and removed. Bardram (2004) used an iterative design process based on scenarios to develop design principles for a context-aware medical application. Another study (Wacheter et al, 2003) reported that frequent and inexpensive design iteration improved the overall intuitiveness of the system considerably. With each iteration, paper prototypes were developed rapidly and tested with a minimal number of subjects.

2.5. Summary
Patient care requires complex information processing, for which proper IT support is essential. However, the literature review reveals that hospitals have been sluggish in adopting IT, and that clinicians have been resistant to using technology. This can be attributed to shortcomings of
existing systems, such as heterogeneous information formats, lack of system integration, poor user interfaces, lack of context awareness, and lack of notifications. The need for improved IT solutions with flexible and intuitive user interface is evident.

This chapter reviewed a number of usability engineering methodologies used in healthcare. In the research described in the following chapters, user data are collected using ethnographic observation, and user’s goals and needs are identified using hierarchical task analysis. The review also identified previous research that used iterative design with usability testing as a method of evaluation of healthcare applications. These methods will also be employed to design and evaluate the prototype in the research discussed below.
This chapter begins by introducing the methodology used to collect user data and the findings. The requirements analysis that was carried out is then discussed, and the chapter concludes with scenario development based on the requirements identified.

3.1. Methodology

In order to generate a comprehensive set of information requirements from the user’s perspective, we adopted an empirical design methodology introduced by Kirwan & Ainsworth (1992), where the design is based on observation of users. We began by studying the contexts of use through a series of unstructured interviews and observational studies. Qualitative data on the ED physicians’ day-to-day tasks, workflow, management of patient information, and pain points were collected. Figure 3.1 illustrates the design process that was followed (this process was abstracted from empirical and participatory design methodologies that have been widely used in the literature).

![The design process](image)
3.1.1 Unstructured Interviews

Unstructured interviews were conducted with 6 ED physicians from 4 hospitals in Ontario. Since the goal of the interviews was to gain a general understanding of their work in the ED and the use of technology, an open-ended and loosely structured interview format was chosen. The interviews were exploratory, with several questions to guide the conversation through the topics of interest. This allowed the participants to delve deeper into topics that were of strong interest, such as workflow, use of information systems, and communication.

Though unstructured, the following topics were covered in each interview for consistency:

- Typical day at work
- Patient prioritization and management
- Workflow
- Use of information systems
- Communication
- Interruptions
- Clinical decision making

Questions were selected from Appendix A as the moderator saw fit. Each session took place in a meeting room at the participant’s hospital and lasted about an hour. The interview notes were typed up on a laptop, because it was fast, easy, and less obtrusive than a tape recorder. Analysis of the interview data informed the researchers of the types of information management and communication problems they would later witness in the observational study.

3.1.2 Observational Study – Contextual Inquiries

Direct observation was carried out with two of the interviewees to fill the gaps in the interview data. A fellow lab member, Ryan Kealey, and I observed two ED physicians, an attending physician and a resident, at the ED at Sunnybrook Health Sciences Centre. Observing the physicians in their natural work environment while they performed their day-to-day tasks gave us insight into their tasks and environment that they neglected to describe during the interviews. We particularly focused on the use of information and communication technology and the pain points experienced in order to find opportunities for improvement. Due to the qualitative nature
of the study, the sample size was not chosen to ensure statistical significance, but rather to garner appropriate feedback and accommodate the participants' availability.

The physicians were each contacted individually to schedule a shadowing session. The study objectives and methods were explained to them and any questions and concerns were addressed. Each physician was shadowed for 2 shifts and each session lasted for approximately six hours. The first shift was in the Blue zone of Sunnybrook Hospital’s ED, where patients in critical conditions with CTAS scores of 2 or 3 are treated. The second shift was in Purple zone, where non-critical patients with CTAS scores of 4 or 5 are treated.

Different levels of physicians, including medical interns, a chief resident, and an attending physician, were present at the first observation session in the Blue zone. In addition, nurses, administrative clerk, janitorial staff, residents from other services, and paramedics were also present, allowing the researchers to observe the physicians’ interactions with other members of the team. The interactions between the main actor (an attending physician) and the other actors were observed and noted.

As mentioned earlier, two observers were on site at a time and took copious notes on what the physicians being observed were doing, whom they were interacting with, and what their comments and expressions were. Consistent with the requirements of the research ethics protocol, no personally identifiable patient data were recorded. The observers were debriefed within 24 hours of each shadowing session to review and digitize the handwritten notes to ensure minimum loss of data.

During the shadowing session the participants were occasionally asked probe questions on what they were doing, how, and why, to clarify the logic behind their activities and to understand the context of those activities. In response, the participants explained what types of patient information were gathered, how the information was managed and communicated to other clinicians, how and in what sequence their tasks were performed, and what the pain points were.
3.2. Qualitative Data Analysis

The raw data collected from the interviews and observations were categorized into key areas of focus. Among the wide variety of issues observed, we focused on issues pertaining to management and communication of patient information. The categorized data were used to identify users’ needs and establish requirements for solution development. Analyzing qualitative data proved to be a subjective process but yielded valuable requirements for prototype development, particularly with regards to information architecture. Ryan Kealey and I collaborated to interpret and analyze the observational data.

Affinity diagramming technique was used to aggregate, synthesize, and categorize the data into a format consumable in the design process. Raw notes taken during the observation and interviews were first interpreted and transcribed. Observed activities related to information management and communication were identified as use cases and written down on sticky notes; subsequently each sticky note containing a use case was placed into a category. Through this process, the following categories were identified as common patterns across the data: Managing Patients, Documenting Patient Information, Obtaining Patient Information, Communicating Patient Information, and Notification. Figure 3.2 depicts the affinity diagram.
3.3. Requirement Analysis

The following sections discuss the current state and barriers observed. Based on the analysis of the current state, requirements for the proposed system are enumerated.

3.3.1 Managing Patients

The interviews revealed how an incoming patient is processed through the ED and what types of information are delivered in and out of the current information systems as summarized in Figure 3.3. A mix of paper-based and electronic systems is used throughout the process.

The overall patient and bed management in the ED is overseen by the nurses. Upon arrival, a triage nurse assesses the patient to determine the severity of their conditions. At this time, a
Canadian Triage & Acuity Scale (CTAS) score from 1 (most serious) to 5 (least serious) is given to the patient. Based on the CTAS score, the patient is assigned to a minor or major area of the ED. The triage nurse starts a patient chart and documents the score, chief complaints, medication, medical history, as well as basic demographic profile such as date of birth and gender. A physical paper rack is used to organize these patient charts for the physicians. In addition to the paper charts, the nurse uses an electronic whiteboard to keep track of which patients are waiting for beds and which patients have been assigned to beds. Once a patient is assigned to a bed, a nurse in the assigned zone reassesses the patient, takes vital signs, and orders blood work and ECG as needed.
Individual physicians, on the other hand, are less concerned about the overall flow of patients in the department and are more focused on managing patients that have been assigned to them. Typically a physician manages about 8–15 patients at a time in the order determined by the nurses. The physician starts working on a patient by reviewing information collected by the nurses in the electronic system as well as on paper charts. Then the physician visits the patient to interview him and perform physical examination. Patients are typically prioritized in the order they were seen, but factors such as availability of test results and critical changes in patient conditions override this priority. Therefore, when prioritizing patients the following questions may arise: How long have they spent in the ED? Are the lab and diagnostic imaging results back for diagnostic decision making? Figure 3.3 depicts the general flow of information between the ED clinicians and the information systems throughout this process.

Problems:

The Emergency Room Pay-for-Results program is an incentive plan to improve wait time in the EDs in Ontario (Farrell et al., 2008). The provincial government recognizes and rewards EDs that are reducing patients’ length of stay and improving patient flow (Erwin & Morrison, 2009). CTAS guidelines (Punia, 2010) suggest that patients with CTAS score of 1 and 2 should be processed through the ED within 8 hours, CTAS of 3 within 6 hours, CTAS of 4 and 5 within 8 hours. The number of patients processed within this benchmark serves as a measure of individual physicians’ performance and the departments’ throughput, which then determines government funding the department receives.

The participants noted that this guideline is only loosely enforced using checkboxes on paper-based patient charts if at all. Current systems provide no support for tracking the time elapsed for each patient; entry time, consultation times, departure time and length of stay are recorded manually or not at all. Moreover, little support is available for determining the status of each patient and their position in the physician’s queue. Physicians, unable to keep track of each patient’s time of arrival, often neglect to process patients within the benchmarked target.

As mentioned above, each physician may be treating 8-15 patients at a time, each of whom requires different frequencies of different tests and medications. This is often cumbersome to document electronically as they happen, because typing this information into the system is seen
as redundant and unproductive. Physicians keep most of this information in their head and use
the electronic whiteboard and the paper charts as a guide.

Requirements:

The following requirements were derived from these observations.

- Provide a clear indication of how long it has been since each patient was presented to the
  ED.
- Provide a visual representation of where each patient is in the process. For each patient,
  indicate which tests are ordered and when, which tests are reported, and which contain
  critical results.
- Record ambient information such as time and location automatically.

3.3.2 Documenting Patient Information

Sieminowski (2010a) observed that patient charts typically contain the following information:

- narrative
- chief complaint
- history of present illness
- physical examination
- lab results, e.g. electrolytes, etc.
- past medical history pulled from old chart
- medications
- summary of imaging, e.g. chest x ray
- summary of the physician’s thoughts on diagnoses and treatment plans.

Our physicians documented patient information on paper charts over the course of their shifts.
When asked about capturing data on paper, the physicians explained that it was the easiest and
quickest way to offload information. They enumerated the following advantages of using paper
and pen compared to electronic forms:

- Portable: It allows physicians to transcribe data spontaneously while walking or
  interacting with patients.
• Inexpensive: It requires little infrastructure and training. Pens and paper are readily available.
• Reliable: It never crashes or goes down as a computer system would at times.
• Flexible: It allows for the flexibility to add to existing patient charts and share information with nurses and consultants. Furthermore, it saves the hassle of logging in.

On the other hand, capturing data on paper exhibited the following disadvantages:

• Non-searchable: Retrieval of required information was time-consuming and often impossible, unless the physician knew exactly what to look for and where to find it.
• Illegible, misplaced: The paper charts are often misplaced and are prone to illegibility and error, which lead to wasted time.

Problems:

Patient data recorded on paper were rarely digitized. Our physicians perceived typing up reports as tedious, redundant, and time-consuming, and were doubtful that technology such as tablet PCs or other touch screen devices could fully replace paper, due to their potential negative impact on productivity and hygiene, in addition to the cost. Since designing an input device is out of scope for this project, the proposed system is designed to improve support for inputting the types of information that are currently routinely digitized.

Requirements:

From these observations, the following requirement was derived:

• Assist data input on the computer workstation.
• Reduce steps required to record data into the information system.

3.3.3 Obtaining Patient Information

Sometimes information is pushed to physicians via face-to-face conversations, pages, and phone calls, whereas in other instances physicians actively seek and retrieve information.

• Information push via interruptions and notifications: Physicians experience constant interruptions, each of which contain some information about a patient and require a decision to select a task to attend to next. Examples of interruptions include pages, phone
calls, consult requests, patients demanding prompt care, nurses with updates on patient status, arrival of sicker patients, and test results. Information received through these interruptions is often not recorded anywhere and carried in the physician’s head. This causes a burden on the physicians’ working memory and a risk of information loss.

- **Information pull from information system:** As discussed in the previous section, the patient data was commonly kept both in paper and electronic formats. As mentioned in the Literature Review, the heterogeneity of information collected and storage formats used is one of the main challenges in today’s healthcare system. One of the physicians that I observed reported that often it is easier and quicker to find information from paper charts than from an electronic system. The physicians in my study were sampled from 4 different EDs with varying degrees of IT adoption. All 4 EDs used some form of electronic whiteboard, with an overview of patient conditions and statuses. Other commonly used systems include: Electronic Medical Records system for storing patient’s medical history and lab results, diagnostic image viewer, and clinical reference resources.

**Problems:**

Due to the lack of linkage between the information systems, physicians are required to log into multiple systems to gather information on one patient. This causes increased mental workload; not only are physicians required to remember the login credentials for each system, they have to remember the patient of interest and locate his record in each system. Many physicians complained that the distribution of information caused considerable increase in their time spent at the workstations and away from the patients. Figure 3.4 shows two different workstations that were used to access two different information systems.

Moreover, the physicians reported that the existing systems are very slow, difficult to navigate, involve a steep learning curve, and require too many steps and clicks to complete common tasks. Information stored in the systems was often incomplete, which made accessing required information cumbersome and often impossible.
To cope with these issues, each physician developed personal preferences and workarounds. For example, the EDIS system at Sunnybrook lacks personalized support and displays a list of all patients in the ED by default for all users, instead of displaying only the current user’s patients. Consequently, our physicians learned to sort the list by the EP column (responsible physician’s name) and scroll to their name to see the list of patients under their care. This demonstrates the need for a system that is tailored to their individual needs and personalized clinical workflow.

Another issue we observed involves the performance of the systems in terms of speed. For example, hospitals provide comprehensive in-house reference material, both in electronic and physical formats; however, they were rarely used because they were cumbersome and slow. I observed that the physicians frequently bringing up Google in the web browser to find recent publication or photos of the patient condition in discussion. They found Google to be much faster and easier to use than the reference database.
Requirements:

Based on these observations, the following requirements were derived.

- Provide single sign-on to access data from multiple systems throughout a shift.
- Provide a central patient record for each patient, where aggregated information from multiple systems is displayed in a coherent fashion. All information about one patient should be visible on one screen or easily accessible from the screen.
- Tasks identified as “common” should not require complicated steps. Common tasks include:
  - Finding a patient record
  - Ordering a lab test or a diagnostic imaging (radiology) test
  - Checking lab or diagnostic imaging results
  - Finding specific information about a patient (i.e. medication)
- Provide reliable contextual support, for instance, external links to up-to-date and problem-specific references or guidelines regarding treatments, investigation, and drug interactions. For example, when a physician is viewing a diabetic patient’s record, links to relevant recent research on diabetes, and to similar patient records, should be displayed.
- Ensure that Search is readily available at all times and robust.
- Organize interfaces consistently to ensure that information is easy to find.

3.3.4 Communicating Patient Information

In an acute care unit, such as the ED at Sunnybrook, one patient can be taken care of by a number of clinicians including attending physician, medical student, senior resident, radiologist, registered nurse, elective student, and consulting services. Therefore, there is a constant need for efficient communication. Communication from physicians to nurses and specialists is usually done in writing by way of orders. Placing an order for a lab test involves the following steps:

- Determining the type of test that needs to be ordered
- Filling out an order form for the particular type of test,
- Placing the form in a physical order box, and
- Verbally reminding the responsible nurse about the order.
These forms were collected in a physical order box, such as ones depicted in Figure 3.5, and processed by nurses. The following statement captures the state of current lab test ordering process:

_We have different processes for ordering different tests. I have to remember what the process is and who to speak to depending on the time of day. It would be nice if it told me it's before 4, so you need to speak to X (Dr. Jacques Lee, personal communication, Dec. 4, 2009)._  

Requesting a consult to another service or specialist involved the following steps:

- Determining what the process is for that particular type of consult,
- Finding out who is on shift,
- Finding the contact information,
- Paging the specialist through either the hospital switchboard or the online paging system,
- Leaving a message summarizing the case, and
- Waiting for a call back.

These processes are time consuming to complete and cognitively burdensome to keep in memory.

The physicians identified the following tests as being very common in the ED setting:

- Electrocardiogram (ECG)
- Blood tests
  - Hematology
  - Electrolytes
- Urinalysis
- Diagnostic imaging
  - X-ray
  - CT
  - Ultrasound
Problems:

In addition to placing the written forms in order boxes, the physicians verbally communicated the intent of the orders to the nurses to confirm the order and prevent errors. The physicians emphasized the importance of this verbal dialog; lack of it often caused communication slowdown or breakdown. For instance, if the physician forgot to verbally remind the nurse about an order or if the nurse forgot to check the box, the order would get missed. In addition, the nurses have little awareness of the physicians’ other priorities, hence they are unable to provide needed information in a timely manner and filter relevant information from the irrelevant.

In terms of requesting consultation, sometimes it is difficult to reach specialists when, for example, they are in an operating room. The current system lacks contextual information around the user, such as staff schedule, their location, and time of day. Due to the nature of their role, it is difficult for communication with specialists to be synchronous.
Requirements:

The following requirements were derived:

- Allow users to communicate specific details about a patient through means of contextual annotation.
- Facilitate timely order entry and confirmation.
- Store and use information about the clinicians’ shift schedule.

3.3.5 Getting Notified about Updates

Time-sensitive information, such as sudden deterioration of patient condition and arrival of a new patient in critical condition, was typically delivered by a nurse in person or through a page; however, physicians had little ability to control how notifications on new test results are received, how the user sees the list of patients under their care, and what device is used to request consultation. The system needs to allow users to specify how, when, for what, and in what contexts they want to be notified. Different physicians may have different user preferences and levels of control; furthermore, a particular physician's preferences may vary depending on the situation.

The Emergency Department Information System (EDIS) at Sunnybrook uses indicators for new lab or radiology results; however, these are of little help, because the system is unaware of who the current user is and is unable to suggest whether or not the new information is actually ‘new’ to the user. The following overview indicates how each system used at Sunnybrook notifies the physicians of updated information.

- EDIS: In the Tracking screen, there are columns labeled Rad (for radiology) and Lab. A red box in either of these columns indicate a new test result, yellow indicates a relatively new result that became available 10 min ago, and green means stale. This colour-coding scheme is only dependent on time, does not indicate whether the information has been seen by the user, and does not signify any details of the results. Moreover, the flags are not linked to the test results. For example, newly available CT scans were flagged in the EDIS at Sunnybrook, but no other information was provided until the physician logged into IMPAX and searched for the patient.
• In Oacis, the physician needs to check the column called “time elapsed”, where bold indicates new and unopened, red in this case indicates abnormal results.

• In IMPACS, preliminary reports (not yet reviewed by a senior radiologist) done overnight are collected. IMPACS is not connected with EDIS, and these preliminary reports do not get flagged in the RAD column on the Tracking Screen, requiring the physicians to separately log into IMPACS continually and search for them.

Feedback from our physicians suggests that deployment of mobile notifications is desired. The proposed system should use its knowledge of the users, their schedules, patients under their care, and their progress to provide timely and intelligent notifications to the user.

**Problems:**

With most processes there is no notification mechanism to notify physicians of newly available information, such as new tests, blood work, images, or radiologist reports. Since there are no notifications, physicians have to keep checking the system to see if any new information has arrived. Having to remember to check for multiple patients’ results in multiple systems strains the physician’s prospective memory. One physician stated, “I’d like to be notified on the go. I think you’d find that all the physicians would.”

**Requirements:**

• Notify users of updated patient status, including critical changes in patient condition and new test results

• Follow simple, intuitive, and consistent conventions to visualize information such as: when the update occurred, whether the update is critical, whether the update has been seen by the current user
3.4. Hierarchical Task Analysis

Existing information systems passively store user input and display them upon retrieval, demanding active engagement on the users’ part to carry out the rest of the tasks to achieve their goals. This distribution of tasks between the system and the users need to be reconsidered, because some tasks carried out by the users can be offloaded to the system. Kirwan & Ainsworth (1992) note that tasks requiring rapid, precise, and repetitive actions are generally best carried out by computers, whereas tasks involving unexpected events and complex logic are best served by human operators.

From the analysis of the observational data, it can be inferred that a majority of physicians' work leads to making a diagnostic decision. They gather information from various sources, filter signals from noises, interpret the signals, and make appropriate diagnosis and treatment plans. In order to determine what functionality the system should include, and how these functions should be provided, I decomposed the physicians’ main goal of diagnosing a patient into tasks and subtasks using Hierarchical Task Analysis (HTA), as shown in Figure 3.6. In the diagram, the activities performed to attain the goal are described at various levels of detail.

The analysis begins by stating the goal, Diagnose Patient. Diagnosis generation is a major aspect of medical cognition, which is decomposed into main tasks of seeking, gathering, documenting, organizing, and processing patient information. Further subtasks were then defined within each of these categories.

While the hierarchical task analysis was useful for categorizing and decomposing tasks, it failed to capture the iterative nature of differential diagnosis, and the interactions between tasks. This became clear when the analysis was shown to a physician for validation. For instance, the physician noted that sometimes medication is ordered and given to patients in the ED, and after some time the patient is reevaluated to see the effect of the drugs. However, in spite of its limitations this task analysis was useful for identifying representative tasks that were then used in user testing, during the evaluation phase of this study.
Figure 3.6  A graphical representation of the hierarchical task analysis result
3.5. Model of Diagnostic Decision Making in the ED

As seen in the preceding Hierarchical Task Analysis, the physicians’ ultimate goal is to make correct diagnostic decisions for each patient in the shortest possible amount of time. While decision support is out of scope for this thesis, the proposed system must support the tasks performed to assist the decision making process. The factors involved in the decision making process were analyzed to deepen our understanding of physicians’ internal cognitive processes and identify information requirements.

Patel et al. (2001) states that clinical data are interpreted based on prior knowledge and clinical data gathered in a particular context. Generalizable knowledge may be produced during this interpretation and applied to other contexts. Figure 3.7 represents this cognitive process of interpreting clinical data. In Figure 3.8, we further break down information types by the source of the information: general clinical knowledge gained from formal training, literature, and past experience; patient-specific information gathered from patient chart, other clinicians, physical examination, conversations with patient, and various test results. Physicians combine general and patient-specific clinical information on a case-by-case basis to arrive at a diagnostic decision. Figure 3.8 also indicates the types of information supported by existing information systems. In developing a new application for supporting ED physicians, these unsupported information types are of particular interest.

Figure 3.7  Schematic representation of the comprehension process – the interpretation of clinical data (Patel et al., 2001)
Figure 3.8  Model of diagnostic decision making in the ED
3.6. Scenario Development

Based on the user research, current and future scenarios were developed to model the use of information systems and related issues.

3.6.1 Current Scenario

The current scenario summarizes the data gathered in a narrative format and communicates the detailed aspects of users’ tasks, particularly the workflow and context around them. It does so by describing how the actors achieved the goal of providing care for multiple patients as their day progressed.

Handoff

Dr. Stevens, an attending at a Toronto hospital, comes into the ED to start her evening shift in the Green zone. She briefly meets with Dr. Yang, who was on the previous shift, to go over each patient’s case. She logs into the electronic whiteboard system to see the roster of all patients in the ED on her workstation, then walks over to the chart rack to see the patient charts the nurses have arranged for her. She scans the charts and grabs the first one in her stack. The chart is for Mr. Parson, a 50 year-old patient with abdominal and back pain. Before going to see Mr. Parson, Dr. Steven starts ordering lab tests for him. Dr. Stevens learns from the chart that Mr. Parson is located in Room 20, and visits him to see how he is doing and to examine his abdomen. Though Dr. Yang has performed a physical examination and has briefed Dr. Stevens on it already, Dr. Stevens finds that it helps to redo the examinations for accuracy. Dr. Stevens adds a few of her own observations in Mr. Parson’s patient chart. She has ideas of what the diagnosis might be, and she waits for the CT scans that Dr. Yang had ordered to make any conclusions.

Notification

Back at the workstation, the whiteboard indicates that Mr. Parson’s CT results have come in. She goes over to another workstation with dual monitor setup and brings up the image viewer. She types in her login credentials but system does not allow her in. She
calls the system administrator to reset her password. After a few minutes, she regains access to the system. Unable to find Mr. Parson’s scans upon browsing, she searches for the patient’s name. Mr. Parson’s record comes up at the top of the search results with a red icon next to it, indicating abnormality. She clicks on the link to bring up Mr. Parson’s CT scans.

Communication with Other Services

Dr. Stevens has questions about the radiologist’s report and requests a consult. She looks up radiology department’s extension number and makes a call. She then asks to speak with the radiologist responsible for Mr. Parson’s CT report. The radiologist is unavailable, and Dr. Stevens leaves the patient’s name and a synopsis of the case with the nurse and waits for a call back.

Dr. Kim receives Dr. Stevens’ message and brings up Mr. Parson’s scan in the image viewer. After some inspection, Dr. Kim calls the Green zone to speak with Dr. Stevens. Both doctors sit at their respective workstations with Mr. Parson’s CT scan on their screens and discuss over the phone.

Finding Patient Information

Dr. Stevens gets clarification on the scan results, and proceeds to prescribe medications for Mr. Parson. To see if Mr. Parson has a history of allergic reactions to the meds, she looks for his patient chart in her chart rack. Unable to locate his chart, she asks a passing nurse, who informs her that the chart has been taken out of the rack by another nurse to add EKG results.

She skims the patient chart but is not able to locate information on allergies. She goes back to her workstation, logs into the EMR, and pulls up Mr. Parson’s medical records. Dr. Stevens finally finds Mr. Parson’s history of allergies in the EMR, and fills out a prescription form for appropriate antibiotics and painkillers accordingly. She hands this form to a nurse to process.
Prioritizing Patients

Dr. Stevens resumes her duties in the Green zone. She checks the list of patients to decide which patient to see next. The system shows all 45 patients in the ED, so Dr. Stevens sorts the list by responsible physician’s name to see which patients are under her care. She prioritizes the patients in her head by looking at each patient’s wait time and availability of recent test results. The system shows that Mrs. Bona, a 24 year-old woman with a sprained ankle, has been in the ED for over 5 hours. Based on her CTAS score, the government guidelines dictate that someone with her CTAS score should be processed through the ED system within 4 hours. Realizing that there are no urgent patients and that Mrs. Bona can be easily discharged, Dr. Stevens proceeds to check Mrs. Bona’s X-ray result that has been back for about 45 minutes. Everything looks fine, and no fractures are found. Dr. Stevens decides that it is safe for the patient to be discharged, prints out an information package for the patient, and fills out a discharge form. Dr. Stevens then goes to Mrs. Bona’s room, briefs her on the condition of her ankle, explains the homecare procedure, and sends her home.

3.6.2 Future Scenario

The future scenario illustrates the potential application of the proposed system in the ED. It is used to guide the prototyping process by acting as a basis for creating wireframes that depict a sequence of system-user interactions. This scenario includes details around context-awareness and push notifications.

Hand-off

Dr. Stevens comes into the ED to start her evening shift, and meets with Dr. Yang from the previous shift to get briefed on the current patients in the Green zone. Dr. Yang goes over the patients and the tests that have been ordered for each patient. Once Dr. Yang leaves the hospital, Dr. Stevens brings up the electronic whiteboard on her workstation to see which patients need to be seen and what their complaints are. The system recognizes Dr. Stevens and brings up a list of patients that have been assigned to her. The list shows brief information about each patient and their test results. Since there are
no urgent patients, she proceeds to check the progress of each patient in the order assigned by the nurses.

**Notification**

*While at the workstation, Dr. Stevens notices a new icon on Mr. Parson’s Progress Bar, indicating that a new test result became available. Dr. Stevens clicks on the icon, which immediately brings up Mr. Parson’s CT scan result.*

**Communication with Other Services**

*Dr. Stevens realizes that she needs a radiologist’s help on interpreting the CT report. She leaves a contextual message on the report asking questions about specific areas and indicates that it is an urgent message. Dr. Kim, the radiologist, sees the message on his computer and clicks on it. Mr. Parson’s CT scan is brought up along with Dr. Steven’s full message. Upon reading the message, Dr. Kim decides that it would be faster and easier to have a verbal conversation with Dr. Stevens. He quickly finds Dr. Stevens’ extension on Mr. Parson’s patient record and calls her.*

**Finding Patient Information**

*To prescribe medications, Dr. Stevens checks Mr. Parson’s medical history and allergies. In Mr. Parson’s patient record, Dr. Stevens performs a quick text search for “allergies”, and the matches are highlighted.*

**Prioritizing Patients**

*Having taken care of Mr. Parson, Dr. Stevens goes back to her workstation to see the progress on her other patients. At a glance of the visual patient list, she reviews how long each patient has spent in the ED and which patients have new test results. She is informed that a diagnostic decision can be made for Ms. Bona, since all of her test results are back.*
3.7. **Scope of the Design Solution**

Technological solutions that promise to replace human interactions and manual information management need to be carefully considered, because these activities are essential to maintaining productivity. The tasks that existing technology can sufficiently support need to be identified. The participants showed willingness to try new technological solutions; however, they expressed concerns about the effect of technology on productivity and stated they would be reluctant to adopt the system if it introduced extra steps rather than simplifying the current workflow.

Hence, the goal of this project was to propose a design for a system focused on information management and communication to optimize physicians’ workflow and minimize the time spent at the computers, through user-centered design.
4. Design and Prototyping

The requirements established in the previous chapter were used to inform the user interface and interaction design process. Through iterations of sketching and wireframing, the requirements were translated into visual formats and laid out on the screens. The design exercise primarily focused on proposing a design solution that:

- *Increases physicians’ situational awareness:* Physicians deal with a flood of information at any given time but are cognitively limited in balancing and maintaining awareness of individual patients and overview of all patients. Providing updated statuses on their patients in a quickly digestible format would help increase the physicians’ situational awareness.

- *Increases productivity:* EDs and physicians are evaluated in terms of the number of patients who are processed within a benchmarked amount of time. Making key information available and simplifying workflows would expedite the process and increase physicians’ productivity.

- *Minimizes time spent on obtaining previously collected patient information:* Physicians consider the time spent on computers unproductive. The system interface was designed to perform as expected, and be easy to use and efficient, so that it minimized the time spent on completing various tasks. Minimizing the time spent on locating the necessary information was of primary importance.

A set of wireframes was produced as a result of the design exercise. This chapter discusses the details of the interface, along with the interaction design decisions made, and the rationale behind them.

4.1. Prototype Development

The majority of physician interactions with information systems consist of patient information gathering and dissemination; therefore, the design was primarily concerned with these activities. In particular, design solutions for the following tasks were explored:
- See an overview of patients in the ED
- See aggregated information about an individual patient
- Order lab or diagnostic imaging tests
- See test results
- Communicate with other clinicians

The early conceptual ideas for each of these tasks were developed through brainstorming and sketching. Fellow lab members, Anita Ko and Mehdi Ravandi, participated in the brainstorming sessions, offered their expertise on interaction design, and helped evolve design ideas. An example of such design evolutions is illustrated in Figures 4.1 and 4.2, where drastic changes in the layout and interaction can be observed. The details of this design are further explained in section 4.2.3.

![Figure 4.1 An early sketch of a patient record](image-url)
A high-fidelity prototype was developed based on the sketches. For the purpose of testing and evaluation, the prototype followed the workflow depicted in the future scenario closely.

### 4.2. Design solution

This section discusses the design solution produced in the first design iteration in detail.

#### 4.2.1 List View

When the user logs in to the system, a list of all patients in the ED is displayed to provide an overview. Similar to the existing electronic whiteboard systems, this list includes information such as patient name, complaints, bed location, responsible physician, time of arrival, and lab and imaging result notifications.
The number inside each cell in the Lab and Radiology columns indicates the time elapsed since the last set of test results in minutes. In addition to this explicit display, varying shades of green were used to represent the “freshness” of the test results. Figure 4.3 shows the colour scale used to represent the time elapsed. Deepest green represents for the most recent results, and gradually lighter and yellower greens represent older results. In addition, bolding of the time stamp represents unread test results, which follows the common web convention. Once the results have been opened and read, the time stamp in the list becomes regular again.

![Colour scale for indicating the “freshness” of lab and radiology results](image)

Figure 4.3  Colour scale for indicating the “freshness” of lab and radiology results

Figure 4.4 depicts the All Patients list, which shows brief information about all patients in the ED in a sortable tabular format. At a glance, the physician can gain a sense of how many patients are waiting to be seen and whether there are new test results for patients who are being seen.
The toggle button shown in Figure 4.5 is placed at the top of the page and allows for switching back and forth between the list of all patients in the ED and the individualized list of patients assigned to the current user. When the My Patients button is clicked, the list shrinks down to only current user’s patients as shown in Figure 4.6.
4.2.2 Progress View

The progress view shows a personalized list of patients under the user’s care, with a visual representation of each patient’s progress, their target exit time, and test results. This view simplifies the List View by only displaying information essential to patient prioritization, namely, patient’s name, time of admission, estimated time of departure, and times of reported test results. This screen focuses on supporting physicians’ decisions on which patient to act on next rather than providing comprehensive details, conscious of the fact that extraneous information may cause distraction and slow-down. The patients are listed in the order of priority based on two factors: length of time the patient has spent in the ED and the availability of test results. Another toggle button, depicted in Figure 4.7, is used to switch to the Progress view.

<table>
<thead>
<tr>
<th>Bed</th>
<th>Patient name</th>
<th>Age</th>
<th>EP</th>
<th>CTAS</th>
<th>Presenting condition</th>
<th>Lab</th>
<th>Rad</th>
<th>Time of admission</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Jeffrey Lieber</td>
<td>42</td>
<td>Stevens</td>
<td>1</td>
<td>A large ruptured aneurysm, unconscious</td>
<td>62</td>
<td>26</td>
<td>Today, 2:39pm</td>
</tr>
<tr>
<td>18</td>
<td>Patrick Parson</td>
<td>39</td>
<td>Stevens</td>
<td>2</td>
<td>Chest pain</td>
<td>61</td>
<td>26</td>
<td>Today, 11:23am</td>
</tr>
<tr>
<td>25</td>
<td>Kate Austen</td>
<td>60</td>
<td>Stevens</td>
<td>3</td>
<td>Syncope</td>
<td>38</td>
<td>26</td>
<td>Today, 9:32am</td>
</tr>
<tr>
<td>22</td>
<td>Adam Tobin</td>
<td>49</td>
<td>Stevens</td>
<td>3</td>
<td>Abdo pain</td>
<td>13</td>
<td>26</td>
<td>Today, 12:40pm</td>
</tr>
<tr>
<td>26</td>
<td>Maureen McElheron</td>
<td>30</td>
<td>Stevens</td>
<td>4</td>
<td>Laceration</td>
<td></td>
<td>26</td>
<td>Today, 2:39pm</td>
</tr>
<tr>
<td>17</td>
<td>Clara Zanni</td>
<td>52</td>
<td>Stevens</td>
<td>5</td>
<td>Difficulty swallowing</td>
<td>01:21</td>
<td>26</td>
<td>Today, 11:23am</td>
</tr>
<tr>
<td>21</td>
<td>Jesse Hutch</td>
<td>21</td>
<td>Stevens</td>
<td>5</td>
<td>Allergic to shrimp</td>
<td></td>
<td>26</td>
<td>Today, 12:40pm</td>
</tr>
</tbody>
</table>

Figure 4.6 Wireframes – My Patients list

Length of Stay

The wireframe for the progress view is shown in Figure 4.8. This Gantt-chart-like visualization of each patient’s progress through the system shows the benchmarked discharge time as well as the duration of time the patient has spent in the ED. At a glance, the user can see how much time
they have left to process each patient to meet the benchmark. The benchmark is determined by
the patient’s CTAS score, and is 4, 6, or 8 hours from the time of admission.

**Test Results**

The balloon-like icons indicate notable activities such as lab or imaging results. The location of a
balloon icon on the Progress Bar indicates when it was reported. Of the number of other types of
information the balloons can represent, the read or unread status of the test results was identified
to be of primary importance. Conventionally bolded text is used to indicate unread updates in
both web and desktop applications; however, since the balloons do not contain any text,
difference in colours is used for this purpose. Blue indicates that the results are new and have not
been seen by the current user, and gray indicates that the results have been seen.

![Wireframe – Progress view](image)
While a detailed algorithm for ordering patients is out of scope of this thesis, the following design recommendations suggest how the patients can be prioritized in this view. The patients are listed in the order of priority based on two factors: length of time the patient has spent in the ED and the availability of test results. The order of patients changes dynamically based on their status updates. If a patient’s test results are back and are ready for the physician to make the next step, the patient moves up the list. If a patient can easily be discharged and free up a bed, so that another patient can be treated, they are also considered high priority and moves up. If patient crashes or shows abnormality, they are unquestionably high priority and moves to the top of the list. This display conveniently displays a visual overview of patient status, but fails to represent the iterative nature of the differential diagnosis.
4.2.3 Patient View

The Patient View is displayed upon selection of a patient from the List View or the Progress View. The Patient View aggregates all the information about a patient from multiple databases and presents them in one screen. Figure 4.1 shows an early sketch of a centralized patient record, where information from the EMR is displayed in the center, and all other related records such as test results are displayed in the periphery. We have since moved away from this design and adopted a chronological organization of updates as shown in Figure 4.2 and refined in Figure 4.9. This layout is adopted from web-based email clients and social networking sites. By placing the recent and relevant updates at the top of the page, this eliminates the need for scanning and searching. The composition of a patient record is explained further below.

![Figure 4.9 Wireframe – centralized patient record](image-url)
Figure 4.10 Composition of a patient record

**Header Section**

The header at the top of the screen contains a set of key status information items so that the physician can quickly establish a context around the patient by identifying the patient and summarizing the progress that has been made. The graphical representation of patient progress introduced earlier is used again here for consistency, ease of recognition, and ease of data consumption (DeZegher-Geets, 1988, and Politser, 1984). The Progress Bar notifies the user of any recent development on the patient and highlights any unread test results. The design of the header including the Progress Bar is shown in Figure 4.11.

Similar to the time line display introduced by Tang et al. (1992), the Progress Bar uses icons to denote patient event, such as physical examination, lab test result, diagnostic imaging result, and medication. However, unlike their time line display, the Progress Bar includes visual information on the patient’s progress towards the benchmark.
The header also includes information on the current user and a link for sign-out. The placement of these links follows the standard web application convention; any physician who is familiar with web technology would be expected to find the user account information and the sign-out link there without any difficulty.

**Tasks Section**

A list of tasks the user may perform on the current patient is displayed in the Tasks panel on the right side as depicted in Figure 4.12. The tasks include: ordering a lab test, ordering a diagnostic imaging test, writing a medication prescription, referring the patient to another service, requesting nursing surveillance, and discharging the patient. Clicking on one of these items brings up an appropriate order form, pre-populated with already-existing patient information. This supports a usability heuristic proposed by Neilson (1994b), “recognition rather than recall”; by making the actions visible and easy, the Tasks panel removes physicians’ burden of having to remember the complicated steps to order a test and thus reduces physician memory load.
Contacts

Also listed on the left panel are the names of all clinicians involved with the patient. This is particularly convenient, because this type of information cannot be easily gathered from patients. Patients often cannot remember the names of the clinicians they were seen by. The notion of “recognition rather than recall” introduced in the Tasks section is applied again here.
Updates

The comment field allows the user to enter their clinical notes on the patient for future reference.

![Comment field wireframe](image1)

**Figure 4.14** Wireframe – Comment field

The updates section lists outgoing order forms, incoming test results, and comments from other clinicians on the patient. This list is ordered chronologically with the latest item on top by default.

![Updates section wireframe](image2)

**Figure 4.15** Wireframe – Updates section
Details

The right panel shows patient identification information, demographic profile, allergies, medication, and vital signs. These details are typically available at the top of the paper charts and in the current electronic systems as a way of identifying the patient and their status; therefore, it was important to make them visible at a glance. In addition, the snapshots of vital signs are displayed on the right, providing updates on the patient’s current status.

Figure 4.16  Wireframe – Details section, which includes vital signs and triage notes

<table>
<thead>
<tr>
<th>Vital Signs</th>
<th>Today, 8:25am</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respirations</td>
<td>26</td>
</tr>
<tr>
<td>Pulse</td>
<td>112</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>164/95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vital Signs</th>
<th>Today, 6:39am</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respirations</td>
<td>22</td>
</tr>
<tr>
<td>Pulse</td>
<td>109</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>150/90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Triage</th>
<th>Yesterday, 11:39pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
</tr>
<tr>
<td>Birthdate</td>
<td>June 8, 1960</td>
</tr>
<tr>
<td>Weight</td>
<td>180</td>
</tr>
<tr>
<td>CTAS</td>
<td>2 - Red</td>
</tr>
<tr>
<td>Bed</td>
<td>28</td>
</tr>
<tr>
<td>Condition</td>
<td>50-year-old white male. Came in complaining of severe pain in lower back and abdomen. Weight approximately 180 lbs. He is on the following medications: Slow-K, Minipress, and Lozol. No known allergies. See vital signs.</td>
</tr>
<tr>
<td>OHIP</td>
<td>5623-564-764-PR</td>
</tr>
</tbody>
</table>
4.3. **Summary**

The prototype largely consists of the patient overview, and the individual patient records. Physicians’ information needs would either be addressed on these screens or be linked from them, providing users with a central access point. The two different versions of patient overview screens – List View and Progress View – serve different purposes: the List View includes textual information on each patient and allows for various sorting mechanisms, whereas the Progress View displays graphical summary of patient statuses. The patient record screen consists of an overview of the patient’s progress, quick links to various order forms, a list of involved clinicians’ contact information, and updates such as new test results.

Since this type of interface is fairly new, it was important to evaluate it with potential users to see its efficacy in the clinical environment. I was particularly interested in how the visual progress overview, the integrated patient records, and the Facebook-like updates of patient information would be received. The evaluation that was carried out is reported in the following chapter.
5. Usability Evaluation: Methodology and Findings

This chapter discusses the evaluation phase of the study aimed at verifying the usability and usefulness of the proposed interface at an early stage of the design process. By using a sample of ED physicians to collect feedback, flaws in the interaction and workflow were identified, and design improvements were recommended.

5.1. Participant Selection and Recruitment

A sample of three users who satisfy the following user requirements was invited to take part in the usability testing:

- Must read, write, and understand English
- Must be aged 25 or older
- Must have one or more years of experience working in the ED as a physician

This was to ensure that their knowledge and experience in emergency medicine are adequate, and they are able to provide noteworthy feedback. Each participant was given the compensation, a $100 Chapters gift certificate, upon signing the consent form prior to the study.

5.2. Background Questionnaire

A questionnaire was used to collect demographic data and other background information on their experience with the existing systems in the ED. No personally identifiable information was collected. The background information was used to provide context around the participants to better interpret the findings from the user testing. The questionnaire can be found in Appendix E.

The participants recruited for the study had varying degrees of experience in the ED and were from hospitals with different levels of technology adoption. Two of the three participants were attending physicians and had worked in the ED for more than 7 years; whereas one participant was a resident and had less than 3 years of experience. All participants felt comfortable working
with technology; however, it is probable that bias had been introduced in the recruitment process, since physicians with greater interest in technology are more likely to have agreed to participate. Table 5.1 summarizes the demographic profile of the participants.

Table 5.1  Participants’ demographic profile

<table>
<thead>
<tr>
<th>Question</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Male</td>
<td>Male</td>
</tr>
<tr>
<td>Age Group</td>
<td>41-50 years</td>
<td>22-30 years</td>
<td>41-50 years</td>
</tr>
<tr>
<td>Role</td>
<td>Attending</td>
<td>Resident</td>
<td>Attending</td>
</tr>
<tr>
<td>Years of experience in the ED</td>
<td>7-10 years</td>
<td>1-3 years</td>
<td>Over 11 years</td>
</tr>
<tr>
<td>Comfort level with technology</td>
<td>Very comfortable</td>
<td>Very comfortable</td>
<td>Very comfortable</td>
</tr>
</tbody>
</table>

The participants were asked to indicate the frequency of key tasks listed in Table 5.2, to validate the findings from the user research and the set of features designed. Based on their responses, most key tasks are frequently performed and require IT support.

Table 5.2  Frequency of key tasks in the ED

<table>
<thead>
<tr>
<th>Question</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Page other clinicians</td>
<td>A few times a month</td>
<td>All the time</td>
<td>Never</td>
</tr>
<tr>
<td>Request consults</td>
<td>A few times a week</td>
<td>A few times a week</td>
<td>Never</td>
</tr>
<tr>
<td>Order lab tests</td>
<td>All the time</td>
<td>All the time</td>
<td>Never (paper-based)</td>
</tr>
<tr>
<td>Order imaging tests</td>
<td>All the time</td>
<td>All the time</td>
<td>Never (paper-based)</td>
</tr>
<tr>
<td>Check lab test results</td>
<td>All the time</td>
<td>All the time</td>
<td>All the time</td>
</tr>
<tr>
<td>Check imaging results</td>
<td>All the time</td>
<td>All the time</td>
<td>All the time</td>
</tr>
<tr>
<td>Check individual patient status</td>
<td>All the time</td>
<td>All the time</td>
<td>All the time</td>
</tr>
<tr>
<td>Check overall ED status</td>
<td>A few times a day</td>
<td>A few times a day</td>
<td>A few times a day</td>
</tr>
</tbody>
</table>

Subsequently, the participants were asked to identify the frequency of use of a number of common information items in the ED and indicate whether they are stored on paper. The
participants used the following electronic systems on a regular basis: patient roster, electronic patient record, diagnostic imaging viewer, paging, and referral systems. The participants’ responses are summarized in Table 5.3.

Table 5.3 Frequency of use of information systems in the ED

<table>
<thead>
<tr>
<th>Question</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Whiteboard</td>
<td>Never</td>
<td>A few times a day</td>
<td>A few times a month</td>
</tr>
<tr>
<td>Patient list/roster</td>
<td>All the time (paper-based)</td>
<td>A few times a day</td>
<td>All the time</td>
</tr>
<tr>
<td>Electronic Patient Record</td>
<td>All the time</td>
<td>All the time</td>
<td>Never</td>
</tr>
<tr>
<td>Diagnostic imaging viewer</td>
<td>All the time</td>
<td>All the time</td>
<td>All the time</td>
</tr>
<tr>
<td>Patient discharge portal</td>
<td>Never</td>
<td>A few times a week</td>
<td>Never</td>
</tr>
<tr>
<td>Paging and communication</td>
<td>All the time</td>
<td>All the time</td>
<td>All the time</td>
</tr>
<tr>
<td>Prescription and referral</td>
<td>All the time (paper-based)</td>
<td>All the time</td>
<td>All the time (paper-based)</td>
</tr>
</tbody>
</table>

One participant raised concerns regarding usability and learnability of the existing whiteboard system at his hospital:

*Out of 30 ED docs, maybe 6 use the electronic whiteboard. It’s not very user friendly, the learning curve is steep, and it is a hassle to go to a computer. So not a lot of people want to use it. The rest of us just use stickers.* – User 3

The participants were also asked to indicate how often they perform common online and offline tasks listed in Table 5.4 in and outside of the ED to gauge their familiarity with web services. In particular, they were asked to report how often they use Facebook, a popular social networking site, to assess their familiarity with the chronological ordering of relevant updates, namely Facebook’s News Feed. All participants were fairly comfortable with email and Google search, but their experiences with other services such as weather and social networking varied.
<table>
<thead>
<tr>
<th>Purpose</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google search</td>
<td>All the time</td>
<td>All the time</td>
<td>A few times a month</td>
</tr>
<tr>
<td>Literature search</td>
<td>A few times a month</td>
<td>A few times a week</td>
<td>Never</td>
</tr>
<tr>
<td>Instant messaging</td>
<td>Never</td>
<td>All the time</td>
<td>Never</td>
</tr>
<tr>
<td>Email (work)</td>
<td>All the time</td>
<td>All the time</td>
<td>A few times a week</td>
</tr>
<tr>
<td>Check personal email</td>
<td>All the time</td>
<td>All the time</td>
<td>A few times a week</td>
</tr>
<tr>
<td>Use calendar</td>
<td>A few times a week</td>
<td>A few times a week</td>
<td>Never</td>
</tr>
<tr>
<td>Check weather</td>
<td>A few times a week</td>
<td>A few times a week</td>
<td>Never</td>
</tr>
<tr>
<td>Use Facebook</td>
<td>Never</td>
<td>All the time</td>
<td>Never</td>
</tr>
</tbody>
</table>
5.3. **User Testing**

Descriptions of plausible clinical cases were developed to provide a controlled context for the participants and to stimulate their clinical decision making process. The participants were asked to complete a set of tasks using the interface prototype and provide verbal feedback as they walked through the tasks. The tasks were selected based on the common information management activities observed in the initial research phase.

Practical Implications, barriers to going forward

A note taker recorded the participants’ feedback on structure, layout, workflow, usability, learnability, and aesthetics of the interface. The participants’ performance on the tasks and expressions were also closely observed and noted. No photos or videos of the user were taken. As is typical in user testing, the focus was placed on qualitative feedback, such as users’ comments and expressions, rather than on quantitative performance measures such as time taken to complete a task, number of clicks, and number of errors. The user testing protocol and tasks can be found in Appendix D.

The initial design iteration was shared with the group of three physicians and the user test results generated concrete recommendations for improvements at a very low cost. The following sections describe the findings, recommendations, and improved design solution.

5.3.1 **Login**

One participant suggested that login would not be necessary until there is a need to interact with individual patient records, because the master list of patients is available physically in the ED. Another participant mentioned, “It would be nice to login at the beginning of the shift, and never have to log in again.”

5.3.2 **Patient List**

CTAS is only designed to prioritize patients at triage and control wait times. All participants stated that they did not consider CTAS scores to be an important factor in their decision-making. They explained that the CTAS scores are assigned and used primarily by nurses and tend to be
subjective. Physicians “listen for the stories rather than the scores,” especially in the case of urgent patients. The scores, however, are useful for distributing patients to different zones and setting a target exit time for each patient.

As learned from the requirement analysis, physicians are more focused on managing, diagnosing, and treating patients who have been assigned to them, rather than managing the overall flow of patients in the ED, though they stay mindful of wait times and bed availabilities. All three participants looked for ways to see the reduced list of patients under their care, which is more relevant to their work than the master list. One participant suggested that the personalized list should be the default landing page upon login, with an option to see the master list. This participant also suggested adding the “Unassigned patients” option that lists patients who are waiting to be seen.

The radiologist reports are more meaningful to the physicians than the actual images. One physician stated, “I don’t care if there is an image. Radiologists are much more experienced than me; I’ll just look at what they have to say.” Physicians typically rely on radiologists’ interpretation of CT and ultrasound scans, whereas they often interpret x-rays on their own. Therefore, easy access to the textual reports, especially for CT and ultrasound, is required; whereas access to the scanned images is desirable but not essential.

One of the participants felt uncertain when asked to interpret the two-digit numbers in the Radiology and Lab columns. The numbers were mistakenly understood as the number of reported test results. The shades of green used for test results columns were reasonably intuitive, as all users guessed the green to mean recent results when probed; however, they had not noticed the colours until asked, and colours are often associated with the content of the test result.

Two participants recognized that clicking on a patient from the list would lead to the patient record page; on the other hand, one participant expected it to filter the updates on the right and show only the ones related to the selected patient.

5.3.3 Progress View
The participants responded very positively to the Progress Bars. All participants preferred the progress view to the traditional List View, because “it [had] more useful information.” They
were pleased with the convenience of having both the visual representation of overall progress for each patient and quick access to the detailed test results.

Upon seeing the progress view for the first time, the participants immediately understood that the coloured bars and 6- and 8-hour benchmarks represented the patients’ progress towards the benchmarked exit times. The participants were less concerned about the benchmarked target itself but more about how much time is left until the target. With the current paper-based system, there are checkboxes at the bottom of the charts for time presented, time seen by physician, and expected exit time based on CTAS-based guidelines. There is no continually updated visual representation available for this, and “[the ED physicians] just glance at these numbers at the bottom of the paper charts and forget about them.” One participant stated,

*The hospital management is always trying to enforce the target. If this information were available in this graphical format, it would definitely help me keep track of things.* – User 3

One of the participants felt uneasy about the use of red on the Progress Bars for the overdue patients, because red is often associated with urgent, critical patients.

*In the system we use, if a lab value is critical, it’s indicated in red. It will stay red even when it’s read. If it hasn’t been read, it will be bold.* – User 2

Another user, however, thought the colour directed her attention on the overdue patients and motivated her to process them quickly. The use of colours needs to be carefully reconsidered based on these comments. Neilson (2005) emphasizes consistency and standards in his usability heuristics; users should not have to wonder whether different words, situations, or actions mean the same thing.

Participants wanted to see the patients listed in the order they were seen instead of the dynamically changing order suggested in the prototype; furthermore, two participants wanted the option of sorting the list by patients’ total time spent in the ED. Two participants expressed the need to be able to customize the list to place critical patients with CTAS 1 or 2 at the top of the list. It became clear that users need multiple predefined or “canned” sorting methods, including
sorting by time of arrival (how much time they have spent in the ED), CTAS score, and order of being seen, as well manual reordering of the patients in the list.

Using the balloon icons for incoming test results was intuitive to the participants; however, they were puzzled by the use of blue and gray colours. All three participants thought the blue and grey balloons indicated radiology and lab results respectively, when in fact the blue indicated unread results. Further discussions with the participants revealed the need for the balloons to include the following information:

- when the test was reported,
- whether it has been seen by the user,
- whether the value is critical, and
- what type of test it is.

The participants confirmed that they rarely check when the tests were ordered; this information is unnecessary in the decision-making and need not be indicated on the Progress Bar, though it should to be kept for quality control. The times when the tests are reported, however, were considered crucial, and the participants appreciated them being represented on the Progress Bars.

All participants said it would be useful to see the distinction between the lab test results and radiology results, and suggested putting the letter L or R respectively inside each balloon icon to indicate the test type. The participants did not see the use of specifying the test type in finer granularity, such as displaying a U for urinalysis rather, because 1) they felt they had a fair sense of what they have ordered on a patient, and 2) with such a wide variety of tests that can be ordered, many of them are ordered and reported together. The balloons were redesigned to include the type of test (either L or R) as shown in Figure 5.1.

The participants also expressed that it would be helpful to see which tests have come back and which tests are still outstanding, because often all test reports are required to make a diagnostic decision. The revised design includes placeholder balloons as shown in Figure 5.1 to indicate the estimated time of arrival of outstanding test results, helping users remember what they are still waiting on and when to expect them.
5.3.4 Patient Record

Header

The participants indicated that the header is lacking useful information about the patient’s condition. In order for the physicians to readily establish a patient context, the header needs to provide a brief description of the chief complaint, in addition to the patient name, as a quick reminder of what the case was. Unchanging information about the patient such as the demographic profile and physical description should also be displayed in the header, as all participants wanted them to be visible and easily accessible at all times.
Tasks

The participants expected the items listed under Tasks to be actionable, however, two participants commented that the way the items were displayed made them look static. When asked to order a CT scan for the patient, all participants clicked on CT under Tasks without hesitation. The order form displayed as a result, however, was longer and more complicated than anticipated. One participant suggested that the system should be able to infer from the existing data and automatically populate some of the fields in the order form, such as age, allergy, and date. It is recommended that the system automatically fill out the known information, so that the user can scan and correct the default values but are not required to enter them from scratch.

Contacts

The participants suggested listing the other clinicians’ extensions along with their names as a quick reference, rather than providing a messaging service, because it would eliminate the time spent on looking up contact information. While instant messaging is a good idea in theory, the participants were unsure of its effectiveness and perceived phone calls to be more effective.

Due to the mobile nature of physicians’ work, a messaging service tied to a workstation would not achieve instant and meaningful communication, because the chances of both the sender and receiver being at their computers and logged into the system at the same time are slim. In general, the participants did not see computer-based systems as a communication tool. One participant explains:

\textit{If there’s something I need to know, I’ll get a call. I’m not going to walk up to a computer to see if there is an urgent message for me.} – User 3

Two participants pointed out that the ED nurses and lab technicians need not be included in the Contacts list. The nurses are collocated with the physicians in the ED; therefore, the majority of communication with the nurses happens in person. Two participants indicated that communication with the lab technicians occur infrequently, and when it does occur, it happens in person, because the technicians are physically located near the ED. However, this cannot be verified for all EDs, hence the revised design includes the lab technicians in the Contacts list.
Figure 5.3  Wireframes – Contacts section, before (left) and after (right) the user testing

Updates

The participants found the reverse-chronological ordering of information confusing. This display required an excessive mental workload, having to read through the list and detect relevant information from the noise. The participants reported that the updates seemed disorganized even though they were in chronological order, and expressed the need for viewing related information in groups.

*It’s confusing to me. It makes me think of email. I only want to know relevant stuff, like a list of active things.* – User 1

*I know it’s ordered chronologically, but it seems out of order. I want to see blood work in one section, lab results in one section, imaging in another section, etc.* – User 2

Moreover, the responsible clinicians’ names are prominently displayed, when in fact the type of tests and results are of greater importance. For instance, for an ultrasound test result, the key pieces of information are “ultrasound”, “abdomen”, and the result itself, rather than the name of the doctor who ordered it.

*I don’t need to know Tim Burgess ordered something. I don’t really care who ordered it.* – User 2

*I want to see what happened to [the patients], like the test results.* – User 3
Based on these comments, it is recommended that the system provide an option to display updates on the patient by categories, such as Lab, Radiology, Medication, and Administrative as shown in Figure 5.4. Clicking on the Lab category, for instance, would display items related to lab orders and results only. In this design each update corresponds to a balloon icon on the Progress Bar to help users’ cognitive processing when viewing “All” updates.

Figure 5.4 Wireframe – Updates section after the user testing. Compares with Figure 4.15 (before)
Details

The participants were pleased with the display of triage notes on the right side. A participant commented

*This is useful, because usually the triage information is buried on, say, page 4 of the paper chart, and I have to flip through to find it. Half the times I can’t even read the handwriting.* – User 3

*Patients get reassessed periodically, but it is helpful to see what the initial complaint was.* – User 1

Two participants stated that the latest vital signs are the most important and useful data for decision making. In the revised design, only the latest vitals are shown in the Details panel with the option of showing a graph of historic trends.

<table>
<thead>
<tr>
<th>Details</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vital Signs</strong></td>
<td>Today, 8:25am</td>
</tr>
<tr>
<td>Respiration</td>
<td>26</td>
</tr>
<tr>
<td>Pulse</td>
<td>112</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>164/95</td>
</tr>
<tr>
<td><strong>Vital Signs</strong></td>
<td>Today, 6:39am</td>
</tr>
<tr>
<td>Respiration</td>
<td>22</td>
</tr>
<tr>
<td>Pulse</td>
<td>109</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>150/90</td>
</tr>
<tr>
<td><strong>Triage</strong></td>
<td>Yesterday, 11:39pm</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
</tr>
<tr>
<td>Birthdate</td>
<td>June 8, 1960 50 yrs old</td>
</tr>
<tr>
<td>Weight</td>
<td>180</td>
</tr>
<tr>
<td>CTAS</td>
<td>2 - Red</td>
</tr>
<tr>
<td>Bed</td>
<td>28</td>
</tr>
<tr>
<td>Condition</td>
<td>50-year-old white male. Came in complaining of severe pain in lower back and abdomen. Weight approximately 180 lbs. He is on the following medications: Slow-K, Minipress, and Lozol. No known allergies. See vital signs.</td>
</tr>
<tr>
<td>OHIP</td>
<td>5623-564-764-PR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Details</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vital Signs</strong></td>
<td>Today, 10:21pm</td>
</tr>
<tr>
<td>BP</td>
<td>164/95</td>
</tr>
<tr>
<td>HR</td>
<td>105 bpm</td>
</tr>
<tr>
<td>Temp</td>
<td>36.1 °C</td>
</tr>
<tr>
<td>RR</td>
<td>18 breaths/min</td>
</tr>
<tr>
<td>O2 sat</td>
<td>95% RA</td>
</tr>
<tr>
<td><strong>Triage</strong></td>
<td>Today, 4:49pm</td>
</tr>
<tr>
<td>Complaint</td>
<td>Past medical history of coronary artery disease, hypertension and diabetes. Presents with 30 minutes of retrosternal chest pain.</td>
</tr>
<tr>
<td>Current medications</td>
<td>Aspirin, 81 mg daily Metoprolol 50mg BID Nitroglycerin spray PRN</td>
</tr>
<tr>
<td><strong>Guidelines</strong></td>
<td>(7)</td>
</tr>
<tr>
<td>Relevant Publications (4)</td>
<td></td>
</tr>
<tr>
<td>Guidelines (1)</td>
<td></td>
</tr>
<tr>
<td>Relevant Cases (2)</td>
<td></td>
</tr>
<tr>
<td>Kyle Palms</td>
<td>Male, 55, sharp chest pain</td>
</tr>
<tr>
<td>Squeezing substernal chest pressure, light headedness. Pressure 96/50, pulse 48. Skin is cool and clammy. Ordered a bol...</td>
<td></td>
</tr>
<tr>
<td>Bill Moore</td>
<td>Male, 52, chest pain</td>
</tr>
<tr>
<td>Noticed spasm of his breast bone after working out. Shaking so hard that ECG was unreadable. Normal vital signs. Chest wall ...</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.5 Wireframes – Updates section before (left) and after (right) the user testing
5.4. User Satisfaction Questionnaire

The questionnaire shown in Appendix F was developed based on question items used in the User Evaluation of Interactive Computer Systems (Shneiderman, 1992) and System Usability Scale (Brooke, 1996) to quantify the participants’ level of satisfaction with the experience and to gather additional feedback on the experience. The questionnaire covers topics such as clarity of terminology, navigation, layout, and general ease of use. The results are shown in Table 5.5.

Overall, the participants responded positively to the interface prototype and were excited by the prospect of an integrated system and the convenience of finding information quickly and easily. However, the participants had difficulties envisioning how the user would input information. One participant mentioned, “I can’t see myself sitting in front of a computer typing stuff in.” This sentiment was consistent with the interview results from earlier in the study.

The system was seen as an auxiliary tool to accompany the existing paper charts, rather than to replace them, to aid the physicians’ routine tasks, communication, and decision-making. The participants found the proposed system incredibly useful for pulling information but thought the support for inputting information was inadequate. Further design work is needed to address what types of data would be supplied by the users and how they would be fed into the system.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>The terminology used is clear and relevant</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>Strongly agree</td>
</tr>
<tr>
<td>It is useful to have a list of patients under my care</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>Strongly agree</td>
</tr>
<tr>
<td>It is easy to find a particular patient record</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>Strongly agree</td>
</tr>
<tr>
<td>It is easy to order a test for a particular patient</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>It is easy to request a consult/ refer patient to other services</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>Neutral</td>
</tr>
<tr>
<td>It is a satisfying experience overall</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>Agree</td>
</tr>
</tbody>
</table>
6. Conclusion

Ultimately ED physicians strive to provide quality care to as many patients as possible with given resources. A key aspect of their work involves processing patient information to make diagnoses. I attempted to design a system that supports this goal and related tasks, through analyzing the physicians’ needs upfront and incorporating their feedback iteratively throughout the design process.

6.1. Summary of Contributions

Though the importance of good user interface is becoming more widely recognized in healthcare, few systems are designed around user needs. The primary contribution of this study is in the design of an intuitive electronic patient information management system that provides an overview and notifications. The design of the progress bars summarized a large amount of information in an easily digestible graphical format to increase physicians’ situational awareness and decrease time spent at the computers.

The study uses user-centered design methodologies and demonstrates the benefit of involving healthcare domain experts, ED physicians in this case, in the iterative design process, both in the requirement gathering phase as well as in the design and evaluation phase. Input from physicians had a direct impact on the design decisions and helped shape the system’s form and functionality.

By combining observation and interview, I gathered a large amount of qualitative data on how physicians work in the ED, particularly how they find, record, and use patient information. Analysis of the findings allowed us to generate comprehensive information requirements from the users’ perspective. I introduced scenarios as a way of modeling physicians’ tasks and context of use. Use of current and future scenarios demonstrated the clear need for an improved information management system. The analysis of users’ tasks and environment was complemented by the analysis of individual physicians’ mental processing of information. This research showed the value of considering physicians’ internal processing of information in the
design process; the mental model refined our requirements and influenced our design decisions on what information to display and how to display them to optimize physicians’ workflow.

Quick paper prototyping and inexpensive user testing led to copious feedback and design improvements. Physicians indicated their preference for categorized rather than chronological display of updates. They very much appreciated the progress display of patients and expected it to improve their workflow.

6.2. Challenges and Limitations

A major limitation in the user research phase was that the participating hospitals and physicians recruited for the observational study lacked variety in terms of their levels of technology adoption. The observational study was carried out at Sunnybrook Hospital, whose information management largely consisted of paper-based patient management and disparate electronic information systems. I was aware that other hospitals in the region deployed more integrated systems but was not able to establish partnerships and observe how their systems are used and how they are different from Sunnybrook’s. Observing and comparing the use of different information systems at multiple hospitals would have allowed me to perform a benchmark analysis and observe the advantages and disadvantages of various system functionalities. Findings from such study would guide the design process so that the successful components of the observed systems can be adopted and the deficiencies and interaction flaws can be improved.

The usability evaluation raised another set of challenges. Firstly, due to the lack of a working prototype, the study focused on qualitative feedback and excluded quantitative measures such as error rate or time to complete tasks. The combination of quantitative and qualitative data would have yielded meaningful insight into the system’s effect on user’s workflow and productivity. For example, the time it takes for an ED physician to perform a routine task, such as looking for a patient’s blood type or ordering a lab test for a patient, can be measured both with the existing system and the proposed system for comparison. Secondly, since patient data were of sensitive nature, it was infeasible to access and use real patient data to derive sample data. The sample records used in the prototype were based on a medical publication (Freed, Mayer, & Platt, 1997) and were refined by a physician. Though this was adequate for the purposes of this study, sample
data based on real data would be beneficial when testing a working high-fidelity prototype. Realistic data would provide believable context for the participants and likely stimulate thoughtful and rich response.

6.3. Future work

This study describes the first cycle of an iterative design process. Additional cycles of user feedback and redesign are needed to further refine the design and produce a more usable and desirable interface. To gather feedback on the revised prototype, another round of usability testing sessions in a controlled lab setting would need to be organized. New participants who are unbiased and unfamiliar with the design would be recruited for these sessions to determine whether the problems reported by the initial set of participants, such as the poor organization of information updates on the patient records, have been sufficiently addressed. In addition to the new participants, the initial set of participants may be invited to take part in the study to gauge their level of satisfaction with the revised design and garner further feedback.

It would also be worthwhile to prototype and test the following design alternatives:

- Combine the List View with the Progress View to display graphical and textual information in one screen and eliminating the toggle button used to switch between the two views
- Considering the incentive to process patients quickly no longer applies once they are over the time limit, more emphasis needs to be placed on patients approaching target exit time rather than patients who are overdue. Use red to represent the progress of patients who are getting close to their targets to alert the user of their urgency, grey to represent overdue patients, and green to represent patients who are well-below target.

Though these alternatives are projected to improve usability, testing with physicians would validate their practicality and intuitiveness.

Once a working prototype has been developed through iterations of usability studies, it would be worthwhile to conduct a pilot study in a natural clinical environment, namely an emergency department at a local hospital. This would help us discover unexpected use cases to design for,
observe when and how the system is used, and determine whether the system is adequately supporting physicians’ routine tasks as well as their interaction with the changing environment. In addition to these benefits, the pilot study would bring a set of challenges with regards to the following:

- Setting up an infrastructure for the prototype to handle real patient data
- Formulating unobtrusive methods of data collection
- Compensating for contextual variables and constraints
- Identifying measures of system performance for determining success and recommending design improvements
- Obtaining consent from real patients and ED staff and interacting with them throughout the study

These challenges need to be fully addressed for the pilot study to run successfully and to carry out a meaningful evaluation of the efficacy of the system.

Observing participants interact with the system in a natural setting over an extended period of time would help determine how quickly the user learns and adopts to the system, how their behaviour and workflow change over time, and whether the usability flaws observed initially are persistently observed with experienced users.

The topic of patient data input method was brought up by many of the participants in this study. There is a need for this task to be offloaded or assisted by technology. Potential input methods discussed with the participants include speech-to-text dictation and intelligent checkbox-based charting on portable tablets. These methods would allow users to digitize information immediately without having to walk up to a computer and type.
References


Punia, S. (February, 2010). Reducing wait times despite increasing patient volumes. Hours matter, Sunnybrook Health Sciences Centre.


Sujansky, W. V. (1998). The benefits and challenges of an electronic medical record: Much more than a "word-processed" patient chart. Western Journal of Medicine, 169, 176-183.


Appendix A. Interview Questions

Some or all of the following questions were asked to guide the unstructured interview conversations.

- Describe your typical day.
- What are the steps involved in diagnosing and treating a patient?
  - Describe how you make decisions regarding diagnosis and treatment plans.
- How do you decide which patient to see next?
  - What are some factors you need to be aware of?
- Describe how information is communicated.
  - How do you communicate with other physicians?
  - How do you communicate with nurses and other clinicians?
  - Can you take me through the steps of requesting a consult?
  - What are some of the pain points you experience regarding communication?
  - What can you do to improve the quality and speed of communication at a personal level? In what ways can technology improve the current situation?
  - Once an order is placed, are you able to edit it? Is there a need for editing an order?
- What information systems do you use day to day?
  - Describe what each of them does.
- Recall a time where you were in the middle of a task and were interrupted.
  - What are the causes of the interruption?
  - What other types of interruptions do you experience on a daily basis?
  - How do you deal with interruptions? Which task takes priority and how do you make the decision?
Appendix B. Recruitment Email

The following email was sent out to the potential participants to garner their interest and invite them to participate.

Hi [Participant Name],

My name is Erin Yu, and I am a Masters student in the department of Mechanical and Industrial Engineering at the University of Toronto. As part of my thesis, I am conducting a research under the supervision of Professor Mark Chignell on the use of information and communication systems in the Emergency Department to design a solution for an improved system. This research is funded by IBM Canada’s Centre for Advanced Studies.

I would like to invite you to participate in a study to evaluate an interface prototype developed for use in the Emergency Department. We are looking for physicians with 1 or more years of experience working in the Emergency Department.

In the first part of this research, we went to Sunnybrook hospital to shadow physicians in the Emergency Department to see how they manage the patients and their data. Based on the findings from this research, requirements for an integrated context-aware information system were developed and were used to inform the design and development process for the user interface (UI) prototype.

This usability testing session is aimed at verifying the usability and usefulness of the UI prototype by collecting direct feedback from a sample of potential users. The findings from this study will be analyzed to derive recommendations for design improvements. Any personally identifiable information will not be collected. All other information will be kept confidential and will only be used by the researchers. You are free to withdraw from the study at any time.

If you are available to take part in the study, please respond to this email or contact me at 416.258.9833 to schedule a session.

Thank you,
Erin
Title:
Evaluation of Smart Emergency Department Information System Prototype

Investigator:
Erin Yu, Interactive Media Lab, Mechanical and Industrial Engineering, University of Toronto
Researchers from the Interactive Media Lab are conducting feedback sessions of the user interface prototype of an Emergency Department Information System. Please read this form carefully and ask any questions you may have before agreeing to take part in the study.

What the study is about:
In the first part of this research, we went to Sunnybrook hospital to shadow and observe physicians in the Emergency Department to see how they manage the patients and their data. Based on the findings from this research, requirements for an integrated context-aware information system were developed and were used to inform the design and development process for the user interface (UI) prototype.

This usability testing session is aimed at evaluate the UI prototype and verifying its usability and usefulness by collecting direct feedback from a sample of potential users. The findings from this study will be analyzed to derive recommendations for design improvements.

What we will ask you to do:
If you agree to take part in this study, we will conduct a user testing session with you at the Interactive Media Lab at the Bahen Centre. It will begin with a brief questionnaire concerning your day-to-day tasks in the ED and your experience with the current information systems. Then you will be asked to complete simple tasks using interface prototypes provided. The interview will take about 20 minutes to complete. Following the interview, we will ask you to walk through the pictures of the system and complete given tasks, which will take about 30 minutes. After this, we will ask you how you felt about the experience and collect any additional feedback you have. The session will take about an hour in total.

Risks and benefits:
This research poses no risks to you other than those normally encountered in daily life. All of the information from your session will be kept confidential. Your data will have a number
associated with it instead of your name. After the research is completed, we may save the notes for future use by ourselves or by others, but your name will not be included. There are no immediate benefits to you other than helping to improve the user experience of the information systems used in the Emergency Department. A $100 gift certificate will be offered as an incentive and a token of appreciation.

Confidentiality:
Your answers will be confidential. The records of this study will be kept private. In any sort of report we make public we will not include any information that will make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records.

Taking part is voluntary:
Your participation in this research is voluntary, and you are free to withdraw at any time.

If you have questions:
Please feel free to ask any questions you have. If you have questions later, feel free to contact the researcher Erin Yu at erin.yu@utoronto.ca or at 416-258-9833. You will be given a copy of this form to keep for your records. If you have any questions about your rights as participants, please contact the Office of Research Ethics at ethics.review@utoronto.ca or 416-946-3273.

Your consent:
I have had the opportunity to read and understand the above information. I agree with the terms and hereby consent to participate in the study.

Participant signature: ________________________________
Participant name (printed): __________________________
Date: ________________________________

Our acknowledgement:
Investigator signature: ______________________________
Investigator name (printed): __________________________
Date: ________________________________
Appendix D. User Testing Protocol

The following scripts will be used at each session to ensure all participants were given the same set of instructions. Each participant was greeted using the following script, briefed on the goals of the study and test protocols. The participant was then seated at a computer screen.

Greeting Script:
Hi [user's name]. My name is Erin, and I'm a researcher at the Interactive Media Lab. This project is a collaboration with IBM, where we explore the opportunity to improve the healthcare information systems used in the Emergency Department and allow physicians to focus more on patient treatment rather than information entry and access and administrative tasks.

Description of the Study Protocol:
We would first like to ask you some background questions to gather demographic information and learn about your experience with the current information systems used in the Emergency Department.

Then we are going to present you with a series of screens, and give you a set of simple and typical tasks to perform using the screens. Please speak all your thoughts aloud as you go through the tasks. This helps us better understand why you are making certain choices.

After the testing, we'll ask you to fill in a simple feedback form to collect any additional Thoughts you might have about your experience with the interface.

The study will take about an hour. We will answer any questions you have at the end of the session. If you feel uncomfortable you can stop at any time during the study.

Do you have any questions?

First we'll need you to sign this Consent Form.

Background Questionnaire
Please fill out the background questionnaire.
Tasks

We will start with a general overview of the information system. It is a browser-based application that keeps track of all of the patient records in one place. The idea is to keep everything from the list of all patients in the ED, test orders, test results, to medical history all in one place.

The following five tasks were developed based on our previous conversations with the ED physicians at Sunnybrook. Tasks frequently performed in their day-to-day routine will be tested. We’ll read each task to you one at a time. We are not going to track how long it takes you to complete each task. We are more interested in your reaction, behaviour, and qualitative feedback. Please keep in mind that we are evaluating the system, not you.

Before we begin, please have a look and explore the screens for 5 minutes. Let us know if you have any questions.

Please think aloud as much as you can as you perform the following tasks. Let’s get started!

Use the following questions to guide the participant through the tasks.

- Access the system
  a. What do you expect to see when you first bring up the system?
  b. Would you expect to log in?
- See patients under your care
  c. This screen shows a list of all patients who are currently in the ED. You want to see which patients are under your care. How would you go about doing that?
- From here, what would you do to determine which patient to see next?
  a.
- See individual patient record
  a. You want to see what the triage nurse said about Mr. Parson’s condition. How would you go about doing that?
  b. What information should be shown at all times (e.g. at the top of the page)? What information about a particular patient should be shown at all times?
- Order a CT scan for Mr. Parson
  a. From the triage report, it is clear that a CT scan is needed for Mr. Parson. How would you go about ordering a CT scan?
- Find Mr. Parson’s CT report
  a. Would you like to be notified when the CT scan results comes back for Mr. Parson?
  c. If yes, how would you like to be notified?
  d. Which pieces of the information should the notification contain?
  e. When is not a good time to notify you of these updates?
  f. If no, why not? When and how would you learn about Mr. Parson’s CT scan results?
  g. Did you notice the visual cue for the new test results? How useful was it?
- Request a radiology consult for Mr. Parson’s CT scans
  a. How would you find out which radiologist is in charge right now?
  b. How would you request a consult?
- Refer Mr. Anderson to General Medicine
  a. How would you find out whom to contact using the system?
b. How would you refer Mr. Anderson to General Medicine?

This is the end of the tasks.

**User Satisfaction Questionnaire**

Do you have any additional feedback?

Please fill out the questionnaire.
Appendix E.  Background Questionnaire

Gender:
- Male
- Female

Age group:
- 22 - 30 years
- 31 - 40 years
- 41 - 50 years
- 51 - 60 years
- Over 60 years

What is your comfort level with technology?
- Uncomfortable
- Not very comfortable
- Somewhat comfortable
- Comfortable
- Very comfortable

What is your role on in the Emergency Department?
- Physician
  - Intern/medical student
  - Resident
  - Attending
  - Other: Please specify _________________________
- Nurse
- Admin
- Other: Please specify _________________________

How long have you worked in the Emergency Department?
- Less than one year
- 1-3 years
- 4-6 years
- 7-10 years
- 11 years or more
What systems do you have available in the ED and how often do you use each of them?

**Patient roster:**
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

**Electronic Patient Record:**
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

**Radiology/imaging software:**
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

**Patient discharge portal:**
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

**Paging and communication:**
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

**System for prescription and referral:**
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

**Other:**
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never
How often do you do any of the following tasks on a desktop computer?

### Google search:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Literature search:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Instant messaging:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Work email:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Page other clinicians:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Request consults:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Order lab tests:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Order imaging tests:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Check lab test results:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

### Check imaging results:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never
Check individual patient status:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

Check overall ED status:
- All the time
- A few times a day
- A few times a week
- A few times a month
- Never

Do you do any of the following using your web browser and if so, how often?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check personal email:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- All the time</td>
</tr>
<tr>
<td></td>
<td>- A few times a day</td>
</tr>
<tr>
<td></td>
<td>- A few times a week</td>
</tr>
<tr>
<td></td>
<td>- A few times a month</td>
</tr>
<tr>
<td></td>
<td>- Never</td>
</tr>
<tr>
<td>Use Facebook:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- All the time</td>
</tr>
<tr>
<td></td>
<td>- A few times a day</td>
</tr>
<tr>
<td></td>
<td>- A few times a week</td>
</tr>
<tr>
<td></td>
<td>- A few times a month</td>
</tr>
<tr>
<td></td>
<td>- Never</td>
</tr>
<tr>
<td>Check weather:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- All the time</td>
</tr>
<tr>
<td></td>
<td>- A few times a day</td>
</tr>
<tr>
<td></td>
<td>- A few times a week</td>
</tr>
<tr>
<td></td>
<td>- A few times a month</td>
</tr>
<tr>
<td></td>
<td>- Never</td>
</tr>
<tr>
<td>Use calendar:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- All the time</td>
</tr>
<tr>
<td></td>
<td>- A few times a day</td>
</tr>
<tr>
<td></td>
<td>- A few times a week</td>
</tr>
<tr>
<td></td>
<td>- A few times a month</td>
</tr>
<tr>
<td></td>
<td>- Never</td>
</tr>
</tbody>
</table>
Appendix F. User Satisfaction Questionnaire

Was there anything confusing about the interface? Yes  No
If yes, what was confusing?

Are there any changes you would suggest to make it less confusing?

What did you like about the interface?

What would you say needs improvement?
Please indicate your agreement or disagreement with the following statements:

<table>
<thead>
<tr>
<th></th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The terminology used is clear and relevant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is useful to have a list of patients under my care</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is easy to find a particular patient record</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is easy to order a test for a particular patient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is easy to request a consult/ refer patient to other services</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is a satisfying experience overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>