2018

The Application of Usability Engineering Methods to Evaluate and Improve a Clinical Decision Support System

Kristine DeSotto

THE APPLICATION OF USABILITY ENGINEERING METHODS TO EVALUATE AND IMPROVE A CLINICAL DECISION SUPPORT SYSTEM

A Thesis Presented

by

KRISTINE M. DESOTTO

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN
INDUSTRIAL ENGINEERING AND OPERATIONS RESEARCH

May 2018

Mechanical and Industrial Engineering

THE APPLICATION OF USABILITY ENGINEERING METHODS TO EVALUATE AND IMPROVE A CLINICAL DECISION SUPPORT SYSTEM

A Thesis Presented

by

KRISTINE M. DESOTTO

Approved as to style and content by:

_____
Jenna Marquard, Chair

_____
Hari Balasubramanian, Member

_____
Elizabeth A. Henneman, Member

_____
Tamar Taddei, Member

_____
Sundar Krishnamurty, Department Head
Mechanical and Industrial Engineering

ACKNOWLEDGMENTS

I would like to sincerely thank my advisor, Professor Jenna Marquard, for her guidance, encouragement, and support in helping me to complete this study and further my knowledge in the field of human factors. The different opportunities I was able to experience while working with her were the most rewarding part of my time at the University of Massachusetts. I also wish to express my gratitude to the other members of my committee: Professor Elizabeth Henneman, Professor Hari Balasubramanian, and Dr. Tamar Taddei. I continue to be inspired by their meaningful work and their passion for mentoring and I am thankful that they were willing to be part of my journey.

Throughout the design and execution of this study I have received generous support from Dr. Tamar Taddei, Rajni Mehta, and the rest of the Cancer Coordination and Tracking System (CCTS) team. I am so thankful for the time and support from all of these individuals and the opportunity to collaborate on such an important topic. The Department of Veterans Affairs is filled with passionate, kind, and intelligent individuals and I am proud to work alongside them.

I would also like to thank my teammates in Professor Marquard's lab, Vanessa Martinez and Swaminathan Kandaswamy, and the other students at UMass who supported me along the way. Finally, I am unbelievably grateful to my family and boyfriend for their endless encouragement and belief in me.

ABSTRACT

THE APPLICATION OF USABILITY ENGINEERING METHODS TO EVALUATE AND IMPROVE A CLINICAL DECISION SUPPORT SYSTEM

May 2018

KRISTINE M. DESOTTO, B.S., WORCESTER POLYTECHNIC INSTITUTE

M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professor Jenna Marquard

Delays in the process of diagnosing and treating cancer are common and lead to confusion and undesirable outcomes. Care coordinators are often embedded within the system of care to manage follow-up care. Electronic and real-time reminder systems can be used to support the care coordinator's work, but electronic health record (EHR) usability is known to be poor. This study, completed in collaboration with the Department of Veterans Affairs (VA) Connecticut Healthcare System, evaluated the Cancer Coordination and Tracking System (CCTS), an EHR-linked, web-based tool for cancer care management.

A set of expert-driven and user-driven usability engineering methods was applied to comprehensively identify and analyze usability problems within the system. Ten current CCTS users were engaged in the study to help identify problem. 101 (62.3%) problems were identified through expert-driven methods, 56 (34.6%) were identified by user-driven methods, and 5 (3.1%) were identified through both types of methods. The list of 162 unique problems were prioritized and twelve high priority problems were highlighted. Design recommendations were developed to address each of these high priority problems.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER 1

INTRODUCTION

The diagnosis and treatment of cancer requires close management of numerous imaging and lab results over time. A survey of physicians at two large teaching hospitals showed that most (59%) were unsatisfied with how they manage test results and the vast majority (83%) reported a delay in reviewing test results over the prior two months (Poon et al., 2004). When delays like this occur and the cancer care process does not work as intended, patients are at risk of experiencing delays in treatment initiation and poor health outcomes.

In recent years, healthcare organizations have deployed care coordinators to serve patients with suspicious or confirmed cancer to improve the timeliness and quality of their care. These care coordinators are tasked with managing complex, time-sensitive imaging, lab results, and follow-up appointments for a panel of patients. They require effective tools to aid them in their tasks, but electronic health records (EHRs) are not often configured to effectively manage longitudinal care, and lack robust functionality for cancer imaging, lab, and appointment reminders.

The Veterans Health Administration (VHA), part of the Department of Veterans Affairs (VA), is the largest integrated healthcare system in the United States and employs nurse care coordinators within many of its hospitals. The VA Connecticut Healthcare System (VA Connecticut) implemented a cancer care coordination program in 2008 and designed an EHR-linked, web-based tool and infrastructure for managing abnormal image results and follow-up actions. The Cancer Coordination and Tracking System (CCTS) supports care coordinators in identifying new abnormal lung nodules and liver

lesions through International Classification of Diseases (ICD) codes or natural language processing (NLP) and provides a mechanism to help care coordinators manage patients' follow-up care.

It is well known that EHR usability is poor and that these systems do not integrate well into clinic workflow. While CCTS addresses some functional deficiencies in the EHR, care coordinators still view it as having usability problems. Usability engineering methods can help understand user workflows and identify methods for better integrating healthcare information technology (health IT) tools – which may or may not include EHRs – into those workflows. The purpose of this study was to apply a series of usability engineering techniques to comprehensively evaluate, understand, and improve the usability of CCTS.

Chapter 2 details relevant literature from the domains of 1) cancer care and coordination, 2) EHR usability problems, and 3) usability engineering methods. Chapter 3 outlines the expert-driven and user-driven methods used to improve the usability of the CCTS. Chapter 4 discusses the main results from the study and the execution of these methods and Chapter 5 reviews the design recommendations for twelve high priority usability problems. Finally, a discussion of the overall study and conclusions are provided in Chapters 6 and 7, respectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Cancer Care and Coordination

Cancer is a highly prevalent chronic condition with 42% of men and 38% of women being diagnosed in their lifetime (Siegel, Miller, & Jemal, 2017). Diagnosis and treatment of cancer requires management of complex, longitudinal care and often involves coordination of care among multiple specialists.

The experience of one patient with a suspicious 5-cm liver mass exemplifies the complexities of the diagnosis and care process (Press, 2014). After identification of the mass through an abdominal computerized tomography (CT), the patient received five additional procedures and was cared for by 12 clinicians over the next several months. A report titled "Optimising Cancer Care in Australia", published in 2003, details some of the key challenges experienced by patients receiving care, including delays and confusion throughout the process (Clinical Oncological Society of Australia, 2003).

Established treatment timeliness guidelines for many types of cancer exist, but these are not always met in practice (Asch, Kerr, Hamilton, Reifel, & McGlynn, 2000). A study at two Department of Veteran Affairs (VA) medical centers shows results of a retrospective review of patients diagnosed with lung cancer between 2004 and 2007. Reviewers found that over one third of providers did not identify or follow-up on clinical concerns leading up to a cancer diagnosis. A large proportion of these delays were due to lack of recognition of abnormal chest CT and x-ray results, putting the median time for cancer suspicion to diagnosis well over the established guidelines.

Due to the complex and multidisciplinary nature of cancer care, responsibility of decision-making and follow-through can often become lost (Stavert & Lott, 2013). To help streamline cancer care processes, care coordinators are often employed within the system of care to monitor follow-up actions and ensure care is provided in a timely manner (Yates, 2004). Implementation of a cancer care coordinator within one healthcare system led to significant improvements in timeliness and quality of cancer care with the average number of days from cancer suspicion to treatment decreasing by 81 (Hunnibell, 2012).

Health IT may serve as a valuable tool for cancer care coordinators as they conduct their work. The VA Cancer Coordination and Tracking System (CCTS) was developed to support care coordinators within one healthcare system in identifying new cases and managing follow-up actions during the process of diagnosing lung and liver cancer (Taddei, 2012). Systems like CCTS are often used to support care teams in managing patients with complex conditions such as cancer (Epping-Jordan, Pruitt, Bengoa, & Wagner, 2004).

2.2 Electronic Health Record Usability Problems

While the push to adopt EHRs is significant, 30% of implementations fail, often due to complicated EHR systems that require more time from already overburdened clinicians (Connolly, 2005; Smelcer, Miller-Jacobs, & Kantrovich, 2009). A survey administered by the American College of Physicians (ACP) and the National Institutes of Health (NIH) reported an average loss per attending physician of 48 minutes per day after their healthcare system adopted an EHR (McDonald et al., 2014).

Inadequate EHR design can lead to ineffective or improper use of EHRs, errors, and patient safety risks (Bates et al., 2003; Bowman, 2013). For instance, analysis of a Computerized Physician Order Entry (CPOE) system at a teaching hospital showed that usability problems

were prevalent (Koppel, Metlay, & Cohen, 2005). Clinicians mistook pharmacy inventory levels as dosing guidance and the lack of a comprehensive ordering system led to improperly entered orders. Another analysis of 100 reported EHR safety concerns from a large integrated health care system uncovered that the largest group of reported incidents were due to lack of proper information displayed on the EHR (Meeks et al., 2014).

A key recommendation from the American Medical Informatics Association's EHR Task Force asks the field to "improve the designs of interfaces so they support and build upon how people think" (Payne et al, 2015). A second paper explains that, to improve the implementation of evidence-based medicine through health IT, it is critical to align the system with the user's workflow (Bates et al., 2003).

Although these recommendations exist, the application of usability engineering methods is not often a component of health IT design. These methods can identify critical design problems and even seemingly minor modifications to design can have a large impact on the overall usability of a system (Bates et al., 2003). Usability testing of a commercial EHR for a pediatric hospital system prior to implementation identified 134 potential usability problems, 10% of which were classified as having potentially severe consequences for patients (Edwards, Moloney, Jacko, & Sainfort, 2008).

2.3 Usability Engineering Methods

Usability engineering methods are intended to improve the design and use of systems for the intended user (Kushniruk & Patel, 2004). These methods have been in use since the 1990s and more recently have been applied to health IT (Hollingsed & Novick, 2007; Peute, Spithoven, Bakker, & Jaspers, 2008). The methods are diverse and include both qualitative and quantitative

data collection and analysis. Because various methods provide unique information, multiple methods are often used in combination with one another.

While questionnaires and interviews are often used to gather usability feedback, they require participants to reflect on prior use of a system, which may lead to incomplete information (Kushniruk & Patel, 2004). Pairing these methods with real-time observations of individuals using the system helps to ensure studies are more comprehensive. A review of 52 health IT usability studies found that 23% combined two or more qualitative usability methods and 44% combined survey and interview methods with qualitative usability methods (Peute, 2008).

We provide a high-level overview of the following usability engineering methods: 1) heuristic evaluation, 2) cognitive walkthrough, 3) observations using screen capture and think aloud, 4) debriefing interviews, and 5) usability questionnaires.

2.3.1 Heuristic Evaluation

A heuristic evaluation involves a usability expert reviewing a user interface against a set of known usability design principles, taking note of usability problems, and assessing the severity of each problem (Hollingsed & Novick, 2007). It is a cost-effective method for identifying and prioritizing usability problems prior to partial or full implementation of a system (Kushniruk & Patel, 2004). Table 1 shows a common list of usability design heuristics, originally proposed by Neilsen (Nielsen, 2009; Kushniruk & Patel, 2004; Longo & Kane, 2011).

2.3.2 Cognitive Walkthrough

Cognitive walkthrough is a method that allows either usability experts or end users to walk through users' workflows and identify potential usability problems. It helps determine how easy or difficult a system is in executing key actions associated with completing these

workflows. The following steps are involved in a cognitive walkthrough: 1) define users of the system, 2) define the task(s) for the walkthrough, and 3) walk through the actions and critique the system (Kushniruk & Patel, 2004). During the walkthrough, user goals and actions and potential usability problems are documented. An example of this documentation from Kushniruk and Patel (2004) is provided in Table 2 below.

Table 1: Usability Heuristics

Heuristic	Description
1. Visibility of system status	Does the system always keep you informed about what is going on through appropriate feedback within reasonable time?
2. Match the system to the real world	Does the system speak the users' language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms?
3. User control and freedom	Does the system support undo and redo functionalities to leave the unwanted state without having to go through an extended dialogue?
4. Consistency and standards	Does the user have to wonder whether different words, situations, or actions mean the same thing?
5. Error prevention	Does the system present a lot of error messages?
6. Minimize memory load – support recognition rather than recall	Does the system minimize the user's memory load by making objects, actions, and options visible?
7. Flexibility and efficiency of use	Does the system provide shortcuts to jump quickly to a certain functionality accelerating the interaction with frequent actions?
8. Aesthetic and minimalist design	Does the system show dialogues that contain information which is irrelevant or rarely needed?
9. Help users recognize, diagnose, and recover from errors	Does the system present error messages expressed in plain language precisely indicating the problem, constructively suggesting a solution?
10. Help and documentation	Does the system provide help/documentation easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large?

Table 2: Cognitive Walkthrough Example

GOAL:	Enter a patient's problem into the system
Subgoal 2:	Enter the Problem
Action 1:	Click on the button labeled "Add New Problem"
System Response:	A keyword search window (the MED-Viewer) appears for the user to enter the problem
Potential Problem:	User may not realize that they must now enter a term in the search terms window
Subgoal 3:	Use the Search Term Window (the MED-Viewer) to Select an Appropriate Term
Action 1:	Note that a search term window (the MED-Viewer) appears, for entering the users term describing the problem
Action 2:	Enter the term (for the problem) in the search words text box
System Response:	The system returns a list of controlled terms that most closely match the users' input
Action 3:	The user must select from the list returned by the system the term most closely matching their needs
System Response:	The system accepts the selected term, the search term window disappears, and the list of problems becomes updated with the new problem
Potential Problem:	The user may misspell the term they wish to enter in the system

2.3.3 Observations using screen capture and think aloud

Live or simulated observation sessions are often use as part of a usability study to capture how users engage with a system. Many usability studies have used video-taped observational sessions so the content from the session can be further analyzed (Kushniruk & Patel, 2004; Li et al., 2012).

Think aloud observations involve capturing audio recording of participants as they talk through their cognitive processes while using a system. A think aloud protocol, as used in one study, allows user interactions with the system to be recorded and later reviewed by the user to gain additional insights about how they approached their use of the system (Wright & Moretti, 2013). Questions from the evaluator are often limited to ensure the participant can provide valid

insight as to what they are normally thinking when completing a task (Someren, Barnard, & Sandbert, 1994).

2.3.4 Debriefing Interviews

Debriefing interviews let users reflect on their use of a system and provide more general high-level feedback about how a system is used and usability problems they identify (Wright & Moretti, 2013). These interviews can also be used to identify needs specific to the users (Kantner & Rosenbaum, 1997).

2.3.5 Usability Questionnaires

Questionnaires are often completed to gain additional insights, including perceptions of the user, during a usability study (Walji et al., 2014). The System Usability Scale (SUS) is a commonly used questionnaire that gathers feedback on the overall usability of a system (Brooke, 1996). SUS questions are listed in Figure 1.

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

Figure 1: System Usability Scale Questions

CHAPTER 3

METHODS

3.1 Overview

The objective of this study was to apply a set of usability engineering methods to evaluate the workflow for managing cancer care using the Cancer Coordination and Tracking System (CCTS). Insights gained from these methods informed development of a set of design recommendations to demonstrate options for enhancing the usability and efficiency of CCTS.

In this section we provide a more detailed description of CCTS and the methods used to complete this study. The methods were executive in three phases: 1) expert-driven problem identification, 2) user-driven problem identification, and 3) design recommendation development.

The expert-driven methods included the heuristic evaluation and cognitive walkthrough. Both of these methods were executed without involvement of the CCTS users. The user-driven methods involved sessions with CCTS users. Each session included observations with screen capture and think aloud, debriefing interviews, user perception of cognitive walkthrough problems, and a usability questionnaire. Design recommendations were developed after all usability problems were collected and prioritized. A description of each method and its benefits and limitations is provided in Table 3.

Table 3: Description of Methods

Method	Benefits	Limitations	Duration
Expert-Driven Problem Identification			
Heuristic evaluation	Compares a system against a set of known usability design principles	Only one evaluator due to protected health information in system; usually there are two or more	5 hours
Cognitive walkthrough	Identifies usability problems by mimicking the user's cognitive workflow through a system	Focused on key tasks completed by users, not other functionality within CCTS	4 hours
User-Driven Problem Identification			
Observations with screen capture and think aloud	Records a user's interaction with a system to better understand how they search for and use information and captures what the user is thinking during system use	Screen capture may not fully capture user actions	20 minutes per user
Debriefing Interview	Gathers user reflections on their own use of a system	Time constraints limited amount of feedback gathered from staff	10 minutes per user
User perception of cognitive walkthrough problems	Gathers user perceptions of severity for previously-identified cognitive walkthrough problems	User severity scores not gathered for problems identified outside cognitive walkthrough	10 minutes per user
Usability Questionnaire	Gathers user perceptions and feedback on overall usability of system	Results of usability questionnaire not further discussed with users to gain additional insight	5 minutes per user
Design Recommendations			
Create and display design recommendations	Develops design recommendations for high priority usability problems	Design recommendations only developed for high priority problems and impact of proposed changes could not be implemented or tested due to time limitations	2 hours

3.2 Cancer Coordination and Tracking System

The Cancer Coordination and Tracking System (CCTS) is a web-based EHR-linked care management tool developed at VA Connecticut and in use since 2008. It is used by cancer care coordinators to support identification of new cases and management of follow-up actions. CCTS pulls in lung and liver radiology imaging reports and identifies abnormal lung nodules and liver lesions through International Classification of Diseases (ICD) codes or natural language processing (NLP). These cases are automatically imported into CCTS alert queues for care coordinators to process.

The system also allows care coordinators to enter reminders for future follow-up actions (e.g. follow-up appointments, imaging, blood work). The coordinators work with the system daily to review new coded alerts, review new NLP (search) alerts, enter follow-up actions, and review the list of follow-up actions now due. Within the larger system of care, the coordinators work with attending physicians to manage cases and often help prepare for cases to be presented at tumor board, an interdisciplinary meeting where new or suspicious cancer cases are reviewed and an action plan is developed. While the EHR is the primary method for managing and documenting patient care, CCTS provides additional functionality that is not available in the EHR.

This study focused on three key tasks within CCTS: 1) reviewing a new coded alert and entering follow-up actions, 2) reviewing a new NLP (search) alert and entering follow-up actions, and 3) reviewing an existing follow-up list, determining next steps in care, and closing out or adding additional follow-up actions as needed. Execution of these tasks requires the user to navigate through CCTS and the EHR.

3.3 Expert-Driven Problem Identification

The expert-driven methods included the heuristic evaluation and cognitive walkthrough which were completed without involvement of the users.

3.3.1 Heuristic Evaluation

The purpose of the heuristic evaluation was to compare CCTS against a predefined list of design criteria. The detailed nature of the heuristic evaluation, and attention to the specific heuristics, helps uncover a variety of usability problems.

3.3.1.1 Approach

The heuristic evaluation was executed and any usability problems, based on the set of heuristics for usability design in Table 4, were noted (Nielsen, 2009; Kushniruk & Patel, 2004). Due to the scope and protected health information (PHI) restrictions of this study additional experts were not able to complete a heuristic evaluation.

Colleagues with experience in human factors and usability evaluation reviewed the template for collecting heuristic evaluation data, noted any recommendations to consider when completing the evaluation, and asked for clarifications as needed after reviewing the results of the heuristic evaluation. Guidance from these colleagues helped ensure the evaluation was as comprehensive as possible given our constraints.

Each usability problem was scored using the severity scale in Table 5 to quantify how detrimental each problem appeared to be to the overall usability of the system (Kushniruk & Patel, 2004).

Table 4: Usability Heuristics

Heuristic	Example
1. Visibility of system status	Indicate that a follow-up was successfully entered
2. Match the system to the real world	Avoid use of computer system terms
3. User control and freedom	Allow users to undo and reverse actions as needed
4. Consistency and standards	Ensure menu options are consistently located throughout system
5. Error prevention	Use drop-down menus to avoid typos
6. Minimize memory load – support recognition rather than recall	Ensure key functions are easily to locate without
7. Flexibility and efficiency of use	Allow users to set up their own preferences for system display
8. Aesthetic and minimalist design	Present complex information on simple, layered screens
9. Help users recognize, diagnose, and recover from errors	Provide clear error messages
10. Help and documentation	Ensure easy access to frequently asked questions

Table 5: Usability evaluation severity scale

Value	Description
1	Cosmetic problem only; fix if extra time is available
2	Minor usability problem: fixing this should be given low priority
3	Major usability problem: important to fix, so should be given high priority
4	Usability catastrophe: imperative to fix this before product can be released

3.3.1.2 Data and Analysis

The data were aggregated to count the number of usability problems by heuristic. Results from the heuristic evaluation were used to uncover potential usability problems and guide recommendation development. For example, if the evaluation indicated that there was not an effective way to undo or reverse a user action, we would have noted this as a problem and determined ways to improve this feature in the recommendations.

3.3.2 Cognitive Walkthrough

The purpose of the cognitive walkthrough was to document user actions, user goals, and potential usability problems. Literature shows that a strong understanding of the cognitive workflow of a system is important to designing more effective health IT (Kushniruk & Patel, 2004). Due to the comprehensive nature of the cognitive walkthrough we may be able to uncover problems that are not identified through other means.

3.3.2.1 Approach

A cognitive walkthrough of CCTS focused on the following key goals: 1) reviewing a new coded alert and entering follow-up actions, 2) reviewing a new NLP (search) alert and entering follow-up actions, and 3) reviewing an existing follow-up list, determining next steps in care, and closing out or adding additional follow-up actions as needed. For each goal, the system was reviewed to identify sub-goals, actions, system responses, and potential problems that the user may face.

3.3.2.2 Data and Analysis

The number of potential problems was totaled and compared to the number of sub-goals and actions for each of the three overarching goals. This comparison is used to estimate how likely problems are to occur based on the ratio of actions to potential problems (Kushniruk & Patel, 2004). Results of the cognitive walkthrough helped identify problems to address when developing design recommendations. For example, if the cognitive walkthrough indicated that the area for entering a new follow-up action was difficult to find, we would have considered relocating this feature in the recommendations.

3.4 User-Driven Problem Identification

A proposal for this project was submitted to the VA Connecticut Healthcare System and University of Massachusetts IRB Committees and they determined that this study did not need further IRB review or consenting from participants. Sixteen current CCTS users were invited to participate in this study through one-on-one virtual user observation sessions. A list of potential participants was developed by CCTS stakeholders and email invitations were sent to these users. The invitations communicated that the sessions were voluntary and that the purpose of the study was to identify problems with CCTS and recommend future interface changes. Once a user volunteered to participate a mutually agreeable meeting time was determined.

Ten users from seven different VA medical centers participated in an observation session (Table 6). The sessions were conducted in a virtual setting with software that provided audio and screen-sharing functionality (Microsoft Lync). Each session included observations with screen tracking and think aloud, a debriefing interview, an activity that gathered user perception of cognitive walkthrough problems, and a usability questionnaire.

Table 6: Observation Session Participants

Location	Number of Users
West Haven, CT	3
Brooklyn, NY	2
Augusta, ME	1
Dayton, OH	1
Lebanon, PA	1
Phoenix, AZ	1
White River Junction, VT	1

3.4.1 Observations using screen capture and think aloud

The purpose of the observations was to understand what information in the system the users were looking at, how much time they spent looking at that information, and how much time they spent completing each task. The think aloud component was used to help trigger recollection of usability problems during their use of the system.

3.4.1.1 Approach

Users were asked to share their screen at the start of the observation session and were told the session would be recorded but not shared outside the session. During each session, the user addressed coded alerts, search alerts, and follow-ups as available and as within their normal scope of work. Participants were asked to complete one or more of these tasks as they would normally. Microsoft Lync captured video and audio as the users interacted with CCTS and the EHR.

After completing their set of one or more cases, participants were shown their screen capture video and were asked to think aloud, commenting on why they were looking where they were and on any usability problems they encountered as they completed these tasks.

3.4.1.2 Data and Analysis

The screen capture observations provided video and audio recordings of the users managing cases in CCTS and providing reflections on these tasks. The data were coded to capture the time spent in each area of interest in CCTS and the EHR, the time spent on each key task, and any usability problems noted during the session. The areas of interest within CCTS and the EHR are listed in Table 7 below. Any actions taken outside of these areas of interest was coded as “Other”.

Table 7: Key Components of CCTS and the EHR

CCTS	EHR
Patient Lookup	Patient Lookup
Patient Action	Cover Sheet
Patient History	Orders
Action Lists	Notes
Enter Case Details	Consults
	Labs
	Reports

The coded think aloud audio recordings were analyzed to identify the number of problems noted. A severity scale, mentioned above, was also applied to the think aloud data to help prioritize changes. These problems were used to help inform development of design recommendations. For example, if a significant amount of time was spent reviewing lab or imaging results in the EHR, we would have recommended pulling in additional information from the EHR to streamline workflow.

3.4.2 Debriefing Interview

The purpose of the debriefing interview was to understand the context of a user's interaction with the system and solicit any additional feedback on the usability of the system.

3.4.2.1 Approach

After the observations, the audio recording software continued to run and participants were guided through a list of interview questions, detailed in Figure 2.

1. Can you tell me about a time when you felt frustrated when using CCTS?
2. Do you feel that specific parts of CCTS are more difficult to use or tend to cause errors? If yes, which parts or areas?
3. Do you feel like a new staff member would have trouble with specific areas within CCTS?
4. What changes could be made to improve how useful CCTS is?
5. What changes could be made to improve how easy to use CCTS is?
6. What features of CCTS do you not use? Why don't you use these? Are they not helpful or do you not have time to use them?
7. What other ideas or feedback do you have to improve CCTS?

Figure 2: Debriefing Interview Questions

3.4.2.2 Data Analysis

Audio recordings from each interview were transcribed and reviewed to identify any usability problems noted by the users. These problems were added to a list of problems identified through other methods. If the participants indicated that a particular component of the system was more difficult for new users to learn, we may have applied this information when developing the design recommendations.

3.4.3 User Perception of Cognitive Walkthrough Problems

The purpose of this section was to gather user perceptions of severity for the problems identified during the expert-driven cognitive walkthrough.

3.4.3.1 Approach

Problems identified during the cognitive walkthrough were displayed on individual PowerPoint slides with an image of the problem area, if available. Users were asked to rank the severity of the problem using the scale described in Table 5. An additional category (Not a problem; Severity = 0) was provided to users to select if they felt the described problem was not a problem to them.

3.4.3.2 Data Analysis

User severity scores for each cognitive walkthrough problem were aggregated across all users. An average user severity score was calculated for each problem. This information helped prioritize usability problems. For example, if more than half of users felt that a problem identified during the cognitive walkthrough was a major usability problem, this problem may have been a high priority to address.

3.4.4 Usability Questionnaire

The purpose of the usability questionnaire was to gather a final set of information about the users and their experience with CCTS. Use of the System Usability Scale (SUS) provided a way to use a validated measurement tool to assess the system.

3.4.4.1 Approach

At the end of the user session, participants were provided with a survey link containing questions about the user and their experience with CCTS as well as the SUS questions. The user-focused questions gather the user's age, sex, years of experience in healthcare, highest degree of education, and the length of time they have been using CCTS. The second part of the survey asked users to respond to the SUS questions using a standard scale from 1 (strongly disagree) to 5 (strongly agree). The SUS questions are provided in Table 8 (Brooke, 1996).

3.4.4.2 Data and Analysis

Results from the usability questionnaire were analyzed to better understand the users and their impressions of CCTS. User information was aggregated to understand the average and ranges of experience with healthcare and CCTS. Results from the SUS questions helped prioritize areas of CCTS that are of greatest concern to the users. For example, if users

collectively gave a poor rating for “I find this system unnecessarily complex”, this would have been a key area to address.

Table 8: System Usability Scale Questions

Questions on a scale from 1 (strongly disagree) to 5 (strongly agree)

1. I like to use this system frequently
2. I find this system unnecessarily complex
3. I think the system is easy to use
4. I need support of a technical person to use this system.
5. I find the various functions in this system to be well integrated
6. I think there is too much inconsistency in this system
7. Most people learn to sue this system very quickly
8. I find the system very cumbersome to use
9. I feel very confident using the system
10. I needed to learn a lot of things before I could get going with this system

3.5 Design Recommendations

3.5.1 Development of Design Recommendations

The purpose of developing design recommendations is to provide ideas to address the high priority problems identified through the study.

3.5.1.1 Approach

Usability problems and severity scores were combined from the expert-driven and user-drive methods mentioned above. All problems were aggregated and ranked using the severity scale or the number of times a problem was brought up by a user. Duplicates were noted and removed to create a single list of prioritized usability problems. The prioritized list of usability problems was used to develop design recommendations.

3.5.1.2 Data and Analysis

The prioritized list of usability problems and the design recommendations were shared with CCTS stakeholders. Any feedback from these individuals was noted and changes were made as appropriate.

CHAPTER 4

RESULTS

4.1 Overview

The six usability engineering methods identified a total of 162 usability problems ranging from minor cosmetic problems to concerns regarding the overall workflow of CCTS. Expert-driven methods were completed without any users present and included a heuristic evaluation and cognitive walkthrough. The heuristic evaluation compared CCTS against a set of known usability design principles while the cognitive walkthrough identified usability problems by mimicking the user's cognitive workflow through the system. User-driven methods comprised of observations including screen capture and think aloud component, debriefing interviews, user perception of cognitive walkthrough problems, and a usability questionnaire. The user-driven methods were executed during observation sessions held individually with 10 current CCTS users.

101 (62.3%) problems were identified uniquely through expert-driven methods, 56 (34.6%) were identified uniquely through user-driven methods, and 5 (3.1%) were identified through both types of methods. Problems were categorized to describe the main location or feature of CCTS that each problem was related to. Several additional categories describe higher level problems identified by users related to areas such as system performance or workflow. Table 9 provides a description of these categories and Table 1Table 10 shows the number of problems identified by each method. The usability questionnaire is excluded from this visualization since it gathered contextual information about the user experience with CCTS instead of individual usability problems.

Table 9: Description of Usability Problem Categories

Category	Description	Example
Alerts	Problems related to the coded alert and search alert key tasks	After entering a lesion, the next section does not always expand on its own and requires an extra click.
Errors	Problems related to error messaging or allowing users to recover from errors	Errors are hard to fix. A follow-up can only be deleted within 24 hours. If you switch screens after making an error you can mark it as an error but it stays in the system.
Follow-ups	Problems related to the follow-up key task	It is difficult to add a new follow-up for a patient. You have to go to the patient action tab.
General	Problems related to the overall functioning of the system and not specific to a particular task or area	The default font is impossible to read. You have to change the font every time you enter the system. Some pieces don't seem to work over font size 10.
Help	Problems found within the Help tab of CCTS	The help menu does not clarify what the display errors feature on the follow-up list does.
Navigation	Problems related to navigation between areas within CCTS	The blue button navigates to different options depending on what screen you are on (e.g. Timeliness of care report).
Patient History	Problems found within the Patient History tab of CCTS	When there is no content available on the Patient History - Liver screen only the headers are shown.
Patient Look-up	Problems found within the Patient Look-up tab of CCTS	To search for a patient name, you have to go back to CPRS to look up the patient and find their last 4 in order to look them up in CCTS. This is an extra step.
Radiology	Problems related to how Radiologists review images or code imaging reports	Sometimes the radiology codes do not line up with the impression text.
Reports	Problems related to the display and use of process and outcome measure data within the Reports tab of CCTS	The report section is not user friendly. I don't even know where to begin. It took me a lot of time to filter things to get the numbers we needed.
Scope	Problems related to the current clinical scope of care that CCTS is involved with	It might be interesting to have an alert list that is new cancers.

System Performance	Problems related to the reliability and speed of CCTS	When the system is slow or goes down it greatly disrupts workflow (sometimes search alert functionality is not available for a whole day, etc.).
Training	Problems related to training of new users and ongoing training of all staff using CCTS	I cracked the user guide but it's so huge.
Workflow	Problems related to integration of the software within the normal workflow of the users	It is hard to find the patients/follow-ups assigned to me, especially when someone else has to cover for me. Users fear that they may lose a patient in the system.

Table 10: Problems Identified by the 5 Usability Engineering Methods

Category	**HE**	**CW**	**OTA**	**DI**	**CWS**
Alerts					
Errors					
Follow-ups					
General					
Help					
Navigation					
Patient History					
Patient Look-up					
Radiology					
Reports					
Scope					
System Performance					
Training					
Workflow					
Total number of problems identified by a method	91 (56%)	22 (14%)	31 (19%)	36 (22%)	6 (4%)

Abbreviations: HE–heuristic evaluation, CW – cognitive walkthrough, OTA – observations with think aloud, DI – debriefing interview, CWS – cognitive walkthrough severity

Color Scale: Black cell – method identified at least 50% of problems in category, Gray cell – method identified at least 25% of problems, Light gray cell – method identified at least one problem

- "It's always frustrating when you start a new system."
- "I think visually if [CCTS] looked a little different it might feel easier to use"
- "I don't think it's difficult to use, it's just a matter of understanding where everything is."
- "As long as you keep using something every day I think you get used to it"
- "Even when I felt like at the beginning it was a little frustrating and a little difficult I felt like I always had someone to talk to."
- "I'm a pretty happy user"
- "This has been an absolute lifesaver for me. I literally could not function without it. I'd probably quit this job."

Figure 3: User Experience Quotes Describing CCTS

The heuristic evaluation identified more than half of all problems while the interviews identified 22%. An expert severity score was applied to all problems identified through expert-driven methods. Users provided severity scores only for problems identified during the cognitive walkthrough.

In addition to identifying usability issues, the user sessions also provide an opportunity to gain insights to the overall user experience. In general, users had fairly positive feelings about the system. The quotes in Figure 3 describe the overall user experience.

4.2 Results from Expert-Driven Methods

4.2.1 Heuristic Evaluation

The heuristic evaluation identified a total of 91 problems, 84 of which were uniquely identified through the heuristic evaluation and 7 of which were identified through the heuristic evaluation and cognitive walkthrough. Each problem was assigned a severity level using the scale in

Table 5. The problems were sorted into categories that described the main location or feature of CCTS that each problem is related to. A count of problems and average severity level is provided in Table 11. The average expert severity level for all problems identified through the heuristic evaluation is 2.1.

4.2.2 Cognitive Walkthrough

The cognitive walkthrough identified a total of 22 problems, 15 of which were uniquely identified through the cognitive walkthrough and 7 of which were identified through the heuristic evaluation and cognitive walkthrough. Each problem was assigned a severity level using the scale in

Table 5. The problems were sorted into categories that describe the main component of CCTS that each problem is related to. A count of problems and average severity level for each category is provided in Table 12. The average expert severity level for all problems identified through the cognitive walkthrough is 2.0.

Table 11: Usability Problems Identified Through Heuristic Evaluation

Category	Average Expert Severity Score	Usability Problems Identified
Navigation	3.0	3
System Performance	2.5	4
Help	2.5	2
Errors	2.4	12
General	2.3	10
Reports	2.1	29
Alerts	1.9	17
Follow-ups	1.9	8
Patient Look-up	1.7	3
Patient History	1.3	3

Table 12: Usability Problems Identified Through Cognitive Walkthrough

Category	Average Expert Severity Score	Usability Problems Identified
Navigation	3.0	1
General	2.5	2
Follow-ups	2.0	8
Alerts	1.8	9
System Performance	1.5	2

Results from the cognitive walkthrough were also analyzed for each key task: 1) reviewing a new coded alert and entering follow-up actions, 2) reviewing a new NLP (search) alert and entering follow-up actions, and 3) reviewing an existing follow-up list, determining next steps in care, and closing out or adding additional follow-up actions as needed. The respective abbreviations for these key tasks are coded alert, search alert, and follow-up. The number of sub-goals, actions, and problems for each key task is provided in Table 13. As the table shows, the follow-up task had a higher number of problems identified per action than the other two key tasks. The average expert severity score by key task is also provided in the table. The follow-up task, which included 22 actions, identified 15 problems. These problems had an average expert severity score of 2.2.

Table 13: Cognitive walkthrough results by key task

Key Task	Sub-goals	Actions	Problems	Problems per action	Average Expert Severity Score
Coded Alert	5	31	15	0.48	2.0
Search Alert	5	31	16	0.52	1.9
Follow-up	4	22	15	0.68	2.2

4.3 User Observation Session Results

The average age of participants involved in the observation sessions was 46 (ranging from 36 to 57) and all participants were female. Participants had an average of 16.1 years in

healthcare (ranging from 4 to 29). Six users had a bachelor's degree and four had a Master of Science in Nursing. Participants had been using CCTS for an average of 3.3 years (ranging from 0.3 to 10.0 years). More than half of the users who participated in this study had been using CCTS for over 12 months while other users had less experience with the system and have used it for 4 - 12 months.

4.3.1 Observations including screen capture and think aloud

During the user observation session, seven users completed the coded alert task, five users completed the search alert task, and six users completed the follow-up task. Whether or not a user completed a task depended on their normal scope of work and whether or not they had an alert or follow-up present during the scheduled observation session.

The time to complete the coded alert task ranged from 1.30 to 6.08 minutes and the search alert task ranged from 1.32 to 9.90 minutes (Figure 4). Time to complete the follow-up task ranged from 1.37 to 11.17 minutes. One user navigated away from CCTS and the EHR for a significant amount of time to review the user guide since this user was having trouble entering a new follow-up after closing one out. For all tasks, users tended to transition between CCTS and the EHR fairly often, depending on the complexity of the alert and their normal process for using CCTS. The number of transitions shows that for the majority of cases information is needed from the EHR and CCTS to complete these tasks and that neither system has the full functionality required.

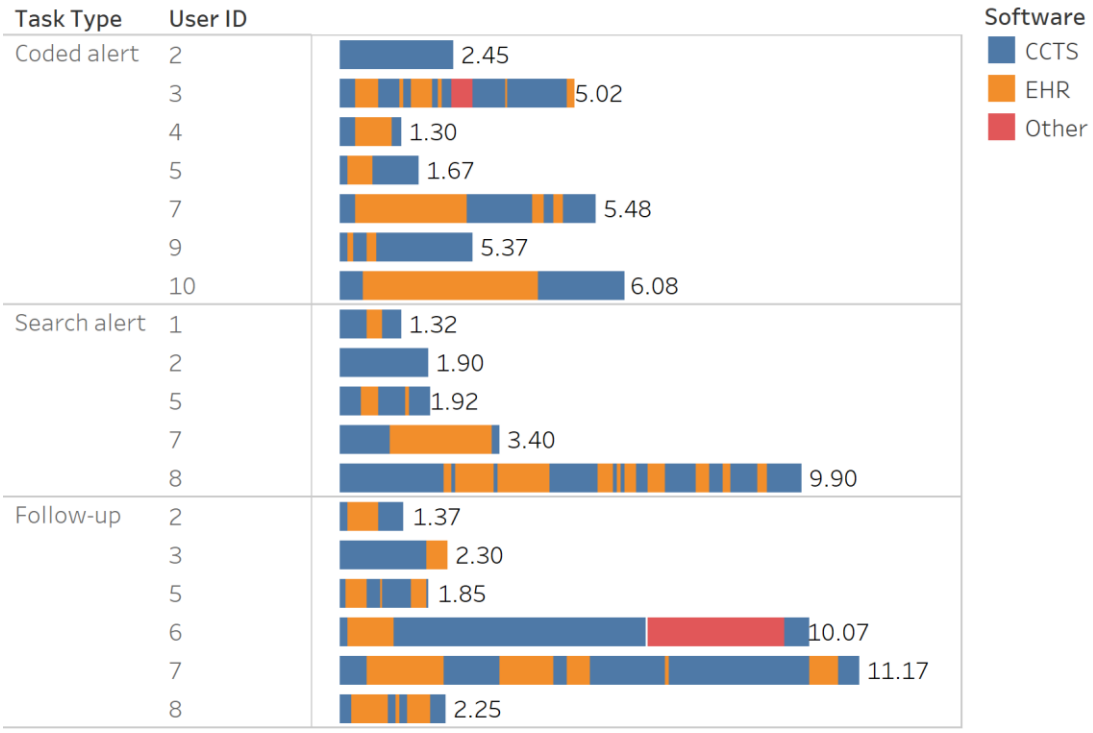


Figure 4: Task Duration (Minutes)

While the users were instructed to complete their tasks as normal, they often brought up usability problems during the observation session. After they completed their tasks in CCTS, users watched a video replaying the steps they took and were asked to think aloud and identify any usability problems. Thirty-one problems were also brought up by users during the observation or think aloud session. The time to complete each task was highly variable. The complexity of the patient's case as well as the experience of the user with CCTS likely contributed to the variation.

4.3.2 Debriefing Interview

During the debriefing interview users were asked a series of six questions to better understand their use of and experience with CCTS as well as to identify any additional usability

problems. The debriefing interview identified 36 usability problems. All users identified several problems during this part of the session, ranging from 4 to 10 problems each.

4.3.3 User perception of cognitive walkthrough problems

Through this method users provided their perception of problems identified during the previously completed cognitive walkthrough. A comparison of the average expert severity score and average user severity score for each of these problems is provided in Table 14.

Table 14: Usability Problems Identified Through Cognitive Walkthrough

Category	Usability Problems Identified	Average Expert Severity Score	Average User Severity Score
Alerts	9	1.8	0.3
Follow-ups	8	2.0	0.4
General	2	2.5	0.8
Navigation	1	3.0	0.3
System Performance	2	1.5	0.9

In general, many users did not have significant concerns with the problems identified during the cognitive walkthrough, stating feelings like “The more I use it I’m getting the hang of it”. Four problems stood out as having a user-assigned severity score of greater than 1.0: 1) In some areas there is no indication that a page or report is loading, 2) Some users have a difficult time determining when a patient is and is not selected, 3) When returning to the follow-up list, follow-ups aren’t displayed until the user clicks “Refresh List”, and 4) Users may not know how to get back to a follow-up to edit it. The first of these problems was scored 1.0 (cosmetic problem) or higher by eight users, the second and third by five users, and the fourth by four users.

4.3.4 Usability Questionnaire

The System Usability Scale (SUS) was provided to participants at the end of the observation session. The components of the survey are evaluated on a scale from 1 (strongly disagree) to 5 (strongly agree). The largest areas of opportunity are highlighted in blue below and focus on consistency and integration of the system as well as user perception of confidence and familiarity with the system (Figure 5).

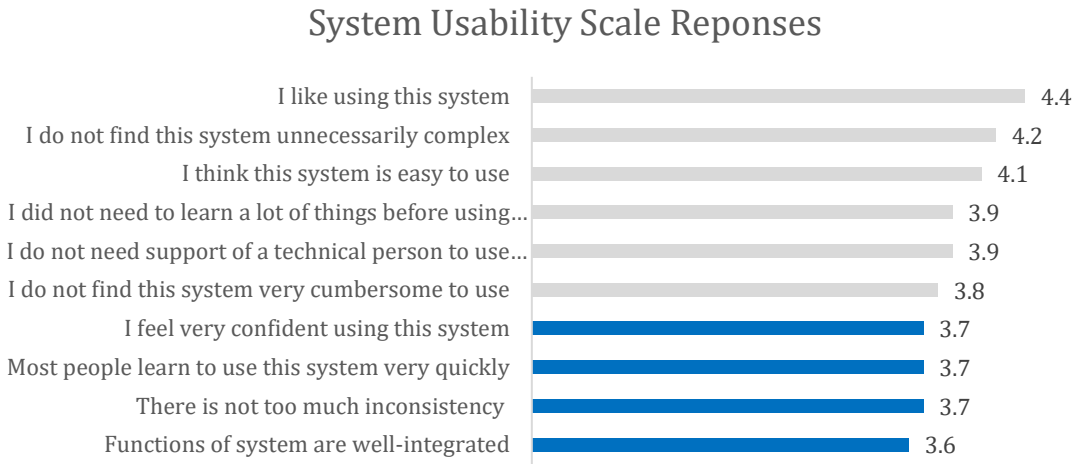


Figure 5: CCTS System Usability Scale (SUS) Responses

4.4 High Priority Problems

After results from the expert-driven and user-driven methods were analyzed, a list of 12 high priority problems was developed. These 12 problems are provided in Figure 6. Eight of the high priority problems were brought up by at least two out of ten users. Four of the problems were identified during the cognitive walkthrough and scored by users of having a severity score of 1.0 or higher. A list of all problems identified is available in APPENDIX A CANCER COORDINATION AND TRACKING SYSTEM USABILITY REPORT – USER EXPERIENCE & KEY PROBLEMS.

Embedding CCTS Within Workflow

1. It is difficult to find patients or follow-ups assigned to a specific user, especially when there are multiple users from one facility.

General Problems

2. The default font size is too small and has to be adjusted each time a user enters the system.
3. Some users have a difficult time determining when a patient is and is not selected.

Entering and Managing Follow-ups

4. Adding a new follow-up for a patient is challenging and requires users to go to a separate tab.
5. Existing follow-ups are not visible until after a user submits a follow-up for an alert they are working on.
6. Users may not know how to get back to a follow-up to edit it.
7. When returning to the follow-up list, follow-ups aren't displayed until the user clicks "Refresh List".

Patient History

8. The patient history section is not often used and most users do not find it to be helpful.

Reports

9. The report section is designed in a way that makes it challenging for users to access the information they need.

System Performance

10. When the system is unavailable or performs slowly user workflow is greatly disrupted.
11. In some areas there is no indication that a page or report is loading.

User Errors

12. Errors are difficult, if not impossible, to fix and tend to remain in the system permanently.

Figure 6: High Priority Usability Problems Identified Throughout Study

CHAPTER 5

DESIGN RECOMMENDATIONS

Design recommendations were generated for each of the twelve high priority problems identified through the study (Table 15). The goal of these recommendations is to help address the gap identified by the users of the system or the expert-driven methods. When possible, one design recommendation was used to address multiple problems. For example, problems 4 and 5 share a design recommendation that would help address both problems.

When valuable, a layout of the design recommendation was developed to conceptualize how the recommendation could be implemented within CCTS. Design recommendations for problems 4 and 9 are provided in Figure 7 and Figure 8. A full design recommendation report, provided to stakeholders of CCTS, is available in Appendix B.

Table 15: Design Recommendations for High Priority Usability Problems

High Priority Usability Problem	Design Recommendations
1. It is difficult to find patients or follow-ups assigned to a specific user, especially when there are multiple users from one facility.	Create an "assign to" field and add this as a column that can be sorted on the action list page.
2. The default font size is too small and has to be adjusted each time a user enters the system.	Increase the default font size to 12 and configure all areas of CCTS to function properly with this font size.
3. Some users have a difficult time determining when a patient is and is not selected.	Include patient information at the top of all screens so users can tell when a patient is still selected.
4. Adding a new follow-up for a patient is challenging and requires users to go to a separate tab.	After a user opens an alert, allow users to view, edit, and add to the patient's current list of follow-ups.
5. Existing follow-ups are not visible until after a user submits a follow-up for an alert they are working on.	After a user opens an alert, allow users to view, edit, and add to the patient's current list of follow-ups.

6. Users may not know how to get back to a follow-up to edit it.	Ensure follow-ups are displayed in the system immediately, if possible, and show a list of recent cases to help users navigate back to these patients' cases.
7. When returning to the follow-up list, follow-ups aren't displayed until the user clicks "Refresh List".	Configure the follow-up list to automatically reset when a user navigates to this page.
8. The patient history section is not often used and most users do not find it to be helpful.	Consider removing or simplifying the Patient History area of CCTS since it adds a layer of complexity to the system and is not often used.
9. The report section is designed in a way that makes it challenging for users to access the information they need.	Simplify the display of reports and add information to explain the validity of the information being presented.
10. When the system is unavailable or performs slowly user workflow is greatly disrupted.	When possible, limit service interruptions during normal working hours.
11. In some areas there is no indication that a page or report is loading.	Display a loading bar on all pages where there may be a lagged response after an action is performed.
12. Errors are difficult, if not impossible, to fix and tend to remain in the system permanently.	Consider allowing users to delete errors instead of having them mark an entry as an error.

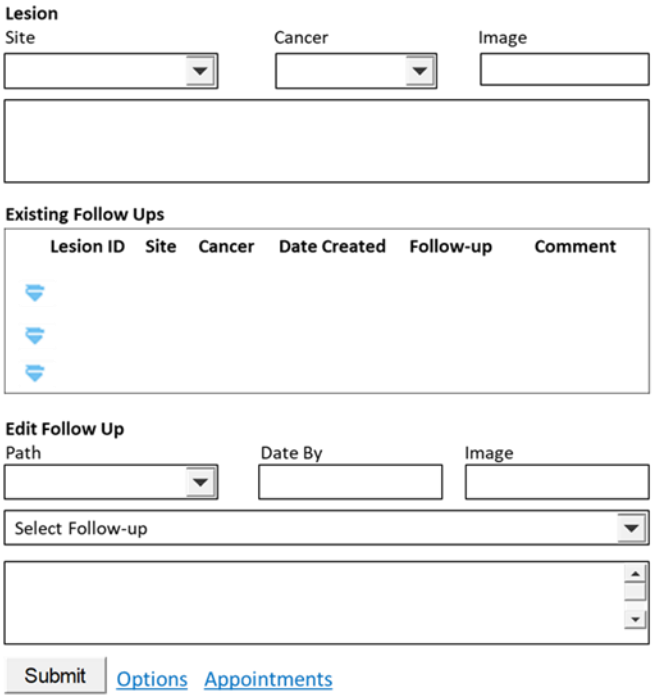
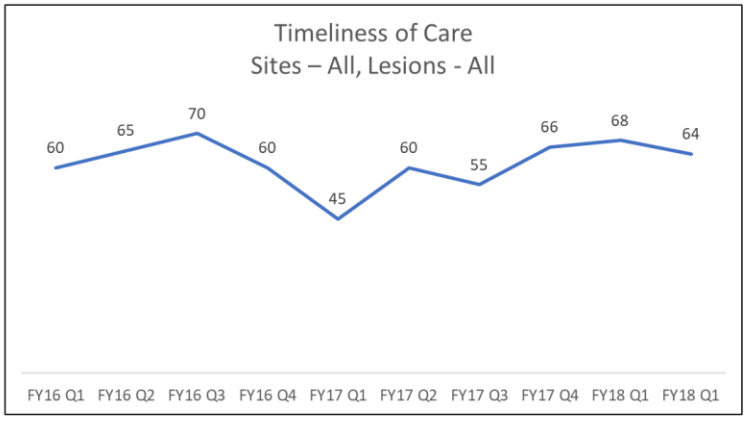


Figure 7: Design Recommendation for High Priority Problem 4

Timeliness of Care

Diagnosis to Treatment



Quarter	Lesions	Average Time
FY16 Q1	2	60
FY16 Q2	10	65
FY16 Q3	8	70
FY16 Q4	6	60
FY17 Q1	7	45
FY17 Q2	3	60
FY17 Q3	9	55
FY17 Q4	10	66
FY18 Q1	4	68
FY18 Q1	7	64

30% of patients for this station are missing a diagnosis date
45% of patients for this station are missing a treatment start date

Figure 8: Design Recommendation for High Priority Problem 9

CHAPTER 6

DISCUSSION

The results of this study show the benefits of including a range of methodologies within a usability study. Table 10 displays the number of problems identified by category for each method. The user-driven methods exclusively identified problems in areas related to radiology, scope, training, and workflow. A smaller percentage of problems in areas such as help, navigation, and reports were identified by users due to the focus of the user sessions on three key tasks within CCTS. The expert-driven methods did not solely identify problems within a particular category, but the wider reach of these methods allowed problems across all areas of CCTS to be identified.

While 162 problems were identified overall, only twelve were selected as high priority due to their appearance through multiple methods or their consensus from multiple users. The methods that was most effective in identifying high priority problems was the debriefing interviews. Eight of the twelve high priority problems were identified using this method. While the debriefing interviews included a standardized set of questions for users to address, the interviews were conducted in a semi-structured manner and users were asked to expand upon or clarify ideas as needed. This structure helped gather additional problems from users. The observations with screen capture and think aloud also identified a high proportion (7 of 12) of the high priority problems and 19% of the overall problems.

It was not surprising to see that the user perception of cognitive walkthrough problems component of the user sessions identified the smallest number of problems. The purpose of this method was to gather user severity scores for problems previously identified during the expert-driven cognitive walkthrough. The problems that were shared by the researcher seemed to trigger

the memory of several users so that six new problems were brought up during this time. In general, the user-provided severity scores were greatly helpful in identifying problems that the majority of users found to be of concern.

Gathering user perception of the cognitive walkthrough problems was also an effective way to bring up micro-level problems to users and get feedback. While 82% (18 of 22) of the problems identified during the cognitive walkthrough were not considered to be a problem by the majority of users, this method identified four problems with an average user severity score of 1.0 or higher that were placed on the high priority problem list.

The results from this study also show a distinct difference between the findings of expert and user-driven methods. In general, users tend to focus on higher-level problems such as the reliability of the system and how it fits within their normal workflow. The expert-driven methods more effectively identified micro level usability problems. While these more minor problems may not have seemed significant enough for users to bring up, they likely impact overall user perceptions of the system. One user noted that “I definitely have had more challenges learning to use this particular program than other programs. It's a little less intuitive for me.”

In addition to the benefits listed above, the expert-driven methods also supported the researcher in better understanding how CCTS functions. This understanding allowed for more in-depth conversations during the user sessions and supported the development of design recommendations that address the concerns of users. While not all studies may be able to achieve this, a combination of user-driven and expert-driven methods seems to be highly effective.

It is interesting to note that the problems identified during the heuristic evaluation were most difficult to integrate into the list of high priority problems. Of the 91 usability problems identified through the heuristic evaluation, only 11 of these were also identified through other

methods. This lack of overlap made it difficult to justify adding problems identified just through the heuristic evaluation to the high priority problem list. A full list of these problems was provided to the CCTS team and could be referred to when redesigning the interface but were not of the highest priority to address.

This study has several limitations. Due to scope and protected health information (PHI) restrictions, additional experts were not able to complete a heuristic evaluation which is a recommended practice (Kushniruk & Patel, 2004). In addition to this, usability methods are often used several times to review and evaluate iterative improvements to a system but implementing and evaluating recommendations fell outside the scope of this study.

While the three key tasks that were the focus of the user sessions cover the main functionality of CCTS, not all users perform all of these tasks on a regular basis. These gaps led to a smaller sample size for the observations. Seven users reviewed a coded alert during observations, five users reviewed a search alert, and six users managed a follow-up.

The natural variation within patient cases was also a challenge to drawing further conclusions from the observation task duration data. Seven users reviewed a coded alert within CCTS during the observation session, but two of these patients were being newly added to the system while five had previously been entered within the system. Beyond this factor, the cases also varied in the type of nodule or lesion involved, the role of the user in caring for the patient, and the complexity of the case. A more thorough data collection effort would have required many more resources but may have provided additional insights as to users' interaction with the system and their workflow between CCTS and the EHR.

Finally, implementation of the design recommendations was not a large focus of this study. While design recommendations were provided for each high priority problem, it is not

clear how feasible these changes are. One recommendation discusses the performance and reliability of the system which could be outside the control of the CCTS development team in the short-term.

Other recommendations suggest changes to the structure of the system, such as allowing users to delete errors or removing/simplifying the Patient History section. These types of recommendations will likely require more in-depth conversations about the pros and cons of these changes and the impact to individual users. Due to the scope of this study the full ramifications of these changes were not analyzed. Finally, some recommendations may seem simple (such as increasing the default font size) but may require significant programming hours to accomplish.

Overall, improving the usability of a long-standing, multi-site clinical decision support tool is complex. While a significant redesign of the system may not be possible in the short-term, it is the hope of the researchers that some of the key problems can be addressed and the CCTS stakeholders will consider the power of usability methods and the voice of the user in the future.

CHAPTER 7

CONCLUSIONS

The purpose of this study was to use a set of usability engineering methods to comprehensively identify and analyze usability problems within the Cancer Coordination and Tracking System (CCTS). The time-sensitive and complex nature of cancer care often requires the role of a care coordinator to track follow-up care and ensure timeliness. CCTS is an EHR-linked web-based tool used by the care coordinators for cancer care management.

A set of user-driven and expert-driven usability engineering methods were applied to the system and identified a total of 162 usability problems ranging from minor cosmetic problems to concerns regarding the overall workflow of CCTS. Expert-driven methods were completed without any users present and included a heuristic evaluation and cognitive walkthrough. User-driven methods were executed during observation sessions held individually with 10 current CCTS users and comprised of observations with screen capture and think aloud, debriefing interviews, user perception of cognitive walkthrough problems, and a usability questionnaire.

The full list of usability problems identified was analyzed and prioritized resulting in twelve high priority usability problems. Design recommendations were developed for each of these problems. Eight of the twelve high priority problems were identified using debriefing interviews and seven through observations with screen capture and think aloud. While these two methods identified a majority of the high priority problems, the expert-driven methods were critical in helping the researcher understand the system and how users interact with it. All methods used helped characterize the user experience with CCTS and inform development of the design recommendations.

While improving the usability of healthcare information technology (health IT) tools is complex, this study severs as a case study for how to identify and address usability problems using a comprehensive set of methods. The benefits of applying a range of qualitative and quantitative methods are demonstrated in the study and it is clear that usability engineering methods can help understand user workflow, identify usability problems, and ensure the experience of the user is heard and integrated into the design of a system.

APPENDIX A

CANCER COORDINATION AND TRACKING SYSTEM USABILITY REPORT –

USER EXPERIENCE & KEY PROBLEMS

Cancer Coordination and Tracking System Usability Report

USER EXPERIENCE & KEY PROBLEMS

MARCH 2018

PREPARED FOR:

Tamar Taddei, MD
Rajni Mehta, MPH
VA Connecticut Healthcare System
Department of Veterans Affairs

PREPARED BY:

Kristine DeSotto, Master's Candidate
Jenna Marquard, Associate Professor
Department of Mechanical and Industrial Engineering
University of Massachusetts Amherst

Contents

Overview & Key Findings

The purpose of this study was to apply a set of usability engineering methods to comprehensively identify usability problems within the Cancer Coordination and Tracking System (CCTS). The following report provides a description of the usability engineering methods used and a review of the overall user experience, including key usability problems.

The following twelve high priority usability problems were identified during this study:

Embedding CCTS Within Workflow

1. It is difficult to find patients or follow-ups assigned to a specific user, especially when there are multiple users from one facility.

General Problems

2. The default font size is too small and has to be adjusted each time a user enters the system.
3. Some users have a difficult time determining when a patient is and is not selected.

Entering and Managing Follow-ups

4. Adding a new follow-up for a patient is challenging and requires users to go to a separate tab.
5. Existing follow-ups are not visible until after a user submits a follow-up for an alert they are working on.
6. Users may not know how to get back to a follow-up to edit it.
7. When returning to the follow-up list, follow-ups aren't displayed until the user clicks "Refresh List".

Patient History

8. The patient history section is not often used and most users do not find it to be helpful.

Reports

9. The report section is designed in a way that makes it challenging for users to access the information they need.

System Performance

10. When the system is unavailable or performs slowly user workflow is greatly disrupted.
11. In some areas there is no indication that a page or report is loading.

User Errors

12. Errors are difficult, if not impossible, to fix and tend to remain in the system permanently.

Project Methodology

This study combined expert-driven and user-driven usability engineering methods to identify a wide range of problems with the system. Expert-driven methods were completed without any users present and include a heuristic evaluation and cognitive walkthrough. The heuristic evaluation compared CCTS against a set of known usability design principles while the cognitive walkthrough identified usability problems by mimicking the user's cognitive workflow through the system. User-driven methods included live observations with a think aloud component, debriefing interviews, severity prioritization of usability problems identified during the cognitive walkthrough, and a usability questionnaire. The user-driven methods were executed during observation sessions held individually with 10 current CCTS users.

These methods identified a total of 162 usability problems ranging from minor cosmetic problems to concerns regarding the overall workflow of CCTS. A majority of the problems (62.3%) were identified through expert-driven methods, 34.6% were identified through user-driven methods, and the remaining 3.1% of problems were identified through both sources.

A list of twelve high priority usability problems will be the highlight of this report. A list of all usability problems identified through this study are available in Appendix A. Eight of the high priority problems were brought up by at least two out of ten users. Four of these problems were identified during the cognitive walkthrough and scored by users of having a severity score of 1.0 or higher. A description of the severity scale is provided below.

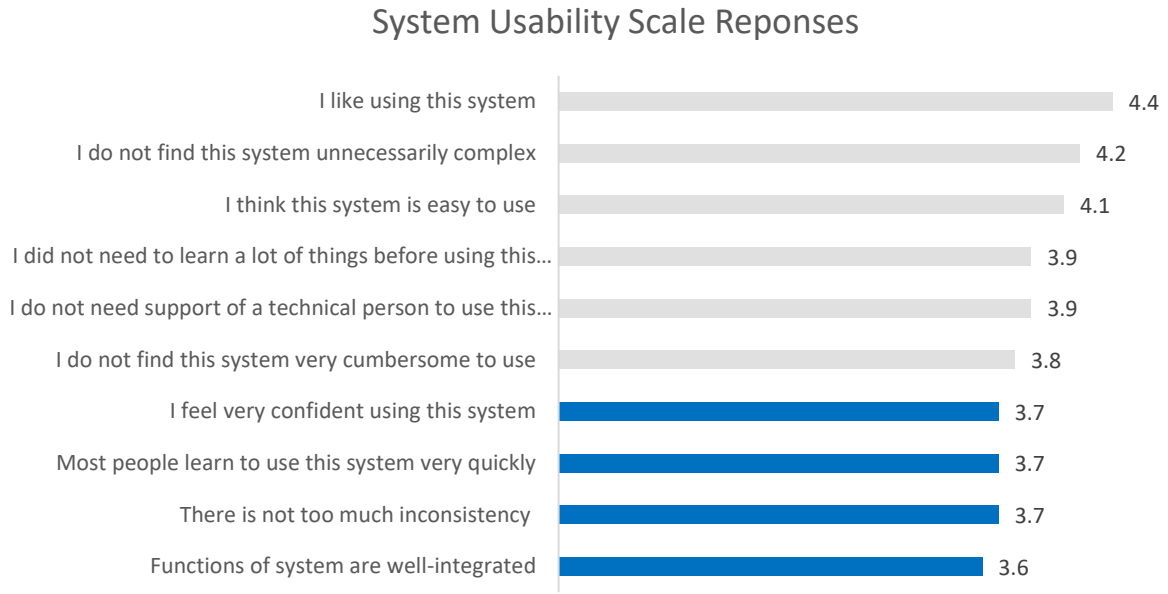
Value	Description
0	Not a problem
1	Cosmetic problem only; fix if extra time is available
2	Minor usability problem: fixing this should be given low priority
3	Major usability problem: important to fix, so should be given high priority
4	Usability catastrophe: imperative to fix this before product can be released

Overall User Experience

In general, users have a fairly positive response to the system. More than half of the users who participated in this study have been using CCTS for over 12 months and feel familiar with the system. Other users have less experience with the system having used it between 4 and 12 months. The following quotes describe the overall user experience.

- *"It's always frustrating when you start a new system."*
- *"I think visually if [CCTS] looked a little different it might feel easier to use"*
- *"I don't think it's difficult to use, it's just a matter of understanding where everything is."*
- *"As long as you keep using something every day I think you get used to it"*
- *"Even when I felt like at the beginning it was a little frustrating and a little difficult I felt like I always had someone to talk to."*
- *"I'm a pretty happy user"*
- *"This has been an absolute lifesaver for me. I literally could not function without it. I'd probably quit this job."*

The System Usability Scale (SUS) was provided to participants at the end of the observation session. The items are evaluated on a scale from 1 (strongly disagree) to 5 (strongly agree). The largest areas of opportunity are highlighted in blue below and focus on consistency and integration of the system as well as user perception of confidence and familiarity with the system.



High Priority Problem Description

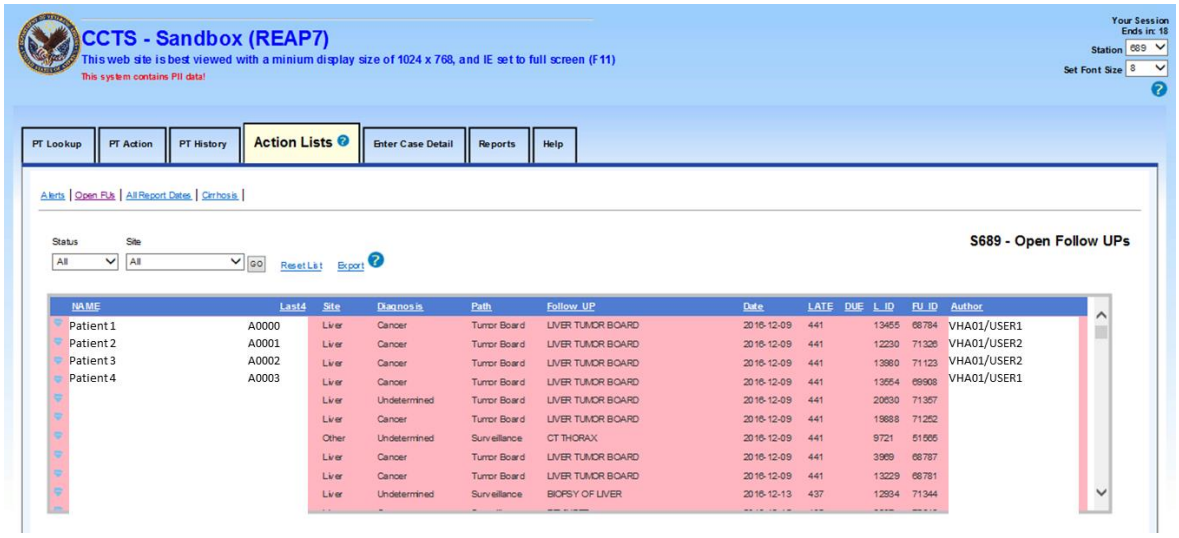
The following section provides a description of the high priority problems identified through this study. If a problem was brought up during a user observation session the number of users who identified this problem will be provided. If a problem was identified during the cognitive walkthrough and users provided their opinion of its severity, the expert and user severity score will be provided. User quotes and a screenshot will also be provided, if available.

Embedding CCTS Within Workflow

1. Users report that it is difficult to find patients or follow-ups assigned to them, especially when there are multiple users from one facility. This can be particularly challenging in specific instances such as when one user is on vacation and others must cover for them. Users fear that they may lose a patient in the system.
   Identified by: 2/10 users

   Severity: N/A

   "I wish there was a way to just pull those up and see the things that I've entered. But it doesn't work that way… when I was on vacation, one of the other navigators entered stuff for me, so it's under her name too."



2. The default font size is too small for some of the users. CCTS is set to a default font of size 8 and this must be changed each time a user enters the system. One user commented that some parts of the system do not work with a larger font size so she has limited herself to increasing the font size to no more than 10.
   Identified by: 2/10 users

   Severity: N/A

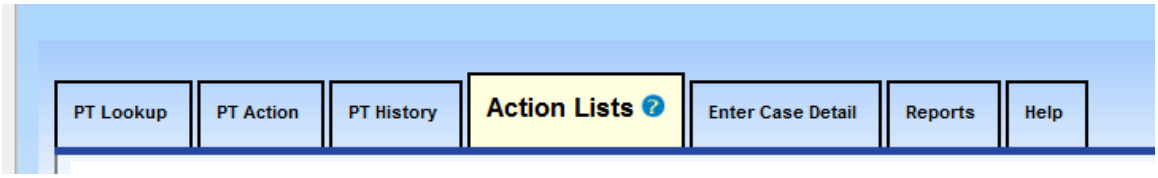
   "The font thing is actually fairly significant to me visually enjoying this experience. 8 is a super tiny default font, but also I feel that when I try to increase the font to over 10, certain things weren't working in here."

   "I know [my coworker] is like why do you care about the font? Because I want to see it! I need something big."

3. It is hard for users to tell when a patient is selected and when this selection clears. Switching tabs sometimes clears the patient selection and sometimes does not. The screenshots below show that when a patient is selected and a user is on the Patient History tab, switching to the Action List does not clear this selection but the patient's identifying information is not displayed at the top of the screen.
   Identified by: N/A

   Severity: Expert 3.0, User 1.20 (0: 5 users, 2: 3 users, 3; 2 users)

   "This is only a problem for new users."



4. Users report that it is difficult to add a new follow-up for a patient. This task requires users to go to a separate tab which disrupts how efficiently they can manage a patient's case. It took one user nearly 10 minutes to add a new follow-up for a patient since she had to click through the various tabs and eventually open up the user guide.
   Identified by: 2/10 users

   Severity: N/A

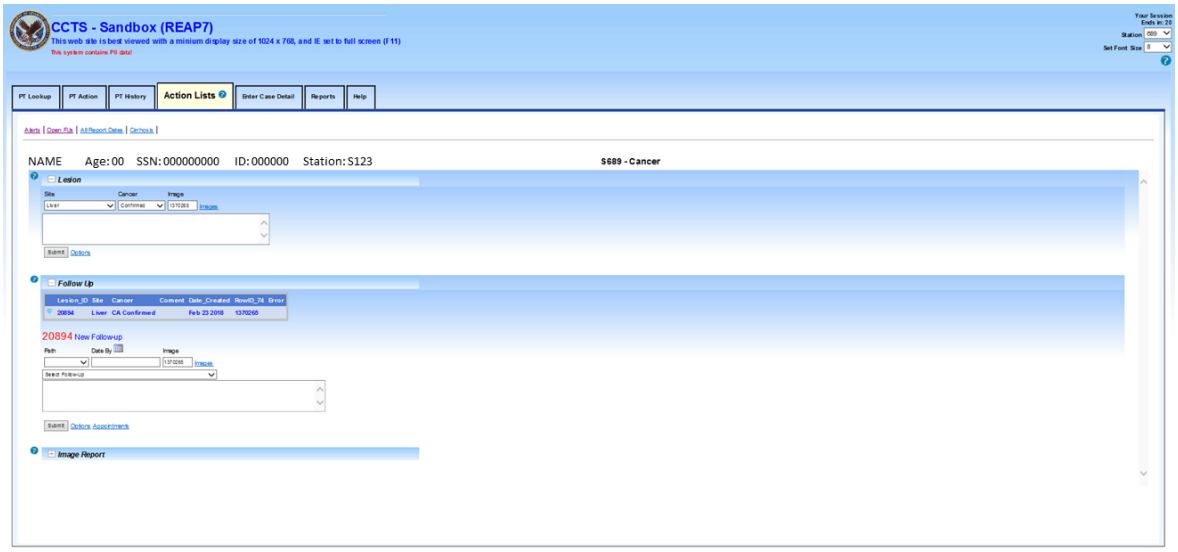
   "Re-entering a new follow-up is the hardest part"

   "I didn't know how to create a new follow-up after one was completed."

5. Existing follow-ups are not visible until after a user submits a follow-up for an alert they are working on. Several users report that it would be better to see a full list of reminders for a patient on the screen when they are processing an alert. A few users noted that this problem has caused duplicate follow-ups to be added.
   Identified by: 2/10 users

   Severity: N/A

   "It would be really helpful, before you create the follow-up, to see a list of existing follow-ups. I think the feedback I've gotten is well you can go into this other screen. Well that's more time than I have many days, looking at a different screen."



6. Users may not know how to get back to a follow-up to edit it. This action requires looking up a patient and navigating to existing follow-ups. Also, one user was under the impression that her newly entered follow-ups may show up 24 hours after being entered. If this is true for all users it may contribute to the confusion around this problem.
   Identified by: Cognitive Walkthrough

   Severity: Expert 3.0, User 1.0 (0: 6 users, 2: 2 users, 3: 2 users)

7. After processing a follow-up, users are sent back to the main open follow-up list. The list will be filtered only for the previously selected patient and users must click “Reset List” to see the list of follow-ups for all patients.
   Identified by: Cognitive Walkthrough

   Severity: Expert 3.0, User 1.10 (0: 5 users, 2: 4 users, 3: 1 users)

Patient History

8. The Patient History section is not often used and most users do not find it to be helpful. They commented that patient comorbidities and other information has to be manually entered into CCTS but is readily available in the electronic medical record.
   Identified by: 7/10 users

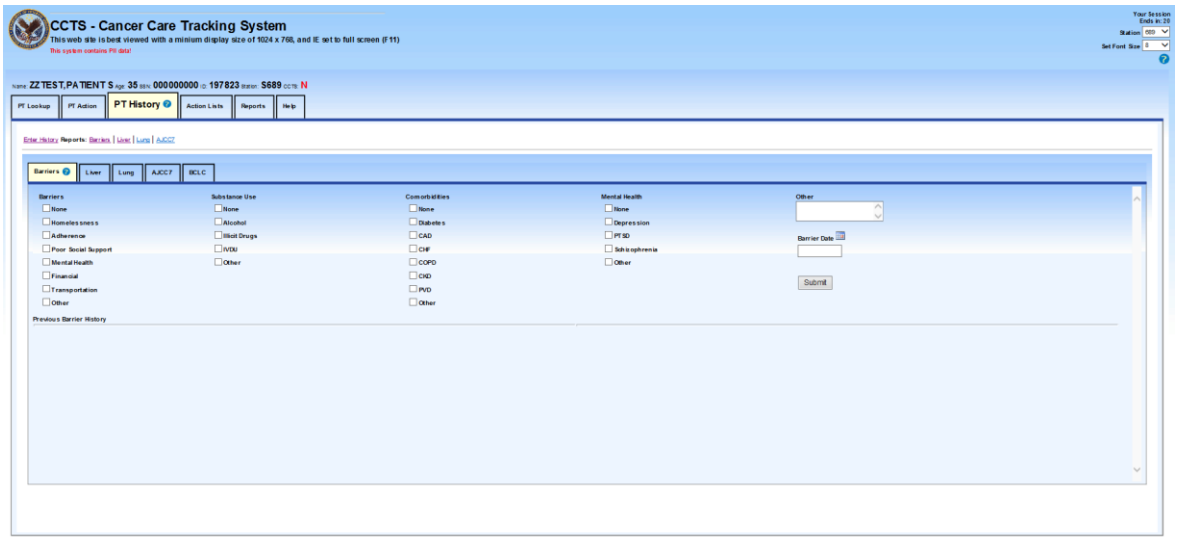
   Severity: N/A

   "I'm just thinking this is already in VistA. Why do we need to put the patient history? Can't it just be there?"

   "Patient History… really it's a waste of their time. Because we still have to go to CPRS. I don't think that's something that should be there."

   "I don't do this for every patient because it's so time consuming. I try my very best so I can get some graphs and stuff but I can't, no… It's just too much. I'll be here all night. I would prefer not to use it."

   "We don't have time. And I don't think for the purposes we're using it for. It's not necessary."



Reports

9. Several users do not use the report section and do not know where to begin when it comes to using this section. Users mentioned that it takes them a lot of time to filter the data to get the information they need.
   Identified by: 4/10 users

   Severity: N/A

   "I've gone over to the reports to kind of look at it… but I don't even know where to begin. We didn't have access to it during the Sandbox trial so I'm not for sure how it works."

   "The report tab has a lot of good information but I can't just click on something and generate a report that is useful to me. It ends up being a piece of the data I use when I go to create a report... But I think particularly now with so many people using the same data in many different ways I don't trust it."

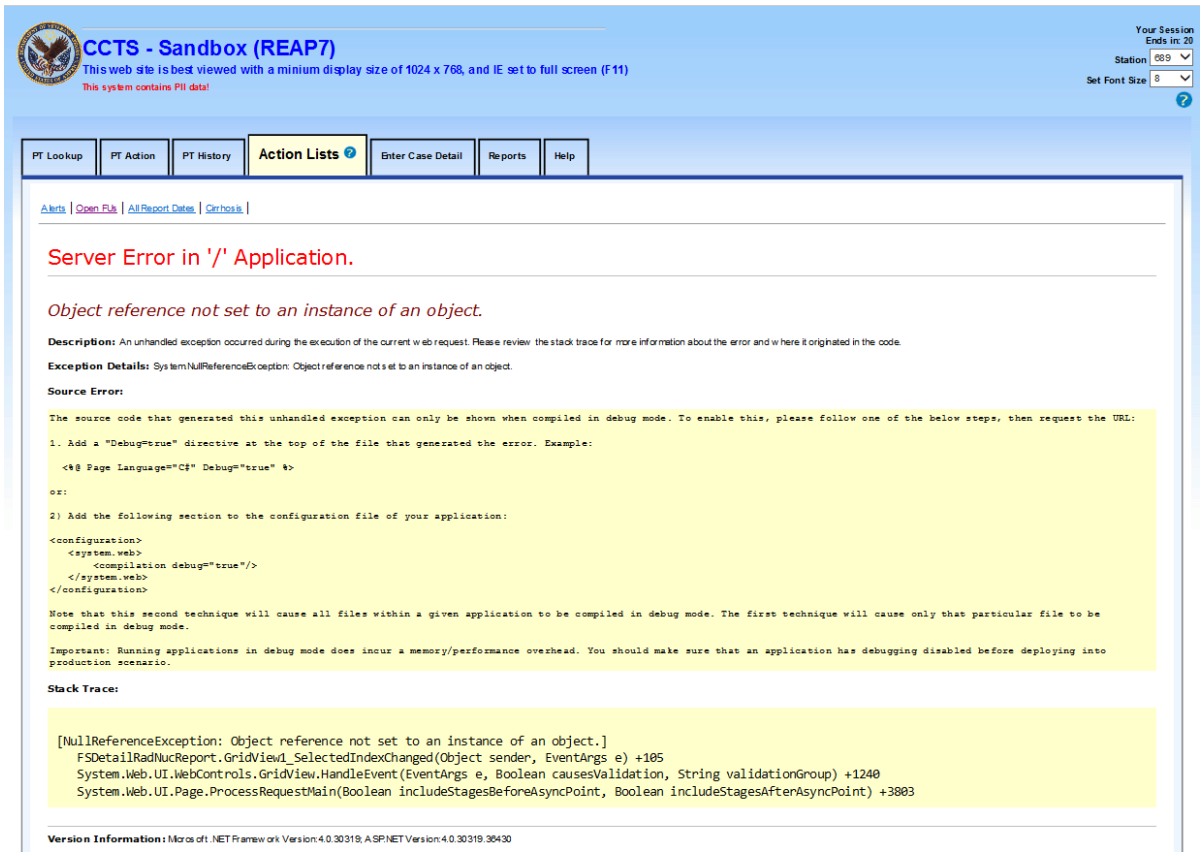
10. When the system is unavailable or performs slowly workflow is greatly disrupted. Several users found the performance of CCTS to be a barrier for them working with the system. Some users have select times during the week that they can use CCTS and it is frustrating when the system is down during these times.
    Identified by: 4/10 users

    Severity: N/A

    "I see patients as a nurse practitioner… I want to be able to come in and do CCTS before clinic and not have to worry about it when I have to take care of patients the rest of the day. But when it's down, it disrupts the workflow."

    "Now that they've expanded it and made it more open to other sites, I feel that it's a little slower and goes down more frequently."

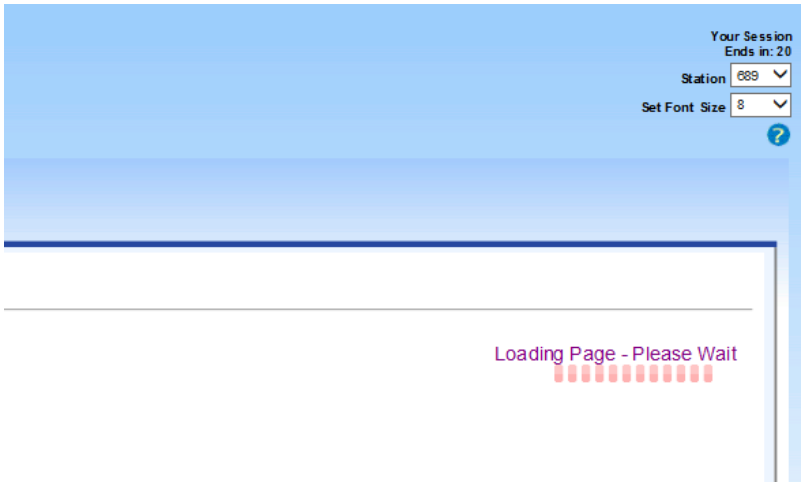
    "I just wish it was faster and didn't go down as much. It has been a little better lately but I would say this Fall it was slowing down at least once a week."



11. Several areas of CCTS do not indicate when a page or report is loading. The loading bar, displayed in the screenshot below, is present on some but not all screens. When a loading bar is not present users may click multiple times and cause an error.
    Identified by: Cognitive Walkthrough

    Severity: Expert 2.0, User 1.70 (0: 2 users, 2: 7 users, 3: 1 user)

    "It is frustrating when this happens. Sometimes I have to refresh the screen."

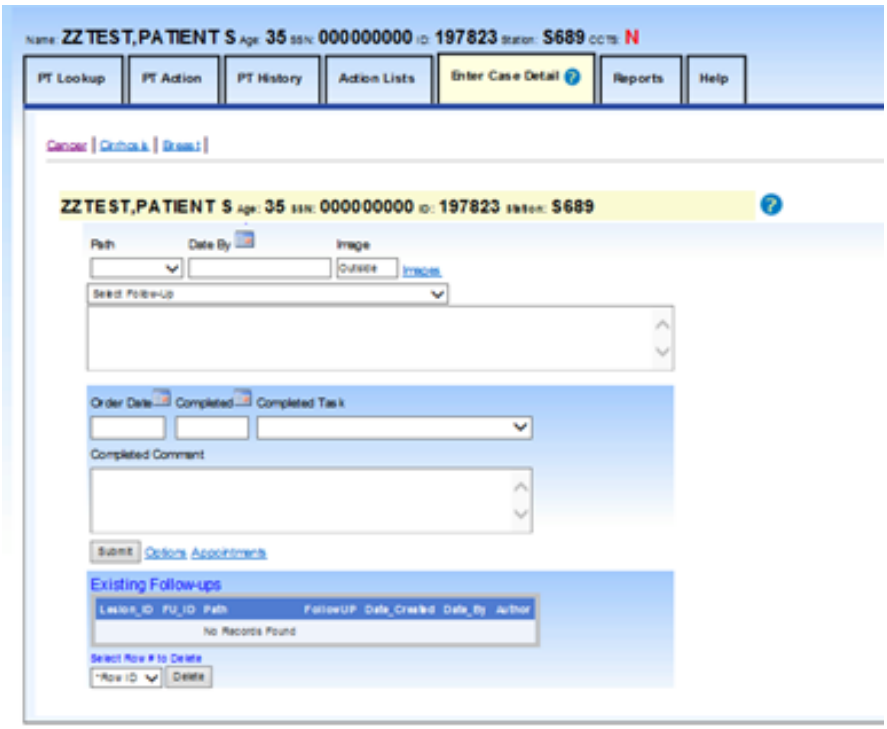


User Errors

12. Users find that errors are difficult, if not impossible, to fix. Nearly half of users find it frustrating that errors can't be addressed if you navigate away from the screen where the error was made. An issue can be marked as an error but still remains in the system permanently.
    Identified by: 4/10 users

    Severity: N/A

    "Sometimes you just want to change something but it's kind of too late."



Appendix A: All Usability Problems Identified

Category	Problem Description	High priority?	Source	Expert Severity	Average User Severity
Alerts	I don't like to open an alert right away because it goes away. I don't want to lose anything and don't see the advantage of having these on another screen.		Both	3	0.00
Alerts	On the alert detail page Lesion ID is highlighted in red and stands out, but the user may not need this information.		Expert	1	0.60
Alerts	Users may not know what "Y" or "N" means under the Tracked column.		Expert	2	0.00
Alerts	After clicking on a search alert, users may not know what False Positive means or when to click it.		Expert	1	0.00
Alerts	After entering a lesion, the next section does not always expand on its own and requires an extra click.		Expert	3	0.89
Alerts	Clicking on options on the Alert page opens up new features above and below the options button, which can be confusing.		Expert	3	
Alerts	I would like to see a false positive option on the coded alerts page too. Sometimes if it's a totally negative CT screening that they end up putting in the alert section I end up putting addressed.		User		
Alerts	It is not clear that you can sort using the underlined columns on the action list - alerts page.		Expert	1	
Alerts	It is not clear when to use the different options (Addressed vs. Notification vs. New Lesion).		Expert	2	
Alerts	It is not clear why the follow-up drop-down is labeled "path".		Expert	1	
Alerts	It is not clear why the image ID is present next to the imaging link.		Expert	2	
Alerts	Once a lesion is entered, you have to click on the blue icon under follow-up to see the follow-up options which is an extra click.		Expert	3	
Alerts	Patients show up multiple times on alerts page (for breast cancer). I have to go through and address the duplicates.		User		
Alerts	Sometimes the alert page says outside imaging but this isn't accurate. This can be frustrating.		User		
Alerts	The appointments link opens in a small window.		Expert	1	
Alerts	The image link on the alert page opens in a small screen.		Expert	3	
Alerts	The start date and end date features don't filter the data like expected but pull up past alerts instead.		Expert	2	

Alerts	The table headers under lesion and follow-up have dashes between the words which makes them harder to read.		Expert	1	
Alerts	There are a lot of abbreviations on the alert detail screen which may be confusing		Expert	1	0.90
Alerts	There are a lot of columns on the alerts screen.		Expert	2	
Alerts	There is a lot of excessive information on the alert detail screen.		Expert	2	
Alerts	Users may not know what TB (tumor board) means.		Expert	1	0.00
Alerts	Users may not know what to add to the comments textbox on the alerts page.		Expert	2	0.20
Alerts	Users may not know what to do with the image number text box on the alerts page.		Expert	2	0.20
Alerts	We can't go in and change the diagnosis. If you want to add something to the description it doesn't show as being updated.		User		
Alerts	When the opened filter is selected, some DX codes show up in red instead of blue.		Expert	1	
Alerts	You have to scroll to the bottom of the page to see the radiology text.		Expert	2	
Errors	Errors are hard to fix. A follow-up can only be deleted within 24 hours. If you switch screens after making an error you can mark it as an error but it stays in the system.	Yes	User		
Errors	At times an invalid input on the Patient Lookup screen provides an empty patient list but does not give error.		Expert	2	
Errors	Error message for an incorrect input on the Patient Lookup screen uses abbreviation and is not clear.		Expert	2	
Errors	Error message for blank input on the Patient Lookup screen uses abbreviations (PT).		Expert	2	
Errors	The blue selection button is still present on the follow-up list screen when no records are found and no errors present when you click on it.		Expert	2	
Errors	The options button on the alert detail page brings up a way to delete a lesion, even though no lesions have been entered.		Expert	2	
Errors	The Patient History - Enter History screen allows you to submit without entering any content.		Expert	3	
Errors	The Patient History - Enter History screen allows you to submit without selecting a patient		Expert	3	
Errors	There is no pop-up message or warning to ask the user if they definitely want to delete a follow-up.		Expert	2	
Errors	There is no pop-up message or warning to ask the user if they definitely want to delete a lesion.		Expert	2	
Errors	When no patient is selected clicking the barriers link under Patient History gives a server error.		Expert	4	
Errors	When taking something out as an error It's not clear what date I should put in the date box.		User		

Errors	When the user enters a start and end date and presses go, nothing happens if the date range drop down isn't selected.		Expert	3	
Errors	When there is no content the Report Dates section under Patient Action page only shows "comment".		Expert	2	
Follow-ups	It is difficult to add a new follow-up for a patient. You have to go to the patient action tab.	Yes	Expert and User	3	
Follow-ups	You can't see the existing follow-ups until after you submit a follow-up for the alert you're working on. It would be better if we could see all reminders for a single patient.	Yes	User		
Follow-ups	If I want to submit two follow-ups in a row I have to click out of the follow-up screen and then go back into it to refresh it. Otherwise it may mark the new follow-up as completed.		User		
Follow-ups	Wording of completion by date is confusing. I'm not always sure what to put in that date field. [Suggested expected completion date]		Expert and User	2	
Follow-ups	All lesions and follow-ups are displayed for a patient under the alerts list which can look overwhelming		Expert	2	0.20
Follow-ups	I have to open each follow-up to see what's going on with it. I would like to have a column that shows notes so I can see if the follow-up was scheduled.		User		
Follow-ups	I would like to see more information about the patient. Just a little blurb that doesn't change and where key information gets added into it.		User		
Follow-ups	If I need to edit the date on a follow-up but forget to change the drop-down from completed to rescheduled by clinic I might lose the follow-up. And I've probably have done that a few times.		User		
Follow-ups	If you are processing an alert (for a patient already in the system) and know it will be a new follow-up, you have to click into a different tab to complete the current follow-up which is an extra step.		User		
Follow-ups	It is not clear what the display errors menu option on the follow-up list means.		Expert	2	
Follow-ups	It is not clear what the Status column on the open follow-ups detail page means.		Expert	2	
Follow-ups	It is not clear why the error column is included on the open follow-ups detail page.		Expert	1	
Follow-ups	It is not clear why the lesion comments are helpful to display on the screen.		Expert	2	0.20
Follow-ups	It may be hard to notice follow-ups that are not completed when there is long list of follow-ups for a single patient.		Expert	2	0.40
Follow-ups	It may not be clear what the appointments link at the bottom of the alert detail page does.		Expert	1	0.00
Follow-ups	It's not always clear what the order date means and what date should be entered here.		User		

Follow-ups	Many of the columns are IDs on the open follow-up detail page are not needed by the user.		Expert	2	
Follow-ups	The P in up is capitalized on the follow-up page.		Expert	1	
Follow-ups	The SC icon and a second help icon are displayed at the bottom of the screen but it's not clear if they were meant to be placed here.		Expert	2	
Follow-ups	There should be an option of "Scheduled" when you try to edit a follow-up. I have reminders for patients who are coming in during a particular month and when I know the appointment date I want to be able to put "scheduled" instead of "rescheduled". My reports won't be accurate if I try to look at this type of information.		User		
Follow-ups	There's an option list that shows up when you're setting a new follow-up and it is alphabetical and there are 30-40 choices. I wish the options that I use regularly were on top.		User		
Follow-ups	Users may not know how to get back to a follow-up to edit it.	Yes	Expert	3	1.00
Follow-ups	Users may not know what FU stands for		Expert	1	0.00
Follow-ups	Users may not know what to enter in the comment field when closing out a follow-up.		Expert	2	0.20
Follow-ups	When editing a follow-up, selecting "order date" does not change the follow-up date and I'm not sure why.		User		
Follow-ups	When I'm in the action list and then I have to go into patient lookup to look up the patient, that is extra work.		User		
Follow-ups	When returning to the follow-up list, follow-ups aren't displayed until the user clicks "Refresh List".	Yes	Expert	3	1.10
Follow-ups	When you are rescheduling a patient or rescheduling by clinic you have to copy and paste what was in there previously into the comment section. It just doesn't carry over.		User		
Follow-ups	You can't see the status of a follow-up (whether or not the patient is scheduled, etc.) unless you open the follow-up. A comments field would be helpful.		User		
General	The default font is impossible to read. You have to change the font every time you enter the system. Some pieces don't seem to work over font size 10.	Yes	Expert and User	3	
General	If not viewing in full screen content is hard if not impossible to see.		Expert	2	0.30
General	It is hard to tell when you have a patient selected and when this is cleared. Switching tabs sometimes clears the patient selection and sometimes does not.	Yes	Expert	3	1.20
General	A lot of valuable screen space is taken up by the header and tab options which causes the user to scroll more.		Expert	2	
General	I don't fully understand until I look in all of these menus or read my user guide really what all of the headings (action list, patient history, etc.) do. When I'm trying to figure		User		

	it out I frequently get lost in the shuffle and go back and forth to different headings. Action list is kind of a weird term for me.				
General	I'm just kind of afraid that I'm going to make an error which I've been doing.		User		
General	It is not clear what the images link does		Expert	3	
General	It is not clear what the SC icon means.		Expert	2	
General	It is not possible to create shortcuts to frequently used areas.		Expert	2	
General	The all report dates screen under action lists defaults to selecting "None" under the site drop down menu.		Expert	2	
General	The term alert doesn't make sense to me. I think of them as reminders not alerts.		User		
General	The words S689 - cancer alerts are very close to the print button but unrelated to this action.		Expert	1	
General	There are a lot of quirky things that make the system hard to use.		User		
General	There is no "Go" button on the all report dates screen under action lists.		Expert	3	
Help	It is not clear what the purpose of all the help resources is.		Expert	3	
Help	I've never used the help tab. I don't use help, I just call for help but I haven't had to in a while.		User		
Help	The help menu does not clarify what the display errors feature on the follow-up list does.		Expert	2	
Navigation	I thought I lost the little blue icon (by alerts) once because the scroll bar on the bottom was hidden.		Expert and User	3	
Navigation	The blue icon may not be noticeable or look like an actionable feature.		Expert	3	0.30
Navigation	The blue button navigates to different options depending on what screen you are on (e.g. Timeliness of care report).		Expert	3	
Patient History	It is not clear what the abbreviation "AJCC7" means.		Expert	1	
Patient History	The patient history section is not often used. We have to enter comorbidities and other information into CCTS but it's already in VistA. I don't think it's that helpful. Can't the information just be there? It's also not clear what date to add to the barriers section	Yes	User		
Patient History	When there is no content available on the Patient History - Liver screen only the headers are shown.		Expert	1	
Patient History	When there is no content available the Lung and AJCC7 pages are blank. This is not consistent with the Liver report page.		Expert	2	
Patient Look-up	Drop down menu options rise above the drop-down box instead of below on the Patient Lookup screen, blocking the view of the instructions.		Expert	2	

Patient Look-up	If you search for test on the Patient Lookup screen no patients will be available in the drop-down but a test patient will be selected when you click on the patient history tab.		Expert	2	
Patient Look-up	Instructions on the Patient Lookup screen are in red and may be hard to read.		Expert	1	
Patient Look-up	To search for a patient name, you have to go back to CPRS to look up the patient and find their last 4 in order to look them up in CCTS. This is an extra step.		User		
Radiology	It's not just about the system. You really have to consider; do you have support from your radiology? Are they on board? Are they coding things correctly?		User		
Radiology	National tele-radiology is reading a lot of our imaging because we had a situation in radiology and we are down to like one full time radiologist. None of them are putting lung nodule / liver nodule follow-up, possible malignancy.		User		
Radiology	Not all radiologists put the liver segment in the imaging. I have to look through a lot of notes to find this information.		User		
Radiology	Sometimes the radiology codes do not line up with the impression text.		User		
Reports	The report section is not user friendly. I don't even know where to begin. It took me a lot of time to filter things to get the numbers we needed.	Yes	User		
Reports	I have to enter *BK Patient* in the lesion comments to indicate which facility this patient belongs to. This is necessary to do to be able to split the information out in the reports I want to see.		User		
Reports	If you click on the blue icon next to a row to edit the timeliness fields, there is not a way to exit this area and return to the chart.		Expert	3	
Reports	It doesn't seem like there's an option to view data over time for the Cancer/Search Alerts Read, but this graph is hidden near the bottom of the page.		Expert	3	
Reports	It is hard to tell the timeframe of the timeliness of care graph.		Expert	2	
Reports	It takes a while for reports to load (e.g. timeliness of care).		Expert	2	
Reports	On the Cancer/Search Alerts Read report it is not clear why the addressed value is much higher than the sum of the site values.		Expert	3	
Reports	On the Cancer/Search Alerts Read report page you have to click on a blue button to display a graph unlike the Timeliness of Care page where the graph displays automatically.		Expert	2	
Reports	The data is not always reliable. If a navigator puts cancer instead of a nodule when I go into the reports it's going to be showing cancer when it's really not. That part of the reports I don't trust.		User		
Reports	The description column uses phrases that may be less familiar to users (count instead of number).		Expert	2	

Reports	The excessive number of grid lines on the chart make the data hard to read (e.g. Cancer/Search Alerts Read chart).		Expert	2	
Reports	The first table highlights rows in blue (not bolded) if the ST is over 90 days, which doesn't seem necessary since users can sort by this value.		Expert	1	
Reports	The first table under Timeliness of Care uses headers that are not clear (SD, DT, ST, etc.)		Expert	2	
Reports	The fiscal quarter table headers under Timeliness of Care use abbreviations that are not clear (FP=?).		Expert	2	
Reports	The fiscal quarter table highlights the fiscal year to date rows (bold and larger font size) and it's not clear why.		Expert	2	
Reports	The follow-up drop-down menu could be more detailed. This would make it easier to pull reports that are meaningful. Back when we were having issues with Urology and delays in care and if we had had more specific options it would have been far less labor intensive to narrow the data down.		User		
Reports	The font in red under the Download Library contains abbreviations that all users may not be familiar with (e.g. PKI).		Expert	1	
Reports	The last file edited under Timeliness of Care is listed in blue, which doesn't seem necessary.		Expert	1	
Reports	The method of inputting data into the Excel prompts may be challenging for some users since you have to remember the prompts or refer back to the report page.		Expert	2	
Reports	The report column names in the Download Library do not always clearly explain what the data includes (e.g. Active_FU column is called "Count").		Expert	2	
Reports	The report names under the Download Library use abbreviations or are missing appropriate spacing.		Expert	1	
Reports	The shading, color, and marker size of the charts make the data hard to read (e.g. Cancer/Search Alerts Read).		Expert	2	
Reports	The spline and line charts have a blank first chart and it's not clear why (e.g. Cancer/Search Alerts Read).		Expert	3	
Reports	The table headers of the first table under Timeliness of Care do not move when the table is scrolled.		Expert	2	
Reports	The Timeliness of Care chart is impossible to read with all of the vertical bars.		Expert	4	
Reports	The title headers of the first table under Timeliness of Care are formatted inconsistently.		Expert	1	
Reports	There are five scroll bars on the Timeliness of Care page which is confusing for the user.		Expert	2	

Reports	There are multiple chart options for many of the reports which doesn't seem to add value. There is an option to change the Timeliness of Care chart to a bar, line, or marker chart, but all four charts look nearly the same.		Expert	2	
Reports	There is a link to export each table, but not an option to export the chart (e.g. Timeliness of Care chart).		Expert	2	
Reports	There is minimal help available for the report section of CCTS.		Expert	2	
Reports	There is no easy way to see the reliability of the report data (e.g. what percent of rows have complete timeliness information).		Expert	2	
Reports	There is no way to modify the Timeliness of Care chart to show a smaller period of time.		Expert	3	
Reports	Within the download library, the description column does not always align correctly with the report (e.g. Active_FU does not show two counts).		Expert	2	
Scope	I'd like to be able to document when a patient was declared cancer free and out of the remission period. We can't do that now.		User		
Scope	It might be interesting to have an alert list that is new cancers.		User		
Scope	It would be great if we could enter patients with negative lung screening scans. A lot of patients that get screened initially and then they don't get a second-year screening.		User		
System Performance	When the system is slow or goes down it greatly disrupts workflow (sometimes search alert functionality is not available for a whole day, etc.).	Yes	User		
System Performance	On several pages there is no indication that a page or report is loading.	Yes	Expert	2	1.70
System Performance	It is not possible to modify or stop a query if it is taking too long (e.g. All Report Dates under Follow-up List).		Expert	3	
System Performance	It was frustrating when we realized the system wasn't pulling over low-dose CTs. Sometimes when they make updates to the system things get turned off.		User		
System Performance	One time CCTS opened to the wrong station and I accidentally put a patient in there.		User		
System Performance	Sometimes the screen flashes which might be confusing or distracting to users.		Expert	1	0.00
System Performance	The error screen comes up fairly frequently. You have to refresh the page to fix this or return later.		User		
System Performance	The sandbox version of CCTS appears not to show newly added follow-ups immediately (will upload next morning).		User		
System Performance	The search alert list doesn't update until 7:25/7:30 in the morning.		User		

System Performance	There is no indicator to show if the system is running okay or if the tables did not refresh last night.		Expert	2	
System Performance	There's always a delay after hitting submit after processing an alert.		User		
System Performance	When there is not imaging available, the Enter Case Detail - Image Report section is blank but doesn't indicate why.		Expert	3	
Training	I cracked the user guide but it's so huge.		User		
Training	I didn't want to bother people to ask them for help. So I was clicking through [the system].		User		
Training	It can be difficult to learn how to use the system when you are using it only for a low volume of patients.		User		
Training	Sites are using CCTS differently so training can be a challenge.		User		
Training	The system has been challenging for me to learn. I definitely have had more challenges learning to use this particular program than other programs. It's a little less intuitive for me. I think some of it is the terms. The headings and things are not intuitive for me.		User		
Workflow	It is hard to find the patients/follow-ups assigned to me, especially when someone else has to cover for me. Users fear that they may lose a patient in the system.	Yes	User		
Workflow	I had to put all these patients in by myself at the beginning.		User		
Workflow	I think our biggest issues with CCTS have just been managing workload when someone is unexpectedly out. You can't just have one user, you have to have back-up.		User		
Workflow	I'd like to have a case management list. Where you could create your own personalized list of patients that are extremely highly suspicious for cancer. Because I don't want to lose these patients. I keep separate reminders, a separate tracking sheet, and notes all around my desk to manage these patients now.		User		
Workflow	If there was a way for us to add a section for weekly tumor board that would be helpful.		User		
Workflow	It's not clear who is supposed to be putting in dates for the reports. They keep on changing and people just keep on going in, so I don't know who's doing anything anymore. That is really frustrating.		User		
Workflow	You won't be using everything that the system provides. It may not be applicable to you. So we've kind of figured that out and we've worked around it and come up with a good process that works for us.		User		

APPENDIX B

CANCER COORDINATION AND TRACKING SYSTEM USABILITY REPORT – DESIGN RECOMMENDATIONS

Cancer Coordination and Tracking System Usability Report

DESIGN RECOMMENDATIONS

MARCH 2018

PREPARED FOR:

Tamar Taddei, MD
Rajni Mehta, MPH
VA Connecticut Healthcare System
Department of Veterans Affairs

PREPARED BY:

Kristine DeSotto, Master's Candidate
Jenna Marquard, Associate Professor
Department of Mechanical and Industrial Engineering

Contents

Overview & Design Recommendations

The purpose of this study was to apply a set of usability engineering methods to comprehensively identify usability problems within the Cancer Coordination and Tracking System (CCTS). The following report provides a description of the usability engineering methods used and design recommendations for the twelve high priority usability problems identified.

Embedding CCTS Within Workflow

- Create an "assign to" field and add this as a column that can be sorted on the action list page.

General

- Increase the default font size to 12 and configure all areas of CCTS to function properly with this font size.
- Include patient information at the top of all screens so users can tell when a patient is still selected.

Entering and Managing Follow-ups

- After a user opens an alert, allow users to view, edit, and add to the patient's current list of follow-ups.
- Ensure follow-ups are displayed in the system immediately, if possible, and show a list of recent cases to help users navigate back to these patients' cases.
- Configure the follow-up list to automatically reset when a user navigates to this page.

Patient History

- Consider removing or simplifying the Patient History area of CCTS since it adds a layer of complexity to the system and is not often used.

Reports

- Simplify the display of reports and add information to explain the validity of the information being presented.

System Performance

- When possible, limit service interruptions during normal working hours.
- Display a loading bar on all pages where there may be a lagged response after an action is performed.

User Errors

- Consider allowing users to delete errors instead of having them mark an entry as an error.

Project Methodology

This study combined expert-driven and user-driven usability engineering methods to identify a wide range of problems with the system. Expert-driven methods were completed without any users present and include a heuristic evaluation and cognitive walkthrough. The heuristic evaluation compared CCTS against a set of known usability design principles while the cognitive walkthrough identified usability problems by mimicking the user's cognitive workflow through the system. User-driven methods included live observations with a think aloud component, debriefing interviews, severity prioritization of usability problems identified during the cognitive walkthrough, and a usability questionnaire. The user-driven methods were executed during observation sessions held individually with 10 current CCTS users.

These methods identified a total of 162 usability problems ranging from minor cosmetic problems to concerns regarding the overall workflow of CCTS. A majority of the problems (62.3%) were identified through expert-driven methods, 34.6% were identified through user-driven methods, and the remaining 3.1% of problems were identified through both sources.

A list of twelve high priority usability problems were identified. Design recommendations addressing each of these problems will be the highlight of this report.

Design Recommendations

The following section provides a description of the design recommendations for each high priority usability problem identified through this study.

Embedding CCTS Within Workflow

1. Users report that it is difficult to find patients or follow-ups assigned to them, especially when there are multiple users from one facility. This can be particularly challenging in specific instances such as when one user is on vacation and others must cover for them. Users fear that they may lose a patient in the system.

   Design recommendation: Create an “assign to” field and add this as a column that can be sorted on the action list page.

General

2. The default font size is too small for some of the users. CCTS is set to a default font of size 8 and this must be changed each time a user enters the system. One user commented that some parts of the system do not work with a larger font size so she has limited herself to increasing the font size to no more than 10.

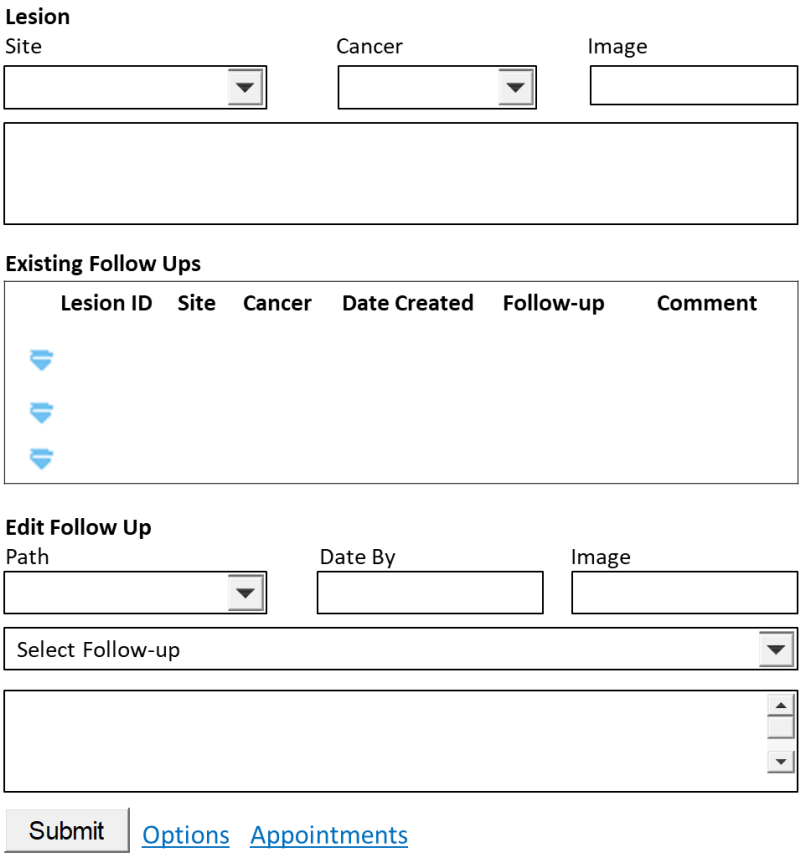
   Design recommendation: Increase the default font size to 12 and configure all areas of CCTS to function properly with this font size.

3. It is hard for users to tell when a patient is selected and when this selection clears. Switching tabs sometimes clears the patient selection and sometimes does not. When a patient is selected and a user is on the Patient History tab, switching to the Action List does not clear this selection but the patient’s identifying information is not displayed at the top of the screen.

   Design recommendation: Include patient information at the top of all screens so users can tell when a patient is still selected.

4. Users report that it is difficult to add a new follow-up for a patient. This task requires users to go to a separate tab which disrupts how efficiently they can manage a patient's case. It took one user nearly 10 minutes to add a new follow-up for a patient since she had to click through the various tabs and eventually open up the user guide.

   Design recommendation: After a user opens an alert, allow users to view, edit, and add to the patient's current list of follow-ups.



5. Existing follow-ups are not visible until after a user submits a follow-up for an alert they are working on. Several users report that it would be better to see a full list of reminders for a patient on the screen when they are processing an alert. A few users noted that this problem has caused duplicate follow-ups to be added.

   Design recommendation: After a user opens an alert, allow users to view, edit, and add to the patient's current list of follow-ups.

6. Users may not know how to get back to a follow-up to edit it. This action requires looking up a patient and navigating to existing follow-ups. Also, one user was under the impression that her newly entered follow-ups may show up 24 hours after being entered. If this is true for all users it may contribute to the confusion around this problem.

   Design recommendation: Ensure follow-ups are displayed in the system immediately, if possible. Show a list of patients who were recently selected in the Patient Look-up tab so users can quickly navigate back to cases they were recently reviewing.

7. After processing a follow-up, users are sent back to the main open follow-up list. The list will be filtered only for the previously selected patient and users must click “Reset List” to see the list of follow-ups for all patients.

   Design recommendation: Configure the follow-up list to automatically reset when a user navigates to this page.

Patient History

8. The Patient History section is not often used and most users do not find it to be helpful. They commented that patient comorbidities and other information has to be manually entered into CCTS but is readily available in the electronic medical record.

   Design recommendation: Consider removing or simplifying the Patient History area of CCTS since it adds a layer of complexity to the system and is not often used. If the team decides to keep some of this functionality, it may be helpful to make small adjustments or expand training related to this area. For example, if a patient has a comorbidity, users are often not clear as to what is an appropriate barrier date to enter for a specific comorbidity.

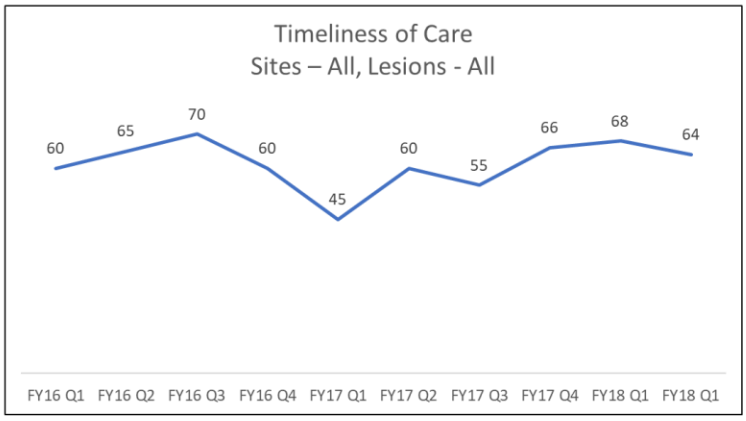
Reports

9. Several users do not use the report section and do not know where to begin when it comes to using this section. Users mentioned that it takes them a lot of time to filter the data to get the information they need.

   Design recommendation: Ensure the reports that are most often requested are easiest to access. Remove the option to display different chart types and provide a chart that is simplified, easier to read, and works best for the type of data being displayed. Show relevant information about the validity of the information being presented, if possible, (e.g. number of completed date fields, etc.). Remove or simplify the table of summary data.

Timeliness of Care

Diagnosis to Treatment



Quarter	Lesions	Average Time
FY16 Q1	2	60
FY16 Q2	10	65
FY16 Q3	8	70
FY16 Q4	6	60
FY17 Q1	7	45
FY17 Q2	3	60
FY17 Q3	9	55
FY17 Q4	10	66
FY18 Q1	4	68
FY18 Q1	7	64

30% of patients for this station are missing a diagnosis date
45% of patients for this station are missing a treatment start date

System Performance

10. When the system is unavailable or performs slowly workflow is greatly disrupted. Several users found the performance of CCTS to be a barrier for them working with the system. Some users have select times during the week that they can use CCTS and it is frustrating when the system is down during these times.

    Design recommendation: When possible, limit service interruptions during normal working hours.

11. Several areas of CCTS do not indicate when a page or report is loading. The loading bar is present on some but not all screens. When a loading bar is not present users may click multiple times and cause an error.

    Design recommendation: Display a loading bar on all pages where there may be a lagged response after an action is performed.

User Errors

12. Users find that errors are difficult, if not impossible, to fix. Nearly half of users find it frustrating that errors can't be addressed if you navigate away from the screen where the error was made. An issue can be marked as an error but still remains in the system permanently.

    Design recommendation: Consider allowing users to delete errors instead of having them mark an entry as an error. Add a confirmation dialogue box to help ensure users understand what information they are removing.

BIBLIOGRAPHY

Andrienko, G., Andrienko, N., Burch, M., & Weiskopf, D. (2012). Visual Analytics Methodology for Eye Movement Studies. *IEEE Transactions on Visualization and Computer Graphics,18*(12), 2889-2898. doi:10.1109/tvcg.2012.276

Asch, S. M., Kerr, E. A., Hamilton, E. G., Reifel, J. L., & McGlynn, E. A. (2000). Quality of care for oncologic conditions and HIV: A review of the literature and quality indicators. *Rand Corporation, Santa Monica, CA*. Retrieved from https://www.rand.org/pubs/monograph_reports/MR1281.html.

Bates, D. W., Kuperman, G. J., Wang, S., Gandhi, T., Kittler, A., Volk, L., . . . Middleton, B. (2003). Ten Commandments for Effective Clinical Decision Support: Making the Practice of Evidence-based Medicine a Reality. *Journal of the American Medical Informatics Association,10*(6), 523-530. doi:10.1197/jamia.m1370

Bowman, S. (2013). Impact of electronic health record systems on information integrity: quality and safety implications. *Journal of the American Medical Informatics Association,10*(Fall), 328-333.

Brooke, J. (1996). "SUS-A quick and dirty usability scale." *Usability evaluation in industry, 189(*194), 4-7.

Connolly, C. (2005). Cedars-Sinai Doctors Cling to Pen and Paper. *The Washington Post,March 21,* A01. Retrieved from http://www.washingtonpost.com/wp-dyn/articles/A52384-2005Mar20.html

Clinical Oncological Society of Australia, The Cancer Council Australia and the National Cancer Control Initiative 2002: Optimising Cancer Care in Australia. National Cancer Control Initiative, Melbourne, 1–122

Crandall, B., Klein, G., & Hoffman, R. R. (2006). *Working minds: a practitioners guide to cognitive task analysis*. Cambridge, MA: MIT Press.

Edwards, P. J., Moloney, K. P., Jacko, J. A., & Sainfort, F. (2008). Evaluating usability of a commercial electronic health record: A case study. *International Journal of Human-Computer Studies,66*(10), 718-728. doi:10.1016/j.ijhcs.2008.06.002

Epping-Jordan, J. E., Pruitt, Bengoa, & Wagner. (2004). Improving the quality of health care for chronic conditions. *Quality and Safety in Health Care,13*(4), 299-305. doi:10.1136/qhc.13.4.299

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis*. Cambridge, MA: MIT press.

Hollingsed, T., & Novick, D. G. (2007). Usability inspection methods after 15 years of research and practice. *Proceedings of the 25th annual ACM international conference on Design of communication - SIGDOC 07*. doi:10.1145/1297144.1297200

Hunnibell, L., Rose, M., Connery, D., Grens, C., Hampel, J., Rosa, M., Vogel, D. (2012). Using nurse navigation to improve timeliness of lung cancer care at a Veterans Hospital. *Clinical Journal of Oncology Nursing, 16*(1), 29-36. 10.1188/12.CJON.29-36

Kantner, L., & Rosenbaum, S. (1997). Usability studies of WWW sites: Heuristic Evaluation vs. Laboratory Testing. *Proceedings of the 15th annual international conference on Computer documentation - SIGDOC 97*. doi:10.1145/263367.263388

Koppel, R., Metlay, J., & Cohen, A. (2005). Role of Computerized Physician Order Entry System in Facilitating Medical Errors. *JAMA,293*(10), 1197-1203. doi:10.1001/jama.293.10.1197

Kushniruk, A. W. (2001). Analysis of Complex Decision-Making Processes in Health Care: Cognitive Approaches to Health Informatics. *Journal of Biomedical Informatics,34*(5), 365-376. doi:10.1006/jbin.2001.1021

Kushniruk, A. W., & Patel, V. L. (2004). Cognitive and usability engineering methods for the evaluation of clinical information systems. *Journal of Biomedical Informatics,37*(1), 56-76. doi:10.1016/j.jbi.2004.01.003

Kushniruk, A. W., & Patel, V. L. (2004). Cognitive and usability engineering methods for the evaluation of clinical information systems. *Journal of Biomedical Informatics*, *37*(1), 56–76. https://doi.org/10.1016/j.jbi.2004.01.003

Li, A. C., Kannry, J. L., Kushniruk, A., Chrimes, D., McGinn, T. G., Edonyabo, D., & Mann, D. M. (2012). Integrating usability testing and think-aloud protocol analysis with "near-live" clinical simulations in evaluating clinical decision support. *International Journal of Medical Informatics*, *81*(11), 761–772. https://doi.org/10.1016/j.ijmedinf.2012.02.009

Longo, L., & Kane, B. (2011). A novel methodology for evaluating user interfaces in health care. *2011 24th International Symposium on Computer-Based Medical Systems (CBMS)*.

McDonald, C. J., Callaghan, F. M., Weissman, A., Goodwin, R. M., Mundkur, M., & Kuhn, T. (2014). Use of Internists Free Time by Ambulatory Care Electronic Medical Record Systems. *JAMA Internal Medicine,174*(11), 1860-1863. doi:10.1001/jamainternmed.2014.4506

Meeks, D. W., Smith, M. W., Taylor, L., Sittig, D. F., Scott, J. M., & Singh, H. (2014). An analysis of electronic health record-related patient safety concerns. *Journal of the American Medical Informatics Association,21*(6), 1053-1059. doi:10.1136/amiajnl-2013-002578

Nielsen, J. (2009). *Usability engineering*. Amsterdam: Kaufmann.

Payne, T. H., Corley, S., Cullen, T. A., Gandhi, T. K., Harrington, L., Kuperman, G. J., . . . Zaroukian, M. H. (2015). Report of the AMIA EHR-2020 Task Force on the status and future direction of EHRs. *Journal of the American Medical Informatics Association,22*(5), 1102-1110. doi:10.1093/jamia/ocv066

Peute, Spithoven, Bakker, & Jaspers. (2008). Usability studies on interactive health information systems; Where do we stand? *Proceedings of the MIE 2008,136*, 327-332. IOS Press.

Poon, E. G., Gandhi, T. K., Sequist, T. D., Murff, H. J., Karson, A. S., & Bates, D. W. (2004). "I Wish I Had Seen This Test Result Earlier!". *Archives of Internal Medicine,164*(20), 2223-2228. doi:10.1001/archinte.164.20.2223

Press, M. J. (2014). Instant Replay — A Quarterbacks View of Care Coordination. *The New England Journal of Medicine,371*(6), 489-491. doi:10.1056/nejmp1406033

Siegel, R. L., Miller, K. D., & Jemal, A. (2017). Cancer statistics, 2017. *CA: A Cancer Journal for Clinicians,67*(1), 7-30. doi:10.3322/caac.21387

Singh, H., Hirani, K., Kadiyala, H., Rudomiotov, O., Davis, T., Kahn, M. M., & Wahls, T. L. (2010). Characteristics and predictors of missed opportunities in lung cancer diagnosis: an electronic health record-based study. *Journal of Clinical Oncology,28*(20), 3307-3315.

Smelcer, J. B., Miller-Jacobs, H., & Kantrovich, L. (2009). Usability of electronic medical records. *Journal of usability studies,4*(2), 70-84.

Someren, M. V., Barnard, Y. F., & Sandberg, J. A. (1994). The think aloud method: a practical approach to modelling cognitive processes. Academic Press.

Stavert, R. R., & Lott, J. P. (2013). The Bystander Effect in Medical Care. *New England Journal of Medicine,368*(16), 8-9. doi:10.1056/NEJMp1210501

Taddei, T. H., Hunnibell, L., Delorenzo, A., Rosa, M., Connery, D., Vogel, D., . . . Rose, M. G. (2012). EMR-linked cancer tracker facilitates lung and liver cancer care. *Journal of Clinical Oncology,30*(34_suppl), 77-77.

Walji, M. F., Kalenderian, E., Piotrowski, M., Tran, D., Kookal, K. K., Tokede, O., ... & Kimmes, N. S. (2014). Are three methods better than one? A comparative assessment of usability evaluation methods in an EHR. International journal of medical informatics, 83(5), 361-367.

Wright, M. C., Dunbar, S., Moretti, E. W., Schroeder, R. A., Taekman, J., & Segall, N. (2013). Eye-Tracking and Retrospective Verbal Protocol to Support Information Systems Design. *Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care,2*(1), 30-37. doi:10.1177/2327857913021007

Yates, P. (2004). Cancer care coordinators: Realising the potential for improving the patient journey. *Cancer Forum,28*(3), 128-132.